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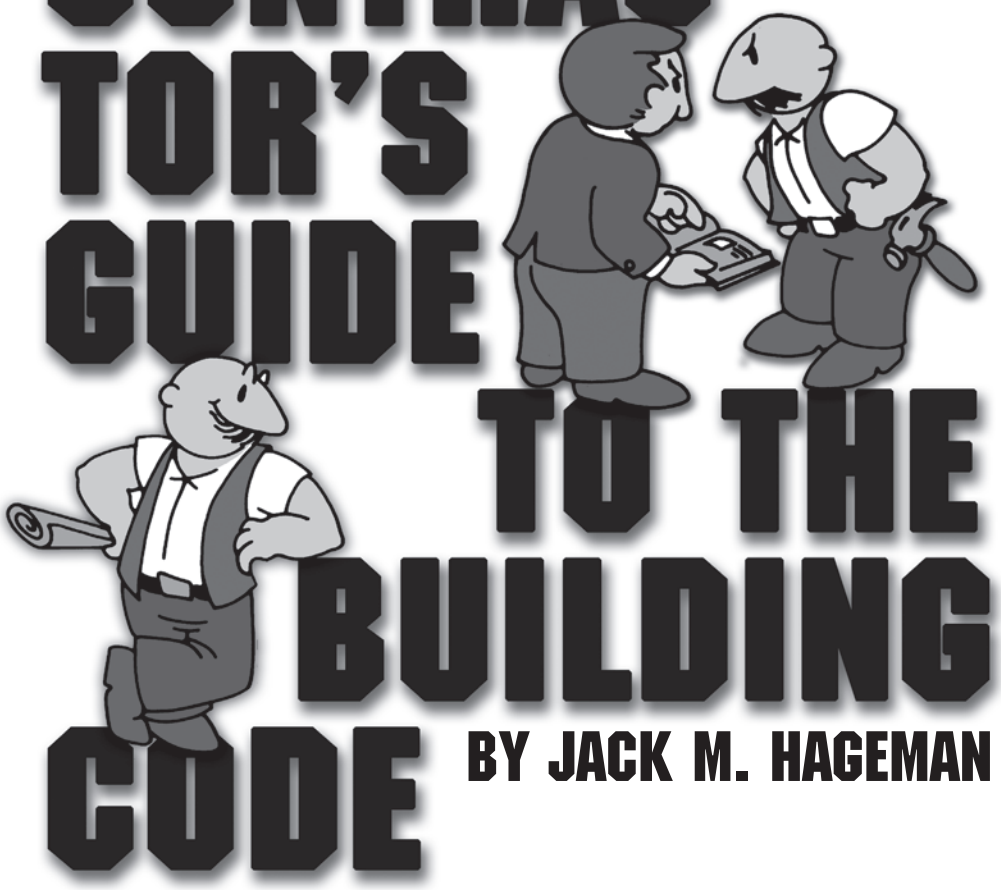
CONTRACTOR'S GUIDE TO THE BUILDING CODE



BY JACK M. HAGEMAN

UPDATED BY BRIAN E.P. BEESTON
AND KEN HAGEMAN

Based on the
2006 IBC & IRC

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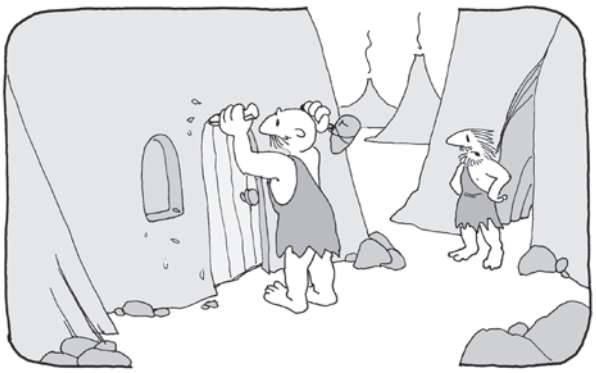


How We Got Where We Are

I think mastering the code today is a huge challenge for both contractors and inspectors — much more so than 40 years ago. Back then, many building codes were no more than a slim little pamphlet containing a collection of whatever ordinances the city council had decided to enact. That worked OK at the time, though it may have given inspectors a little too much discretion. What one inspector would approve, others in the same office might reject. That's what happens when there isn't clear guidance.

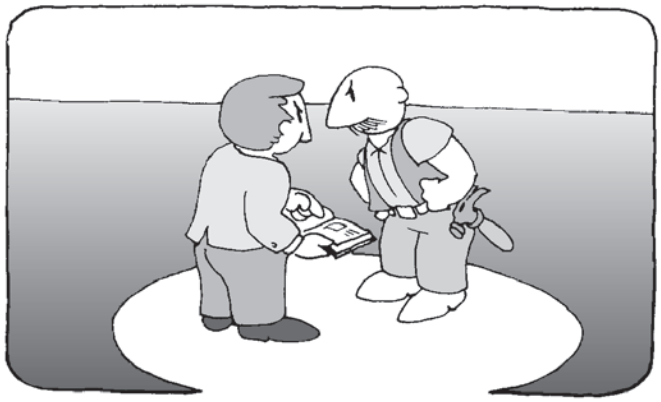
The 2006 IBC and IRC are a tremendous improvement on what inspectors and contractors had to rely on back then. But not all jurisdictions have adopted the IBC and IRC. The IAPMO plumbing and mechanical codes are used by many communities. The NEC has been widely adopted as the local electrical code. And then there's the NFPA 5000.

The National Fire Protection Association, publisher of the NFPA 5000, isn't exactly a newcomer to the model code business. For 20 years BOCA, ICBO, SBCCI, and NFPA tried to blend their codes. In the mid-90s BOCA, ICBO, and SBCCI formed the ICC. NFPA split from the group, and published its first comprehensive model building code in 2002. The ICC promptly sued NFPA for copyright violation. The ICC won the first round in March 2006. But the court's decision left some key issues unresolved: Can the I-codes be protected by copyright? Did NFPA actually infringe on the IBC copyright?

Code battles can become contentious, with no ground given up on either side. But why does it have to be so difficult? The intent of code compilation was to make code compliance easier for builders, not harder. You simply want to know what the code requires so you can move on and get your Certificate of Occupancy. However, the code developers are in business, the same as you. They want to make a profit to expand their business and improve their products. That's why they protect their turf so stubbornly. Wouldn't you?

In their June 21, 2004 edition, the Arizona Republic reported on one of these turf battles taking place in Phoenix: "[Phoenix] set out to replace its current, and outdated, set of construction regulations, called the Uniform Building Code. But officials struggled with whether to use a set of standards known as NFPA 5000 or the more commonly-used International Building Code." A legal battle ensued, with both sides firing their best shots. When the dust settled, the ICC had won the day, and the Phoenix city fathers adopted the I-codes. Similar struggles took place in cities across the nation.

Today, nearly all states, the District of Columbia and the Department of Defense have adopted one of the three editions of the IBC and the IRC. You don't need to know about these battles — you just need to know who won, and which code to use in your area. You can find out if your city, county or state has adopted the I-codes by going to the ICC website at www.iccsafe.org/government/jurisdictionadoptions.xls.



"Cuz it says so in The Book!*"*

C H A P T E R 1

Why Do I Need a Permit?

Years ago, the building code was a very small book. Every city, county and state had its own laws regulating construction. You had to know each local code. What was good in one area wasn't good in another.

That's no longer the case. The current code in your area could be over 600 pages long. Construction has become more complex in the last few decades, and the code reflects that.

By the mid-1990s, most communities had adopted one of three model codes, written by:

- BOCA (Building Officials and Code Administrators International)
- ICBO (International Conference of Building Officials), or
- SBCCI (Southern Building Code Congress International).

In 1994, these three code-writing organizations founded the International Code Council (ICC). In 2000, the ICC published the first editions of:

- The International Building Code (IBC)
- The International Residential Code (IRC) for One- and Two-Family Dwellings

By 2006, nearly all states, Washington, D.C. and the Department of Defense (DOD), had adopted one of these ICC codes — the 2000, 2003 or 2006 edition of the IBC and the IRC. Go to www.iccsafe.org/government/jurisdictionadoptions.xls. This website will tell you what code(s) are used in your state, county or city. Not all jurisdictions have adopted the most recent edition(s). And some cities and counties have made amendments to modify the code.

Other ICC codes cover:

- Energy conservation
- Existing buildings

TABLE R301.2(1) CLIMATIC AND GEOGRAPHIC DESIGN CRITERIA										
GROUND SNOW LOAD	WIND SPEED[d] (mph)	SEISMIC DESIGN CATEGORY[f]	SUBJECT TO DAMAGE FROM			WINTER DESIGN TEMP[e]	ICE BARRIER UNDERLAYMENT REQUIRED[h]	FLOOD HAZARDS[g]	AIR FREEZING INDEX[i]	MEAN ANNUAL TEMP[j]
			Weathering[a]	Frost line depth[b]	Termite[c]					

For SI: 1 pound per square foot = 0.0479 kPa, 1 mile per hour = 0.447 m/s.

a. Weathering may require a higher strength concrete or grade of masonry than necessary to satisfy the structural requirements of this code. The weathering column shall be filled in with the weathering index (i.e., "negligible," "moderate" or "severe") for concrete as determined from the Weathering Probability Map [Figure R301.2(3)]. The grade of masonry units shall be determined from ASTM C 34, C 55, C 62, C 73, C 90, C 129, C 145, C 216 or C 652.

b. The frost line depth may require deeper footings than indicated in Figure R403.1(1). The jurisdiction shall fill in the frost line depth column with the minimum depth of footing below finish grade.

c. The jurisdiction shall fill in this part of the table to indicate the need for protection depending on whether there has been a history of local subterranean termite damage.

d. The jurisdiction shall fill in this part of the table with the wind speed from the basic wind speed map [FigureR301.2(4)].Wind exposure category shall be determined on a site-specific basis in accordance with Section R301.2.1.4.

e. The outdoor design dry-bulb temperature shall be selected from the columns of $97^1/_2$-percent values for winter from Appendix D of the *International Plumbing Code.* Deviations from the Appendix D temperatures shall be permitted to reflect local climates or local weather experience as determined by the building official.

f. The jurisdiction shall fill in this part of the table with the seismic design category determined from Section R301.2.2.1.

g. The jurisdiction shall fill in this part of the table with (a) the date of the jurisdiction's entry into the National Flood Insurance Program (date of adoption of the first code or ordinance for management of flood hazard areas), (b) the date(s) of the currently effective FIRM and FBFM, or other flood hazard map adopted by the community, as may be amended.

h. In accordance with Sections R905.2.7.1, R905.4.3.1, R905.5.3.1, R905.6.3.1, R905.7.3.1 and R905.8.3.1, where there has been a history of local damage from the effects of ice damming, the jurisdiction shall fill in this part of the table with "YES". Otherwise, the jurisdiction shall fill in this part of the table with "NO".

i. The jurisdiction shall fill in this part of the table with the 100-year return period air freezing index (BF-days) from Figure R403.3(2) or from the 100-year (99%) value on the National Climatic Data Center data table "Air Freezing Index- USA Method (Base 32°Fahrenheit)" at www.ncdc.noaa.gov/fpsf.html.

j. The jurisdiction shall fill in this part of the table with the mean annual temperature from the National Climatic Data Center data table "Air Freezing Index-USA Method (Base 32°Fahrenheit)" at www.ncdc.noaa.gov/fpsf.html.

Figure 1-1 Climatic and geographic design criteria

- Fire
- Fuel gas
- Mechanical
- Performance
- Plumbing
- Private sewage disposal
- Property maintenance
- Urban-wildlife interface
- Zoning

The IRC was written for one- and two-family homes and townhouses. The IBC regulates engineering and design standards for all building types. Don't cite the IRC if you're working on a nonresidential job.

The IRC is a "prescriptive" code. That means the IRC has the formula (the prescription). You don't need a licensed engineer to sign off on the plans if you follow IRC tables. That's a major concession. And it makes sense. Tables in the IRC follow generally-accepted standards for material strength. The IRC also includes its own sections for Mechanical (M), Plumbing (P), Fuel Gas (G), and Electrical (E) codes.

But what if the IRC tables don't cover something you need in your single-family residential job? That's easy. You can use the IBC. But anything that isn't in an IRC table will need approval by a licensed architect or engineer.

The codes are republished every three years. Each state, county or city decides if it wants to adopt the new codes. Until they're adopted, the codes aren't legal documents. They only have the force of law after adoption as Ordinances. A sample ordinance is shown on page v of the introductory sections of both the 2006 IBC and IRC. It's called *Sample Ordinance for Adoption of the International Building (or Residential) Code Ordinance No. _____.*

Each building department provides information about local conditions before codes are adopted. See IRC Section R301.2, Climatic and Geographic Design Criteria, and Table R301.2(1) (Figure 1-1).

Almost every state changes something before adopting the code. Washington State, where I worked, made a lot of amendments. They chose the Uniform Plumbing Code over the International Plumbing Code. Like many states, they use the *National Electrical Code (NEC)* even for residential construction. Local authorities often amend what's been adopted at state level. Some cities use the IBC for all houses 3,000 square feet and larger. They only use the IRC for "little" houses. I've always lived in less than 1,900 square feet. That never felt "little" to me!

California has been somewhat of a holdout. Many of its cities use the 2001 California Code, based on the 1997 Uniform Building Code (UBC). However, California intends to adopt the IBC as of January 1, 2008. If you plan to build in California, contact your local building department. They'll tell you which code is currently in force.

The IRC is designed as a subset of the IBC. This sixth edition of *Contractor's Guide to the Building Code* covers the 2006 editions of both the IBC *and* the IRC. So each reference to a specific section in one of these codes includes which code it is.

Following the Code

The building code is a fact of life. You won't get paid until you have an inspector's approval. You have to follow the code and build how it says to build. But you want to do this as simply and economically as you can. That's why I wrote this book.

Most contractors have had an inspector hold up a job or a permit because of a violation. Meeting code requirements can be both annoying and costly. But following the code prevents poor practice and saves lives. And it's the owner's best defense against shoddy work.

To comply with the code, you must know which code to follow, which is easy. Just ask at the local building department. That's where plans get approved. The next step is harder. The building code is written to be enforced, and as with any legal document, it's not always easy to read and understand. But you can't spend your career trying to master the code. At least you shouldn't. Your job is building, not nit-picking. You need to know just enough to stay out of trouble and avoid mistakes. This book will help.

This manual isn't a code book. It's a *guide to understanding the codes*. Use the index to find the topic of interest. Read the part of this manual that covers your problem. When you understand what the manual says, go to the code itself. Read the words carefully. Then refer back to this manual. It will help you understand the code.

Authority of the Inspector

Inspectors know they can only enforce what the code requires. But there is some "wiggle room" in the code. That may allow some negotiation, as long as the intent of the code is carried out. IRC Section R104.1 says:

> ***R104.1 General.*** *The building official is hereby authorized and directed to enforce the provisions of this code. The building official shall have the authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions. Such interpretations, policies and procedures shall be in conformance with the intent and purpose of this code. Such policies and procedures shall not have the effect of waiving requirements specifically provided for in this code.*

Basic Code Concepts

Some points apply on every job, no matter what type of construction and materials are used. They make a good place to start.

The building department has a certain amount of leeway. Every contractor has had an inspector say, "It'll be OK if you do it this way." No, the inspector isn't giving away the store. He or she is just getting the result intended by the code. This often saves you time, trouble and money.

If an inspector tries to help you out, cooperate. It's probably because he or she wants you to concede on another point. When an inspector complains about something, listen! If you insist on compliance with the code, you may get more than you bargained for. The inspector can cite dozens of sections that require strict enforcement. But that's not what you want. You want to be able to work with the inspector. The point is that cooperation works much better than arguing.

Purpose of the Code

IRC Section R101.3 makes it clear that health, safety and protecting property are the primary aims of the code:

> ***R101.3 Purpose.*** *The purpose of this code is to provide minimum requirements to safeguard the public safety, health and general welfare through affordability, structural strength, means of egress facilities, stability, sanitation, light and ventilation, energy conservation and safety to life and property from fire and other hazards attributed to the built environment.*

The first sentence uses the words *minimum requirements.* You can always build to a higher standard. But every structure has to meet code minimums.

If you decide to dispute the inspector's interpretation of a code requirement, there's an important point in IRC Section R101.3. If what you want protects public health, safety and property, you could win your argument. It's important to prove that your way is just as good as, or even better than, what the code specifies.

Can I Use That Material?

The code also gives you the option of using different methods and materials. IRC Section R104.11 states:

> ***R104.11 Alternative materials, design and methods of construction and equipment.*** *The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code. Compliance with the specific performance-based provisions of the International Codes in lieu of specific requirements of this code shall also be permitted as an alternate.*

If you want to do something in a different way, it must conform to the intent of the code. This also applies if you want to use materials that are new. You have to prove to the building official that you've done your research. The building official is the senior person in the building department. He or she is the one who makes the final decision.

For example, earth-sheltered structures were once popular. Some inspectors threw up their hands when asked to inspect an underground home. Why? They're just not covered very well in the code. This is where you have to look at the *intent* of the code, not just the literal meaning.

A good inspector or plan checker will do a little homework when asked to approve something different. Less-experienced inspectors may not want to approve something that's not in "The Book." Fortunately, that isn't what the code says.

IRC Section R104.11 allows use of any material or method approved by the building department; it doesn't even have to be covered in the code. An experienced inspector may take the time to look at something unusual. What's the best way to get the building department to see it as you do? Give them the information they need. Inspectors have a lot of common sense. Give them the respect they deserve.

Handling Code Disputes

Everyone will have a few disputes with an inspector. This will happen even if you know the code. You're not going to win many direct disputes. But there's a lot you can do to get the inspector to see things your way.

You have to accept that the building department holds the best cards. It has the full power of the law behind it. Building department personnel can use this power to make you comply. But they'd much rather have you cooperate willingly.

A good attitude goes a long way with an inspector. Explain, "You and I are construction professionals. We both have a job to do. Together we're going to put up a building we'll be proud of." Think of the inspector as a partner, not the enemy.

What are the two most important things to remember when you have a dispute with the building department?

1. Inspectors don't make the rules.
2. Inspectors can't rewrite the code to suit you. They only enforce the code as written.

Let's say that the inspector insists on something that you don't think is in the code. Have him or her cite the specific section and words. Then study those words in your copy of the code. If the words don't support the inspector's position, you're likely to win your point.

Inspectors make their living by knowing the code. They probably know it far better than you ever will. But they can be wrong. So don't be afraid to ask for the code section they're talking about. Study it and form your own opinion of what's required. If you believe the inspector's interpretation is wrong, appeal it. I'll explain that process later.

Going to the Next Level

What if you have a dispute on a code issue that's so important that you don't want to give in? Then you'll have to take it up with the head of the building or planning department. Try to avoid going through the formal appeal procedure. If you can work things out without an appeal, it's better for everyone.

Request a meeting with one of the senior inspectors or the building official. Offer to meet early in the morning, before inspectors start their fieldwork. Be sure both the inspector involved and his or her supervisor can be at the meeting. Prepare your case carefully. Show that the code doesn't really require what you're being asked to do.

Point out that your way still meets the code. Be professional. This goes a long way. Ask for compromise on the issue. You're sure to get a fair hearing. And, who knows? You may even win!

Inspectors aren't going to waive clear code requirements. Their major concern is safety. The code wasn't written to save you money or trouble. Code protection is too valuable for anyone to get special treatment. If you've been to countries where codes don't exist or aren't enforced, you know their importance. But there's more at stake than just upholding codes.

Did you know that cities and counties are liable for the mistakes of their building departments? If a building is defective, the local government takes the blame. Owners of defective buildings have recouped lots of money from local governments. But that rarely happens when local governments enforce the building codes. All building officials know the importance of the code. They also know that they can be held liable for mistakes. And mistakes cost them money — sometimes lots of money.

The Appeal Process

If talking to the inspector doesn't work, the next step is a formal appeal. IRC Section R112 is entitled *Board of Appeals*. You have the right to appeal any inspector's decision.

> ***R112.1 General.*** *In order to hear and decide appeals of orders, decisions or determinations made by the building official relative to the application and interpretation of this code, there shall be*

and is hereby created a board of appeals. The building official shall be an ex officio member of said board but shall have no vote on any matter before the board. The board of appeals shall be appointed by the governing body and shall hold office at its pleasure. The board shall adopt rules of procedure for conducting its business, and shall render all decisions and findings in writing to the appellant with a duplicate copy to the building official.

R112.2 Limitations on authority. *An application for appeal shall be based on a claim that the true intent of this code or the rules legally adopted thereunder have been incorrectly interpreted, the provisions of this code do not fully apply, or an equally good or better form of construction is proposed. The board shall have no authority to waive requirements of this code.*

R112.3 Qualifications. *The board of appeals shall consist of members who are qualified by experience and training to pass on matters pertaining to building construction and are not employees of the jurisdiction.*

A key phrase here is that the board members *"...are qualified by experience and training..."* If unusual material or construction is involved, the inspector may prefer an appeal. It always helps to hear opinions from other experts.

IRC Section R112.2 states: *"The board shall have no authority to waive requirements of this code."* That means you won't be able to slip something past the board just because you asked nicely and smiled.

Time to Get Your Permit

Nearly all of your work will require a permit. There are exceptions, but it's always best to check before starting work. IRC Section R105.1 covers this:

R105.1 Required. *Any owner or authorized agent who intends to construct, enlarge, alter, repair, move, demolish, or change the occupancy of a building or structure, or to erect, install, enlarge, alter, repair, remove, convert or replace any electrical, gas, mechanical or plumbing system, the installation of which is regulated by this code, or to cause any such work to be done, shall first make application to the building official and obtain the required permit.*

For types of construction that are exempt, see IBC Section 105.2 and IRC Section R105.2. Some of these are:

- Small outbuildings such as tool sheds and playhouses (under 120 square feet)
- Small retaining walls (less than 4 feet high, measured from the bottom of the footing). (If the walls support a surcharge or they impound Class IA, IIA or IIIA combustible liquids, a permit will be required.)
- Fences (less than 6 feet high)
- Sidewalks and driveways
- Finish work like painting and paperhanging

These code sections have complete lists of exemptions. But remember to check your local ordinance. The list may have been amended when the code was adopted.

Figure 1-2 shows a sample building permit. There's always a charge for issuing the permit. Permit fees go up with the value of the job. The state, county or city sets the fees. There's no fee schedule in the building code. But these fees can be high. They're designed to offset the cost of running the planning and building departments.

Permit fees usually start at about $50 for a $500 job. The fee for a $1,000,000 job will be about $6,000. Above $1,000,000, the permit fee will usually be 3 to 4 percent of the estimated job cost. The plan-check fee is extra, usually about 65 percent of the building permit fee for residential buildings. Plan-check fees jump to 100 percent of the building permit fee for nonresidential buildings.

City of Bellevue

Development Services • 450 110th Ave NE • Bellevue 98004

Permit and Inspection Record

Job Address: **1465 W Lk Samm Pkwy SE** **Permit Number:** **06 102642 BS**

Issued: 05/05/2006 **Start Work By: 05/05/2007** **Expires: 05/04/2009**

Type: Single Family New Combo SubType: New Work:

Property Owner: Richard J Johnson Applicant: Richard J Johnson

Project Name: New Single Family Residence Phone: **(206) 555-1111**

Description: Construct new single family residence on vacant lot. Includes plumbing, mechanical, and clearing and grading. Does not include electrical (until sub is named).

Construction Lender: NONE Phone:

Seasonal Restrictions?:	**Yes**	No. of Stories:	**3**	No. of Basements:	**0**
Building Department Value:	**477683**	Fire Sprinkler Type:	**NFPA-13D, Q**	Category 1 Occupancy Group:	**R-3**
Category 1 Construction Type:	**VB**	Category 1 Area (Sq. Ft.):	**4656**	Category 1 Shell?:	**No**
Category 2 Occupancy Group:	**U**	Category 2 Construction Type:	**VB**	Category 2 Area (Sq. Ft.):	**990**
Category 2 Shell?:	**No**	Category 3 Occupancy Group:	**R-3**	Category 3 Construction Type:	**VB**
Category 3 Area (Sq. Ft.):	**1226**	Category 3 Shell?:	**No**		

Post this permit in a visible and accessible location at the job site and have the approved plans available for the inspector.

Inspection Scheduling Information

Call **425-452-6875** to schedule, cancel, or reschedule all inspections.

To get an estimated inspection time after the inspection is scheduled, call the appropriate number below.

***** Do not call the following numbers to schedule inspections *****

(425) 452-4570: **Building, Mechanical, Electrical, Plumbing, Clearing & Grading Inspections** - Call between 7 and 8 a.m. the morning of the inspection.

(425) 452-6872: **Fire Inspections** - The inspector will call you the morning of the inspection to set up the time.

(425) 452-6864: **Land Use Inspections** - An inspection time is set when the inspection is scheduled.

(425) 452-6966: **Transportation Inspections** - Call between 7 and 8 a.m. the morning of the inspection.

(425) 452-6977: **Utility Inspections** - An inspection time is set when the inspection is scheduled.

Occupancy & Final Inspection Information

It is your responsibility to call for all required inspections. The inspection process is not complete until the final inspection(s) has been approved, which must be prior to the permit expiration date noted above.

If a Certificate of Occupancy (CO) is required, you must obtain that document before you can legally occupy the building. The CO is a document -- separate from this permit -- that indicates approval by all appropriate city staff and the building official. The CO is required for:

- All new commercial and multifamily projects
- Some substantial commercial and multifamily additions
- Tenant improvements involving a change in use

Consult your inspector if you have questions about the final inspection or Certificate of Occupancy process.

Figure 1-2 Typical building permit

City of Bellevue Inspection Record

Job Address: 1465 W Lk Samm Pkwy SE **Permit Number:** 06 102642 BS

Related Job #: Tenant: Floor: Suite:

Contractors:

HAMBROILER PLUMBING INC JOHN C HAMBROILER License: HAMESI*224BK Phone: (425) 485-2230
PUGET SOUND HEATING & SHEET MTL DAVE K DAVIDSON License: SUMMIHS10555 Phone: (425) 844-2036
MCNUGGETS CONST & DESIGN LLC ROGER K MCNUGGETS License: MACNGCD001KR Phone: (425) 391-3398

Construction Contact: Bobson Construction and Design Bob Bobson Phone: (425) 333-3333

Special Inspections Required for:

For each discipline, schedule inspections in order (read left --> to --> right). Your project may not need all the listed inspections; ask your inspector.

Required Inspection	Inspector	Date	Required Inspection	Inspector	Date
100 ClGr-Precon/Jobcon			102 ClGr-Initial Erosion Cntl		
104 ClGr-Footing Drain			106 ClGr-Roof Drain		
108 ClGr-Strm Systm Connect			114 ClGr-Rockery/Block Wall		
124 ClGr-Final			902 ROW-Precon		
995 ROW-Final			200 Bldg-Precon/Jobcon		
210 Bldg-Footing			212 Bldg-Foundation		
220 Bldg-Insulation Slab			230 Bldg-Underfloor		
236 Bldg-Roof Diaphragm			242 Bldg-Ext Lath		
245 Bldg-Ext/Int Shearwall			252 Bldg-Framing		
254 Bldg-Insulation			256 Bldg-Interior Gypsum		
268 Bldg-Final			304 Mech-Undrgrnd Ducts		
308 Mech-Gas Piping			320 Mech-Rough In		
322 Mech-Refer Lines			340 Mech-Final		
406 Elec-Trenching			410 Elec-Grounding		
414 Elec-Service			415 Elec-Rough In		
450 Elec-Low Voltage			458 Elec-Final		
502 Plbg-Water Service			506 Plbg-Groundwork		
514 Plbg-Tub Test/Shwr Subpan			516 Plbg-Rough In		
524 Plbg-Backflow Device			528 Plbg-Final		

Figure 1-2 Typical building permit (continued)

The building department will probably accept your estimate of the job value, including labor and materials. If the estimate looks too low, your application can be denied. See IBC Section 108.3. Remember, the building department has seen many job value estimates. Don't try to pull a fast one. You'll be sorry.

Usually, a copy of each permit issued goes to the tax assessor. It's the assessor's cue to do some checking. This usually means a change in someone's property taxes.

You'll need a permit to remove or demolish a building, as you'll see in IRC Section R101.2. Many cities and counties have ordinances regarding unsafe buildings. Even if your city makes you demolish a building, you'll need a permit. What happens if you find hazardous materials like lead or asbestos during demolition? In most areas, you need to notify the building department immediately.

Newcomers to this business may think they don't need a permit for work inside an existing building. That may be true, but not because it's inside. Replacing kitchen cabinets falls under one of the exemptions. But any remodeling or renovation that isn't exempted requires a permit. This is true no matter where the work is done.

No contractor wants to be cited for doing work without a permit. Licensed contractors play by the rules. That's just good business. Sometimes the building owner doesn't agree. Explain that building departments can easily identify where materials are being delivered. And how can you hide a demolition in progress? It's not easy. Bootleg construction — without a permit — may make a property hard to sell. Even if a future buyer doesn't care, their lender and insurance company will.

Posting Your Permit

Most cities and counties require permit posting. The building permit and the inspection card must be in plain view on site. The inspector will sign the card after each inspection and approval. It's your proof that the inspector has approved work up to that point.

Inspections

Section 104.6 of both the IBC and the IRC give the building official authority to come on the premises to make inspections:

> ***104.6 Right of entry.*** *Where it is necessary to make an inspection to enforce the provisions of this code, or where the building official has reasonable cause to believe that there exists in a structure or upon a premises a condition which is contrary to or in violation of this code which makes the structure or premises unsafe, dangerous or hazardous, the building official or designee is authorized to enter the structure or premises at reasonable times to inspect or to perform the duties imposed by this code, provided that if such structure or premises be occupied that credentials be presented to the occupant and entry requested. If such structure or premises be unoccupied, the building official shall first make a reasonable effort to locate the owner or other person having charge or control of the structure or premises and request entry. If entry is refused, the building official shall have recourse to the remedies provided by law to secure entry.*

A permit always requires at least one inspection. The number of inspections depends on the scope of the job. On a reroofing job, the inspection may be a simple walk-around. For a large commercial project, there may be as many as 16 approvals needed. Some may be very technical. Each of them may take more than one inspection. For most residential and small commercial jobs, there are four inspections required. See IRC Section R109:

R109.1.1 Foundation inspection. The foundation inspection is made after the following are complete:

- Excavation for footings
- Reinforcing steel in place, if required
- Poles or piers set, if required
- Forms in place and inspected before concrete is poured (for concrete foundations)

Excavations for thickened slabs to support bearing walls, partitions and other structures require foundation inspections. Foundations made from treated wood require special inspection.

R109.1.2 Plumbing, mechanical, gas, and electrical systems inspection. These types of inspections must be made before the following:

- Covering or concealment
- Fixtures or appliances installed
- Framing inspection

R109.1.4 Frame and masonry inspection. Frame and masonry inspections are made after the following are complete:

- Roof
- Framing
- Masonry construction
- Fire stopping
- Draft stopping
- Bracing

R109.1.6 Final inspection. The final inspection is made after the permitted work is complete and before occupancy.

While the code calls for only four inspections, your local jurisdiction may ask for more. They may want two inspections for the foundation — one for the footing and one for the walls. Many departments will want to inspect under the floor or slab.

Plumbing may need as many as four or five separate inspections. Each plumbing inspection could involve other inspectors or departments. Most inspectors won't look at framing until all the subcontractors have finished. Why? Because the plumber, HVAC installer, electrician, and others may have to modify the carpenter's work.

Following the framing inspection, there may be separate insulation and wallboard inspections. Also, final grading or landscaping might have to be approved. Before you know it, you've got 12 or more inspections required for a new house.

When the permit is issued, you'll be advised of the inspections or tests needed. These tests may be required during the following phases of construction:

- Concrete pouring
- Reinforcing steel
- Prestressing steel
- Welding
- High-strength bolting
- Structural masonry
- Reinforced gypsum concrete
- Insulating concrete fill
- Spray-applied fireproofing
- Piling
- Drilled piers and caissons
- Special grading, excavation, or backfill

Many jurisdictions have special inspectors for activities that require observation. These may include, but are not limited to:

- Grouting structural masonry
- Site welding
- Placing epoxy-set anchors

If advanced or complicated engineering is involved, building officials may have another requirement. They may want the engineer to observe the work. After it's done, they'll report that it complies with the engineering design. Other inspections may be necessary if there are special requirements, such as:

R109.1.3 Floodplain inspections. To be made for construction in flood-prone areas, as indicated in column 9 of IRC Table R301.2(1) (Figure 1-1).

R109.1.5.1 Fire-resistance-rated construction inspection. To be made where fire-resistance-rated construction is required between dwelling units. This inspection is done after all lath and wallboard is in place. After the inspection, wallboard joints and fasteners can be taped and finished, and plaster can then be applied.

The building department can require more inspections if it thinks they're needed. The most important thing is to comply with code and local ordinance; see IRC Section R109.1.5. Section R109.2 allows the inspector to accept reports from approved agencies, provided the agencies are qualified and reliable.

If the inspector finds a code violation, an inspection/correction notice (Figure 1-3) will be issued. The notice explains what must be done.

City of Bellevue Inspection Record

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254 Bldg-Insulation			256 Bldg-Interior Gypsum		
268 Bldg-Final			304 Mech-Undrgrnd Ducts		
308 Mech-Gas Piping			320 Mech-Rough In		
322 Mech-Refer Lines			340 Mech-Final		
406 Elec-Trenching			410 Elec-Grounding		
414 Elec-Service			415 Elec-Rough In		
450 Elec-Low Voltage			458 Elec-Final		
502 Plbg-Water Service			506 Plbg-Groundwork		
514 Plbg-Tub Test/Shwr Subpan			516 Plbg-Rough In		
524 Plbg-Backflow Device			528 Plbg-Final		

Figure 1-3 Inspection/correction notice

When that work is corrected, schedule another inspection. In some jurisdictions you have to pay a fee for reinspection. Other jurisdictions will only charge if you need more than one reinspection. Work may not have to stop until the reinspection. But you won't be able to move to the next step or cover the work in question until the corrections have been made.

Some building departments will perform inspections after hours and on weekends. This is a big help. But expect to pay big for it, too. A larger project may require a full-time special inspector. Shopping malls and high-rise buildings are good examples. The owner pays for the special inspector either directly or through the contractor. The building official must always approve special inspectors.

Passing final inspection qualifies a new building for a Certificate of Occupancy. This is an important milestone. After it's issued, utility companies can start providing service in the name of the owner. A Certificate of Occupancy isn't issued until the inspector signs off on the final inspection.

One additional point on inspections: Inspectors don't assume anything. They want to see everything with their own eyes. For example, a framing inspector isn't going to approve framing that's already covered. An electrical inspector will want to see the full length of conduit. If you leave just a little stub poking out of the wall at each end, that won't do. Don't ask for approval of anything not in plain sight.

The Next Step

Chapter 1 has laid out the playing field. You know how the code works. You understand the importance of the code to every project and every contractor. You've learned how to deal with both the inspectors and the building department. You know how the permit system works and how inspections are done.

In Chapter 2, we'll look at what you need to do to get your permit. Then we'll begin to study the rules. The most basic code concept is based on occupancy groups. We'll look at them in Chapter 3. Occupancy groups are categories of buildings that share the same code requirements. The code will begin to make more sense once you understand these categories.

Gender Bias

From this point on in the book, I've opted to use the terms "he" and "his" rather than "he or she" and "his or hers" as was done in this chapter. It's just too cumbersome. This is simply for ease of reading, and definitely not meant as a slight to my female associates who make up a large and critical portion of the nation's building departments and the construction industry as a whole.

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Who Drew These Crazy Plans?

I've been a building inspector and plans examiner for a number of years. What I do most is find mistakes made by architects, designers and contractors. That puts me on the hot seat. No one likes to be told they've made a mistake, especially a dumb mistake. But that's my job. So I try to do it without ruffling any more feathers or crushing any more inflated egos than necessary.

Sometimes I can't settle a dispute without a squawk. Architects hate to admit they blew it. But most architects don't have more than a basic knowledge of the building code. Architecture schools teach good design, not code compliance. Very few offer classes on the building code. And I don't know any that require a test on the code before graduating. Maybe that's a mistake.

I'd like to say that all building inspectors and plans examiners are code experts. Like architects, they should be. But many aren't, and that's too bad. Plan checking is an important part of what should happen in every building department. If both the architect and the plans examiner miss something, the owner's going to have to live (or die) with the mistake.

Over the years, I've talked to lots of building inspectors. Nearly all claimed to run a tight ship. But I've also talked to the contractors they dealt with, and I often got quite a different story from them. One contractor I talked to said his local building department sent all plans out to a plan checking company for review and approval. Why? Didn't anyone at the building department know enough about the code to approve plans? No, chances are they were too short staffed to do an adequate review in a timely manner. Plan review is usually better and more suited to your locality when done in-house at your local building department. But often it's not practical, or there are budgetary reasons why adding more permanent employees isn't feasible. I guaranty that it costs more to send plans for outside review, but I also know first-hand how it goes when you tell a contractor it'll be 10 weeks, if he's lucky, before anyone can get to his plans.

Heck, when I'm not working at my day job, I'm doing plan review for other cities. But the money comes out of a different budget. It seems to be easier to find additional money for expenses than for salaries. It seems short-sighted to me, but I'm no economist.

So what kind of mistakes do I find on plans for a home or small commercial building? Nothing serious, usually. Sometimes it's just updating for the current codes. I do recall one time, however, when I found a room that had no door. I'm serious! No way in or out. I used to draw plans, back in the days when I was a contractor. I can guess what happened — the owner asked the designer to move the door from one wall to another. The draftsman erased the old door, filled in the wall section, went for a coffee break, and then, on his return, forgot to add the new opening. And no one caught it!

The point is that construction is too expensive and too permanent to be careless about design and code compliance. And, unfortunately, codes are written so that only the careful and determined will understand them completely, and there will always be some room for interpretation — that's just the nature of detailed and complex documents. Remember, the code is just the *bare minimum* allowed for health and safety.

"His Nibs will see you now."

C H A P T E R 2

Getting Your Permit

If you're just replacing worn-out shingles, getting a permit is simple. All you do is pay the fee at the building department. The plans examiner can check your plan (or sketch) right at the counter. Usually he'll issue a permit immediately. But if you're building something more complex, the process takes more time.

The plans examiner may need a week or more to study your plans. But he may not start on yours right away. If you're working within a specific time frame, it doesn't hurt to ask where you stand in line.

The plans examiner will return your plans with any required changes. Your architect or designer will make the revisions. Then you have to resubmit the plans for approval. If the revised set gets the OK, your permit should be granted in about a week. If more changes are required, you might have to resubmit the plans again.

How long will it take to get your plans approved? That depends on the size and complexity of the project, the backlog in the plans examiner's office and how good your plans are. As a rule of thumb, allow about a month for a custom home or a small commercial building.

What Plans Are Needed?

The plans and specs don't have to be drawn by an architect or engineer. IRC Section R106.1 says:

> ***R106.1 Submittal documents.*** *Construction documents, special inspection and structural observation programs and other data shall be submitted in one or more sets with each application for a permit. The construction documents shall be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed. Where special conditions exist, the building*

official is authorized to require additional construction documents to be prepared by a registered design professional.

Exception: The building official is authorized to waive the submission of construction documents and other data not required to be prepared by a registered design professional if it is found that the nature of the work applied for is such that reviewing of construction documents is not necessary to obtain compliance with this code.

The IRC allows exceptions which vary by location. Check the requirements for your area.

Building departments have charts and tables they use. Most builders know that 2 × 4s, 16 inches on center, will hold up the roof. No problem getting plan approval there! But if you need to know if something's strong enough to support a load, that's when you need to hire an engineer. The engineer will review your plans and make sure walls, headers, joists and supports are the proper strength. Many building departments don't have a licensed engineer on staff. If they think you need one to review your plans, they'll let you know.

The engineer certifies that the plans meet accepted engineering standards, stamps them with a seal, and sends you back to plan check. The plans examiner usually accepts the opinion of any state-licensed engineer, but does a final check to make sure that the engineer started with the right information, such as wind speed, exposure, or many of the other factors that would apply. If the plans have a mistake, obviously, you won't get immediate approval.

Most building departments request plans for remodeling work. Usually they just want to make sure you know what you're doing. If you rip out a wall, is the ceiling going to collapse? Load-bearing walls are pretty important. Check with your inspector to find out what plans are needed for your remodeling project.

What about new construction? To get a permit, you'll need three things:

1. Plans
2. Specifications
3. Engineering data and notes to back up what's on the plans or the specs

Plans vs. Specifications

Plans (also known as blueprints or drawings) show what's going to be built, and how. Specifications show the details that aren't on the plans. For example, the plans may show only an exterior door and a 3′0″ × 6′8″ opening. The specs will go further and give more detail. They may describe the door as solid core, exterior grade, two-lite, and left-hand swing. What won't fit on the plans goes in the specs. On a small job the specs may be just one page.

If the specs and the plans are different, the plans will be rejected until the conflict is cleared up. For example, suppose the specs describe a 3′6″-wide door and the plans show a 3′0″-wide opening. It's not the inspector's job to fix that. It's the owner's and his architect's responsibility. Plans and specs are equally important. What's in the plans and specs has to be consistent. The building code sees all documents as a part of the whole.

Most plans for new construction will include the following:

- Plot plan
- Foundation plan
- Floor plan
- Roof plan
- Elevations
- Any other sections or details needed to show what's being built, and how

For larger projects, the plans will usually be divided into the following:

- Architectural plans
- Structural plans
- Electrical plans
- Plumbing plans
- Mechanical plans (heating, cooling and ventilation)

For smaller projects, like houses, information on structural, electrical and mechanical parts of the building can be included in the architectural drawings.

The Plot Plan

The plot plan shows a bird's eye view of the lot and where the proposed building will be situated. It also shows parking areas and yard improvements. The plans examiner will check the plot plan carefully. He wants to be sure the building complies with local zoning ordinances.

Zoning Laws

Zoning ordinances aren't building codes, so I won't focus on them in this book. The local planning department takes care of zoning. That's where you need to go before applying for a permit. The planning department, usually found in city hall, will tell you what your local zoning ordinances require.

Can a duplex be built on this lot? What setbacks are required from the street and the property lines? How much of the lot area can the building cover? Are there any height restrictions? These are all questions that the planning department can answer.

Zoning ordinances have four broad land use categories:

1. Residential — where we live
2. Commercial — where we shop and work
3. Industrial — where goods are produced
4. Agricultural — where food is produced

Each category can also have several subcategories. For example, one zoning subcategory could be for single-family residences. Another could be for high-density residential, which could allow up to 20 dwelling units or more per acre.

What are the most important things you should know about where you're building? The zones that have been established in your community, what the restrictions are in each zone, and what's allowed in your zone, in particular.

Sometimes it's hard to tell how a neighborhood is zoned just by looking at it. You'd think your client could build a store on his lot if there's one next door. But that's not always true. The dividing line between residential and commercial zones might run right down the property line.

You can usually build "up" but not "down;" residential zoning being the highest use, followed by commercial, industrial and agricultural. So you could build a house in any of those zones if you wanted to, though it might be hard to sell. Could you put up a store in a residential zone? No. How about a factory in a residential or commercial zone? Not going to happen. What would your neighbors say if you wanted to run a hog farm in a residential, commercial or industrial zone? Well, it makes no difference what they'd say. You wouldn't be allowed to do it in the first place. Make sure you understand your local zoning ordinances.

This rule of building up, but not down, also applies within zones. Suppose there are three residential zones — single-family, duplex and multifamily — in your locale. You can usually build a single-family home in a duplex or multifamily zone. But don't try putting an apartment house in an area zoned for single-family dwellings.

The planning department can tell you what's allowed and what isn't. Zoning can sometimes be changed, but only if you have the time and money to try and get a variance approved. It's easier and cheaper to buy property zoned for the use that you want.

Other Approvals

So, you've satisfied local zoning ordinances and met requirements in the building code. What's next? Well, there may be other approvals you'll need. For one, your local fire and health departments could regulate the business you're planning. There might be requirements for water, sewer, or surface water (storm) drainage. If so, the building department may forward a set of your plans to the appropriate departments. They'll also need to give their approval. I can't stress this enough — a permit can be delayed if errors are found in your documents, so be thorough and follow the rules to the letter.

A land covenant may also affect your plans. Most communities permit landowners to make agreements called *CC&Rs*. That stands for *covenants, conditions and restrictions*. The landowners decide what type of construction or use is acceptable for their land, and file a legal document that states those conditions. When approved, CC&Rs stay with the land from one owner to the next. If you buy land in the covenant, you're obligated to comply with this agreement.

Many CC&Rs require landowners to submit plans to an architectural review board prior to construction. Your local building department isn't responsible for enforcing the CC&Rs. Be well-versed in the applicable CC&Rs before you begin drawing up plans. Some CC&Rs may seem to conflict with zoning. For instance, you could buy a plot in a zone that allows duplexes, but the CC&Rs prohibit them. This seems contradictory, but is quite legal.

You may be required to mitigate environmental aspects of your planned construction. Do your research before the plans are submitted to improve your chances of approval the first time you submit them.

What the Inspector/Plan Checker Looks At

The inspector or plan checker's job is to ensure that your plans meet code. The inspector isn't an adversary. He helps you find possible code violations before your project gets off the ground. Now's the time to find them — while they're still on paper. Changes are cheap at this stage, but substantially more expensive once you've started to build. Plan-checking is relatively straightforward if you're building to the IRC. However, if you're doing nonresidential construction, your plans must comply with the IBC, which means more specific examination. The inspector will probably use a checklist with the following guidelines.

Building Classification

Are the following aspects of the building classified correctly?

- Occupancy classification — compute the building's (or portion thereof) floor area and occupant load.
- Type of construction — determine the type of construction of the building by its use of building materials and the fire resistance of the building's parts.
- Location on property — determine the building's location on the site and appropriate clearances to property lines and other buildings from the plot plans.
- Allowable floor area — determine the building's allowable floor area.
- Height and number of stories — compute the building's height and determine the number of stories.

Code Requirements

Does the building meet the following code requirements?

- Occupancy requirements
- Construction requirements
- Egress requirements
- All other code requirements
- Structural engineering regulations and requirements for materials of construction

We'll be reviewing each of these points in the next few chapters. Chapter 3 begins with Occupancy Classification, the first subject in the checklist above.

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"Affordable? That's a matter of interpretation."

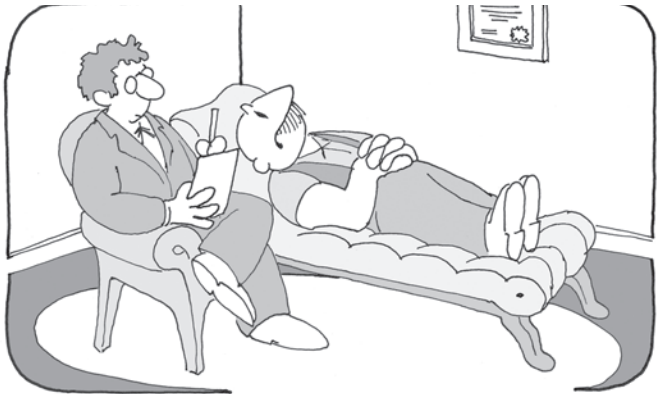
How the Code Got Affordable

The purpose of the code is to protect the safety, health and welfare of the public through better building practices. No surprise there. But some new wording has been added to the IRC. It lists *affordability* as one of your considerations in building for the welfare of the public. You can read the exact reference in IRC Section R101.3. What's important is that when faced with two good options, one being expensive and one affordable, you can opt for making the structure affordable as long as you're not sacrificing safety. The ICC has added affordability to every residential code compliance decision. I like that. Cost is important, since many Americans are getting priced out of today's housing market.

The affordability issue is one of the reasons that the ICC and the new model codes came about. Over time, the building codes became more technical and complex with each new edition. The Uniform Building Code (UBC) eventually became three volumes. But that didn't make it any easier to understand. It got to the point where contractors felt that they couldn't comply with the code without hiring an engineer and an architect — and that just added to the expense of building. The IRC, a simplified *prescriptive* code (one that tells you what to do), was created from the engineering-based performance requirements of the building code to help contractors more easily understand and comply with code requirements.

The final push for affordability becoming part of the code came from Anne VonWeller of Murray City, Utah. Anne wanted to add the words ". . . by providing construction regulations which do not unnecessarily increase construction costs." The language was debated and what you see in the 2006 IRC is the result. The goal of the code is to ensure that we continue to get so much (in safety and durability) for such a small cost. I'm all for that! If I sat on a city council or board of supervisors, I wouldn't vote to adopt any code that completely ignored cost. In truth, affordability has always influenced model codes. There are an unlimited number of requirements that could be proposed, if cost were no object. But we all know that's never the case.

So where should affordability come in when debating a point with the inspector? That's a matter of opinion, and here's mine. Affordability under the code isn't about your bank account. It's about providing a well-constructed finished product at a reasonable cost to the buyer. Adopt the role of advocate for the potential occupants. Argue that a well-informed prospective owner, understanding both sides of the issue, will generally come in on the side of saving money. If both options protect public safety, health, and welfare equally, and yours is less expensive, the code allows the building official to let affordability tip the balance.



"Yes, definitely Group I."

C H A P T E R 3

Occupancy Classifications

What's the first thing the building inspector does when he gets your plans? He confirms your building's occupancy type, which determines the Occupancy Group.

Types of Occupancy

Occupancy means a building's use or type of activity. *Occupant load* is the number of people who can safely use the space inside. These two terms are very different. We'll cover occupancy in this chapter and occupant load in the next. Hazard varies with occupancy load.

If you build only one- and two-family homes or townhouses, they're covered by the IRC, and you have no occupancy concerns. But what if you plan to build something else? Then you'll need to understand occupancy classification. That's a big subject, and it's covered in the IBC.

Occupancy Classifications

The IBC has 10 major occupancy classifications.

1. Assembly (see Section 303): Groups A-1, A-2, A-3, A-4 and A-5
2. Business (see Section 304): Group B
3. Education (see Section 305): Group E
4. Factory and Industrial (see Section 306): Groups F-1 and F-2
5. High Hazard (see Section 307): Groups H-1, H-2, H-3, H-4 and H-5
6. Institutional (see Section 308): Groups I-1, I-2, I-3 and I-4
7. Mercantile (see Section 309): Group M
8. Residential (see Section 310): Group R-1, R-2, R-3 (see also Section 101.2), and R-4

9. Storage (see Section 311): Groups S-1 and S-2
10. Utility and Miscellaneous (see Section 312): Group U

Occupancy Is Based on Degree of Hazard

Occupancy for any one building boils down to the degree of hazard associated with the type of activity that occurs there. For instance, buildings used for large gatherings (theaters, for example) have special requirements. Here's why. In an emergency, everyone wants to get out at the same time. People rush to the exits, often fighting and climbing over each other. It takes much longer to evacuate a panic-stricken mob than it does an organized group. To make buildings safe, the code focuses on two things:

1. Setting the minimum number of exits per occupant
2. Making sure the building can resist structural failure long enough for everyone in the building to get out

Occupant safety comes first. Reducing property damage comes second. So, let's look at risks to human life first.

Common Hazards

People are their own worst enemy. They gather in large groups. They use flammable liquids. They smoke, work, ignore rules, and then when something bad happens, they panic — which creates an even bigger hazard.

Day and Night Occupancy

There are two broad types of occupancy — where people work (*day* occupancy), and where they rest or sleep (*night* occupancy). Day occupancy is generally considered more hazardous. How hazardous depends on three things:

1. The type of work involved
2. The size of the work groups
3. The materials and equipment used

As you know, day and night occupancy may not be the same as actual day and night. Many people work at night or on swing shifts. Remember this when classifying a building's occupancy.

Night occupancy includes hotels, motels, apartment houses and dormitories. It *excludes* one- and two-family homes and townhouses. They're covered by the IRC, as discussed in Chapter 2 of this book. Buildings with a primary description of night occupancy can be hazardous, too. Fire may burn longer before its discovery if no one's awake.

Commercial and Industrial Hazards

This is a big category because it includes many types of use. The level of hazard depends on what's happening in the building. If it's used to store highly-combustible materials, there are special risks. And if people in the building are using combustible materials, there are even greater risks.

What lowers a building's hazard level? Two main things:

1. Fewer people per square foot of floor space
2. People in the building being familiar with exit locations and hazards

Employees in manufacturing plants know what to do in case of fire. They know where to go and where the fire extinguishers are. They have regular safety classes reinforcing how to respond in emergencies. On the other hand, the majority of shoppers in a department store don't know where all the exits are, much less the fire extinguishers.

The type of occupancy determines:

- Floor area per story and number of stories allowed
- Minimum fire and safety precautions
- Protective devices required

The code tries to balance safety and economy. It sets the minimum requirements for each type of occupancy. With this information, the decision can be made how to build.

Height and Area Hazards

How can a building's height and floor area be hazardous? Hazards to life increase as the building's height increases. You could be on a floor that firefighters can't reach by ladders from the street. And what about basement fires? Many basements don't have a direct exit to the street. That makes them difficult to evacuate in an emergency. Firefighters fear basement fires, and with good reason.

Area (or *fire area*) means the space on a single story — separate and enclosed by a fire-resisting barrier. If there's no separation and no fire barrier, *fire area* means *the entire floor space on each story*. A larger fire area means greater risk. It's harder for people to reach an exit. There could be more obstacles in the way, such as pallets or equipment. Finally, it can take longer for firefighters to reach the source of the fire.

Hazards in General

These are some obvious hazards:

- Height and floor area of the building
- Type of work being done in the building
- Spread of fire due to:
  - air currents
  - dirt and lint
  - combustible decorations and draperies
  - combustible finishes and trim
  - the structure itself
- Toxic and heated gases
- Unprotected openings
- Lack of adequate separation between areas
- Exposure or lack of separation between buildings

Again, these are the most commonly-encountered hazards. But there's one more. It's something we've talked about already: People. They panic. They act unpredictably. What's the most important thing the building official considers when he's making a decision about occupancy, especially of Group A occupancy? It's the estimated number of people who'll be in the building. We'll discuss this in depth in the next chapter, Occupant Loads.

Occupancy Groups

Under the IBC, every building or structure falls into one of 10 groups. Some groups have several divisions, intended to make classification easier. Let's look at these groups and divisions, one at a time. We'll see which activities fall into which group.

Group A Occupancies

Group A is composed of *assembly occupancies*, spaces usually intended to accommodate large numbers of people. The IBC says this:

> ***303.1 Assembly Group A.*** *Assembly Group A occupancy includes, among others, the use of a building or structure, or a portion thereof, for the gathering together of persons for purposes such as civic, social or religious functions, recreation, food or drink consumption, or awaiting transportation.*

The hazards for Group A areas are ranked high, because these areas are meant to hold a lot of people who are probably not familiar with the area. Group A has five divisions distinguished by the type of activity. The first division is considered the most hazardous to human life, followed by the other four, diminishing in risk to the last, least-hazardous division. Let's look at each of them now.

> ***A-1:*** *Assembly uses, usually with fixed seating, intended for the production and viewing of the performing arts or motion pictures including, but not limited to: motion picture theaters, symphony and concert halls, television and radio studios admitting an audience, and theaters.*

Theaters are included in the highest hazard category. Why? Because so many people are at

risk in the event of a theater fire. These fires can start with a simple spark on stage or in a backstage area. Stage productions that include fire in any form are allowed only under highly-controlled conditions.

There are two basic types of theaters — live and movie. A live theater with a stage taller than 50 feet must have a *proscenium wall*. This is a fireproof curtain of sorts that can be dropped in an emergency. When it's down, it completely separates the stage and backstage areas from the auditorium. Movie theaters aren't required to have proscenium walls.

> ***A-2:*** *Assembly uses intended for food and/or drink consumption including, but not limited to: banquet halls, night clubs, restaurants, taverns and bars.*
>
> ***A-3:*** *Assembly uses intended for worship, recreation or amusement and other assembly uses not classified elsewhere in Group A including, but not limited to: amusement arcades, art galleries, bowling alleys, places of religious worship, community halls, courtrooms, dance halls (not including food or drink consumption), exhibition halls, funeral parlors, gymnasiums (without spectator seating), indoor swimming pools (without spectator seating), indoor tennis courts (without spectator seating), lecture halls, libraries, museums, waiting areas in transportation terminals and pool and billiard parlors.*
>
> ***A-4:*** *Assembly uses intended for viewing of indoor sporting events and activities with spectator seating including, but not limited to: arenas, skating rinks, swimming pools and tennis courts.*
>
> ***A-5:*** *Assembly uses intended for participation in or viewing outdoor activities including, but not limited to: amusement park structures, bleachers, grandstands and stadiums.*

People also congregate for meetings and classes in offices or schools. Why are office and educational buildings not in Group A? Remember what I said about being familiar with the surroundings? That's the deciding factor. Most Group A buildings will be occupied by people who don't know the building layout. Office workers and students are in the same building every day. They're usually familiar with their location, allowing them to evacuate more efficiently should the need arise.

There are some exceptions to Group A occupancies.

> ***Exceptions:***
>
> *1. A building used for assembly purposes with an occupant load of less than 50 persons shall be classified as a Group B occupancy.*
>
> *2. A room or space used for assembly purposes with an occupant load of less than 50 persons and accessory to another occupancy shall be classified as a Group B occupancy or as part of that occupancy.*
>
> *3. A room or space used for assembly purposes that is less than 750 square feet (70 m²) in area and is accessory to another occupancy shall be classified as a Group B occupancy or as part of that occupancy.*

Group B Occupancies

IBC Section 304.1 describes Group B occupancies as follows:

> ***304.1 Business Group B.*** *Business Group B occupancy includes, among others, the use of a building or structure, or a portion thereof, for office, professional or service-type transactions, including storage of records and accounts. Business occupancies shall include, but not be limited to, the following...*

The code lists 17 specific uses, including:

- Animal hospitals
- Banks
- Beauty shops
- Motor vehicle showrooms
- Post offices
- Professional services (doctors, dentists)
- TV stations

These buildings have fairly low occupant loads. Employees will know the layout and where the exits are. Visitors and customers may not. But if there's an emergency, usually there'll be enough employees to show others to the exits.

This group includes Educational Occupancies for students above the 12th grade. Educational Occupancies for students in 12th grade or below are included in Group E.

Group E Occupancies

Group E occupancies are day-use education buildings, as shown in IBC Section 305.1.

> ***305.1 Educational Group E.*** *Educational Group E occupancy includes, among others, the use of a building or structure, or a portion thereof, by six or more persons at any one time for educational purposes through the 12th grade. Religious educational rooms and religious auditoriums, which are accessory to places of religious worship in accordance with Section 508.3.1 and have occupant loads of less than 100, shall be classified as A-3 occupancies.*

> ***305.2 Day care.*** *The use of a building or structure, or portion thereof, for educational, supervision or personal care services for more than five children older than 2½ years of age, shall be classified as a Group E occupancy.*

That's all pretty clear. Group E includes all buildings used for educational purposes for six or more children K-12, and day care of five or more children over 2½ years old.

There's an exception, however, when the structure is attached to a church. If used for religious education and meetings of fewer than 100 people, it's classified as Group A-3.

Group F Occupancies

Group F covers factories or manufacturing occupancy. It has two divisions; F-1 is for moderate-hazard products and F-2 is for low-hazard products. High-hazard products are covered in Group H, as described in IBC Section 306.1.

> ***306.1 Factory Industrial Group F.*** *Factory Industrial Group F occupancy includes, among others, the use of a building or structure, or a portion thereof, for assembling, disassembling, fabricating, finishing, manufacturing, packaging, repair or processing operations that are not classified as a Group H hazardous or Group S storage occupancy.*

So, if the intended use of the building is hazardous, it belongs in Group H (hazardous). If it will be used for storage, the correct category is Group S (storage). If it doesn't fit either of those groups, check Group F-1 (moderate-hazard occupancy) or F-2 (low-hazard occupancy).

F-1 Moderate-Hazard Occupancy

Section 306.2 lists 42 types of products that are moderately hazardous. Some of these are:

- Automobiles
- Brooms or brushes
- Clothing
- Electronics
- Furniture
- Metals
- Paper
- Photographic film
- Plastics

These end products aren't necessarily inherently combustible. But their manufacturing processes may use combustible materials.

F-2 Low-Hazard Occupancy

Section 306.3 lists just eight different product types.

1. Beverages (12 percent alcohol or less)
2. Bricks
3. Ceramics
4. Foundry products
5. Glass products

6. Gypsum
7. Ice
8. Metal products (fabrication and assembly)

These end products aren't considered combustible. And their finishing, packaging and processing don't involve a significant fire hazard. However, their fabricating and manufacturing may use a lot of heat. For instance, finished glass isn't combustible, but producing glass requires very high temperatures. And molten glass can set almost anything combustible on fire.

IBC Section 306.3 says that F-2 occupancies are: *Factory industrial uses that involve the fabrication or manufacturing of noncombustible materials which during finishing, packing or processing do not involve a significant fire hazard...*

Is F-2 occupancy strictly limited to the finishing, packaging and processing of these products? Or does it also include their fabrication or manufacturing? The code wording is a bit confusing. Check with your building official if you encounter a situation like this.

There's one thing that concerns me: the disclaimer before each list, "*...shall include, but not be limited to, the following...*" There's a very wide range of products manufactured today. The long list of items, some of which I gave you, in Group F-1 and the short list in Group F-2 are just examples. What if the product your factory intends to produce isn't listed? It's often hard to find a similar product in these lists, especially in the short Group F-2 list, which varies from bricks to ice. If there's no similar product listed to what you intend to manufacture, consult the local building official before you decide on an occupancy category.

Substantial heat is used to make many of these products. For ice it's exactly the opposite. How can high-heat manufacturing processes be listed under low-hazard occupancy? And why is the manufacture of brooms or brushes listed under medium-hazard occupancy? Clearly, there's some room for interpretation. But, basically it depends upon the fire load — the amount of combustible matter present that can act as a fuel to feed a fire. It's imperative for you to confirm occupancy type with your building official.

Group H Occupancies

Group H occupancies are high hazard. There are five divisions of Group H occupancies in IBC Section 307.1, based on their level of hazard.

> ***[F] 307.1 High-hazard Group H.*** *High-hazard Group H occupancy includes, among others, the use of a building or structure, or a portion thereof, that involves the manufacturing, processing, generation or storage of materials that constitute a physical or health hazard in quantities in excess of those allowed in control areas constructed and located as required in Section 414. Hazardous uses are classified in Groups H-1, H-2, H-3, H-4 and H-5 and shall be in accordance with this section, the requirements of Section 415 and the International Fire Code.*

There are 15 exceptions to this group. If you're a small-to-medium-sized contractor, you probably work mostly on dwellings and small commercial buildings, not building something to house highly-hazardous materials — that's a job for a specialty contractor. So, we'll just cover the main points of this section. The details are in the code if you need them.

IBC Section 307.2 covers the definitions of highly hazardous materials. Table 307.1(1) shows the *Maximum allowable quantities per control area of hazardous materials posing a physical hazard*. Table 307.1(2) shows the *Maximum allowable quantity per control area of hazardous materials posing a health hazard.* Above these quantities, a building is classified as High-hazard Group H. Below them, the building can be given a different classification. The level of hazard depends not only on the type of material, but also on its quantity and how it's stored.

The divisions in the high-hazard group are:

- Section 307.3 for explosive materials
- Section 307.4 for flammable materials
- Section 307.5 for materials supporting combustion
- Section 307.6 for toxic and corrosive materials, and

- Section 307.7 for semiconductor fabrication plants

Modern semiconductor fabrication plants cost approximately $1.5 billion (that's with a "b"). You probably won't be building many of them just yet.

Group I Occupancies

Group I buildings, addressed in IBC Section 308.1, usually house people who are closely supervised.

> ***308.1 Institutional Group I.*** *Institutional Group I occupancy includes, among others, the use of a building or structure, or a portion thereof, in which people are cared for or live in a supervised environment, having physical limitations because of health or age, are harbored for medical treatment or other care or treatment, or in which people are detained for penal or correctional purposes or in which the liberty of the occupants is restricted.*

The four divisions are based on:

- The ability of the occupants to respond to an emergency
- The degree of supervision

> ***308.2 Group I-1.*** *This occupancy shall include buildings, structures or parts thereof housing more than 16 persons, on a 24-hour basis, who because of age, mental disability or other reasons, live in a supervised residential environment that provides personal care services. The occupants are capable of responding to an emergency situation without physical assistance from staff. This group shall include, but not be limited to, the following: residential board and care facilities, assisted living facilities, halfway houses, group homes, congregate care facilities, social rehabilitation facilities, alcohol and drug centers and convalescent facilities.*

The distinction here is that occupants are capable of exiting the building in an emergency without physical assistance.

Also, notice the words *housing more than 16 persons*. An institutional building with five or fewer people can be classified under Group R-3. Or it can be built to comply with the IRC for one- or two-family dwellings or townhouses. If it houses between six and 16 people, it's classified in the IBC as Group R-4.

> ***308.3 Group I-2.*** *This occupancy shall include buildings and structures used for medical, surgical, psychiatric, nursing or custodial care on a 24-hour basis of more than five persons who are not capable of self-preservation. This group shall include, but not be limited to, the following: hospitals, nursing homes (both intermediate-care facilities and skilled nursing facilities), mental hospitals and detoxification facilities.*

The main point here is that occupants are not capable of self-preservation. They're not able to exit the building under their own power in an emergency. This group includes childcare facilities housing, on a 24-hour basis, six or more children 2½ years old or younger. See IBC Section 308.3.1.

If the building houses five or fewer people, it can be classified under Group R-3. Or it can be built to comply with the IRC for one- or two-family dwellings or townhouses. You have a choice.

> ***308.4 Group I-3.*** *This occupancy shall include buildings and structures that are inhabited by more than five persons who are under restraint or security. A Group I-3 facility is occupied by persons who are generally incapable of self-preservation due to security measures not under the occupants' control. This group shall include, but not be limited to, the following: prisons, jails, reformatories, detention centers, correctional centers and prerelease centers.*

Group I-3 is subdivided into five different categories. These depend on whether or not an occupant is able to move around the facility. Inmates are generally confined to particular areas.

> ***308.5 Group I-4, Day care facilities.*** *This group shall include buildings and structures occupied by persons of any age who receive custodial care for less*

than 24 hours by individuals other than parents or guardians, relatives by blood, marriage or adoption, and in a place other than the home of the person cared for.

Notice the words *for less than 24 hours*. The first three divisions were for occupants housed on a 24-hour basis. The time period makes the difference in this category.

Again, if the building houses five or fewer people, it can be classified under Group R-3. *Or* it can be built to comply with the IRC for one- or two-family dwellings or townhouses.

What about an adult care facility for more than five unrelated people? If it operates on a less-than-24-hour basis, it's classified as Group I-4. But if the occupants can respond to an emergency without help, it's classified as Group I-3. See IBC Section 308.5.1.

This group also includes child care facilities looking after six or more children, 2½ years old or younger, on a less-than-24-hour basis. If the facility houses up to 100 children, all rooms are on the exit level, and each room has an exit to the outside, it should be classified as Group E. See IBC Section 308.5.2. Finally, day care during religious functions at a place of worship doesn't qualify the facility for Group I-4.

Group M Occupancies

Group M (IBC Section 309.1) includes drug stores, department stores, shopping centers gas stations and other types of commercial occupancy.

309.1 Mercantile Group M. *Mercantile Group M occupancy includes, among others, buildings and structures or a portion thereof, for the display and sale of merchandise, and involves stocks of goods, wares or merchandise incidental to such purposes and accessible to the public. Mercantile occupancies shall include, but not be limited to, the following: department stores, drug stores, markets, motor fuel-dispensing facilities, retail or wholesale stores and sales rooms.*

Are you surprised to find gas stations (*motor fuel-dispensing facilities*) in this group? Gasoline is hazardous, you say, so why isn't it in Group H? Actually, it's rare for a fire to start while someone's pumping gas — though it *can* happen. The reason gas stations are in a less-hazardous group is in part due to the location of storage tanks and the manner in which the material is stored. The precautions required to build these facilities satisfy and can even surpass the requirements set by code. To be safe if you're planning to build a gas station, ask the local building department what its particular jurisdiction requires. It's much easier to jump through hoops if you know where they are!

Retail stores have extensive storage areas for merchandise, not only on the sales floor, but in other areas for back stock. You'll want to look at IBC Section 309.2, which refers to Table 414.2.5(1) shown in Figure 3-1. It gives the maximum allowable quantities of:

- Nonflammable solid hazardous material
- Nonflammable liquid hazardous material
- Noncombustible liquid hazardous material

It sets the limits of what can be safely stored or displayed in a single control area of Group M.

Group R Occupancies

Group R is divided into sections R-1 through R-4, described in IBC Section 310.1. The two main factors in these divisions are whether people live there all the time or just stay for a short while, and the number of people being housed.

310.1 Residential Group R. *Residential Group R includes, among others, the use of a building or structure, or a portion thereof, for sleeping purposes when not classified as an Institutional Group I. ...Residential occupancies shall include the following:*

R-1 *Residential occupancies where the occupants are primarily transient in nature, including: boarding houses (transient), hotels (transient) and motels (transient).*

TABLE 414.2.5(1)
MAXIMUM ALLOWABLE QUANTITY PER INDOOR AND OUTDOOR CONTROL AREA IN GROUP M AND S OCCUPANCIES. NONFLAMMABLE SOLIDS AND NONFLAMMABLE AND NONCOMBUSTIBLE LIQUIDS [d,e,f]

CONDITION		MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA	
Material[a]	Class	Solids pounds	Liquids gallons
A. Health-hazard materials—nonflammable and noncombustible solids and liquids			
1. Corrosives[b, c]	Not Applicable	9,750	975
2. Highly toxics	Not Applicable	20[b, c]	2[b, c]
3. Toxics[b, c]	Not Applicable	1,000	100
B. Physical-hazard materials—nonflammable and noncombustible solids and liquids			
1. Oxidizers[b, c]	4	Not Allowed	Not Allowed
	3	1,150[g]	115
	2	2,250[h]	225
	1	18,000[i, j]	1,800[i, j]
2. Unstable (reactives)[b, c]	4	Not Allowed	Not Allowed
	3	550	55
	2	1,150	115
	1	Not Limited	Not Limited
3. Water (reactives)	3[b, c]	550	55
	2[b, c]	1,150	115
	1	Not Limited	Not Limited

For SI: 1 pound = 0.454 kg, 1 gallon = 3.785 L.
a. Hazard categories are as specified in the *International Fire Code*.
b. Maximum allowable quantities shall be increased 100 percent in buildings that are sprinklered in accordance with Section 903.3.1.1. When Note c also applies, the increase for both notes shall be applied accumulatively.
c. Maximum allowable quantities shall be increased 100 percent when stored in approved storage cabinets, in accordance with the *International Fire Code*. When Note b also applies, the increase for both notes shall be applied accumulatively.
d. See Table 414.2.2 for design and number of control areas.
e. Allowable quantities for other hazardous material categories shall be in accordance with Section 307.
f. Maximum quantities shall be increased 100 percent in outdoor control areas.
g. Maximum amounts are permitted to be increased to 2,250 pounds when individual packages are in the original sealed containers from the manufacturer or packager and do not exceed 10 pounds each.
h. Maximum amounts are permitted to be increased to 4,500 pounds when individual packages are in the original sealed containers from the manufacturer or packager and do not exceed 10 pounds each.
i. The permitted quantities shall not be limited in a building equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.
j. Quantities are unlimited in an outdoor control area.

Figure 3-1 Maximum quantities of nonflammable items

R-2 *Residential occupancies containing sleeping units or more than two dwelling units where the occupants are primarily permanent in nature, including: apartment houses, boarding houses (not transient), convents, dormitories, fraternities and sororities, monasteries, vacation timeshare properties, hotels (nontransient) and motels (nontransient).*

There's a new exception to R-2 in the 2006 IBC. It allows congregate living facilities with 16 or fewer people to comply with Group R-3; see below.

R-3 *Residential occupancies where the occupants are primarily permanent in nature and not classified as Group R-1, R-2, R-4 or I.*

These include:

- Buildings with no more than two dwelling units
- Adult care facilities accommodating five or fewer people for less than 24 hours
- Child care facilities accommodating five or fewer children for less than 24 hours
- Congregate living facilities with 16 or fewer persons

This section is important if you're a small-to-medium-sized contractor, building mostly residential property. If your building doesn't clearly fit into Group R-1 or R-2, there's a good chance you can build according to the IRC for one- and two-family dwellings and townhouses. Townhouses are multiple single-family dwellings of three stories or less with separate exits. However, if your building doesn't fit the IRC you must build to the IBC.

> ***R-4*** *Residential occupancies shall include buildings arranged for occupancy as residential care/assisted living facilities including more than five but not more than 16 occupants, excluding staff.*

Group R-4 buildings must meet the IBC code requirements for Group R-3 or comply with the IRC.

Group S Occupancies

Group S includes buildings or structures used for storing nonhazardous materials. (Hazardous occupancies are included in Group H.) Group S has two divisions listed under IBC Section 311.1:

1. S-1 (Section 311.2) — for storing combustible moderate-hazard materials
2. S-2 (Section 311.3) — for storing noncombustible low-hazard materials

S-1 Moderate-Hazard Storage

Section 311.2 lists 31 products considered moderately hazardous and combustible. Some of these are:

- Aerosols
- Cardboard
- Furniture
- Glues
- Lumber
- Mattresses
- Tobacco
- Upholstery
- Woolen clothing

Car repair garages are also considered moderate-hazard storage. They must comply with the maximum allowable quantities of hazardous materials listed in IBC Table 307.1(1). See IBC Section 406.6.

S-2 Low-Hazard Storage

Section 311.3 lists 30 different materials considered low-hazard and noncombustible. These include:

- Asbestos
- Cement
- Dryers
- Electrical coils
- Empty cans
- Glass bottles
- Metal cabinets
- Mirrors
- Stoves
- Washers

Storage methods are also regulated. They can include wooden pallets, paper cartons, and paper wrappings.

Parking garages are in Group S-2. But, you say, vehicles contain gas — a combustible material. That doesn't make sense. Or does it? Remember, the gas is sealed inside the cars' gas tanks. There are no rules against lighting cigarettes in either parking garages or a vehicle itself. Therefore, in this case, a vehicle is considered noncombustible.

The lists of moderate- and low-hazard materials are by no means complete. How do you judge which category a storage building is in? It depends on whether the stored material is combustible or not. The definition of combustible is found in IBC Section 307.2, Definitions. Combustible material makes the facility S-1. Noncombustible makes it S-2. The building will be rated S-1 if *anything* in its inventory is combustible, even if 99 percent of the material is noncombustible and only one percent is combustible.

TABLE 508.2 INCIDENTAL USE AREAS	
ROOM OR AREA	SEPARATION AND/OR PROTECTION
Furnace room where any piece of equipment is over 400,000 Btu per hour input	1 hour or provide automatic fire-extinguishing system
Rooms with boilers where the largest piece of equipment is over 15 psi and 10 horsepower	1 hour or provide automatic fire-extinguishing system
Refrigerant machinery rooms	1 hour or provide automatic sprinkler system
Parking garage (Section 406.2)	2 hours; or 1 hour and provide automatic fire-extinguishing system
Hydrogen cut-off rooms, not classified as Group H	1-hour in Group B, F, M, S and U occupancies. 2-hour in Group A, E, I and R occupancies.
Incinerator rooms	2 hours and automatic sprinkler system
Paint shops, not classified as Group H, located in occupancies other than Group F	2 hours; or 1 hour and provide automatic fire-extinguishing system
Laboratories and vocational shops, not classified as Group H, located in Group E or I-2 occupancies	1 hour or provide automatic fire-extinguishing system
Laundry rooms over 100 square feet	1 hour or provide automatic fire-extinguishing system
Storage rooms over 100 square feet	1 hour or provide automatic fire-extinguishing system
Group I-3 cells equipped with padded surfaces	1 hour
Group I-2 waste and linen collection rooms	1 hour
Waste and linen collection rooms over 100 square feet	1 hour or provide automatic fire-extinguishing system
Stationary lead-acid battery systems having a liquid capacity of more than 100 gallons used for facility standby power, emergency power or uninterrupted power supplies	1-hour in Group B, F, M, S and U occupancies. 2-hour in Group A, E, I and R occupancies.

For SI: 1 square foot = 0.0929 m^2, 1 pound per square inch = 6.9 kPa, 1 British thermal unit per hour = 0.293 watts, 1 horsepower = 746 watts, 1 gallon = 3.785 L.

Figure 3-2 Incidental use areas

Group U Occupancies

Group U is a catch-all category in the IBC. It includes most of the buildings and structures that don't fall into any of the other categories. Many are accessory to single-family dwellings. They'll often be in a rural setting, but not covered by the IRC.

IBC Section 312.1 General. *Buildings and structures of an accessory character and miscellaneous structures not classified in any specific occupancy shall be constructed, equipped and maintained to conform to the requirements of this code commensurate with the fire and life hazard incidental to their occupancy. Group U shall include, but not be limited to, the following: agricultural buildings, aircraft hangars accessory to a one- or two-family residence (see Section 412.3), barns, carports, fences more than 6 feet (1829 mm) high, grain silos accessory to a residential occupancy, greenhouses, livestock shelters, private garages, retaining walls, sheds, stables, tanks and towers.*

Incidental Use Areas

In addition to the main occupancy area of a building, there can be attached areas that are rarely occupied. Furnace rooms are a good example. Their separation from the main occupancy area is the important factor. See IBC Section 508.2.2. Table 508.2 (Figure 3-2), shows the fire-resistance-rated separation required for incidental use areas. For some areas, Table 508.2 allows the installation of an automatic fire-extinguishing system without a fire barrier. In these cases, a partition must extend from floor to ceiling and resist the passage of smoke.

What about connecting doors? There are three very important requirements for fire doors. According to Section 508.2.2.1 they must:

1. Be self- or automatic-closing when smoke is detected
2. Not have air transfer openings through the opening
3. Not be undercut by more clearance than permitted by the NFPA 80 standard

NFPA 80 is the National Fire Protection Association Standard for Fire Doors and Fire Windows. This standard regulates the installation and maintenance of assemblies and protective devices. Such devices protect openings in walls, floors, and ceilings against the spread

of fire and smoke. This includes smoke inside, into, or out of buildings. The standard can be purchased from the NFPA website at www.nfpa.org or the ICC website www.iccsafe.org.

None of these requirements apply to one- or two-family dwellings or townhouses.

Mixed Occupancies

Each part of a building must be classified for occupancy as shown in IBC Section 302.1. A mixed occupancy building will fall under one of three sections:

1. Accessory occupancies, IBC Section 508.3.1
2. Nonseparated occupancies, IBC Section 508.3.2
3. Separated occupancies, IBC Section 508.3.3

Accessory Occupancies

An accessory use area could be an assembly area where people wait before going to a meeting or a performance. After waiting, they would enter the main occupancy area. Other examples are a lunchroom or support office space in a factory, administrative offices in a school, or a dormitory area in a fire station.

These spaces must be less than 10 percent of the main occupancy area of the story where they're located. Also, they can't exceed the height and area values shown in IBC Table 503 (Figure 3-3).

Accessory areas are classified for occupancy separately from the main area. The most restrictive occupancy applies to both areas. See IRC Section 508.3.1.1. This requirement doesn't apply to the following accessory areas:

- Assembly areas less than 750 square feet
- Assembly areas accessory to Group E occupancies. There is an exception to this. It *does apply* to accessibility occupancy. See IRC Chapter 11, and Chapter 23 of this book.
- Religious education rooms and auditoriums, accessory to buildings for religious worship, with fewer than 100 occupants

No separation is required between accessory occupancy and main occupancy areas. However, there are exceptions. These include Groups H-2, H-3, H-4 or H-5. See IBC Section 508.3.3.

Nonseparated Occupancies

This section applies to areas with different occupancy classifications that aren't separated. When each area is classified independently, the most restrictive requirement applies to both areas. See IBC Section 508.3.2.1.

The allowable height and area of nonseparated occupancy spaces is based on Table 503 (Figure 3-3). You always apply the most restrictive height and area provision, with any permitted increases (which we'll discuss in the next chapter) to both areas. You also apply the most restrictive fire protection provision that applies to either of the areas to both areas. See IBC Section 508.3.2.2.

Obviously, no separation is required between two nonseparated occupancy areas, unless they're in Groups H-2, H-3, H-4 or H-5. See IBC Section 508.3.3.

Separated Occupancies

This section applies to separated areas with different occupancy classifications. In this case, each area is classified independently. The occupancy requirements of each area apply to those individual areas. See Section IBC 508.3.3.1.

The allowable floor areas for separated occupancies are governed by IBC Section 508.3.3.2.

> ***508.3.3.2 Allowable area.*** *In each story, the building area shall be such that the sum of the ratios of the actual floor area of each occupancy divided by the allowable area of each occupancy shall not exceed one.*

TABLE 503
ALLOWABLE HEIGHT AND BUILDING AREAS

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HGT(feet)									
GROUP	HGT(S)	UL	160	65	55	65	55	65	50	40
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	4	5	4	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
H-1	S	1	1	1	1	1	1	1	1	NP
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP
H-2[d]	S	UL	3	2	1	2	1	2	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	3,000
H-3[d]	S	UL	6	4	2	4	2	4	2	1
	A	UL	60,000	26,500	14,000	17,500	13,000	25,500	10,000	5,000
H-4	S	UL	7	5	3	5	3	5	3	2
	A	UL	UL	37,500	17,500	28,500	17,500	36,000	18,000	6,500
H-5	S	4	4	3	3	3	3	3	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
I-1	S	UL	9	4	3	4	3	4	3	2
	A	UL	55,000	19,000	10,000	16,500	10,000	18,000	10,500	4,500
I-2	S	UL	4	2	1	1	NP	1	1	NP
	A	UL	UL	15,000	11,000	12,000	NP	12,000	9,500	NP
I-3	S	UL	4	2	1	2	1	2	2	1
	A	UL	UL	15,000	10,000	10,500	7,500	12,000	7,500	5,000
I-4	S	UL	5	3	2	3	2	3	1	1
	A	UL	60,500	26,500	13,000	23,500	13,000	25,500	18,500	9,000
M	S	UL	11	4	4	4	4	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-3	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	3	3	3	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2[b, c]	S	UL	11	5	4	4	4	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

UL = Unlimited, NP = Not permitted.

a. See the following sections for general exceptions to Table 503:
   1. Section 504.2, Allowable height increase due to automatic sprinkler system installation.
   2. Section 506.2, Allowable area increase due to street frontage.
   3. Section 506.3, Allowable area increase due to automatic sprinkler system installation.
   4. Section 507, Unlimited area buildings.

b. For open parking structures, see Section 406.3.

c. For private garages, see Section 406.1.

Figure 3-3 Allowable height and building areas

That may seem a bit complicated, so let's look at an example using the following equation where the symbol ≤ means less than or equal to (i.e. does not exceed):

$$\frac{\text{Actual floor area, Occup. 1}}{\text{Allowable floor area, Occup. 1}} + \frac{\text{Actual floor area, Occup. 2}}{\text{Allowable floor area, Occup. 2}} \leq 1$$

Let's assume the two separated areas are S-1 and S-2 occupancies, and the construction planned falls under Type IIA. The allowable floor areas for each occupancy on each story, from Table 503 (Figure 3-3), are 26,000 and 39,000 square feet, respectively.

Now, if the actual floor area for the S-1 occupancy is 20,000 square feet, then the actual floor area for the S-2 occupancy can't exceed a certain amount, which we'll call X square feet. Use the following equation to solve for X. (Remember, you must first isolate the term including X by moving the first term to the other side of the equation and changing its sign.)

$$\frac{\text{Actual floor area, S-1}}{\text{Allowable floor area, S-1}} + \frac{\text{Actual floor area, S-2}}{\text{Allowable floor area, S-2}} \leq 1$$

$$\frac{20{,}000}{26{,}000} + \frac{X}{39{,}000} \leq 1$$

$$\frac{X}{39{,}000} \leq 1 - \frac{20{,}000}{26{,}000}$$

$$\frac{X}{39{,}000} \leq 1 - 0.769$$

$$\frac{X}{39{,}000} \leq 0.231$$

$$X \leq 0.231 \times 39{,}000$$

$$X \leq 9{,}009 \text{ square feet}$$

This means that if the actual floor area of the S-1 occupancy in our Type IIA construction is 20,000 square feet, the actual floor area for the S-2 occupancy separated from it in this example must be less than or equal to (i.e. cannot exceed) 9,009 square feet. That's much less than the 39,000 square feet that would be allowed by Table 503 if the S-2 occupancy was a stand-alone building.

For separated occupancies, the most important factor is the amount of separation, in hours of fire resistance. That's not a surprise. The required separation for different occupancies is given in Table 508.3.3 (Figure 3-4).

The required separation between S-1 and S-2 occupancies is shown outlined, as one hour for sprinklered buildings and two hours for nonsprinklered.

Are You Confused?

This chapter is full of information, and at times may seem a little hard to understand. If you're confused, don't worry. It isn't possible to fit every structure ever built into one of 10 neat classifications. There's lots of room for interpretation. But most buildings fit into one of these categories. You just need to figure out which group most closely matches the building you're planning.

If you're a general building contractor with a small- to medium-sized business, there are only a few groups and divisions you need to know. And if you only build one- and two-family dwellings or townhouses, they're covered by the IRC and not the IBC. You don't have to worry about occupancy type at all.

If you have any questions, talk to the local planning or building department *early in the planning process*. They'll usually lean toward the more *restrictive* classification. And you will almost certainly argue for the more *permissive* one. The outcome may affect your building costs. But remember, it's always more expensive to make changes later than to do it right the first time. Get a decision on occupancy group as early as possible.

What's the main cause of disagreements on occupancy group? The way terms are defined and used in the IBC. Hotels and motels are a perfect example. The building code makes no distinction between the two types of buildings.

TABLE 508.3.3
REQUIRED SEPARATION OF OCCUPANCIES (HOURS)

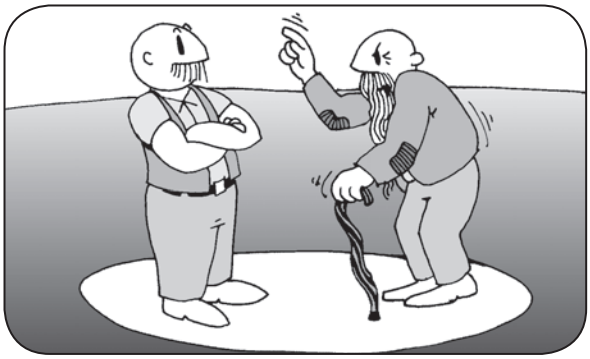
	A[e], E		I		R[d]		F-2, S-2[c,d], U[d]		B[b], F-1, M[b], S-1		H-1		H-2		H-3, H-4, H-5	
OCCUPANCY	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**
A[e], E[e]	N	N	1	2	1	2	N	1	1	2	NP	NP	3	4	2	3[a]
I	—	—	N	N	1	NP	1	2	1	2	NP	NP	3	NP	2	NP
R[d]	—	—	—	—	N	N	1	2	1	2	NP	NP	3	NP	2	NP
F-2, S-2[c,d], U[d]	—	—	—	—	—	—	N	N	1	2	NP	NP	3	4	2	3[a]
B[b], F-1, M[b], S-1	—	—	—	—	—	—	—	—	N	N	NP	NP	2	3	1	2[a]
H-1	—	—	—	—	—	—	—	—	—	—	N	NP	NP	NP	NP	NP
H-2	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	1	NP
H-3, H-4, H-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP

For SI: 1 square foot = 0.0929 m^2.
S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
NS = Buildings not equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
N = No separation requirement.
NP = Not permitted.
a. For Group H-5 occupancies, see Section 903.2.4.2.
b. Occupancy separation need not be provided for storage areas within Groups B and M if the:
1. Area is less than 10 percent of the floor area;
2. Area is equipped with an automatic fire-extinguishing system and is less than 3,000 square feet; or
3. Area is less than 1,000 square feet.
c. Areas used only for private or pleasure vehicles shall be allowed to reduce separation by 1 hour.
d. See Section 406.1.4.
e. Commercial kitchens need not be separated from the restaurant seating areas that they serve.

Figure 3-4 Required separation of occupancies

They're both Group R-1. But planners and zoning officials may say there *is* a difference. Motels have room access directly to the outside. Hotels don't. But for current building code purposes, they're both considered R-1 occupancies. That's just the way it is.

Once you've determined the occupancy group for your building, we'll look at occupant load and how it's determined. That's next, in Chapter 4.



We Didn't Build Them Like That

There's been a lot of change in the construction industry over the last 50 years. Not too long ago, I was talking with a retired carpenter friend about all the changes since he was an apprentice. My friend complained to me about the way things are being done nowadays. "They don't build 'em like we used to," he said.

He's right. And maybe that's a good thing. If you compare the quality of workmanship, today's tradesmen stand up pretty well against the tradesmen of 40 or 50 years ago. I've seen a lot of those houses from the good old days in various stages of reconstruction or remodeling. What's built today is different, and the workmanship may even be better.

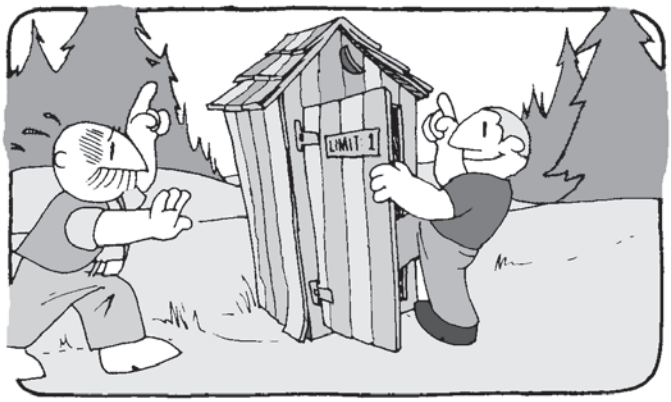
But there've been more changes in materials and techniques than in workmanship. Sheathing used to be diagonal shiplap nailed to toe studding. All the openings were hand-sawn after the walls were sheathed. Then the wall was covered with building paper and siding. It was called double-wall construction and it was used on nearly every home.

That ended in the late 1940s when plywood became popular. Nothing has been the same since. "What happened to double-wall construction?" my old friend asked. "That just don't look safe to me." Well, I'm always polite to old-timers. Maybe one day I'll be one of them myself. I believe the plywood walls we build today are much stronger than the old diagonal shiplap. Authors of the building codes seem to agree. And plywood sheathing sure goes up faster than diagonal sheathing.

There's been another major change in construction in the last 50 years. I think it's the biggest change of all. Maybe you can guess what I'm talking about. It's the building codes. There weren't any in most cities and counties way back when. Even if there *were* codes, they weren't very effective by today's standards. And sometimes they weren't even enforced.

I'm not going to claim that houses built 50 or 60 years ago aren't safe and durable. They are. Many are still being enjoyed today. But most are showing their age. Plumbing, heating and electrical systems may be unreliable or, more likely, inadequate to meet today's needs. Old houses are also more expensive to heat and cool. Floors squeak and sag. Windows stick. And they're drafty.

Don't misunderstand what I'm saying. To me, many older homes have a charm that many newer homes can't match. But you've got to make allowances if you like living in an antique. Most people want all the conveniences, and none of the inconveniences. It's for those people, especially, that building codes are written.



CHAPTER 4

Occupant Loads

Who sets occupant loads for one- and two-family dwellings and townhouses? Not the IRC — there are no occupancy rules in the IRC. It's probably the local Health and Human Services Agency. But what about IBC occupancy groups?

In the last chapter you learned that in the IBC, buildings are classified into 10 occupancy groups. Each group includes buildings with similar hazards. Later, you'll see how code requirements vary for each group. Within each group, hazards depend on occupant load. Hazards to people's lives increase when more people are in a building, which is why occupant loads are so important.

Hazards will be included in every chapter of this book because the primary concern of building codes is to save lives. If all buildings were automatically safe, we wouldn't need building codes. Unfortunately, no building is hazard-free. But we're a lot closer to that goal now than before the first model codes were adopted.

Computing Occupant Loads

So, how do you figure out occupant loads? It isn't easy. You can't just calculate how many people you can squeeze into a certain area. What the IBC is concerned about is the number of people who can safely use the space and exit unharmed in an emergency. Safety comes first in the code.

The occupant load is important to the owner. He's the person who'll be using the property. He needs to know how many people can be in the building. The other interested party is the building official. He's concerned with the risk level. That's what determines the type of occupancy, and usually the type of construction.

Two important factors in building design are:

1. Occupant load
2. The number and types of exits required (I'll discuss this in Chapter 16.)

Occupant load is covered in IBC Section 1004.1 and Table 1004.1.1 (Figure 4-1). Mark this page well in your copy of the IBC. It's one of the most useful of all the charts and tables in the code. The building designer uses this table to calculate how many people can occupy a certain size area. Column 1 describes the *building use.* Column 2 shows the *occupant load factor.* That's the minimum floor area per occupant for each type of building use.

What if the occupants of an accessory area have to exit through the primary area? If so, does the occupant load calculated for the primary area have to include the occupants of the accessory area? Yes, and that makes sense.

Some people say that Table 1004.1.1 isn't a design tool, and that it shouldn't be used that way. They're upset when designers start with the expected number of occupants and use Table 1004.1.1 to figure out the required space. Well, the table *is* a tool for the building official and the fire marshal, so why design a building they won't approve? My advice: When you're planning for a certain occupant load, use Table 1004.1.1.

IBC Section 1004.2 does allow you to exceed the occupant loads shown in Table 1004.1.1. A minimum of 7 square feet of space per occupant is allowed for each type of occupancy, provided that all other requirements of the code are also met.

Required Square Footage for Each Activity

The square footage per occupant in Column 2 goes from 5 to 500 square feet. For instance, for assembly areas without fixed seats, i.e. standing space, it's now 5 square feet per occupant.

The maximum number of people per square foot varies with the type of activity. For example, aircraft hangars are often large buildings with few people per square foot of floor space. The code allows one person in the hangar for each 500 square feet. So for a 5,000 square foot hangar, the design occupant load would be 10.

Compare that to *Assembly areas without fixed seats,* the seventh section in the table.

TABLE 1004.1.1
MAXIMUM FLOOR AREA ALLOWANCES PER OCCUPANT

FUNCTION OF SPACE	FLOOR AREA IN SQ. FT. PER OCCUPANT
Accessory storage areas, mechanical equipment room	300 gross
Agricultural building	300 gross
Aircraft hangars	500 gross
Airport terminal	
Baggage claim	20 gross
Baggage handling	300 gross
Concourse	100 gross
Waiting areas	15 gross
Assembly	
Gaming floors (keno, slots, etc.)	11 gross
Assembly with fixed seats	See Section 1004.7
Assembly without fixed seats	
Concentrated (chairs only—not fixed)	7 net
Standing space	5 net
Unconcentrated (tables and chairs)	15 net
Bowling centers, allow 5 persons for each lane including 15 feet of runway, and for additional areas	7 net
Business areas	100 gross
Courtrooms—other than fixed seating areas	40 net
Day care	35 net
Dormitories	50 gross
Educational	
Classroom area	20 net
Shops and other vocational room areas	50 net
Exercise rooms	50 gross
H-5 Fabrication and manufacturing areas	200 gross
Industrial areas	100 gross
Institutional areas	
Inpatient treatment areas	240 gross
Outpatient areas	100 gross
Sleeping areas	120 gross
Kitchens, commercial	200 gross
Library	
Reading rooms	50 net
Stack area	100 gross
Locker rooms	50 gross
Mercantile	
Areas on other floors	60 gross
Basement and grade floor areas	30 gross
Storage, stock, shipping areas	300 gross
Parking garages	200 gross
Residential	200 gross
Skating rinks, swimming pools	
Rink and pool	50 gross
Decks	15 gross
Stages and platforms	15 net
Warehouses	500 gross

For SI: 1 square foot = 0.0929 m^2.

Figure 4-1 Maximum floor area allowances per occupant

People often stand shoulder to shoulder in any assembly area with standing space only, the second item. In this case, the required space is 5 square feet per occupant. If your assembly area has 1,000 square feet of floor, the design occupant load is 200.

How did the developers of the code arrive at 5 square feet per occupant? That's the normal amount of space a person needs to stand and act normally. For example, if you stood in a space 2 feet wide by 2½ feet long (5 square feet), you'd be comfortable for a while. You'd have some room to turn around and stretch a little, but you wouldn't want to do it for an extended period of time. Just long enough to assemble for an upcoming event.

There are three types of assembly areas described in Table 1004.1.1:

1. Gaming floors
2. Assembly with fixed seats
3. Assembly without fixed seats

Their occupant loads are as follows:

- Gaming floors — one person per 11 square feet, *gross*
- Assembly with fixed seats and no dividing arms — one person per 18 inches of seating length
- Seating booths — one person per 24 inches of seat back length
- Assembly without fixed seats — one person per 5 square feet *net* for standing room only
- Assembly with unfixed chairs in the area — one person per 7 square feet, *net*
- Assembly with both chairs and tables in the area — one person per 15 square feet, *net*

Note the use of the terms *gross* and *net*. *Gross* is the total floor area inside the perimeter of the building's exterior walls. It includes:

- Corridors
- Stairways
- Closets
- Toilet rooms
- Mechanical rooms
- Interior walls
- Columns and other features

Net is simply the occupied area.

Computing the Size of Your Building

The plans examiner/building inspector will use IBC Table 1004.1.1 to check the occupant load when you submit your plans. So it makes sense for your architect or designer to use the same occupant load number. If you know how many people will be using the building, use Table 1004.1.1 to compute the square footage needed. Multiply the number of occupants by the square footage per person in the table. This gives you the total area of floor space required.

This figure is the *minimum* floor space for that occupancy type and number of occupants. As far as the IBC is concerned, you can construct the building larger than this minimum — as large as the owner's wallet will allow. But remember, you *can't* build it smaller than the minimum.

Computing Building Size for Mixed Occupancies

Many buildings house different occupancy groups. What if you're designing a mixed-occupancy building? Go through the same steps as for a single-occupancy building. Just repeat them as many times as necessary. Schools are a good example. Besides classrooms, there are auditoriums, gymnasiums, vocational shops, libraries and administrative offices. Each has its own requirements. Refer again to Table 1004.1.1, Figure 4-1.

Let's look at an example. Suppose the design is for a building to house a lodge (like the one in Figure 4-2), with a membership of 250 people. You're told that on dance nights there may be as many as 400 people in the building. All 400 of them could be on the dance floor at the same time. There must be a dining room for 150

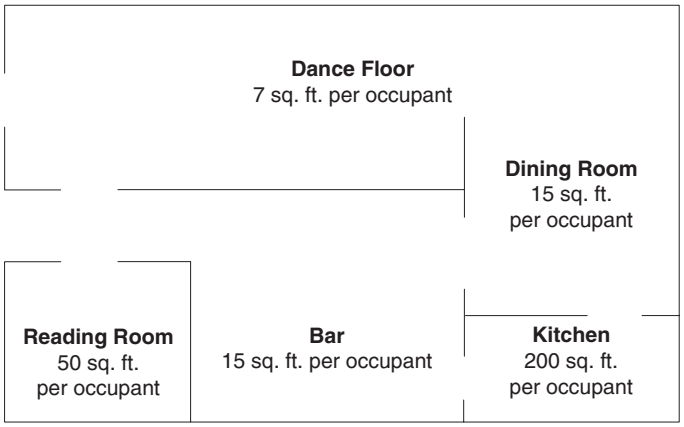


Figure 4-2 Preliminary sketch of a lodge building

people and a bar that will hold 100. The kitchen will have a staff of four. The library or reading room is expected to be used by about 10 people at a time.

How much space do you have to provide? For now, let's assume that other problems such as fire-resistance and type of construction have been solved. What we're after is just the amount of space the building will need.

In Table 1004.1.1, which type of space usage is closest to a lodge? A lodge is where people assemble for meetings, dances, dining, drinking, etc. These are all assembly activities, so your main usages have to fall into one of the three assembly categories:

1. Assembly — gaming floors
2. Assembly with fixed seats — theaters and auditoriums, or
3. Assembly without fixed seats

Assembly without fixed seats is the closest. There are three usage types under this general category:

1. Concentrated (chairs only — not fixed)
2. Standing space
3. Unconcentrated (tables and chairs)

The dance floor will only have chairs, so that will be concentrated. The dining room and bar will have both tables and chairs, so that will be unconcentrated. The reading room will fall under a different category (library/reading room). The kitchen will be categorized as kitchen, commercial. There are different square footage requirements for each area, as shown in Figure 4-3.

Now let's calculate the floor area for each room:

Dance floor:
400 people × 7 sq. ft. = 2,800 sq. ft.

Dining room:
150 people × 15 sq. ft. = 2,250 sq. ft.

Bar:
100 people × 15 sq. ft. = 1,500 sq. ft.

Kitchen:
4 people × 200 sq. ft. = 800 sq. ft.

Reading room:
10 people × 50 sq. ft. = 500 sq. ft.

TOTAL:
664 people = 7,850 sq. ft.

The building will have an occupant load of 664 based on 7,850 square feet of floor area. You'll also need about 250 square feet for the entrance hall, bringing your total building space to 8,100 square feet. That's a rectangular building, approximately 70 × 115 feet.

Remember, the lodge membership is 250. The maximum number of people in the building is only expected to be 400 (including guests). So how must you design the building? Not for just 400 people. The building has to accommo-

MAXIMUM FLOOR AREA ALLOWANCES PER OCCUPANT	
FUNCTION OF SPACE	FLOOR AREA IN SQ. FT. PER OCCUPANT
Assembly without fixed seats:	
Concentrated (chairs only — not fixed)	7 net
Unconcentrated (tables and chairs)	15 net
Library:	
Reading rooms	50 net
Kitchens, commercial	200 gross

Figure 4-3 Maximum floor area allowances per occupant

date the *total* maximum occupant load of each room at any one time. So, even though the total occupant load of the building is only planned to be 400 people, you must design the building for 664 people. That's the total of the *maximum occupant load of each separate room.*

Occupancy Type vs. Occupant Load?

We've determined the occupant load for one particular building. Don't confuse this with occupancy *type*, from Chapter 3. Occupancy type is the kind of business or operation carried on in the building. Occupant load is the number of people allowed to occupy the building while it's in use or open for business.

Type of Construction vs. Occupancy Type

What about the more restrictive requirements of the different occupancy groups? They can change the shape, size and capacity of a proposed building. But there may be tradeoffs you can make. Up to this point we've been dealing mostly in generalities. Let's get a little more specific.

Buildings or parts of buildings in any occupancy group must be built following specific ground rules. These are known as Construction Types: Type I, II, III, IV or V. We'll explain types of construction in a moment. However, they generally can't exceed the area and height limits specified in IBC Sections 503, 504 and 506. These sections govern the gross floor area, and the height of buildings in feet and number of stories, for each occupancy group.

Building Height vs. Type of Construction

The code is safety-driven. The biggest recognized danger to occupants is fire. Building height and type of construction are key elements of:

- How fast a fire spreads
- How hard it is to get the people out
- How difficult it is to fight the fire

Getting people to safety is more critical than firefighting. The code sees a difference between individual safety (occupants) and public safety (everybody else). Good firefighting access helps everyone.

Look at IBC Table 503, Figure 4-4. (This table is featured more than once in this book, as it has information for the subjects covered in several chapters.) Look at the Group row. This gives the maximum building height in feet for each type of construction. For example, the maximum building height for Type IB construction is 160 feet. For Type IIB it's 55 feet. For Type IV it's 65 feet.

TABLE 503
ALLOWABLE HEIGHT AND BUILDING AREAS

HEIGHT LIMITATIONS SHOWN AS STORIES AND FEET ABOVE GRADE PLANE. AREA LIMITATIONS ARE DETERMINED BY THE DEFINITION OF "AREA, BUILDING," PER STORY

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HGT(feet)									
GROUP	HGT(S)	UL	160	65	55	65	55	65	50	40
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	4	5	4	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
H-1	S	1	1	1	1	1	1	1	1	NP
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP
H-2[d]	S	UL	3	2	1	2	1	2	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	3,000
H-3[d]	S	UL	6	4	2	4	2	4	2	1
	A	UL	60,000	26,500	14,000	17,500	13,000	25,500	10,000	5,000
H-4	S	UL	7	5	3	5	3	5	3	2
	A	UL	UL	37,500	17,500	28,500	17,500	36,000	18,000	6,500
H-5	S	4	4	3	3	3	3	3	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
I-1	S	UL	9	4	3	4	3	4	3	2
	A	UL	55,000	19,000	10,000	16,500	10,000	18,000	10,500	4,500
I-2	S	UL	4	2	1	1	NP	1	1	NP
	A	UL	UL	15,000	11,000	12,000	NP	12,000	9,500	NP
I-3	S	UL	4	2	1	2	1	2	2	1
	A	UL	UL	15,000	10,000	10,500	7,500	12,000	7,500	5,000
I-4	S	UL	5	3	2	3	2	3	1	1
	A	UL	60,500	26,500	13,000	23,500	13,000	25,500	18,500	9,000
M	S	UL	11	4	4	4	4	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-3	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	3	3	3	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2[b, c]	S	UL	11	5	4	4	4	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

UL = Unlimited, NP = Not permitted.

a. See the following sections for general exceptions to Table 503:
   1. Section 504.2, Allowable height increase due to automatic sprinkler system installation.
   2. Section 506.2, Allowable area increase due to street frontage.
   3. Section 506.3, Allowable area increase due to automatic sprinkler system installation.
   4. Section 507, Unlimited area buildings.

b. For open parking structures, see Section 406.3.

c. For private garages, see Section 406.1.

d. See Section 415.5 for limitations.

Figure 4-4 Allowable height and building areas

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[e]	B	A[e]	B	HT	A[e]	B
Structural frame[a]	3[b]	2[b]	1	0	1	0	HT	1	0
Bearing walls									
Exterior[g]	3	2	1	0	2	2	2	1	0
Interior	3[b]	2[b]	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[f]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	$1^1/_2$[c]	1[c, d]	1[c, d]	0[c, d]	1[c, d]	0[c, d]	HT	1[c, d]	0

For SI: 1 foot = 304.8 mm.

a. The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.

b. Roof supports: Fire-resistance ratings of structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

c. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

d. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

e. An approved automatic sprinkler system in accordance with Section 903.3.1.1 shall be allowed to be substituted for 1-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of the code or used for an allowable area increase in accordance with Section 506.3 or an allowable height increase in accordance with Section 504.2. The 1-hour substitution for the fire resistance of exterior walls shall not be permitted.

f. Not less than the fire-resistance rating required by other sections of this code.

g. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

Figure 4-5 Fire-resistance rating requirements

The column on the left shows the type of occupancy. The other rows and columns give the number of stories (and the floor area square footage for each story) allowed for each occupancy and type of construction. We'll cover the different types of construction in Chapter 7. For now, all you need to know is that there are five main types of construction. Type I is the most fire-resistant; Type V is the least. Table 503 shows how the type of construction governs the maximum height of a building. If you want your building a certain height, you have to follow the rules for the correct occupancy type.

Four of the five types of construction (I, II, III and V) have two columns, A and B. These are the two different levels of fire resistance, spelled out in IBC Table 601 (Figure 4-5), for different building elements. Generally speaking, column A provides a higher level of fire resistance.

Type IA construction is as fire-resistant as you can get. This type of construction has no height limitations; it's unlimited (UL). Type IB construction may go as high as 160 feet. Less fire-resistant types of construction range from a height of 65 feet to a low of 40 feet. Confused yet? There's more. In addition to height limitation, there are a maximum number of stories allowed. The first row for each occupancy group has an S (for story) in the second column. So, even though in Type IB construction a building can be 160 feet tall, for Group A-1 occupancy it can only have five stories. If you planned to build to the maximum 160-foot height, each story would be about 32 feet high. That's not very practical.

On the other hand, if you plan a Type IB construction building for Group A-2 occupancy, you can have 11 stories in your 160-foot maximum height. This would mean that each story would be about 14½ feet. Or you could have a 40-foot first story with ten 12-foot stories above it. That's still not very practical. But you don't have to build to the maximum allowable height. Perhaps you decide to build 11 stories, each 10 feet high. The total building would then be 110 feet high.

If you plan to use Type IA construction, you can have an unlimited number of stories and unlimited building height, with two exceptions — H-1 and H-5 occupancy types.

Increases in the Maximum Building Height

The IBC allows increases in maximum height limits if you install certain safety equipment, such as an automatic sprinkler system, but only if it's approved in accordance with IBC Section 903.3.1.1. In that case, IBC Section 504.2 allows a 20-foot height increase and one additional story. Other restrictions could apply. See the code for details.

The height of towers, spires, steeples and other roof constructions made of noncombustible material are limited only by structural design, as long as they're not used for living or storage. They must be designed as part of the total structure, as Section 504.3 states. If they're built of combustible material, they can't be more than 20 feet above the height limitations in IBC Table 503 (Figure 4-4).

Allowable Floor Area per Story

Allowable floor area per story is also included in Table 503 for the five construction types and 10 occupancy groups. These are designated by the letter A in the second column in the second row in each occupancy group. For Type IA or IB construction and Group A-1 occupancy, there are no limits on the allowable floor area for each story. However, for Type II construction and Group A-1 occupancy, the floor area limits are 15,500 square feet for Type IIA and 8,500 square feet for Type IIB.

Allowable Area Increases

Table 503 may seem restrictive. The good news is that there are several ways to increase the basic allowable floor area. One way is to use a higher type of construction. Let's say your contract is for a single-story factory building to manufacture ceramics. That puts it in Group F-2 occupancy. You'd like your architect to design it to Type IIB construction to keep the cost down. However, you see that the maximum floor area per story would be limited to 23,000 square feet. That's small for a ceramics manufacturing facility, and doesn't meet the owner's needs. You could add one or two more stories, which are allowed under the IBC. But the owner wants all the space on the ground floor, so that wouldn't work.

What to do? Have your architect design the building to a higher type of construction. By going to Type IIA construction, the allowable floor area expands to 37,500 square feet. If that's still not big enough, the floor area can be unlimited if the building is designed for either Type IA or IB construction. However, higher types of construction cost more money, and may not be realistic.

A more practical solution is found in IBC Section 507, Unlimited Area Buildings. In Section 507.2, you'll find that Group F-2 buildings can be unlimited in size, and may not even require sprinklers, provided they're surrounded by public ways or open spaces at least 60 feet in width. Some other occupancy group buildings can be unlimited in size under different sets of conditions. If you want to construct a larger building than allowed by Table 503, check in Section 507.

There are other ways to increase the allowable floor area for a particular type of occupancy. These are based on either the building frontage or the installation of automatic sprinkler systems, as you can see in IBC Sections 506 and 507. To calculate the floor area increase, refer to Sections 506.1, 506.2, 506.3 and 506.4. The general equation for allowable floor area is given in Equation 5-1, shown below. This includes two important figures, I_f and I_s. The first is an area increase due to frontage and the second an area increase due to sprinklers. These figures are calculated in Sections 506.2 and 506.3. This may look complicated, but if you work through it slowly, it's quite simple.

> ***506.1 General.*** *The areas limited by Table 503 shall be permitted to be increased due to frontage (I_f) and automatic sprinkler system protection (I_s) in accordance with the following:*
>
> $A_a = \{A_t + [A_t \times I_f] + [A_t \times I_s]\}$ *(Equation 5-1)*

where:

A_a = *Allowable area per story (square feet).*

A_t = *Tabular area per story in accordance with Table 503 (square feet).*

I_f = *Area increase factor due to frontage as calculated in accordance with Section 506.2.*

I_s = *Area increase factor due to sprinkler protection as calculated in accordance with Section 506.3.*

A basement area doesn't have to be included in the total allowable area as long as it doesn't exceed the area allowed for a one-story building.

Now we'll calculate I_f and I_s.

Frontage Factor Increase in Allowable Floor Area, I_f

IBC Section 506.2 explains how to calculate I_f.

506.2 Frontage increase. *Every building shall adjoin or have access to a public way to receive an area increase for frontage. Where a building has more than 25 percent of its perimeter on a public way or open space having a minimum width of 20 feet (6096 mm), the frontage increase shall be determined in accordance with the following:*

$I_f = [F/P - 0.25] \times W/30$ *(Equation 5-2)*

where:

I_f = *Area increase factor due to frontage.*

F = *Building perimeter which fronts on a public way or open space having 20 feet (6096mm) open minimum width (feet).*

P = *Perimeter of entire building (feet).*

W = *Width of public way or open space (feet) in accordance with Section 506.2.1.*

It's best to have as much of the building front on a public way or open space as possible. Look at the example following. It shows the difference between a square building and a rectangular one, both with a 1,000-foot perimeter (i.e. P = 1,000).

Square Building

For a square building with just one frontage onto a public way, F = 250 feet (i.e. one side of the square). So:

F/P = 250 / 1,000 = 0.25

From Equation 5-2, you must deduct 0.25 from the F/P factor. Now, (F/P – 0.25) equals *zero,* so I_f also equals zero. There's no floor area increase allowed over Table 503 for this square building — with only one side fronting on a public way or open space.

But if the square building has two frontages onto a public way or open space — front and back (or any two sides), then F is now 500 feet (i.e. two sides of the square).

(F/P – 0.25) = (500 / 1,000 – 0.25) = 0.25

You're now allowed a 25 percent increase in the floor area of the building.

If the building has three or four frontages onto a public way or open space, (F/P – 0.25) equals 0.5 or 0.75, respectively —you're allowed a 50 percent or 75 percent increase in floor area of the building.

For a Square Building

Number of Sides Fronting on a Public Way or Open Space	Allowable Floor Area Increase Over the Table 503 Area
1	0 percent
2	25 percent
3	50 percent
4	75 percent

Rectangular Building (4-to-1)

Let's assume our building has a 4-to-1 length-to-depth ratio (400 feet long x 100 feet deep). The perimeter (P) is still 1,000 feet. If one long side (F) fronts on a public way or an open space:

(F/P – 0.25) = (400 / 1,000 – 0.25) = 0.15

You're allowed a 15 percent increase in area for a 4-to-1 rectangular building with one

long side frontage for the same Table 503 floor area. This compares to no increase in area for a square building of the same perimeter length.

Now let's consider two, three or four sides fronting on a public way or open space. Depending upon whether the frontage sides are short or long, the allowable increases in floor area work out as follows:

For a Rectangular Building (4-to-1)

Number of Sides Fronting on a Public Way or Open Space	Allowable Floor Area Increase Over the Table 503 Area
1 long side	15 percent
2 long sides	55 percent
1 long & 1 short side	25 percent
1 long & 2 short sides	35 percent
2 long & 1 short side	65 percent
All 4 sides	75 percent

You can see the advantage of a rectangular building compared to a square building in increasing allowable floor area. This is especially true for two long sides, or two long sides and one short side, fronting on a public way or open space. But there's a trade-off. A rectangular building has a smaller floor area than a square building with the same perimeter length.

Width of Public Way or Open Space

There's another floor area increase factor to consider, *W/30*. This addresses the width of the public way or open space onto which the building fronts (not the width of the building).

> ***506.2.1 Width limits.*** *"W" must be at least 20 feet (6096 mm). Where the value of W varies along the perimeter of the building, the calculation performed in accordance with Equation 5-2 shall be based on the weighted average of each portion of exterior wall and open space where the value of W is greater than or equal to 20 feet (6096 mm). Where W exceeds 30 feet (9144 mm), a value of 30 feet (9144 mm) shall be used in calculating the weighted average, regardless of the actual width of the open space.*

There are four important points to note here:

1. If the public way or open space onto which the building fronts is less than 20 feet wide, no floor area increase is allowed. See IBC Section 506.2.

2. If the width of the public way or open space is at least 20 feet, but less than 30 feet, you would reduce the allowable floor area increase proportionately. For example, if the public way or open space around the entire perimeter is exactly 20 feet wide, multiply your allowable increase due to frontage by 20/30. This means you'd be allowed to increase the floor area by only $^{2}/_{3}$ of what it would be if the public way or open space were 30 feet wide.

3. If the width of the public way or open space around the perimeter varies between 20 and 30 feet, you must take a weighted average for your width. Then divide the weighted average by 30 to get the fraction of the floor area increase allowable had all the public way been 30 feet wide.

   Let's calculate a weighted average for a public way or open space with varying widths around the perimeter of a building:
   10% is 20 ft wide 10 × 20 = 200
   30% is 24 ft wide 30 × 24 = 720
   60% is 30 ft wide or more 60 × 30 = 1,800
   These total 2,720.

   Divide this total, 2,720, by 100 to get the weighted average width for the public way: 2,720 / 100 = 27.20 feet. Your allowable floor area increase is 27.20/30, or approximately $^{9}/_{10}$ of what it would be if the entire public way were 30 feet wide all the way around the building.

4. If the width of the public way or open space is greater than 30 feet, you must still use a figure of 30 for the value of *W*. So any width greater than 30 feet isn't beneficial in increasing allowable floor area.

There *is* an exception that allows the *W/30* factor to be increased. It's for buildings that meet all the conditions of IBC Section 507, Unlimited Area Buildings, including a requirement that the building *be surrounded and adjoined by public ways or yards not less than 60 feet wide.*

Sprinkler Factor Increase in Allowable Floor Area, I_S

The other way to increase the allowable floor area set by Table 503 is to install an automatic sprinkler system. IBC Section 506.3 says:

> ***506.3 Automatic sprinkler system increase.*** *Where a building is equipped throughout with an approved automatic sprinkler system in accordance with Section 903.3.1.1, the area limitation in Table 503 is permitted to be increased by an additional 200 percent (I_S = 2) for buildings with more than one story above grade plane and an additional 300 percent (I_S = 3) for buildings with no more than one story above grade plane. These increases are permitted in addition to the height and story increases in accordance with Section 504.2.*

If you install an automatic sprinkler system in a multistory building, you're allowed an *additional* 200 percent of the Table 503 area. That's the same as multiplying the original allowed area by 3. And for a single-story building, you're allowed an additional 300 percent of the Table 503 area.

Let's look at an example. We'll say Table 503 currently permits us 10,000 square feet of floor area (A_t = 10,000) in our single-story building. By adding an automatic sprinkler system, we can increase our allowed floor area (A_a) by 300 percent (I_s = 3) using the following formula:

$$A_a = \{A_t + [A_t \times I_s]\}$$

$$A_a = \{10{,}000 + [10{,}000 \times 3]\}$$

$$A_a = 10{,}000 + 30{,}000$$

$$A_a = 40{,}000 \text{ square feet}$$

The automated sprinkler system will increase the allowable floor area from 10,000 to 40,000 square feet. That's like multiplying the original permitted area by 4.

Both of these sprinkler system increases are *in addition to* the percentage increases in floor area allowed by frontage considerations. So if you get no floor area increase allowance for frontage (e.g. a square building with only one frontage), there's still a way to get it. If you install an automatic sprinkler system, multiply the Table 503 numbers by a factor of 3 for a multistory building, or 4 for a single-story building.

But wait! There's an important exception that can eliminate these allowed increases. It's when you're dealing with occupancies in Groups H-1, H-2, or H-3. For mixed-use occupancies, with some areas of H-2 or H-3, you may be allowed an area increase in the non-H-2 or H-3 areas. See IBC Section 508.3.3.2.

Fire Walls

There's one other way to increase the allowable floor area — create area separation. IBC Section 705 allows each portion of a building, separated by one or more fire walls, to be considered a separate building. There are detailed provisions that specify the fire wall requirements and fire-resistance rating that control their application.

What if the occupancy restrictions for a building type limit the building size you can construct to smaller than you require, even after you've applied the frontage factor and sprinkler factor increases available? The solution may be to create "separate buildings" by installing fire walls. Usually, this means you need to install 3-hour fire-resistant-rated fire walls. See IBC Table 705.4 (Figure 4-6). But notice footnote "*a*". If you're using Types II or V construction, you can install a 2-hour fire wall for certain occupancy group buildings.

This may seem like a simple solution to the problem. But be aware that creating "separate buildings" with fire walls will limit the frontage area increases otherwise available to you. You'll no longer have the necessary width of public

TABLE 705.4 FIRE WALL FIRE-RESISTANCE RATINGS	
GROUP	FIRE-RESISTANCE RATING (hours)
A, B, E, H-4, I, R-1, R-2, U	3[a]
F-1, H-3[b], H-5, M, S-1	3
H-1, H-2	4[b]
F-2, S-2, R-3, R-4	2

a. Walls shall be not less than 2-hour fire-resistance rated where separating buildings of Type II or V construction.
b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.4 and 415.5.

Figure 4-6 Fire wall fire-resistance rating requirements

way or open space on the sides of the "separate buildings" separated by fire walls. So there are trade-offs which you'll probably need professional advice to resolve.

Also be sure to check the specific provisions on vertical and horizontal continuity and the configuration of the fire-resistant elements in Chapter 7 and the section on fire walls in Chapter 8 of this book.

Building Floor Area Limitation

There's one final situation to be aware of when calculating allowable floor area, A_a, and the number of stories you can build. IBC Section 506.4 says that you can build two or three stories above grade, each with the same allowable floor area, A_a. But if you want to build more than three stories above grade, you must do one of the following:

- Restrict the average floor area of each story to the allowable first floor area, A_a, multiplied by three and divided by the number of stories.
- Construct an unlimited area building as set out in Section 507.
- Install an automatic sprinkler system throughout the building in accordance with IBC Section 903.3.1.2, providing each story with the maximum allowable floor area, A_a.

Say you want to build a four-story building (assuming Table 503 permits four stories). You're planning it for Group S-2 occupancy with Type IIB construction. Table 503 allows a 26,000-square-foot first-floor area. But you're only allowed a total building floor area of 3 × 26,000 square feet. That's 78,000 square feet for the four stories. So if you want to build the first story with a 26,000-square-foot floor area, you have to build the second, third and fourth stories with an average floor area of 17,333 square feet each ([78,000 – 26,000 = 52,000] ÷ 3).

You could build all four stories with 19,500 square feet of floor area, since 78,000 ÷ 4 = 19,500 square feet. Or you could build to an unlimited (UL) type of construction, or install an automatic sprinkler system throughout the building. Then you could build each of the four stories to the full 26,000-square-foot floor area.

Automatic Sprinkler Exception

The automatic sprinkler systems referred to in the exception to IBC Section 506.4 have to meet the requirements of Section 903.3.1.2. This directs you to the NFPA 13R (with an R) standard. Section 903.3.1.1, by comparison, directs you to the NFPA 13 (*without* an R) standard. NFPA 13 systems are much more common. NFPA 13R systems are only applicable to residential-type occupancies.

For other types of occupancy, simply installing an NFPA 13-approved automatic sprinkler system wouldn't allow the floor areas of the upper stories to be increased. But, it *would* allow the first floor area of a Group I-1, Type IIA building to be greater than the 19,000 square feet allowed by Table 503. So in this instance, the 19,000 square feet allowance can be multiplied by 3 for the sprinkler allowance, giving a total first floor allowance of 57,000 square feet. If you want to build a four-story building, you have 3 times that figure (171,000 square feet) to play with for the four stories. You could build each of them as large as 42,750 square feet (171,000 ÷ 4).

As you can see, there are lots of trade-offs if you're resourceful. To get the optimum allowable floor area, building type, sprinklered/nonsprinklered, fire wall, etc. combination, I recommend that you consult an engineering professional.

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Tree Houses Are Buildings, Too

Most building codes require a permit for nearly any type of structure. The codes define a structure as any two or more parts designed to act as a whole. That means nearly anything you can swing a hammer at needs a permit.

I live in a part of Washington where nearly every kid has built at least one tree house in his life. Construction of tree houses in Kennewick is pretty serious business. And it isn't just the kids who get involved. Moms and Dads help with design, purchase the materials, and sometimes get roped into construction, too.

Some of these tree houses were works of art and something to be proud of. But others were less attractive, and of course the people who had to look at them day in and day out considered them eyesores and wanted them removed. I'll admit that in the winter, with the trees bare, they were pretty noticeable. But in the summer they were usually hidden by leaves.

Well, eventually there were enough complaints about tree houses that the city fathers had to take official notice. They asked me to research the code and come up with a proposal. I took the police chief and the fire chief into my confidence. We toured the town, looking at tree houses, and talking to the kids, their parents and their neighbors.

We found that not one tree house had been built with a permit. Some had electrical power from extension cords run up from the house below. Several even had small heaters in them.

After our research was completed, the three of us drafted an exception to the code. Tree houses would be legal as long as they didn't exceed 36 square feet of floor, had no artificial lights except flashlights, and were built in trees behind the setback line of the house. That kept them out of the front yards.

The city council agreed with our suggested ordinance, held the necessary public hearings (no one showed up!), and duly enacted our draft into law. It didn't cause much of a stir in town, but it did make the national press. I heard from places all around the country about our "tree house ordinance."

And to think it all started in Kennewick.

"What height and area requirements?"

CHAPTER 5

Special Detailed Occupancy Group Requirements

This chapter covers detailed requirements specific to each occupancy group. Remember, there are 10 different occupancy groups. Let's go through them one at a time. Later, we'll look at general requirements for all types of occupancy.

Group A Occupancies

Group A occupancies are buildings or areas where people gather. They include areas for:

- Civic, social or religious functions
- Recreation
- Food or drink consumption
- Awaiting transportation

Movie theaters and theaters showing live performances fall within this group. There are special requirements for theaters, especially for projection rooms, as explained in IBC Section 409. Projection system lamps produce considerable heat. And cellulose acetate film is flammable. The move to digital-based movie storage will reduce or eliminate this hazard, but as long as theaters are still running film, strict rules will remain to address this issue.

Automatic Sprinklers

Group A occupancies usually need automatic sprinklers. See IBC Section 903.2.1.

Groups A-1, A-2, A-3 and A-4 require sprinklers throughout the occupancy floor area. Sprinklers must also be installed on all floors between the occupancy area and the exit discharge level. Sprinklers are only required in specific Group A-5 areas when the space exceeds 1,000 square feet, as detailed under Group A-5 below. Let's look at each of the five divisions.

Group A-1, Theaters, etc.

Sprinklers must be installed for fire areas:

- More than 12,000 square feet
- For more than 300 people
- Not on the exit discharge level
- Containing a multi-theater complex

Group A-2, Restaurants, Banquet Halls, etc.

Sprinklers must be installed for fire areas:

- More than 5,000 square feet
- For more than 100 people
- Not on the exit discharge level

Group A-3, Churches, Exhibition Halls, Sports Facilities, Libraries, etc.

Sprinklers must be installed for fire areas:

- More than 12,000 square feet
- For more than 300 people
- Not on the exit discharge level

What if you're building a facility where people only *play* sports, and there's no area for watching? Then there's an exception to the sprinkler requirement. You won't need them if the occupancy area is on the same level as the main entrance and exit.

Group A-4, Arenas Used for Viewing Sports Events, etc.

Sprinklers must be installed for fire areas:

- More than 12,000 square feet
- For more than 300 people
- Not on the exit discharge level

Group A-5, Outdoor Stadiums, Grandstands, Amusement Park Structures, etc.

Only the following areas need sprinklers if they're larger than 1,000 square feet:

- Concession stands
- Retail areas
- Press boxes
- Other accessory use areas

Other Special Requirements

Theatrical stages, platforms, galleries, dressing rooms, etc. have a number of particular requirements. Refer to IBC Section 410.

Special amusement buildings for 50 or more people have their own requirements. You'll need to consult IBC Section 411 if your building has a pathway or a means of moving people where the exit direction isn't obvious. Requirements include:

- Automatic fire detection
- Automatic sprinkler systems
- Alarms
- Emergency voice/alarm communications systems
- Exit marking
- Class A interior finish

Special amusement buildings for fewer than 50 people are classified in Group B. If the building is designed with an atrium (an opening connecting two or more stories), IBC Section 404 lists even more requirements, such as smoke control, emergency power, space enclosure, interior finish and travel distance.

Group B Occupancies

Group B includes buildings for office, professional or service use. It also includes buildings used to store records and accounts. There aren't many additional requirements for this group unless the building is a high-rise or has an atrium.

A building is considered high-rise if it has occupied floors that are more than 75 feet above the lowest level of fire department access. Note that this is based on the lowest level fire department access, rather than the highest. There are many special requirements for high-rise buildings, as you can see in IBC Section 403.

This group covers schools, for the most part. The trend today is towards consolidating schools. Usually larger contracting firms (or consortiums of smaller firms) get these jobs. Plans for new schools are thoroughly examined for code compliance long before construction begins. State authorities examine the plans

TABLE 503
ALLOWABLE HEIGHT AND BUILDING AREAS
HEIGHT LIMITATIONS SHOWN AS STORIES AND FEET ABOVE GRADE PLANE
AREA LIMITATIONS AS DETERMINED BY THE DEFINITION OF "AREA, BUILDING," PER STORY

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HGT(feet)									
GROUP	HGT(S)	UL	160	65	55	65	55	65	50	40
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	4	5	4	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
H-1	S	1	1	1	1	1	1	1	1	NP
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP
H-2[d]	S	UL	3	2	1	2	1	2	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	3,000
H-3[d]	S	UL	6	4	2	4	2	4	2	1
	A	UL	60,000	26,500	14,000	17,500	13,000	25,500	10,000	5,000
H-4	S	UL	7	5	3	5	3	5	3	2
	A	UL	UL	37,500	17,500	28,500	17,500	36,000	18,000	6,500
H-5	S	4	4	3	3	3	3	3	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
I-1	S	UL	9	4	3	4	3	4	3	2
	A	UL	55,000	19,000	10,000	16,500	10,000	18,000	10,500	4,500
I-2	S	UL	4	2	1	1	NP	1	1	NP
	A	UL	UL	15,000	11,000	12,000	NP	12,000	9,500	NP
I-3	S	UL	4	2	1	2	1	2	2	1
	A	UL	UL	15,000	10,000	10,500	7,500	12,000	7,500	5,000
I-4	S	UL	5	3	2	3	2	3	1	1
	A	UL	60,500	26,500	13,000	23,500	13,000	25,500	18,500	9,000
M	S	UL	11	4	4	4	4	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-3	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	3	3	3	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2[b, c]	S	UL	11	5	4	4	4	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.
UL = Unlimited, NP = Not permitted.
a. See the following sections for general exceptions to Table 503:
1. Section 504.2, Allowable height increase due to automatic sprinkler system installation.
2. Section 506.2, Allowable area increase due to street frontage.
3. Section 506.3, Allowable area increase due to automatic sprinkler system installation.
4. Section 507, Unlimited area buildings.
b. For open parking structures, see Section 406.3.
c. For private garages, see Section 406.1.
d. See Section 415.5 for limitations.

Figure 5-1 Allowable height and building areas

with a fine-tooth comb. The local planning or building department also reviews them.

All the general contractor needs to do is follow the plans. Many smaller construction firms do remodeling work in public schools. They also build smaller private schools, where some unique code specifications may have to be addressed.

Group E Occupancies

Group E may have any of the five types of construction. You will still have to follow IBC Table 503 (Figure 5-1). The required floor area and building height dictate the construction type.

There are serious restrictions on the allowable floor area of an educational building (Table 503). For example, Type IIA construction only allows 26,500 square feet of floor area (solid outlined box in Figure 5-1). That's about 175 x 150 feet. Other types of construction restrict you to even smaller floor areas. But there are exceptions if you build to Type I construction.

What if you build an educational building that's only one story? IBC Section 507.9 says there's no limit to the allowable floor area of a single-story Group E building of Type II, IIIA or IV construction, if all of the following requirements are met:

- Each classroom has at least two exits, one of which is directly to the outside of the building
- A National Fire Protection Association (NFPA)-approved sprinkler system is installed throughout the building
- The building is immediately surrounded by public ways or open space at least 60 feet wide

Remember that this only applies to one-story buildings.

What if you're in an urban setting and you don't have 60 feet of space around the building? Let's say you need a floor area much larger than the 26,500 square feet allowed on the first story of a Type IIA building. You have a number of choices. You could build to Type IA construction, which gives you unlimited floor area and height. But that's expensive. You could build more stories. You're allowed three stories for Type IIA construction for Group E occupancy. That would give you enough floor area. But there's another alternative. Check row E of Table 503 again. Look at Type IIIA construction. It allows three stories, each with 23,500 square feet (dashed-outlined box in Figure 5-1). That's 70,500 square feet. That would give you all the floor area you need — and at a lower construction cost.

Automatic Sprinklers

Buildings in Group E with floor areas of more than 20,000 square feet must have automatic sprinkler systems, as stated in IBC Section 903.2.2. Sprinklers are also required for any part of a smaller building below the exit level. Do you remember the one exception to this rule? When every classroom in the building has at least one exterior exit door at ground level.

Group F Occupancies

Factory and industrial uses fall into either Group F-1 or F-2. Group F-1 includes 46 moderate-hazard industrial uses. Group F-2 lists eight low-hazard uses.

There are detailed requirements for Group F occupancies. One of these is the Application of Flammable Finishes, IBC Section 416. This section is concerned with flammable liquids such as paint, varnishes and lacquers. Building construction and equipment installation must comply with the International Fire Code. Also review IBC Section 417, Drying Rooms. Drying rooms must be built entirely of approved noncombustible materials.

Automatic Sprinklers

Group F-1 buildings require automatic sprinklers (IBC Section 903.2.3), if:

- The fire area is more than 12,000 square feet
- The fire area is located more than three stories above grade level
- The combined Group F-1 fire areas on all floors, including mezzanines, is more than 24,000 square feet

Remember, *fire area* means the entire floor space on each story.

Automatic sprinkler systems aren't required in Group F-2 occupancies. The code specifies the Groups that require systems, and Group F-2, by not being listed, is exempt from the requirement.

Group H Occupancies

Group H has five divisions. The most hazardous uses are in the first division.

Group H occupancies include areas where highly flammable materials are stored, processed or used. They also include areas where highly combustible manufacturing is done. This is a specialized topic with many pages of code to study. First, ask yourself this question — is there enough combustible material in the building for it to be considered hazardous? If so, your structure will probably come under one of the Group H divisions.

A building or structure falls in Group H when quantities of materials are above the maximums in IBC Tables 307.1(1) or 307.1(2) shown in Figures 5-2 and 5-3. Table 307.1(1) deals with *physical* hazards, such as combustible materials and explosives, and 307.1(2) deals with *health* hazards, such as toxic materials.

If the quantity of hazardous material will be more than that shown in these tables, you must be able to answer yes to these two questions:

1. Do you have enough physical space for the size building you want to construct?
2. Can you meet the minimum separation requirements for the type of hazard involved?

You'll find additional information in IBC Table 415.3.1 (Figure 5-4). But your situation may not be exactly what's described in the code, and your interpretation may not be the same as that of the building official on inspection day. In those cases, get a determination in advance from the local building official.

Table 415.3.1 lists the allowable distance from property lines and inhabited buildings for barricaded and unbarricaded Group H buildings. It also gives the required separation of magazines for explosive material storage in arsenal locations. Barricades must effectively screen other buildings and public ways from buildings containing explosive materials.

Group H buildings could be located anywhere, which means you also have to be aware of environmental concerns. Look at the number of uses listed in Group H. Hazardous materials aren't just explosives. Group H also includes materials ranging from combustible dust to toxic chemicals that can be harmful to the health and well-being of nearby inhabitants, as well as being potentially harmful to the environment.

Sometimes Group H occupancies must be detached buildings, as you can see in IBC Sections 415.3.1 and 415.3.2 and Table 415.3.2 (Figure 5-5).

There are specific regulations that apply only to Group H occupancies. If you need details for your particular situation, see the following sections:

Special provisions for Group H-1 occupancies, Section 415.4

Special provisions for Group H-2 and H-3 occupancies, Section 415.5

Group H-2, Section 415.6

Groups H-3 and H-4, Section 415.7

Group H-5, Section 415.8

Group H occupancies are extremely limited in height and floor area. For example, look again at Table 503 (Figure 5-1). It restricts buildings in the most hazardous use group (H-1) to one story and a maximum of 21,000 square feet (150 x 140 feet). And this is for Type 1A construction! All other types of construction are limited to even smaller floor areas, or aren't permitted at all.

Automatic Sprinklers

Automatic sprinklers are required in all Group H buildings. Check IBC Section 903.2.4 for details.

Group I Occupancies

Group I occupancies are for institutional uses.

Group I-1

Group I-1 includes facilities for:

- Assisted living
- Convalescence
- Rehabilitation

TABLE 307.1(1)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD

MATERIAL	CLASS	GROUP WHEN THE MAXIMUM ALLOWABLE QUANTITY IS EXCEEDED	STORAGE[b]			USE-CLOSED SYSTEMS[b]			USE-OPEN SYSTEMS[b]	
			Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet)	Liquid gallons (pounds)
Combustible liquid[c, i]	II IIIA IIIB	H-2 or H-3 H-2 or H-3 N/A	N/A	120[d, e] 330[d, e] 13,200[e, f]	N/A	N/A	120[d] 330[d] 13,200[f]	N/A	N/A	30[d] 80[d] 3,300[f]
Combustible fiber	Loose baled[o]	H-3	(100) (1,000)	N/A	N/A	(100) (1,000)	N/A	N/A	(20) (200)	N/A
Consumer fireworks (Class C, Common)	1.4G	H-3	125[d, e, l]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cryogenics flammable	N/A	H-2	N/A	45[d]	N/A	N/A	45[d]	N/A	N/A	10[d]
Cryogenics, oxidizing	N/A	H-3	N/A	45[d]	N/A	N/A	45[d]	N/A	N/A	10[d]
Explosives	Division 1.1 Division 1.2 Division 1.3 Division 1.4 Division 1.4G Division 1.5 Division 1.6	H-1 H-1 H-1 or 2 H-3 H-3 H-1 H-1	1[e, g] 1[e, g] 5[e, g] 50[e, g] 125[d, e, l] 1[e, g] 1[d, e, g]	(1)[e, g] (1)[e, g] (5)[e, g] (50)[e, g] N/A (1)[e, g] N/A	N/A N/A N/A N/A N/A N/A N/A	0.25[g] 0.25[g] 1[g] 50[g] N/A 0.25[g] N/A	(0.25)[g] (0.25)[g] (1)[g] (50)[g] N/A (0.25)[g] N/A	N/A N/A N/A N/A N/A N/A N/A	0.25[g] 0.25[g] 1[g] N/A N/A 0.25[g] N/A	(0.25)[g] (0.25)[g] (1)[g] N/A N/A (0.25)[g] N/A
Flammable gas	Gaseous liquefied	H-2	N/A	N/A 30[d, e]	1,000[d, e] N/A	N/A	N/A 30[d, e]	1,000[d, e] N/A	N/A	N/A
Flammable liquid[c]	1A 1B and 1C	H-2 or H-3	N/A	30[d, e] 120[d, e]	N/A	N/A	30[d] 120[d]	N/A	N/A	10[d] 30[d]
Combination flammable liquid (1A, 1B, 1C)	N/A	H-2 or H-3	N/A	120[d, e, h]	N/A	N/A	120[d, h]	N/A	N/A	30[d, h]
Flammable solid	N/A	H-3	125[d, e]	N/A	N/A	125[d]	N/A	N/A	25[d]	N/A
Organic peroxide	UD I II III IV V	H-1 H-2 H-3 H-3 N/A N/A	1[e, g] 5[d, e] 50[d, e] 125[d, e] NL NL	(1)[e, g] (5)[d, e] (50)[d, e] (125)[d, e] NL NL	N/A N/A N/A N/A N/A N/A	0.25[g] 1[d] 50[d] 125[d] N/L N/L	(0.25)[g] (1) (50)[d] (125)[d] N/L N/L	N/A N/A N/A N/A N/A N/A	0.25[g] 1[d] 10[d] 25[d] NL NL	(0.25)[g] (1)[d] (10)[d] (25)[d] NL NL
Oxidizer	4 3[k] 2 1	H-1 H-2 or H-3 H-3 N/A	1[e, g] 10[d, e] 250[d, e] 4,000[e, f]	(1)[e, g] (10)[d, e] (250)[d, e] (4,000)[e, f]	N/A N/A N/A N/A	0.25[g] 2[d] 250[d] 4,000[f]	(0.25)[g] (2)[d] (250)[d] (4,000)[f]	N/A N/A N/A N/A	0.25[g] 2[d] 50[d] 1,000[f]	(0.25)[g] (2)[d] (50)[d] (1,000)[f]
Oxidizing gas	Gaseous liquefied	H-3	N/A N/A	N/A 15[d, e]	1,500[d, e] N/A	N/A N/A	N/A 15[d, e]	1,500[d, e] N/A	N/A N/A	N/A N/A
Pyrophoric material	N/A	H-2	4[e, g]	(4)[e, g]	50[e, g]	1[g]	(1)[g]	10[e, g]	0	0
Unstable (reactive)	4 3 2 1	H-1 H-1 or H-2 H-3 N/A	1[e, g] 5[d, e] 50[d, e] NL	(1)[e, g] (5)[d, e] (50)[d, e] NL	10[d, g] 50[d, e] 250[d, e] N/L	0.25[g] 1[d] 50[d] NL	(0.25)[g] (1) (50)[d] N/L	2[e, g] 10[d, e] 250[d, e] NL	0.25[g] 1[d] 10[d] NL	(0.25)[g] (1)[d] (10)[d] NL
Water reactive	3 2 1	H-2 H-3 N/A	5[d, e] 50[d, e] NL	(5)[d, e] (50)[d, e] NL	N/A N/A N/A	5[d] 50[d] NL	(5)[d] (50)[d] NL	N/A N/A N/A	1[d] 10[d] NL	(1)[d] (10)[d] NL

For SI: 1 cubic foot = 0.023 m^3, 1 pound = 0.454 kg, 1 gallon = 3.785 L.
NL = Not Limited; N/A = Not Applicable; UD = Unclassified Detonable

a. For use of control areas, see Section 414.2.
b. The aggregate quantity in use and storage shall not exceed the quantity listed for storage.
c. The quantities of alcoholic beverages in retail and wholesale sales occupancies shall not be limited providing the liquids are packaged in individual containers not exceeding 1.3 gallons. In retail and wholesale sales occupancies, the quantities of medicines, foodstuffs, consumer or industrial products, and cosmetics containing not more than 50 percent by volume of water-miscible liquids with the remainder of the solutions not being flammable, shall not be limited, provided that such materials are packaged in individual containers not exceeding 1.3 gallons.
d. Maximum allowable quantities shall be increased 100 percent in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1. Where Note e also applies, the increase for both notes shall be applied accumulatively.
e. Maximum allowable quantities shall be increased 100 percent when stored in approved storage cabinets, day boxes, gas cabinets, exhausted enclosures or safety cans. Where Note d also applies, the increase for both notes shall be applied accumulatively.
f. The permitted quantities shall not be limited in a building equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.
g. Permitted only in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.
h. Containing not more than the maximum allowable quantity per control area of Class IA, IB or IC flammable liquids.
i. Inside a building, the maximum capacity of a combustible liquid storage system that is connected to a fuel-oil piping system shall be 660 gallons provided such system complies with the *International Fire Code*.
j. Quantities in parenthesis indicate quantity units in parenthesis at the head of each column.
k. A maximum quantity of 200 pounds of solid or 20 gallons of liquid Class 3 oxidizers is allowed when such materials are necessary for maintenance purposes, operation or sanitation of equipment. Storage containers and the manner of storage shall be approved.
l. Net weight of the pyrotechnic composition of the fireworks. Where the net weight of the pyrotechnic composition of the fireworks is not known, 25 percent of the gross weight of the fireworks, including packaging, shall be used.
m. For gallons of liquids, divide the amount in pounds by 10 in accordance with Section 2703.1.2 of the *International Fire Code*.
n. For storage and display quantities in Group M and storage quantities in Group S occupancies complying with Section 414.2.4, see Tables 414.2.5(1) and 414.2.5(2).
o. Densely packed baled cotton that complies with the packing requirements of ISO 8115 shall not be included in this material class.
p. The following shall not be included in determining the maximum allowable quantities:
   1. Liquid or gaseous fuel in fuel tanks on vehicles.
   2. Liquid or gaseous fuel in fuel tanks on motorized equipment operated in accordance with this code.
   3. Gaseous fuels in piping systems and fixed appliances regulated by the *International Fuel Gas Code*.
   4. Liquid fuels in piping systems and fixed appliances regulated by the *International Mechanical Code*.

Figure 5-2 Maximum allowable hazardous materials

TABLE 307.1(2)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIAL POSING A HEALTH HAZARD

MATERIAL	STORAGE[d]			USE-CLOSED SYSTEMS[d]			USE-OPEN SYSTEMS[d]	
	Solid pounds[e, f]	Liquid gallons (pounds)[e, f]	Gas (cubic feet at NTP)[e]	Solid pounds[e]	Liquid gallons (pounds)[e]	Gas (cubic feet at NTP)[e]	Solid pounds[e]	Liquid gallons (pounds)[e]
Corrosive	5,000	500	810[f, g]	5,000	500	810[f, g]	1,000	100
Highly toxic	10	(10)[i]	20[h]	10	(10)[i]	20[h]	3	(3)[i]
Toxic	500	(500)[i]	810[f]	500	(500)[i]	810[f]	125	(125)[i]

For SI: 1 cubic foot = 0.028 m^3, 1 pound = 0.454 kg, 1 gallon = 3.785 L.

a. For use of control areas, see Section 414.2.
b. In retail and wholesale sales occupancies, the quantities of medicines, foodstuffs, consumer or industrial products, and cosmetics, containing not more than 50 percent by volume of water-miscible liquids and with the remainder of the solutions not being flammable, shall not be limited, provided that such materials are packaged in individual containers not exceeding 1.3 gallons.
c. For storage and display quantities in Group M and storage quantities in Group S occupancies complying with Section 414.2.4, see Table 414.2.4(1).
d. The aggregate quantity in use and storage shall not exceed the quantity listed for storage.
e. Quantities shall be increased 100 percent in buildings equipped throughout with an approved automatic sprinkler system in accordance with Section 903.3.1.1. Where Note f also applies, the increase for both notes shall be applied accumulatively.
f. Quantities shall be increased 100 percent when stored in approved storage cabinets, gas cabinets or exhausted enclosures as specified in the *International Fire Code*. Where Note e also applies, the increase for both notes shall be applied accumulatively.
g. A single cylinder containing 150 pounds or less of anhydrous ammonia in a single control area in a nonsprinklered building shall be considered a maximum allowable quantity. Two cylinders, each containing 150 pounds or less in a single control area, shall be considered a maximum allowable quantity provided the building is equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.
h. Allowed only when stored in approved exhausted gas cabinets or exhausted enclosures as specified in the *International Fire Code*.
i. Quantities in parenthesis indicate quantity units in parenthesis at the head of each column.
j. For gallons of liquids, divide the amount in pounds by 10 in accordance with Section 2703.1.2 of the *International Fire Code*.

Figure 5-3 Maximum allowable hazardous materials posing a health hazard

The residents in these buildings are capable of responding to an emergency without physical help from the staff. Because of this, Group I-1 facilities have few special occupancy requirements listed in Chapter 4 of the IBC. But make sure you check out Section 419. Group I-1 facilities must comply with the requirements for separation walls (Section 708) and horizontal assemblies (Section 711).

Group I occupancies have numerous requirements for smoke and fire prevention warning and protection. Two of the most important are emergency escape and rescue, and smoke alarms. Emergency escape and rescue are discussed in IBC Section1026, and smoke alarms in Chapter 9 of this book.

Group I-2

Group I-2 includes institutions whose occupants are *not* capable of self-preservation. These include hospitals, nursing homes, mental hospitals and detox facilities. They're subject to special detailed occupancy requirements, all of which you'll find in IBC Section 407. These include strict details for:

- Corridor design
- Door type
- Smoke barriers
- Refuge areas
- Automatic sprinkler
- Fire detection systems

Group I-3

Group I-3 includes institutions whose occupants are *generally* incapable of self-preservation because of security measures. These include prisons, jails, reformatories, detention centers, correctional centers, etc. Such occupancies also have special requirements, shown in IBC Section 408. There are strict exit details for, among other things:

- Door width
- Spiral stairs
- Locks
- Smoke barriers
- Smoke compartments
- Refuge areas

TABLE 415.3.1 MINIMUM SEPARATION DISTANCES FOR BUILDINGS CONTAINING EXPLOSIVE MATERIALS				
QUANTITY OF EXPLOSIVE MATERIAL[a]		MINIMUM DISTANCE (feet)		
		Lot lines[b] and inhabited buildings[c]		Separation of magazines[d, e, f]
Pounds over	Pounds not over	Barricaded[d]	Unbarricaded	
2	5	70	140	12
5	10	90	180	16
10	20	110	220	20
20	30	125	250	22
30	40	140	280	24
40	50	150	300	28
50	75	170	340	30
75	100	190	380	32
100	125	200	400	36
125	150	215	430	38
150	200	235	470	42
200	250	255	510	46
250	300	270	540	48
300	400	295	590	54
400	500	320	640	58
500	600	340	680	62
600	700	355	710	64
700	800	375	750	66
800	900	390	780	70
900	1,000	400	800	72
1,000	1,200	425	850	78
1,200	1,400	450	900	82
1,400	1,600	470	940	86
1,600	1,800	490	980	88
1,800	2,000	505	1,010	90
2,000	2,500	545	1,090	98
2,500	3,000	580	1,160	104
3,000	4,000	635	1,270	116
4,000	5,000	685	1,370	122
5,000	6,000	730	1,460	130
6,000	7,000	770	1,540	136
7,000	8,000	800	1,600	144
8,000	9,000	835	1,670	150
9,000	10,000	865	1,730	156
10,000	12,000	875	1,750	164
12,000	14,000	885	1,770	174
14,000	16,000	900	1,800	180
16,000	18,000	940	1,880	188
18,000	20,000	975	1,950	196
20,000	25,000	1,055	2,000	210
25,000	30,000	1,130	2,000	224
30,000	35,000	1,205	2,000	238
35,000	40,000	1,340	2,000	248

Figure 5-4 Separation for buildings containing explosive materials

TABLE 415.3.1 continued
MINIMUM SEPARATION DISTANCES FOR BUILDINGS CONTAINING EXPLOSIVE MATERIALS

QUANTITY OF EXPLOSIVE MATERIAL[a]		MINIMUM DISTANCE (feet)		
		Lot lines[b] and inhabited buildings[c]		
Pounds over	Pounds not over	Barricaded[d]	Unbarricaded	Separation of magazines[d, e, f]
40,000	45,000	1,340	2,000	258
45,000	50,000	1,400	2,000	270
50,000	55,000	1,460	2,000	280
55,000	60,000	1,515	2,000	290
60,000	65,000	1,565	2,000	300
65,000	70,000	1,610	2,000	310
70,000	75,000	1,655	2,000	320
75,000	80,000	1,695	2,000	330
80,000	85,000	1,730	2,000	340
85,000	90,000	1,760	2,000	350
90,000	95,000	1,790	2,000	360
95,000	100,000	1,815	2,000	370
100,000	110,000	1,835	2,000	390
110,000	120,000	1,855	2,000	410
120,000	130,000	1,875	2,000	430
130,000	140,000	1,890	2,000	450
140,000	150,000	1,900	2,000	470
150,000	160,000	1,935	2,000	490
160,000	170,000	1,965	2,000	510
170,000	180,000	1,990	2,000	530
180,000	190,000	2,010	2,010	550
190,000	200,000	2,030	2,030	570
200,000	210,000	2,055	2,055	590
210,000	230,000	2,100	2,100	630
230,000	250,000	2,155	2,155	670
250,000	275,000	2,215	2,215	720
275,000	300,000	2,275	2,275	770

For SI: 1 pound = 0.454 kg, 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

a. The number of pounds of explosives listed is the number of pounds of trinitrotoluene (TNT) or the equivalent pounds of other explosive.

b. The distance listed is the distance to lot line, including lot lines at public ways.

c. For the purpose of this table, an inhabited building is any building on the same lot that is regularly occupied by people. Where two or more buildings containing explosives or magazines are located on the same lot, each building or magazine shall comply with the minimum distances specified from inhabited buildings and, in addition, they shall be separated from each other by not less than the distance shown for "Separation of magazines," except that the quantity of explosive materials contained in detonator buildings or magazines shall govern in regard to the spacing of said detonator buildings or magazines from buildings or magazines containing other explosive materials. If any two or more buildings or magazines are separated from each other by less than the specified "Separation of Magazines" distances, then such two or more buildings or magazines, as a group, shall be considered as one building or magazine, and the total quantity of explosive materials stored in such group shall be treated as if the explosive were in a single building or magazine located on the site of any building or magazine of the group, and shall comply with the minimum distance specified from other magazines or inhabited buildings.

d. Barricades shall effectively screen the building containing explosives from other buildings, public ways or magazines. Where mounds or revetted walls of earth are used for barricades, they shall not be less than 3 feet in thickness. A straight line from the top of any side wall of the building containing explosive materials to the eave line of any other building, magazine or a point 12 feet above the centerline of a public way shall pass through the barricades.

e. Magazine is a building or structure, other than an operating building, approved for storage of explosive materials. Portable or mobile magazines not exceeding 120 square feet in area need not comply with the requirements of this code, however, all magazines shall comply with the *International Fire Code*.

f. The distance listed is permitted to be reduced by 50 percent where approved natural or artificial barriers are provided in accordance with the requirements in Note d.

Figure 5-4 Separation for buildings containing explosive materials

TABLE 415.3.2 REQUIRED DETACHED STORAGE			
DETACHED STORAGE IS REQUIRED WHEN THE QUANTITY OF MATERIAL EXCEEDS THAT LISTED HEREIN			
Material	Class	Solids and Liquids (tons)[a,b]	Gases (cubic feet)[a,b]
Explosives	Division 1.1 Division 1.2 Division 1.3 Division 1.4 Division 1.4[c] Division 1.5 Division 1.6	Maximum Allowable Quantity Maximum Allowable Quantity Maximum Allowable Quantity Maximum Allowable Quantity 1 Maximum Allowable Quantity Maximum Allowable Quantity	Not Applicable
Oxidizers	Class 4	Maximum Allowable Quantity	Maximum Allowable Quantity
Unstable (reactives) detonable	Class 3 or 4	Maximum Allowable Quantity	Maximum Allowable Quantity
Oxidizer, liquids and solids	Class 3 Class 2	1,200 2,000	Not Applicable Not Applicable
Organic peroxides	Detonable Class I Class II Class III	Maximum Allowable Quantity Maximum Allowable Quantity 25 50	Not Applicable Not Applicable Not Applicable Not Applicable
Unstable (reactives) nondetonable	Class 3 Class 2	1 25	2,000 10,000
Water reactives	Class 3 Class 2	1 25	Not Applicable Not Applicable
Pyrophoric gases	Not Applicable	Not Applicable	2,000

For SI: 1 ton = 906 kg, 1 cubic foot = 0.02832 m^3, 1 pound = 0.454 kg.

a. For materials that are detonable, the distance to other buildings or lot lines shall be as specified in Table 415.3.1 based on trinitrotoluene (TNT) equivalence of the material. For materials classified as explosives, see Chapter 33 the *International Fire Code.* For all other materials, the distance shall be as indicated in Section 415.3.1.

b. "Maximum Allowable Quantity" means the maximum allowable quantity per control area set forth in Table 307.7(1).

c. Limited to Division 1.4 materials and articles, including articles packaged for shipment, that are not regulated as an explosive under Bureau of Alcohol, Tobacco and Firearms (BATF) regulations or unpackaged articles used in process operations that do not propagate a detonation or deflagration between articles, providing the net explosive weight of individual articles does not exceed 1 pound.

Figure 5-5 Required detached storage

Group I-4

Group I-4 institutions are mostly day care facilities. They're *occupied by persons of any age who receive custodial care for less than 24 hours by individuals other than parents or guardians, relatives by blood, marriage or adoption, and in a place other than the home of the person cared for.* These include both adult care facilities for six or more people and child care facilities for six or more children, 2½ years old or less, when the custodial care is for less than 24 hours. There are no special detailed occupancy requirements described in the code for this group.

Automatic Sprinklers

Group I occupancies require automatic sprinklers, as specified in IBC Section 903.2.5. The sprinklers will usually be NFPA 13-type approved, but for Group I-1 occupancies, either NFPA 13R- or NFPA 13D-type is allowed. See Sections 903.3.1.2 or 903.3.1.3.

Group M Occupancies

Group M is for mercantile (retail) uses. It includes shopping areas, either downtown or in a shopping center. Seven specific uses are listed in IBC Section 309:

1. Department stores
2. Drug stores
3. Markets
4. Motor fuel-dispensing facilities
5. Sales rooms
6. Retail stores
7. Wholesale stores

There are detailed occupancy requirements if the stores are in a covered mall building (see IBC Section 402). The number of exits and exit arrangements are very important. They depend on the following:

- Occupant load
- Distance to exits
- Access to exits
- Mall width
- Type of construction
- Fire-resistance-rated separation
- Automatic sprinkler systems
- Smoke control
- Security grilles and doors
- Emergency voice/alarm communications systems
- Fire department access to equipment

If the building has an atrium, Section 404 has even more requirements.

Automatic Sprinklers

Again, IBC Section 903.2.6 requires automatic sprinklers throughout Group M buildings, if:

- The fire area is more than 12,000 square feet, or
- The fire area is more than three stories above grade, or
- The combined area of all Group M occupancies on all floors, including any mezzanines, is more than 24,000 square feet

Also, automatic sprinklers must be installed wherever merchandise is stored in racks or piled high. See Section 903.2.6.1.

Storage of Hazardous Materials

What if some of the stored materials are hazardous, but not flammable or combustible? IBC Table 414.2.5(1) (Figure 3-1) controls the total quantity of hazardous materials that can be stored in Group M occupancies. See Section 309.2.

Exits

All store exit doors must swing in the direction of the exit when the occupant load exceeds 49 people, according to IBC Section 1008.1.2. These doors can't swing into the public right-of-way, so most exit doors in zero-lot-line buildings are recessed. Property owners don't like that because it robs them of space inside the store. In new construction, this problem can be fixed in the design phase. But what about replacing doors in existing buildings? This is something the inspector will take a hard look at.

There's a lot more to be said about exits, but we'll leave that for Chapter 16.

Group R Occupancies

There are four Group R subdivisions:

1. R-1, temporary living places such as hotels and motels
2. R-2, permanent living places such as apartments
3. R-3, permanent living places for small groups (five or fewer)
4. R-4, permanent living places for larger groups (more than five but no more than 16)

One- or two-family dwellings can be built to the IRC. So can townhouses of three stories or less, with separate exits. There are some minor restrictions that affect these dwelling units, so we'll discuss them here.

What's the difference between a one- or two-family dwelling, which can be built to the IRC, and R-3 occupancy of the IBC? Remember that R-3 is for permanent occupancy of five or fewer people. They sound pretty much the same, don't they? Well, there are a couple of differences. First, if you're planning to build a one- or two-family dwelling or townhouse with four stories, it must be built to the IBC. You're only allowed three stories for a one- or two-family dwelling or townhouse built to the IRC. Second, if your building is going to be a group house, like a day care facility, it has to be built to R-3, R-4 or I-1 occupancy of the IBC.

How do you decide if a group of townhouses that are three stories or less should be built to the IRC or the IBC? Well, they can be built to either code, but you'd probably prefer to build them to the IRC, which is allowed if all of the following requirements are met:

- The building has three stories or fewer above grade level.
- There are separate means of exit for each property and its accessory structures, such as garages.
- Each unit extends from the ground to the roof — no stacking of units.
- Open space is available on at least two sides, i.e. driveways or yards, which allow for fire department access.

Much of the work you'll do as a contractor with a small- to-medium-sized business will probably be:

- IBC Group R (residential)
- IBC Group B (business and commercial)
- IRC One- or two-family dwellings or townhouses

Until you get into large occupant loads, there aren't many special restrictions.

Hotels and motels are both classified as R-1 occupancies under the IBC. You might think the requirements would be different, since each motel room has an exit to the outside of the building, whereas rooms in a hotel generally exit to an internal corridor.

Automatic Sprinklers

Group R occupancy buildings require automatic sprinklers, as specified in IBC Section 903.2.7. There are some exceptions. See Section 903.3.1.1.1.

Separation Walls and Horizontal Assemblies

Make sure you check IBC Section 419 which says that Group R-1, R-2 and R-3 occupancies must meet the requirement for Separation Walls (Section 708) and Horizontal Assemblies (Section 711).

Home Day Care

A new appendix in the IRC covers exits and smoke detectors in Group R-3 occupancies used for home day care. If you're planning to build a home day care facility, study Appendix M carefully.

One- or Two-Family Dwellings

One- or two-family dwellings or townhouses of no more than three stories are probably the least restricted of all occupied buildings. Most of the requirements are based on common sense. For example, living, dining and sleeping rooms must have windows, or be provided with artificial light and an approved mechanical ventilation system. The amount of artificial light and mechanical ventilation required are detailed in the IRC, Section R303.1. Windows must open directly to the outside. They can open to a roofed porch if the porch has a ceiling height of at least 7 feet, and is 65 percent open on the longer side. The porch must open directly to the outside.

The total area of windows must be at least 8 percent of the floor area of all habitable rooms, or at least 8 square feet. Windowed bathrooms must have windows at least 3 square feet in area, half of which must be openable. Bathrooms without windows must have mechanical ventilation directed to the outside.

A room with a toilet must be separated from food preparation or food storage rooms by a tight-fitting door. The code used to say that the door couldn't open into a food area at all. This restriction has been relaxed, but I still think the old restriction was a good idea.

Every dwelling unit must have a toilet, washbowl and either a bathtub or shower. The kitchen must have a sink. These fixtures, with the exception of the toilet, must have hot and cold running water.

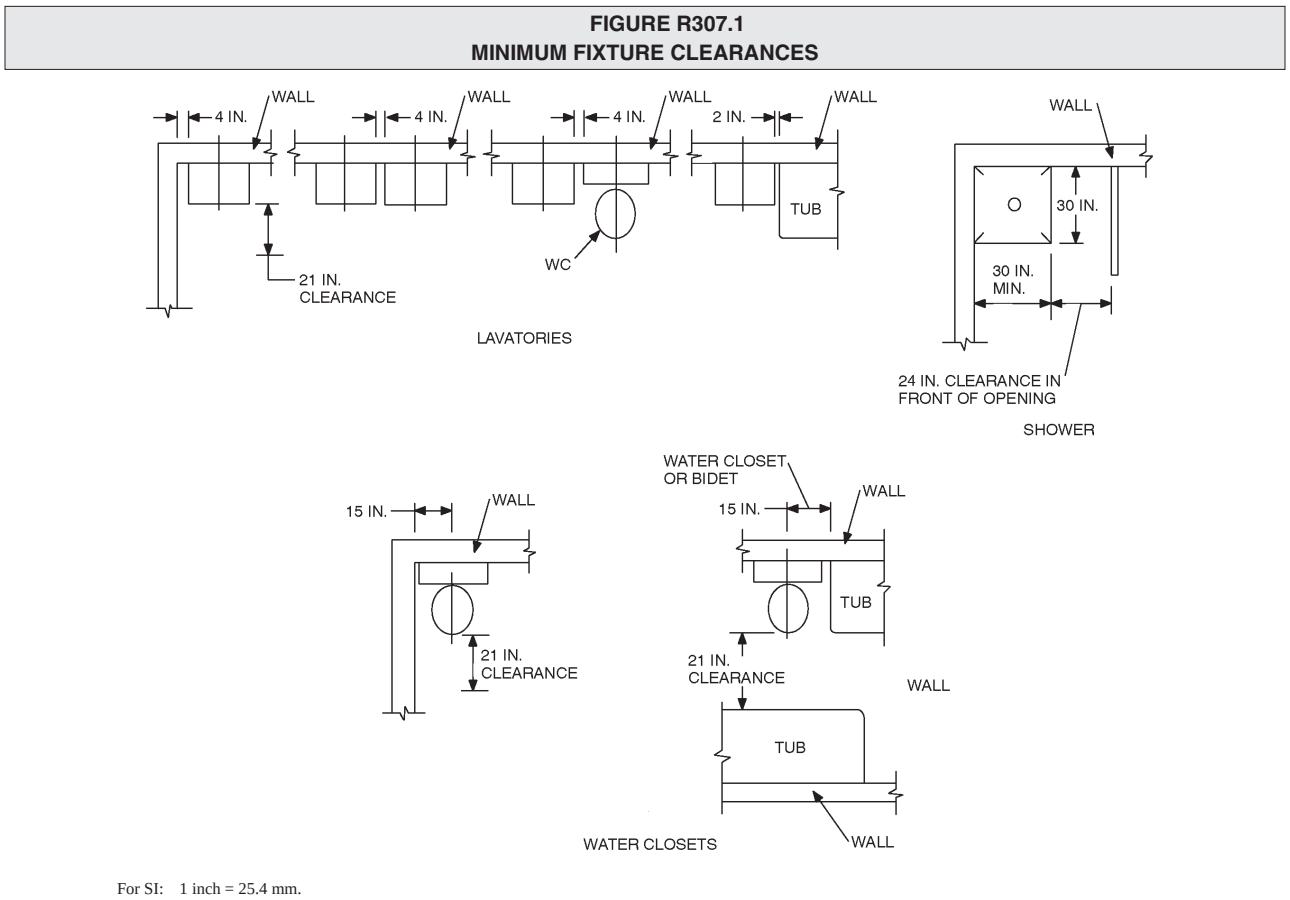


Figure 5-6 Minimum fixture clearances

Ceiling Height

The IRC gives standard height requirements for:

- Habitable rooms
- Hallways and corridors
- Bathrooms
- Toilet rooms
- Laundry rooms
- Basements

Generally, the ceiling height must be at least 7 feet. There are exceptions, of course, as you can see in IRC Section R305. Some of these are listed below.

- Beams and girders spaced at least 4 feet on center can project up to 6 inches below the required ceiling height.
- Basement ceilings, when the basement has no habitable spaces, need only be 80 inches high. Beams, girders, air ducts or other obstructions can be within 76 inches of the finished floor.
- Bathrooms must have a minimum ceiling height of 80 inches over each fixture, and at the front clearance area of each fixture. See IRC Figure R307.1 (Figure 5-6). The ceiling height over a shower or a tub equipped with a showerhead must be at least 80 inches above an area of at least 30 inches by 30 inches at the showerhead.
- The ceiling height in rooms with sloped ceilings can't be less than 7 feet for more than 50 percent of the room area. Any areas of the

room with a ceiling height less than 5 feet can't be counted towards the room area requirements in the next section.

Room Area

The IRC gives minimum room areas, too. See Section R304. Each dwelling unit must have at least one room with no less than 120 square feet of floor area. Other habitable rooms, including bedrooms, but not kitchens, must be at least 70 square feet. No habitable room (except a kitchen) can have any horizontal dimension less than 7 feet. A toilet room must be at least 30 inches wide and have at least 21 inches in front of the toilet.

Attached Garages

Openings between a private garage and residence must have one of the following types of doors, as specified in IRC Section R309.1:

- Solid wood door at least 1⅜ inches thick
- Solid or honeycomb core steel door at least 1⅜ inches thick
- 20-minute fire-rated door

The door from the garage can't open into a bedroom or any other sleeping room.

This separation requirement between the garage and the residence may seem a little excessive. A survey once found that four out of five house fires began in the residence. What's the code trying to protect — cars or the occupants? But on the other hand, that means that one out of five fires does start in the garage. Those odds are great enough to warrant the attention.

If you're building to the IBC, there's a requirement to install a self-closing, self-latching, solid-core door between the garage and the residence (IBC Section 406.1.4).

In addition, IRC Section R309.2 says the garage/dwelling wall/ceiling separation must meet the following criteria:

- The garage must be separated from the residence and its attic area by at least ½-inch gypsum board applied to the garage wall side.
- The garage must be separated from all habitable rooms above it by at least ⅝-inch Type X gypsum board or equivalent.
- If the garage/dwelling separation is a floor/ceiling assembly, the structure supporting the separation must be protected by at least ½-inch gypsum board or equivalent. This also applies to structural elements like posts and beams.
- If the garage is a stand-alone structure, but separated by less than 3 feet from the residence, it must be protected by at least ½-inch gypsum board applied to the interior side of exterior walls within the area.

Group S Occupancies

Group S has two subdivisions that cover nonhazardous storage areas. Hazardous materials can be stored in control areas of Group S occupancies, but the quantities can't exceed the amounts shown in IBC Section 414.2.5 and Table 414.2.5(1) (refer back to Chapter 3, Figure 3-1).

Group S-1 is a moderate-hazard category, used for storage of combustible materials. Group S-2 is for storage of low-hazard items, such as:

- Beer or wine
- Cement in bags
- Frozen foods
- Dairy product in nonwaxed coated paper containers
- Stoves, washers and dryers

Parking garages, open or enclosed, are included in Group S-2. Cars are seen to be noncombustible, as a rule. However, under high heat conditions, gas in the tanks can be very

combustible. That's why sprinkler systems are required for enclosed parking garages (IBC Section 903.2.9). Private garages under Group R-3 occupancies are not included in this requirement.

Special provisions apply when an open or enclosed parking garage is under a building used for Group A, B, M, R or S occupancy (IBC Section 509). This also includes Group S-2 enclosed parking garages with an open parking garage above or below Group R occupancies.

Sprinkler Systems

There are different requirements for sprinkler systems in Group S-1 and Group S-2 occupancies.

Group S-1

Automatic sprinklers are needed throughout the building for any one of the following (IBC Section 903.2.8):

- A storage fire area more than 12,000 square feet
- A storage fire area more than three stories above grade level
- A combination of all Group S-1 areas on all floors, including any mezzanines, more than 24,000 square feet
- A one-story building with a repair garage more than 12,000 square feet
- A building two or more stories, including basements, that has a fire area containing a repair garage larger than 10,000 square feet
- A building with a repair garage servicing vehicles parked in the basement
- A building used for storing tires, with a tire storage space of more than 20,000 cubic feet. (That's *cubic feet*, not square feet. So, if the storage space is 10 feet high, you're allowed a floor area of 2,000 square feet before you have to install a sprinkler system.)

Group S-2

Group S-2 occupancies are low-hazard storage areas, so they usually don't require sprinklers. However, you must install sprinklers in an enclosed parking garage (as required in IBC Section 406.4), or if the garage is located under any other occupancy except R-3. Also, buildings larger than 5,000 square feet used to store commercial trucks or buses must have sprinklers.

Group U Occupancies

Group U occupancies cover accessory structures, such as:

- Private garages
- Carports
- Sheds
- Agricultural buildings
- Grain silos
- Greenhouses
- Tanks
- Towers

These structures aren't intended for permanent occupancy. But some still may have temporary occupants. One particular case is private garages, as shown in IBC Section 406.

To be classified as a Group U motor-vehicle-related occupancy, a building must meet three requirements. It must be:

1. Intended for use as a private garage or carport,
2. One story in height, and
3. An area 1,000 square feet or less, except as allowed below.

The 1,000-square-foot limitation is very important. That's only 33 feet by 33 feet, or just over 10 yards square. However, that area can be increased. If no professional repair work is done or no fuel is dispensed, the area can be increased to 3,000 square feet. The building can still be considered Group U occupancy, if:

- The exterior walls and opening protection are built to the requirements of Group R-1 or R-2 occupancy

TABLE C102.1 BASIC ALLOWABLE AREA FOR GROUP U, ONE STORY IN HEIGHT AND MAXIMUM HEIGHT OF SUCH OCCUPANCY							
I		II		III and IV		V	
A	B	A	B	III A and IV	III B	A	B
ALLOWABLE AREA (square feet)[a]							
Unlimited	60,000	27,100	18,000	27,100	18,000	21,100	12,000
MAXIMUM HEIGHT IN STORIES							
Unlimited	12	4	2	4	2	3	2
MAXIMUM HEIGHT IN FEET							
Unlimited	160	65	55	65	55	50	40

For SI: 1 square foot = 0.0929 m^2.
a. See Section C102 for unlimited area under certain conditions.

Figure 5-7 Basic allowable area for Group U

- The Group U occupancy is part of a mixed-occupancy building and the exterior walls and opening protection of the complete structure are built to the requirements of the major occupancy

Can a Group U motor-vehicle-related occupancy exceed 3,000 square feet? Yes, if each area, of no larger than 3,000 square feet, is separated by a fire wall complying with IBC Section 706.

Agricultural Buildings

IBC Appendix C deals specifically with Group U agricultural buildings, such as:

- Livestock shelters or buildings, including shade structures and milking barns
- Poultry buildings or shelters
- Barns
- Storage of equipment and machinery used only in agriculture
- Horticultural structures, including detached production greenhouses and crop protection shelters
- Sheds
- Grain silos
- Stables

Allowable Height and Area

Group U agricultural buildings are limited in floor area and height, depending on the type of construction. See Table C102.1 in IBC Appendix C (Figure 5-7). However, if the building is only one story, Section C102.2 allows you to build to an unlimited area if the building is surrounded and adjoined by 60 feet of public ways or yards.

If the building is two stories, you can build to an unlimited area if the building is surrounded by 60 feet of public ways or yards *and* you install sprinklers throughout. See Section C102.3.

Exits

The maximum travel distance allowed from any point in a Group U agricultural building to an approved exit is 300 feet or less. One exit is required for every 15,000 square feet of floor area (or fraction of 15,000 square feet) (Section C104.1).

All Occupancies

There's an interesting requirement that applies to all occupancies except Groups R-3 and U. It's found in IBC Section 903.2.10.

Windowless Stories in All Occupancies

An automatic sprinkler system must be installed in any type of building other than Groups R-3 and U, when any story, including the basement, is without windows and the floor area of the story is more than 1,500 square feet.

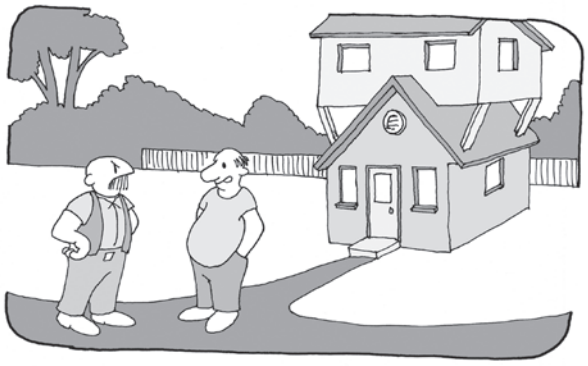
An automatic sprinkler system isn't required if, every 50 feet of exterior wall, there's an aboveground opening, 20 square feet in size, or a below-grade opening that leads directly to the ground level by an exterior stairway or ramp.

Openings

Openings must have a minimum dimension of 30 inches in any direction and provide easy access from the outside for the fire department. If the openings are on only one side of the building, and the opposite side of the building is more than 75 feet away, you must install sprinklers on that story regardless of the floor area. Or, if any part of a basement is more than 75 feet from an opening, the basement must have sprinklers regardless of the floor area. See IBC Section 903.2.10.1.1.

Summary

In this chapter, we've reviewed the specific detailed requirements for the 10 occupancy groups. But we've only scratched the surface of some of the requirements for each group. More specific detail on building requirements will be discussed in the following chapters.



Availability of the Law

If a builder build a house for some one, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death.

The Code of Hammurabi, 1750 B.C.

Codes have changed since Hammurabi's day, mostly for the better. That building code had only six articles —— more than enough, considering the penalty for noncompliance that resulted in a fatality was death. Because then, as now, ignorance of the law was no excuse. Those six articles, carved in black stone, were posted where everyone could see them. I expect at the doughnut shop, or its 1750 B.C. counterpart, where contractors congregated for breakfast on the way to work.

Today, it's more difficult to know exactly what the code requires. The ICC sells the official printed model codes at www.iccsafe.org. The I-codes are also available at the ICC store. But these codes aren't necessarily adopted by your state, county or city. For code information, you'll need to visit the local library or the building department. And that's not always convenient.

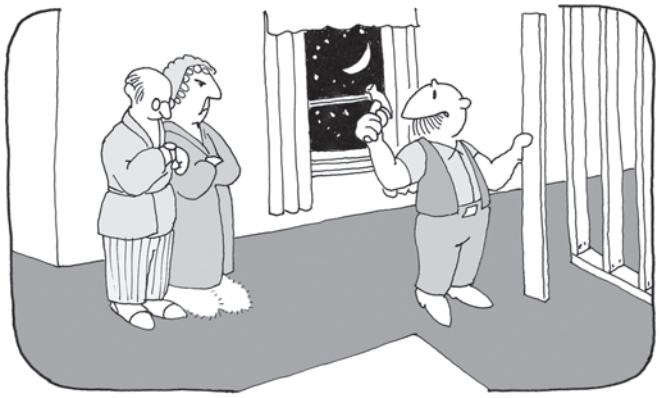
The Web is the modern equivalent of Hammurabi's carved black stone. Wouldn't it be great if the code enforced by your local building department was available for browsing on the Web?

Actually, it's happening even as this book goes to print. Check www.ecodes.biz. Several states and cities make their codes available for browsing at no cost on this ICC website —— and you'll be seeing it more and more. Downloads of laws are available at no cost on the Web, and your local building code, which is also a law, should be no exception. If your building department really wants you to comply with the code, ask them to post it on the Web.

And it's perfectly legal, thanks to Peter Veeck of Denison, Texas. A few years ago, Peter set out to remodel a commercial building in Denison. Naturally, he needed to know the local building code. It wasn't available. So he ordered a copy on disk from the SBCCI, one of the predecessors of the ICC. When the disk arrived, he posted the entire code on his own website. Oops! The SBCCI claimed infringement and filed suit. The issue: Who owns the law? It took some time, but eventually the courts decided in Peter's favor. The building code, once adopted, is in fact available to everyone. No one gets to claim copyright on the law. The model codes are something else. The ICC and others who draft codes can claim copyright on the original —— but not the adopted —— version.

I think that's a good decision. Revenue from sale of model I-codes continues to support the ICC's product-testing and code-drafting programs. But now, contractors and those who have to comply with the code can get free access.

The law shouldn't be a closely-guarded secret. Hammurabi understood that nearly 4,000 years ago.



"Well, now that you're up, how about a cup of coffee?"

C H A P T E R 6

Remodeling

How much remodeling can you do? The answer is: a lot. But remember — more changes mean more code requirements. What about repairs, renovations, alterations and reconstruction of one- or two-family dwellings or townhouses? Before we move on to types of construction, we'll take a few minutes to look at remodeling requirements.

This is an area of interest to many readers, so we'll discuss it now. Briefly, any remodeling must meet the requirements of the code. You'll need to refer to Chapter 34 of the IBC, or Appendix J of the IRC.

Do You Need a Permit?

For most jobs, you will. But even if you don't, you'll still have to meet all the code requirements that apply. Some projects don't need a permit. In IBC Section 105, you'll no doubt be glad to see that oil derricks don't need permits — but that's probably outside your line of work. Seriously though, in addition to minor repairs and replacements, there are several types of projects that don't need permits — at least, not yet. Among them are painting, papering, tiling, carpeting, cabinets, countertops and other finish work.

You might think that constructing cabinets and countertops should be considered significant remodeling, but as far as the code is concerned, they're not. Yet, a lot of builders have had code compliance problems when they thought they were starting simple remodeling projects.

One of the first questions the building official will ask you is why you're remodeling. If you're simply upgrading the property, with no change in occupancy, that's one thing. But if there'll be a new tenant engaged in a different type of activity, it could mean changes to the building that neither you nor the owner had even dreamt of. Then you'll have to check the occupancy group classification. But to keep our example simple, let's say you're only upgrading, without a change in occupancy group.

Code Requirements

You have three alternatives to meet code requirements for alterations or additions to an existing building. Any alterations or additions must:

1. Be in compliance with Chapters 2 through 34 of the IBC, as if they were new construction; or
2. Be in compliance with IBC Sections 3401.3 and 3403 through 3407; or
3. Be in compliance with IBC Section 3410. If this is the method you've chosen, you must go through the evaluation process described in Section 3410.6.

Construction Safeguards

Conditions for alteration, repair, addition and change of occupancy of existing structures are covered in IBC Chapter 34, Existing Buildings. There are a few "housekeeping" items the code requires.

During remodeling, IBC Section 3401.2 says you must:

- Keep the building and structure safe and clean.
- Maintain any devices or safeguards required by the code.
- Retain all fire protection, safety systems and devices.
- Allow the building inspector to reinspect the building at any time.

IBC Section 3302 says you must:

- Maintain required exits.
- Keep existing structural elements, unless they're being remodeled or the building isn't occupied.
- Make sure that waste material is removed. This has to be done in a way that prevents injury or damage to people, adjoining properties and public rights-of-way.

IBC Section 3401.3 says that all alterations, repairs, additions and changes of occupancy to existing structures must meet other codes, including:

- International Fire Code
- International Fuel Gas Code
- International Plumbing Code
- International Property Maintenance Code
- International Private Sewage Disposal Code
- International Mechanical Code
- International Residential Code
- ICC Electrical Code

Historic Buildings

There are exceptions made for historic buildings, in IBC Section 3407. The code says that provisions for *repair, alteration, addition, restoration and movement of structures, and change of occupancy* are not required for historic buildings. However, the inspector must be confident that the building doesn't constitute a *distinct life safety hazard.* That's a judgment call. You can appeal the inspector's decision if it isn't in your favor.

There's usually no problem if the owner is simply bringing the building up to current code standards, or if he's making changes to qualify for better insurance rates. Be sure to accompany the inspector on his walk-through of the building. Point out all areas of noncompliance you can see, and get the inspector to buy into it. It's better to point out the obvious problems early in the project. Chances are you won't have to renovate the whole building if you appear to be forthcoming about the problems. But the inspector will require changes to fix the observable hazards, whether you point them out or he finds them himself.

Moved Buildings

Moved buildings must conform to IBC requirements in Section 3408. Take into consideration that an intended change of occupancy could cause a change in code requirements.

Investigation and Evaluation

If you choose the IBC for compliance, Section 3410.4 says that an investigation and evaluation must be done before any substantial remodeling is begun. This section covers Structural Analysis, Submittal and Determination of Compliance.

The evaluation process is spelled out in Section 3410.6.

> ***3410.6 Evaluation process.*** *The evaluation process specified herein shall be followed in its entirety to evaluate existing buildings. Table 3410.7 shall be utilized for tabulating the results of the evaluation. References to other sections of this code indicate that compliance with those sections is required in order to gain credit in the evaluation herein outlined.*

There are special considerations for mixed occupancy in the second half of Section 3410.6. This section also provides formulas and tables to calculate Fire Safety (FS), Means of Egress (ES), and General Safety (GS) scores for each of the following 18 items:

1. Building height, Section 3410.6.1
2. Building area, Section 3410.6.2
3. Compartmentation, Section 3410.6.3
4. Tenant and dwelling unit separations, Section 3410.6.4
5. Corridor walls, Section 3410.6.5
6. Vertical openings, Section 3410.6.6
7. HVAC systems, Section 3410.6.7
8. Automatic fire detection, Section 3410.6.8
9. Fire alarm systems, Section 3410.6.9
10. Smoke control, Section 3410.6.10
11. Means of egress capacity and number, Section 3410.6.11
12. Dead ends, Section 3410.6.12
13. Maximum exit access travel distance, Section 3410.6.13
14. Elevator control, Section 3410.6.14
15. Means of egress emergency lighting, Section 3410.6.15
16. Mixed occupancies, Section 3410.6.16
17. Automatic sprinklers, Section 3410.6.17
18. Incidental use, Section 3410.6.18

The results are entered in Table 3410.7 (Figure 6-1) and totaled at the bottom of the chart as Building Scores.

Building scores must meet the requirements found in IBC Table 3410.8, Figure 6-2, for the three main categories:

1. Fire safety
2. Means of egress
3. General safety

Different occupancy types require different scores.

However, this isn't the full story on Investigation and Evaluation. For that, you must study the code. Getting a permit for remodeling an existing building is a complex process. It's not something you can slide by the inspector with a few sketches and a good spiel.

Smoke Alarms

If you're remodeling, IRC Section R313.2.1 requires that you install smoke alarms, the same as if it were a new building. They must be interconnected and hard-wired to the main supply when you do any of the following:

- Make repairs requiring a permit
- Make alterations requiring a permit
- Make additions requiring a permit
- Add one or more sleeping rooms
- Make a sleeping room from a nonsleeping room

That last item stumps a lot of contractors. If you make a nonsleeping room into a sleeping room, you have to install smoke alarms and they must be to the standard of new construction. This is a code requirement even if your jurisdiction doesn't require a permit. There's no easy way to enforce this, though, except after the fact. If the owner makes a sleeping room

TABLE 3410.7
SUMMARY SHEET — BUILDING CODE

Existing occupancy _____ Proposed occupancy _____

Year building was constructed _____ Number of stories _____ Height in feet _____

Type of construction _____ Area per floor _____

Percentage of open perimeter _____% Percentage of height reduction _____%

Completely suppressed: Yes _____ No _____ Corridor wall rating _____

Compartmentation: Yes _____ No _____ Required door closers: Yes _____ No _____

Fire-resistance rating of vertical opening enclosures _____

Type of HVAC system _____, serving number of floors _____

Automatic fire detection: Yes _____ No _____, Type and location _____

Fire alarm system: Yes _____ No _____, Type _____

Smoke control: Yes _____ No _____, Type _____

Adequate exit routes: Yes _____ No _____ Dead ends: _____ Yes _____ No _____

Maximum exit access travel distance _____ Elevator controls: Yes _____ No _____

Means of egress emergency lighting: Yes _____ No _____ Mixed occupancies: Yes _____ No _____

SAFETY PARAMETERS	FIRE SAFETY (FS)	MEANS OF EGRESS (ME)	GENERAL SAFETY (GS)
3410.6.1 Building Height 3410.6.2 Building Area 3410.6.3 Compartmentation			
3410.6.4 Tenant and Dwelling Unit Separations 3410.6.5 Corridor Walls 3410.6.6 Vertical Openings			
3410.6.7 HVAC Systems 3410.6.8 Automatic Fire Detection 3410.6.9 Fire Alarm System			
3410.6.10 Smoke control 3410.6.11 Means of Egress 3410.6.12 Dead ends	* * * * * * * * * * * *		
3410.6.13 Maximum Exit Access Travel Distance 3410.6.14 Elevator Control 3410.6.15 Means of Egress Emergency Lighting	* * * * * * * *		
3410.6.16 Mixed Occupancies 3410.6.17 Automatic Sprinklers 3410.6.18 Incidental Use		* * * * ÷ 2 =	
Building score — total value			

* * * *No applicable value to be inserted.

Figure 6-1 Building code summary sheet

TABLE 3410.8 MANDATORY SAFETY SCORES			
OCCUPANCY	FIRE SAFETY (MFS)	MEANS OF EGRESS (MME)	GENERAL SAFETY (MGS)
A-1	16	27	27
A-2	19	30	30
A-3	18	29	29
A-4, E	23	34	34
B	24	34	34
F	20	30	30
M	19	36	36
R	17	34	34
S-1	15	25	25
S-2	23	33	33

a. MFS = Mandatory Fire Safety;
MME = Mandatory Means of Egress;
MGS = Mandatory General Safety.

Figure 6-2 Mandatory safety scores

and doesn't install smoke alarms, and there's a fire, he could be cited for not meeting the code. But that may be the least of his problems at that point.

There are a couple of exceptions to the smoke alarm rule:

1. If the alterations or repairs don't require the removal of interior wall or ceiling finishes exposing the structure, the interconnection and hard-wiring of smoke alarms in existing areas is not required. But if there's an attic, basement, or crawl space that would allow easy access for installation of the system, you have to provide interconnected, hard-wired smoke alarms.
2. If the repairs, alterations or additions are only to the outside of the building, or the replacement of windows or doors, the smoke alarm provision doesn't apply.

In the Line of Duty

Most cities have zoning ordinances that prohibit the accumulation of junk in residential zones. That's a great idea. Piles of junk are unsanitary and hazardous, not to mention unsightly. Some cities don't aggressively enforce these ordinances unless someone complains. Then they have to send someone from the building, fire, police or health department to investigate.

In my city, this chore fell on the building department. After responding to a few of these calls, I began to wish I could get help from other departments. Making house calls to settle disputes between neighbors isn't my favorite way to spend an afternoon.

I even went to the city manager once with a proposal — a compromise. My department would go on calls in rotation with the other departments. We'd handle the first call. After that, the departments would go in alphabetical order: fire, health and the police. Wasn't that the fairest way to spread the wealth?

"Well, sure," the city manager said, "I could divide responsibility. But what will people think when a policeman, fireman or a health department official pulls up to the door? They'll think there's some kind of emergency. The way I see it, your building department has the low profile we need to tackle this problem. Anyhow, nobody's better at arm-twisting than you are, right? You see, it isn't really a matter of fair or unfair. It's who can get the job done — and what's best for our city. That's why we thought you'd be happy to do it."

Funny I didn't see it that way until the city manager explained it to me. I guess that's why he was the city manager and I was just the building inspector.

A few weeks later, I had to make one of these "junk" calls. The homeowner had closed a second-hand furniture store and moved the remaining inventory to his backyard. The yard was jammed with plywood shacks, each bulging with junk. That was violation number one. Number two was that too much of the lot area was covered with these shacks. Number three violation was that I had no permit on file for any of these buildings. It looked like an open-and-shut case to me.

I parked in front of the residence, and got out of the car. Before I could knock on the door, it was flung open and I was looking at the business end of the biggest, ugliest gun barrel I'd ever seen. "What do you want?" demanded a voice somewhere behind the gun.

"I'm the building inspector and . . ."

"I don't care if you're Jesus Christ. Get off my property!"

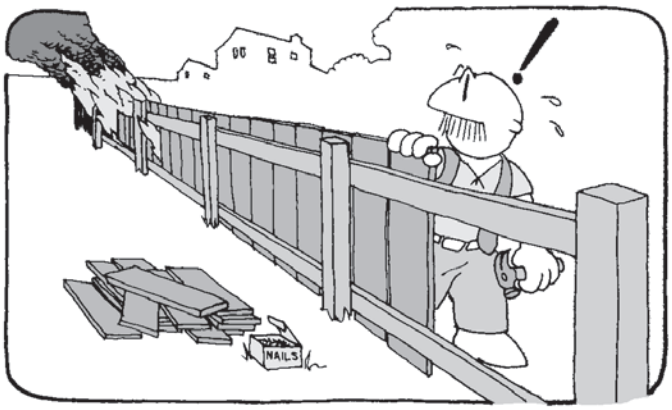
Now, if there's anything I try to avoid, it's antagonizing the citizens of our town. And what I had here was one, clearly unhappy citizen. No use making things worse, I thought. I did a smart about-face and advanced back to my car.

No medals for heroism are given to building inspectors, even a building inspector with a wife and eight kids to support.

Obviously, there was something the city manager had overlooked. They'd sent a boy to do a man's work.

But I solved the problem. Yes sir!

This was no job for the Building Inspector. This was a job for the City Attorney!



CHAPTER 7

Types of Construction and Fire Resistance

Chapters 3 and 4 addressed Occupancy Groups and Occupancy Loads. We learned that each occupancy group could require a different construction type, so in this chapter we'll look into those types of construction.

Buildings Classified by Construction

Usually, the same construction type is used for an entire building. However, different construction types may be used for any part of a building surrounded by fire walls and exterior walls. Fire walls make each part of the structure a separate "building." The complete building (or each separate "building" part) must meet the minimum standards for the applicable occupancy group. The IBC sets the minimum. You can always build to a higher construction type, but why would you do that? Reduced insurance premiums may be a reason, if they offset the higher construction cost.

By dividing a building with fire walls, each area can then have a different construction type. You can also use fire walls to increase the allowable floor area. However, area separations must be complete — from foundation to roof. They also must meet minimum standards for fire walls. The next chapter has further information on fire walls.

IBC Table 602 (Figure 7-1) gives the fire-resistance ratings required for exterior walls. The table shows ratings by:

1. Occupancy group
2. Construction type
3. Fire separation distance

Construction Types

The IBC Section 602 specifies the five different construction types:

602.2 Types I and II. *Type I and II construction are those types of construc-*

TABLE 602 FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE				
FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H	OCCUPANCY GROUP F-1, M, S-1	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2, U[b]
X < 5[c]	All	3	2	1
5 ≤ X <10	IA Others	3 2	2 1	1 1
10 ≤ X< 30	IA, IB IIB, VB Others	2 1 1	1 0 1	1[d] 0 1[d]
X ≥ 30	All	0	0	0

For SI: 1 foot = 304.8 mm.
a. Load-bearing exterior walls shall also comply with the fire-resistance rating requirements of Table 601.
b. For special requirements for Group U occupancies see Section 406.1.2
c. See Section 705.1.1 for party walls.
d. Open parking garages complying with Section 406 shall not be required to have a fire-resistance rating.
e. The fire-resistance rating of an exterior wall is determined based upon the fire separation distance of the exterior wall and the story in which the wall is located.

Figure 7-1 Fire-resistance rating requirements for exterior walls

tion in which the building elements listed in Table 601 are of noncombustible materials, except as permitted in Section 603 and elsewhere in this code.

602.3 Type III. *Type III construction is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by this code. Fire-retardant-treated wood framing complying with Section 2303.2 shall be permitted within exterior wall assemblies of a 2-hour rating or less.*

602.4 Type IV. *Type IV construction (Heavy Timber, HT) is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of solid or laminated wood without concealed spaces. The details of Type IV construction shall comply with the provisions of this section.*

Type IV construction is further classified into these sections:

- Columns, Section 602.4.1
- Floor framing, Section 602.4.2
- Roof framing, Section 602.4.3
- Floors, Section 602.4.4
- Roofs, Section 602.4.5
- Partitions, Section 602.4.6
- Exterior structural members, Section 602.4.7

602.5 Type V. *Type V construction is that type of construction in which the structural elements, exterior walls and interior walls are of any materials permitted by this code.*

Fire-Resistance Requirements

What is fire resistance? It's the property of materials or their assemblies that prevents or retards the passage of excessive heat, hot gases or flames under conditions of use.

What determines fire-resistance rating? The period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by the tests described in Chapter 8 of this book. In simple terms, it's the number of hours a structure will remain viable in the event of a fire — how long a burning building will stand before collapsing. The longer it stands, the better chance people have to get out if there's a fire. The higher number construction types have lower fire-resistance ratings. All construction types except Type IV have A and B subsets. Subset A is more fire-resistant than Subset B.

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[e]	B	A[e]	B	HT	A[e]	B
Structural frame[a]	3[b]	2[b]	1	0	1	0	HT	1	0
Bearing walls Exterior[g] Interior	 3 3[b]	 2 2[b]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[f]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	$1^1/_2$[c]	1[c, d]	1[c, d]	0[c, d]	1[c, d]	0[c, d]	HT	1[c, d]	0

For SI: 1 foot = 304.8 mm.

a. The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.

b. Roof supports: Fire-resistance ratings of structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

c. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

d. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

e. An approved automatic sprinkler system in accordance with Section 903.3.1.1 shall be allowed to be substituted for 1-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of the code or used for an allowable area increase in accordance with Section 506.3 or an allowable height increase in accordance with Section 504.2. The 1-hour substitution for the fire resistance of exterior walls shall not be permitted.

f. Not less than the fire-resistance rating required by other sections of this code.

g. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

Figure 7-2 Fire-resistance ratings requirements for building elements

In Types I and II, all structural elements must be noncombustible. But many nonstructural materials need not be noncombustible. There's a full list of the items and types of materials in Section 603.1. Two of these are thermal and acoustical insulation. In addition, fire-retardant-treated wood is allowed for:

- Nonbearing partitions where the fire-resistance rating required is 2 hours or less;
- Nonbearing exterior walls where no fire-resistance rating is required;
- Roof construction. This includes girders, trusses, framing and decking. But it excludes Type I construction more than two stories high. In that case, you can't use fire-retardant wood if the distance from the upper floor to the roof is less than 20 feet.

Type IIIA construction has limited fire resistance. It's usually only 1 hour, with 1-hour resistance needed for exterior bearing walls. Type IIIB construction has almost no fire-resistance requirement, other than the same 2-hour resistance needed for exterior bearing walls.

Type IV is Heavy Timber (HT) construction, which we'll talk about later in this chapter.

Type VA has the fewest fire-resistance requirements of any construction type. You need only 1 hour of fire resistance for everything except interior nonbearing walls and partitions. They don't have any fire-resistance requirement. Type VB doesn't have any fire-resistance requirements whatsoever.

You'll find fire-resistance requirements for exterior nonbearing walls and partitions in Table 602 (Figure 7-1). This is only for exterior *nonbearing* walls. Exterior *bearing* walls are covered by IBC Table 601, Figure 7-2.

Table 602 is based on fire separation distance. Fire-resistance rating requirements differ depending on construction type and

occupancy group. There's no requirement for exterior *nonbearing* walls at more than 30 feet fire separation distance, so it doesn't matter what type of construction or building occupancy you have.

Fire-Resistance Requirement Defines Construction Type

The fire resistance required for each element of a building's construction defines the construction type, shown in IBC Table 601, Figure 7-2. These elements are:

- Structural frame
- Exterior and interior bearing walls
- Exterior nonbearing walls and partitions
- Interior nonbearing walls and partitions
- Floors
- Roofs

As was discussed previously, building height has a direct impact on survivability in a fire. The higher the building, the longer it takes occupants to vacate the upper floors, and the more time it would take rescuers to reach people trapped there.

IBC Table 601 is very specific. It lists the type of construction needed to provide a particular fire-resistance rating for each of the building elements. Say you want to build a 15-story apartment building. First check Table 503 (Figure 7-3) to find the type of construction required for a Group R-2 occupancy. You see that a 15-story building requires Type IA construction. If you want to cut your costs by using the Type IB construction elements in Table 601, you'll have to limit your building height to 11 stories.

You decide to bite the bullet and build to Type IA. Table 601 shows the difference in the roof's fire-resistance rating requirement. There's only a half-hour difference between Type IA and IB (1½ hours, instead of 1 hour). If you go with the 1-hour roof, you could save a few bucks. After all, a 1-hour roof is still pretty safe.

You draw up your specs. Then the plans examiner shakes his head. What went wrong? The examiner noticed that one element of Table 601 was reduced, which means you've inadvertently reduced the whole structure one grade, from Type IA to Type IB. You still have an adequate building design, but the 1-hour roof fire resistance means you can only build an 11-story apartment building.

You have to make a choice. Are you going to build a 1½-hour fire-resistant roof or reduce your building to 11 stories? The added cost of that 1½-hour roof is probably less than the lost rent from four floors of apartments. Think about all this before you make your decision. And remember, when you reduce one element of the building, the whole building will be classified at the lower grade.

What if your plan calls for 3-hour exterior bearing walls, a 3-hour structural frame, and 1½-hour roof? You'd think that these elements would make your building fall into Type IA construction. That would allow you unlimited stories and unlimited floor area for most occupancies. But somehow you end up with a Type IIB building limitation. What happened? One of the other elements didn't meet the requirements of Table 601. Perhaps your floor construction had a zero fire-resistance rating. That would reduce the height of your apartment building from UL to four stories. Using Type IA construction for the other building elements (at the corresponding added cost) would have been to no advantage whatsoever.

Roof Structures

This is another tricky item. Usually, skylights and roof structures must be of the same construction type as the rest of the building. They also have to be the same distance from the property lines. If a roof structure houses anything other than mechanical equipment, it's counted as an extra story. So be careful what you intend for that space.

We'll cover construction details in later chapters. But the construction type always dictates the construction methods. In other words, if you're putting up a frame building of Type VA construction, the skylight must meet at least Type VA construction requirements.

TABLE 503
ALLOWABLE HEIGHT AND BUILDING AREAS

HEIGHT LIMITATIONS SHOWN AS STORIES AND FEET ABOVE GRADE PLANE. AREA LIMITATIONS ARE DETERMINED BY THE DEFINITION OF "AREA, BUILDING," PER STORY

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HGT(feet)									
GROUP	HGT(S)	UL	160	65	55	65	55	65	50	40
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	4	5	4	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
H-1	S	1	1	1	1	1	1	1	1	NP
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP
H-2[d]	S	UL	3	2	1	2	1	2	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	3,000
H-3[d]	S	UL	6	4	2	4	2	4	2	1
	A	UL	60,000	26,500	14,000	17,500	13,000	25,500	10,000	5,000
H-4	S	UL	7	5	3	5	3	5	3	2
	A	UL	UL	37,500	17,500	28,500	17,500	36,000	18,000	6,500
H-5	S	4	4	3	3	3	3	3	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
I-1	S	UL	9	4	3	4	3	4	3	2
	A	UL	55,000	19,000	10,000	16,500	10,000	18,000	10,500	4,500
I-2	S	UL	4	2	1	1	NP	1	1	NP
	A	UL	UL	15,000	11,000	12,000	NP	12,000	9,500	NP
I-3	S	UL	4	2	1	2	1	2	2	1
	A	UL	UL	15,000	10,000	10,500	7,500	12,000	7,500	5,000
I-4	S	UL	5	3	2	3	2	3	1	1
	A	UL	60,500	26,500	13,000	23,500	13,000	25,500	18,500	9,000
M	S	UL	11	4	4	4	4	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-3	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	3	3	3	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2[b, c]	S	UL	11	5	4	4	4	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

UL = Unlimited, NP = Not permitted.

a. See the following sections for general exceptions to Table 503:
   1. Section 504.2, Allowable height increase due to automatic sprinkler system installation.
   2. Section 506.2, Allowable area increase due to street frontage.
   3. Section 506.3, Allowable area increase due to automatic sprinkler system installation.
   4. Section 507, Unlimited area buildings.

b. For open parking structures, see Section 406.3.

c. For private garages, see Section 406.1.

d. See Section 415.5 for limitations.

Figure 7-3 Allowable height and building areas

Fire-Retardant-Treated Wood

You can use fire-retardant-treated wood for Type I and II construction in nonbearing partitions where the required fire-resistance rating is 2 hours or less. It can also be used for nonbearing exterior walls where no fire rating is needed. And it's allowed for certain unprotected structural members. Check note "c" of IBC Table 601 (Figure 7-2) for guidelines. But this raises some questions, because there are two kinds of fire-retardant-treated wood:

1. Wood that the manufacturer has impregnated with fire retardant under pressure
2. Wood with the retardant sprayed or painted on, often on-site

Both are acceptable which, to the inspector, means that the material is labeled as having passed the test for fire-retardant-treated wood. The IBC gives this definition of approved fire-retardant-treated wood:

> ***2303.2 Fire-retardant-treated wood.*** *Fire-retardant-treated wood is any wood product which, when impregnated with chemicals by a pressure process or other means during manufacture, shall have, when tested in accordance with ASTM E 84, a listed flame spread index of 25 or less and show no evidence of significant progressive combustion when the test is continued for an additional 20-minute period. In addition, the flame front shall not progress more than 10.5 feet (3200 mm) beyond the centerline of the burners at any time during the test.*

Wood *"impregnated with chemicals by a pressure or other means during manufacture"* is acceptable. The important point is this: does the wood have a "*listed flame spread index of 25 or less and show no evidence of significant progressive combustion*" when tested in accordance with ASTM E 84? It's not the manufacturing process that's important. What counts is that it passed the prescribed test. This is where product labeling is important. According to IBC Section 2303.2.1, labeling includes:

- The I.D. mark of an approved agency
- The treating manufacturer
- Fire-retardant treatment
- Species of wood
- Flame spread and smoke-developed index
- Method of drying after treatment

If the manufacturer recommends that a certain retardant material be applied in four coats at eight-hour intervals, there's probably a good reason. It's disturbing to hear subcontractors say that two coats applied at two-hour intervals will work just as well. To many builders, it's a matter of money. It's what they think they can get away with. "After all, the manufacturers are just trying to sell more fire retardant," they say.

Correct, the manufacturers are in business to make a profit. They want to sell lots of fire retardant. But they *also* want their material used correctly. They put a lot of money into testing, and the reputation of their product is at stake. The product has to qualify using the minimum labor and material recommended to make the grade. If it doesn't pass, it won't get the listing. If the listing says it takes four coats at eight-hour intervals to do the job, then that's how it should be done, since that's the bare minimum application and timing necessary. The manufacturer's done the math.

The building inspector usually asks for a copy of the listing, or wants it available at inspection time. This is true for applied materials, hardware, equipment, and sometimes appliances.

What about inferior work that a subcontractor does on-site? By skimping on fire retardant, he can underbid his competitors. Low bids are what clients are after, but someone has to monitor work quality. The building inspector has the last word. If he finds that substandard material has been used, he'll insist that it be replaced. It's going to cost a bundle for the subcontractor to replace all of the unacceptable wood with good. It's much better to do it right the first time. Sometimes, a special on-site inspector (approved by the building official) will be called in to watch the work being done. Remember, the owner has to pay for this on-

site service, and he won't be happy if you've employed a subcontractor who needs to be watched all the time.

Will Retardant-Treated Material Burn?

Yes, it will burn — but only as long as flame is applied. Once the flame is removed, the fire-retardant-treated material will stop burning. If you throw a piece of fire-retardant-treated wood into a lighted fire, it will turn to ashes. This is because the wood is under constant flame conditions. Given enough time, almost all materials are compromised by flame and intense heat. The retardant simply slows down combustion. That helps to keep a building intact long enough for people to get out and fire-fighters to get in to fight the fire.

Evaluation Reports

How does the building inspector know if a certain product is acceptable with so many products on the market? The ICC publishes a listing of all the evaluation reports done by ICC Evaluation Services, Inc. It's on their website www.icc-es.org/Evaluation_Reports/index.shtml. It includes legacy reports converted to new ICC-ESS evaluation reports. You can search for a report by the number, manufacturer or product.

Each report lists the product and the manufacturer's name and address. It includes a detailed description of what the product is, what it does, and where and how it should be used. It also says which codes the material complies with. The reports usually include design and installation details, conditions of use and identification. They give the inspector the information he needs to make a decision on whether or not the product is appropriate for a particular application.

To get the inspector's approval, the product or material must be used according to the manufacturer's specs. No other method will be approved unless you can convince the inspector that your way is better. That could turn out to be more expensive than just doing it as the manufacturer recommends.

Following the Code Saves You Money, But...

Following the code can save you money. Let's talk about nonbearing interior walls and partitions, for example. In all construction types except HT, partitions don't have to meet any fire-resistance rating. You'll see there's a row of "0"s in Table 601 (Figure 7-2). So you could use plain wood panels in these nonbearing partitions.

But be careful. What seems to be the least expensive way to build could end up costing the owner more money. Some builders have used $^{3}/_{16}$-inch wood panels with photo-engraved grain over a shoddy backing for interior partitions. They're so flimsy that you could put a fist right through them. Or, if your recliner accidentally went back too far, it could go right through the partition. It's always a good idea to back partitions with sheetrock. True, this will add to the cost, but it also adds strength and fire resistance. If you can put your fist through a panel, think of what could happen if someone accidentally tripped and fell against it.

In nearly any construction type, wood veneer can be used over noncombustible surfaces. Wood trim and unprotected wood doors can be used where unprotected openings are permitted.

So exactly what are unprotected openings? And how do you know if they're permitted?

Unprotected Openings

Unprotected openings are wall openings, usually intended for doors and windows. The openings are filled using a product (door or window) with no specific fire-resistance rating. So, how do we know if they're permitted? Read IBC Section 704.8 and look at Table 704.8 (Figure 7-4), which cover allowable areas of openings.

Section 704.8 says that the maximum area of unprotected or protected openings in an exterior wall of any story can't exceed the values shown in Table 704.8. The percentage of area allowed depends on the fire separation distance. So, for example, at 3 to 5 feet fire separation, unprotected openings are not permitted (see solid outlined box). However, for

TABLE 704.8
MAXIMUM AREA OF EXTERIOR WALL OPENINGS

CLASSIFICATION OF OPENING	FIRE SEPARATION DISTANCE (feet)							
	0 to 3[f,j]	Greater than 3 to 5[c,g]	Greater than 5 to 10[c,e,g,h]	Greater than 10 to 15[d,e,g]	Greater than 15 to 20[d,g]	Greater than 20 to 25[d,g]	Greater than 25 to 30[d,g]	Greater than 30
Unprotected	Not Permitted	Not Permitted[c]	10%[i]	15%[i]	25%[i]	45%[i]	70%[i]	No Limit[b]
Protected	Not Permitted	15%	25%	45%	75%	No Limit[b]	No Limit[b]	No Limit[b]

For SI: 1 foot = 304.8 mm.
a. Values given are percentage of the area of the exterior wall.
b. See Section 704.7 for unexposed surface temperature.
c. For occupancies in Group R-3, the maximum percentage of unprotected and protected exterior wall openings shall be 25 percent.
d. The area of openings in an open parking structure with a fire separation distance of greater than 10 feet shall not be limited.
e. For occupancies in Group H-2 or H-3, unprotected openings shall not be permitted for openings with a fire separation distance of 15 feet or less.
f. For requirements for fire walls for buildings with differing roof heights, see Section 705.6.1.
g. The area of unprotected and protected openings is not limited for occupancies in Group R-3, with a fire separation distance greater than 5 feet.
h. For special requirements for Group U occupancies, see Section 406.1.2.
i. Buildings whose exterior bearing wall, exterior nonbearing wall and exterior structural frame are not required to be fire-resistance rated by Table 601 or 602 shall be permitted to have unlimited unprotected openings.
j. Includes accessory buildings to Group R-3.

Figure 7-4 Maximum area of exterior wall openings

more than 10 feet and up to 15 feet separation, 15 percent of the exterior wall (dashed outline) can be unprotected openings and 45 percent (dotted outline) can be protected openings.

If both protected and unprotected openings are installed in the exterior wall of any story, the total area of the opening must meet the following formula, named IBC Equation 7-2:

$$\frac{A}{a} + \frac{A_u}{a_u} \leq 1.0$$

where:

A = Actual area of protected openings, or the equivalent area of protected openings, A_e; (see Section 704.7).

a = Allowable area of protected openings.

A_u = Actual area of unprotected openings.

a_u = Allowable area of unprotected openings.

Suppose you design an exterior wall with only unprotected openings, with a fire separation distance of 13 feet. The maximum area of unprotected openings allowed is 15 percent (dashed outline). So, if the wall area on one side of one story is 300 square feet (30 feet wide by 10 feet high), the maximum area of unprotected openings allowed is 45 square feet (15 percent of 300 square feet).

On the other hand, let's say you design the same 300-square-foot exterior wall with both protected and unprotected openings. From Table 704.8 (Figure 7-4), you may think that the maximum allowable unprotected opening is 15 percent, (45 square feet), and the maximum allowable protected opening is 45 percent (dotted outline), or 135 square feet.

But that's not correct because you now have both protected and unprotected openings in your exterior wall. If you want to design both types of openings to the maximum areas, you can't exceed what's allowed in IBC Equation 7-2. In this example:

A is 135

a is 135

A_u is 45

a_u is 45

So:

$$\frac{135}{135} + \frac{45}{45} = 1 + 1 = 2$$

That's clearly greater than the figure of 1 allowed in Equation 7-2. So you have to eliminate either the protected or the unproteced openings. Another option is to reduce each of their actual areas by half, or use some combination of the two. That will bring the total of protected and unprotected percentage areas down to a figure of 1 or less.

There is an exception. If the building has sprinklers, the allowable areas for unprotected openings can be the same as for protected openings, except for Group H-1, H-2 and H-3 occupancies (IBC Section 704.8.1).

There's one more exception (Section 704.8.2) for the first story of a building facing a street with a fire separation of more than 15 feet, or an unoccupied space more than 30 feet wide. In that case, the area of unprotected opening is unlimited. However, this doesn't apply to Group H occupancies. Finally, IBC Section 704.9 says this:

> ***704.9*** *Openings in exterior walls in adjacent stories shall be separated vertically to protect against fire spread on the exterior of the buildings where the openings are within 5 feet (1,524 mm) of each other horizontally and the opening in the lower story is not a protected opening with a fire protection rating of not less than ¾ hour.*

If your building has openings within 5 feet of each other horizontally and the openings in the lower story are not protected with at least ¾-hour fire-resistance rating, you must take special measures to protect upper stories from fire spread on the exterior of the building. Section 704.9 goes on to explain the action you must take.

Double-Wall Construction or Not?

When I was a novice in the home-building trade, we laid the framing on the subfloor and nailed it together. Then we raised it up and braced it in place. Next, the builder applied a layer of building paper right onto the studs and, finally, a single layer of siding. Hence the name, "single-wall construction." Double-walled construction was a layer of sheathing, either shiplap or 1-inch stock, placed horizontally or diagonally on studs, then covered with building paper and siding.

Now, double-walled construction is achieved with plywood or OSB (oriented strand board) sheathing, then #15 asphalt felt, and last, siding. Entire wall sections are assembled on the floor and lifted into place. Some of the sections already have windows and paint. This diaphragm wall is more airtight and may be stronger structurally than walls we used to build.

The IRC permits single-wall construction, as described in R703.2, but some people have their doubts about it. In this type of construction, the walls are only braced with 1- x 4-inch continuous diagonal braces positioned into the top and bottom plates and the intervening studs (IRC Section R602.10.3, Item 1). The siding is then applied directly to the studs. Yes, the IRC *permits* it. But I still prefer double-wall construction, in which the framing is braced with one of the following:

- Wood boards, Item 2
- Wood structural panel sheathing, Item 3
- Structural fiberboard sheathing, Item 4
- Gypsum board, Item 5
- Particleboard, Item 6

Sheathing can be used either with or without the diagonal bracing of Item 1. The siding is then applied on top of the sheathing. Sheathing plus siding equals double-wall construction. An example of wood structural panel sheathing prior to the application of the siding for double-walled construction is shown in Figure 7-5.

Figure 7-5 Wood structural panel sheathing for double-wall construction

TABLE 2304.6 MINIMUM THICKNESS OF WALL SHEATHING		
SHEATHING TYPE	MINIMUM THICKNESS	MAXIMUM WALL STUD SPACING
Wood boards	$^5/_8$ inch	24 inches on center
Fiberboard	$^1/_2$ inch	16 inches on center
Wood structural panel	In accordance with Tables 2308.9.3(2) and 2308.9.3(3)	—
M-S "Exterior Glue" and M-2 "Exterior Glue" Particleboard	In accordance with Tables 2306.4.3 and 2308.9.3(4)	—
Gypsum sheathing	$^1/_2$ inch	16 inches on center
Gypsum wallboard	$^1/_2$ inch	24 inches on center
Reinforced cement mortar	1 inch	24 inches on center

Figure 7-6 Minimum thickness of wall sheathing

Minimum Thickness of Wall Sheathing and Weather Protection

Plywood and OSB are the most common materials for exterior wall sheathing. However, other materials can be used. IBC Table 2304.6 (Figure 7-6) lists the minimum thickness and maximum stud spacing for different sheathing materials. OSB is a wood structural panel sheathing.

Wood panel sheathing used as the exposed finish on exterior walls must have what's called an *exterior exposure durability classification.* To use plywood panel siding for exterior use, see IBC Table 2308.9.3(2) in Figure 7-7.

Exterior grade ⅜-inch plywood meets code requirements. But if it isn't backed by a sheathing panel, most builders use $^7/_{16}$-inch or ½-inch plywood. Either one is a better choice, and isn't that much more expensive. Exterior walls can be weatherproofed using one of the products listed in IBC Section 1405 and in Table 1405.2, Figure 7-8. Weatherproofing of external walls by stucco construction is covered in Section 2510 of the IBC.

Masonry Walls and Parapets

Parapets must have the same fire-resistant rating as supporting walls, addressed in IBC Section 704.11.1. Parapets must be at least 30 inches above the junction of the roof surface and the wall. Figure 7-9 illustrates this requirement. If the slope of a roof toward a parapet is greater than 2-in-12, there are even more restrictions. If wall opening protection is required, the height of the parapet must equal the distance from the inside of the parapet to the highest point on the roof within fire separation distance.

TABLE 2308.9.3(2) EXPOSED PLYWOOD PANEL SIDING		
MINIMUM THICKNESS[a] (inch)	MINIMUM NUMBER OF PLIES	STUD SPACING (inches) Plywood siding applied directly to studs or over sheathing
$^3/_8$	3	16[b]
$^1/_2$	4	24

For SI: 1 inch = 25.4 mm.

a. Thickness of grooved panels is measured at bottom of grooves.

b. Spans are permitted to be 24 inches if plywood siding applied with face grain perpendicular to studs or over one of the following: (1) 1-inch board sheathing, (2) $^7/_{16}$-inch wood structural panel sheathing or (3) $^3/_8$–inch wood structural panel sheathing with strength axis (which is the long direction of the panel unless otherwise marked) of sheathing perpendicular to studs.

Figure 7-7 Exposed plywood panel siding

TABLE 1405.2 MINIMUM THICKNESS OF WEATHER COVERINGS	
COVERING TYPE	**MINIMUM THICKNESS (inches)**
Adhered masonry veneer	0.25
Aluminum siding	0.019
Anchored masonry veneer	2.625
Asbestos-cement boards	0.125
Asbestos shingles	0.156
Cold-rolled copper[d]	0.0216 nominal
Copper shingles[d]	0.0162 nominal
Exterior plywood (with sheathing)	0.313
Exterior plywood (without sheathing)	See Section 2304.6
Fiber cement lap siding	0.25[c]
Fiber cement panel siding	0.25[c]
Fiberboard siding	0.5
Glass-fiber reinforced concrete panels	0.375
Hardboard siding[c]	0.25
High-yield copper[d]	0.0162 nominal
Lead-coated copper[d]	0.0216 nominal
Lead-coated high-yield copper	0.0162 nominal
Marble slabs	1
Particleboard (with sheathing)	See Section 2304.6
Particleboard (without sheathing)	See Section 2304.6
Precast stone facing	0.625
Steel (approved corrosion resistant)	0.0149
Stone (cast artificial)	1.5
Stone (natural)	2
Structural glass	0.344
Stucco or exterior portland cement plaster	
Three-coat work over:	
Metal plaster base	0.875[b]
Unit masonry	0.625[b]
Cast-in-place or precast concrete	0.625[b]
Two-coat work over:	
Unit masonry	0.5[b]
Cast-in-place or precast concrete	0.375[b]
Terra cotta (anchored)	1
Terra cotta (adhered)	0.25
Vinyl siding	0.035
Wood shingles	0.375
Wood siding (without sheathing)[a]	0.5

For SI: 1 inch = 25.4 mm.

a. Wood siding of thicknesses less than 0.5 inch shall be placed over sheathing that conforms to Section 2304.6.

b. Exclusive of texture.

c. As measured at the bottom of decorative grooves.

d. 16 ounces per square foot for cold-rolled copper and lead-coated copper, 12 ounces per square foot for copper shingles, high-yield copper and lead-coated high-yield copper.

Figure 7-8 Minimum thickness of weather coverings

There's one more requirement. The top 18 inches on any side next to the roof needs noncombustible facing. This includes all counterflashing and coping materials.

Type I Construction

So far, we've discussed requirements that apply to almost all buildings. Now let's talk about each individual construction type. We'll start with the most fire-resistant construction, Type I, subsets A and B, as shown in Table 503 (refer back to Figure 7-3).

Type IA building heights are unlimited by the IBC, except for some Group H buildings. H-1 buildings are limited to one story, and H-5 buildings are limited to four stories, but there are no *height* restrictions. So, you could have a 1,000-foot-high one-story H-1 or four-story H-5 building! Type IB buildings are limited to 160 feet, with a maximum number of stories, as follows:

Group	No. of Stories
A-1	5
A-2 thru A-4	11
B	11
E	5
Group	**No. of Stories**
H-1	1
H-2	3
H-3	6
H-4	7
H-5	4
I-1	9
I-2 and I-3	4
I-4	5
M	11
R-1 thru R-4	11
S-1 and S-2	11
U	5

The IBC allows a height increase of 20 feet over and above Table 503 (Figure 7-3) numbers, if an NFPA 13-approved automatic sprinkler system is installed. Then it allows one more story. This was discussed in Chapter 4 of this book, in *Maximum Height of Building Increases*.

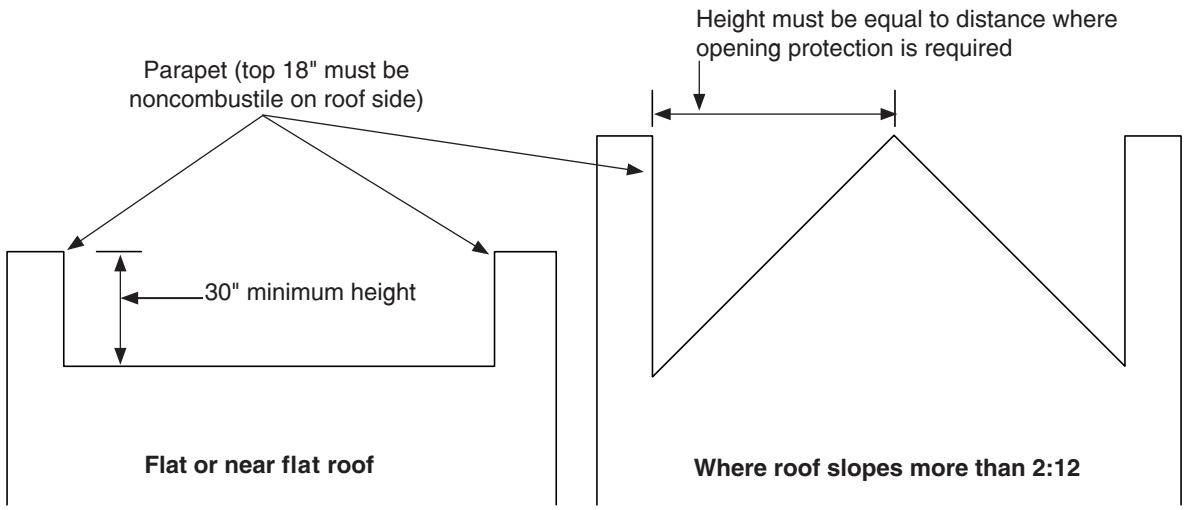


Figure 7-9 Requirements for parapet walls

The floor area for Type IA buildings is limited only for Groups H-1 and H-2. They're allowed a maximum of 21,000 square feet. For Type IB buildings, the maximum floor area is unlimited, except in the following situations:

Group	Maximum Floor Area (Sq. Ft.)
H-1 and H-2	16,500
H-3	60,000
I-1	55,000
I-4	60,500
S-1	48,000
S-2	79,000
U	35,500

Remember, you can increase allowable floor areas. Increases are allowed for NFPA 13-approved automatic sprinkler and frontage factors. This too is covered in Chapter 4, in *Allowable Area Increases*.

A building isn't fireproof just by being fire-resistant. Some of the worst fires in history have been in so-called fireproof buildings. In fact, Type IA buildings — the most fire-resistant — have been called *concrete coffins*. Although the building itself doesn't burn, most everything inside it does.

It's important to note that people seldom burn to death in building fires. More often, they die from smoke and toxic fume inhalation. A fire-resistant building gives occupants a better chance of escaping only if the toxic fumes don't kill them first.

The structural frame of a Type I building must be iron, steel, reinforced concrete, or reinforced masonry. Type IA must have a 3-hour fire-resistance rating. Type IB must have a 2-hour fire-resistance rating, as shown in Figure 7-2. Structural frame members in exterior walls must meet the requirements for exterior walls based on the fire separation distances in Table 602 (Figure 7-1), or the requirements for building elements (measured in hours) in Table 601, whichever is greater.

Type I buildings must have fire-resistant exterior walls meeting the requirements of Table 602. But *nonbearing* exterior walls with fire separations at least 30 feet wide may have unprotected, noncombustible construction.

Table 601 gives the essential fire-resistance rating requirements for all types of buildings. Section 505 states that the total area of a mezzanine or mezzanines in any room must not be greater than one-third of the floor area of the room. The clear height above and below the mezzanine floor construction must be at least 7 feet. Mezzanine floors must have 1-hour noncombustible construction.

Stairs and stair platforms must be made of reinforced concrete, iron or steel. Brick, marble, tile or other noncombustible materials may be used only for the finish of treads and risers in stair enclosures.

Type II Construction

Type II construction also has subsets A and B. The fire-resistance requirements are shown in Table 601(Figure 7-2), and the allowable height and floor area restrictions are in Table 503 (Figure 7-3).

The maximum height for any occupancy of Type IIA construction is 65 feet. For Type IIB the restriction is 55 feet. The number of stories allowed is anywhere from one story for Group H-1 to five stories for Group S-2 occupancy.

Remember, the IBC allows a 20-foot height increase over the Table 503 numbers, and one additional story, but only if an approved automatic sprinkler system is installed. Significant floor area increases are allowed due to automatic sprinkler and frontage factors.

In Type IIA construction, most structural elements require a 1-hour fire-resistance rating. The exceptions are nonbearing interior walls and partitions. Type IIB construction has no fire-resistance requirements for any of the structural elements. Table 601, note "*e*", says the following about Type IIA construction:

An approved automatic sprinkler system in accordance with Section 903.3.1.1 shall be allowed to be substituted for 1-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of the code or used for an allowable area increase in accordance with Section 506.3 or an allowable height increase in accordance with Section 504.2. The 1-hour substitution for the fire resistance of exterior walls shall not be permitted.

So you can add a sprinkler system to gain the allowable area increase, or forego the 1-hour fire-resistance-rated construction requirement, but you can't have it both ways. This also applies to Type IIIA and Type VA construction.

Also, refer to Table 601 note "*c*" for roof construction in Types IA, IB, IIA, IIB, IIIA and VA. The fire-resistance rating requirement is modified as follows:

Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

Certain combustible materials can be used in Type I and Type II construction. Refer back to *Fire-Resistance Requirements* and *Fire-Retardant-Treated Wood*, earlier in this chapter. Also see IBC Section 603.

Type III Construction

Type III construction also has subsets A and B. They're both fairly flexible construction types, as you can see in Table 601 (Figure 7-2). The exception is exterior bearing walls. Both A and B require 2-hour fire-resistance ratings. Interior bearing walls, floors and roofs must have a 1-hour fire-resistance rating for Type A construction. For all other structural elements in Type II construction, there are no fire-resistance rating requirements. Take a good look at Section 602.3 at the start of this chapter.

Type III height restrictions in Table 503 (65 feet for Type A and 55 feet for Type B) are the same as for Type II. However, the number of stories and floor areas allowed for Types IIIA and IIIB construction are a little more restrictive than for Types IIA and IIB. They're identical for all R occupancies, and for A-5 (stadiums, etc.), where there are no height and floor area restrictions for any construction types.

One major difference between the restrictions for Type II and Type III is for Group I-2 occupancies, like hospitals and nursing homes. Type IIB construction allows a one-story building and 11,000 square feet of floor area. However, Type III construction is not allowed for Group I-2 occupancies.

Again, keep in mind that the code allows for an increase of 20 feet in height over and above the Table 503 numbers if an approved automatic sprinkler system is installed. Then one additional story is allowed. Also, significant floor area increases are allowed with approved automatic sprinkler systems and frontage factors.

Type IV Construction

Type IV (Heavy Timber, HT) is mill-type construction using massive columns and joists. This kind of construction is found in many older industrial buildings, especially on the West Coast. Warehouses and shipping docks are often Type IV construction. IBC Section 602.4, at the start of this chapter, gives the general description for Type IV construction. Sections 602.4.1 through 602.4.7 give details of:

- Columns
- Floor framing
- Roof framing
- Floors
- Roofs
- Partitions
- Exterior structural members

We'll cover just the main points here, and you can use the IBC for further details. All measurements are nominal lumber sizes. The members aren't quite as big as the numbers indicate. A 4 x 8 is only about 3½ x 7½ inches, finished or planed on four sides. From now on, we'll just call out the nominal thickness, and you'll know what's meant by the term.

Columns must be at least 8 inches in any cross-sectional dimension when they support floors. If they only support ceilings and roofs they must be at least 6 inches x 8 inches. Wood beams or girders that support floors must be at least 6 inches wide x 10 inches deep, or 8 inches square, depending on the design. Framed timber trusses that support floors must be at least 8 inches x 8 inches. You can see why it's called *heavy timber*.

Wood-frame or glued-laminated arches for roofs that originate at the top of walls must be at least 4 inches wide x 6 inches deep. If they begin at the floor line or grade, they must be at least 6 inches wide x 8 inches deep.

Wood floors have special requirements. They must be made from one of the following:

- Sawn or glued-laminated planks, splined or tongue-and-groove at least 3 inches nominal thickness, covered with 1-inch tongue-and-groove flooring or ½-inch particleboard
- Planks not less than 4 inches wide set on edge close together, well-spiked, and covered with 1-inch flooring, 15/32-inch wood structural panel or ½-inch particleboard

Under-floor areas in Type IV buildings must be well ventilated.

Wood roof decks can be made of any one of the following:

- Sawn or glue-laminated, splined or tongue-and-groove plank at least 2 inches nominal thickness
- 1⅛-inch-thick wood structural panel (exterior glue)
- Planks at least 3 inches wide

Partitions with no fire-resistance rating are not allowed in Type IV construction. They're required to have at least 1-hour fire resistance, and must be formed by at least two layers of 1-inch matched boards, or laminated construction 4 inches thick.

External structural members can be made of wood. They must be heavy timber-sized, and the fire separation distance must be at least 20 feet.

Why is something as combustible as a heavy timber building given a Type IV construction rating? Fire safety doesn't require a noncombustible frame. The issue is how long the building will stand after it starts to burn. The thicker the timber, the longer it will take to burn to the point of failure or collapse. Mill buildings can burn for quite a while before they collapse.

Type V buildings are limited to 50 feet high for A and 40 feet in height for B construction types. The maximum number of stories allowed is between one and four, depending on the occupancy group. The IBC allows a height increase of 20 feet over and above Table 503 numbers, if an approved automatic sprinkler system is installed. Then you can also add one story.

Allowable floor areas range from:

- Unlimited for Group A-5, stadiums, etc., and for Group R-3
- Up to 7,500 square feet for Groups H-1, H-2, and I-3 with Type VA construction
- Up to 3,000 square feet for Group H-2

Floor area increases aren't permitted for Group I-2 with Type VB construction.

For other occupancy types, floor area increases are allowed with automatic sprinkler and/or frontage factors. Again, see Chapter 4 in this book, *Allowable Area Increases*.

Type V Construction

Type V buildings can be wood frame or a combination of wood frame and any other material, but only if the exterior walls aren't required to be noncombustible. However, for Type VA construction, all elements must have a fire-resistance rating of at least 1 hour, except for interior nonbearing walls, which need no fire-resistance rating. Exterior nonbearing walls must meet the requirements of Table 602 (Figure 7-1).

There are some special allowances for Type V construction. Metal Composite Materials (MCM) can be used as exterior wall covering; see IBC Section 1407.12. Timber footings are allowed for Type V construction (IBC Section 1805.4.5), but they must be treated according to the American Wood Preservers' Association standard AWPA U1. The standard is available at the AWPA website, www.awpa.com.

Summary

Let's summarize the five construction types in reference to fire ratings:

Type I: Most building elements must be noncombustible.

Type II: Type IIA — Most elements must have a 1-hour fire-resistance rating.

Type IIB — Construction requires no fire-resistance rating.

Type III: Exterior bearing walls must be noncombustible.

Type IV: Construction requires heavy timber.

Type V: All elements can be constructed of any material permitted by the IBC.

That finishes our review of construction types. In the next chapter, we'll take a closer look at what makes a building fire-resistant.

Fireplaces Are for Friendly Fires

Fireplaces have been warming humans for thousands of years. And unintentional fires have occurred for that long, too. Most accidental fires are preventable. Building inspectors don't have much control over the way fireplaces are used. The best I can do is to make sure that a fireplace will give safe, reliable service for many years. That's what I try to do, anyway.

Before building codes were written, fireplaces were built of nearly every kind of material imaginable. That doesn't happen any more. But even so, it takes real skill and craftsmanship to build a fireplace out of masonry and mortar. Not every mason can build a good fireplace. Even fewer designers can draw plans for a good fireplace. Most don't even try anymore. Modern fireplace materials have greatly simplified fireplace construction. The first major improvement was the metal hood containing the smoke shelf, damper and beginning of the flue. These hoods make it unnecessary to construct a smoke shelf. The second major improvement was the "zero clearance" all-metal fireplace. The third was the double-walled metal flue.

Modern materials also make it easy to inspect a fireplace. I have to make sure that all masonry is either separated from wood framing or that the masonry is thick enough so that the wood framing won't ignite when the fireplace gets hot. Metal hoods have to be properly sealed into the masonry. That isn't always easy to determine after a fireplace is built.

The area where the hood and the front of the fireplace meet always seems to be a trouble spot. I often find this area filled with fiberglass. Now we all know that fiberglass is fireproof. But even though fiberglass won't burn, it can melt, letting fire escape. It's taken a long time to educate some builders about this. Filler between the hood and the front of the fireplace *has to be masonry*.

Modern fireplaces aren't foolproof even when filled correctly. For example, one day I went to inspect a fireplace on a small job. It looked great. I even complimented the mason on the design. Then out of the corner of my eye I saw a slight movement in the corner of the firebox. I looked again. Sure enough, it moved. In fact, *it winked*. I've inspected a lot of fireplaces. But this was the first one that ever winked at me. In a moment the eye was gone. I stuck my pencil through the hole. Someone grabbed my pencil and pulled it through!

There was actually a hole through the back of the fireplace into the adjoining garage. I wondered if a winking fireplace would be safe. Probably not. The mason had some more work to do.

CHAPTER 8

Fire Resistance in Buildings

Public safety is the main concern of the IRC and the IBC. Fire is one of the biggest dangers to people's lives, so fire safety is well-covered in the codes. In Chapter 7, we learned how the IBC classifies building structures according to fire resistance. In this chapter, we'll study the rating system for building materials.

Materials like steel, concrete, glass and most mineral compounds are noncombustible, meaning they don't burn. But they *are* affected by fire. They can melt or give off toxic fumes. The codes have to consider what happens to these materials when they're involved in a building fire.

Noncombustible Is Not Nondestructible

In the late 1800s when the Chicago Coliseum was built, it was billed as noncombustible. It was — but it was still completely destroyed in a fire. The fire couldn't have done more damage if the Coliseum had been built of matchsticks and tissue paper.

There were two things the designers didn't consider:

1. The building was filled with paper, cloth and other combustible materials.
2. The fire started so quickly and grew so fast that it became uncontrollable.

What happened to this so-called noncombustible building? Well, it didn't burn. It just melted into a mass of twisted iron and steel. The planners thought the alarm system sounding in the event of a fire would take care of any risks. They ignored fire *protection* issues.

I try to explain this when someone insists that their metal-framed building is completely "noncombustible." Sure, steel and glass buildings don't burn; but the contents do. And when that happens, the steel frame melts like butter on hot toast. What have we learned from these mistakes? That even steel-frame buildings need built-in fire resistance.

Fire Resistance — How Do We Get It?

After a big fire, the news media are quick to make their reports — and generally find someone to blame. There's nothing wrong with that. It's news. We're all concerned when innocent people die. But the media neglects to report what causes most disastrous fires. Other than arson, a fire that becomes a disaster usually does so because of unenforced code requirements or penny-pinching construction. Owners and contractors try to minimize costs. One way to save money, they think, is to cut corners on fire safety requirements or to delay compliance with code.

Few people die from burns in structural fires. And even fewer die from being trapped in a burning building. But that doesn't lessen the importance of fire resistance.

The majority of people who die in building fires succumb to smoke or toxic fumes. Fire resistance doesn't stop fires and it doesn't prevent deaths. But it *can* slow the building's combustion rate and keep it from collapsing long enough for everyone to get out or be rescued by fire-fighters.

Nothing is completely fireproof. Some building materials are considered noncombustible. Others are said to be fire resistant. But every building material will fail if it gets hot enough — high-strength steel framing is no exception. The failure of the Twin Towers on September 11, 2001 was a tragic example of that.

Noncombustible materials don't burn. But they can transmit enough heat to keep a fire going, and even cause it to spread. Most fire-resistant materials will burn when a flame is applied, and some will continue burning even after the flame is out.

For surface-covering or composite materials, the flame-spread rate is an important factor. It determines the fire's progression rate. Let's look at these terms and what they mean: noncombustibility, flame spread, and fire resistance.

Noncombustibility

The term noncombustible, as used in the IBC, applies to materials that meet the noncombustibility tests in Section 703.4:

> ***703.4 Noncombustibility tests.*** *The tests indicated in Sections 703.4.1 and 703.4.2* [below] *shall serve as criteria for acceptance of building materials as set forth in Sections 602.2, 602.3 and 602.4 in Type I, II, III and IV construction* [in Chapter 7 of this book]. *The term "noncombustible" does not apply to the flame spread characteristics of interior finish or trim materials. A material shall not be classified as a noncombustible building construction material if it is subject to an increase in combustibility or flame spread beyond the limitations herein established through the effects of age, moisture or other atmospheric conditions.*
>
> ***703.4.1 Elementary materials.*** *Materials required to be noncombustible shall be tested in accordance with ASTM E 136.*

ASTM E 136 is the Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 degrees C (1,382 degrees F). It tests the way materials perform when subjected to high heat in a confined space for 30 minutes. The standard was developed by the American Society for Testing Materials (ASTM), and can be found at their website, www.astm.org. ASTM E 136 is considered the industry standard for differentiating between combustible and noncombustible materials.

You're not expected to perform this test yourself. Usually, the manufacturer has a licensed laboratory perform the test and the results are published as a product data sheet. However, if you're planning to use some exotic new material, you'll probably have to pay a lab to do the testing for you. The inspector will have to see evidence that the test has been performed and that your material passed.

Noncombustible but Still Not Acceptable!

Just because a material isn't combustible at 750 degrees C doesn't necessarily mean that it's

still structurally sound at that temperature. If it isn't sound, the material can't be used as a load-bearing member. For example, aluminum, a common material for window frames, melts at 660 degrees C (1,220 degrees F). That's 90 degrees C below the test furnace temperature of 750 degrees C. So aluminum clearly can't be used as a load-bearing building material. In addition, most metals *soften* before they melt. That makes the temperature at which they remain structurally sound well below their melting point.

Here are the melting points of some metals:

- Steel — 1,370 degrees C (2,498 degrees F)
- Cast iron — 1,204 degrees C (2,199 degrees F)
- Copper — 1,083 degrees C (1,981 degrees F)
- Lead — 163 degrees C (325 degrees F)

Steel is an excellent structural building material. It's used in the construction of most modern commercial buildings, and is the foundation of virtually all tall buildings. Steel framing is also very flexible, as characterized by the swaying that can be felt in the upper stories of a tall building during high winds.

Cast iron was once popular as a structural component. The Iron Bridge, built in England in 1779, was the first structure built of cast iron. It's still in use today, by pedestrians, after more than 225 years. But due to the lack of flexibility and brittleness of cast iron, you won't find many iron structures any more.

Plumbing used to be made out of lead, but not since it was determined that lead is poisonous. Besides, its low melting point makes it a poor building material. Think about having lead sprinkler lines in your building. They'd be useless — they'd melt right away in the event of a fire. Copper, on the other hand, has a high melting point, and can withstand all but the most intense fire. Although copper is now fairly expensive, it's still the best material available for plumbing. Most residential plumbing today is made out of either copper or plastic.

Flame Spread

Not long after WWII ended, there was a rash of fires in numerous nightclubs and hotel ballrooms resulting in many fatalities. On December 7, 1946, a fire at the Winecoff Hotel in Atlanta killed 119 people. Fire investigators sifting through debris at these fires found that they had one thing in common: rapid flame spread along interior finish surfaces. Walls in two of the rooms at the Winecoff where the fire had started were covered in burlap, a highly-flammable material. The ballroom fire investigations resulted in the development of a standard test to measure the flame spread rate of various materials, including wall and ceiling coverings.

Interior nonbearing walls and ceilings in most building types don't need a fire-resistance rating. But it's mandatory to have a flame spread classification for the finish materials on most walls and ceilings. IBC Section 803 states that interior wall and ceiling finishes must be tested to the flame spread and smoke-developed standard, ASTM E 84, and classified A, B or C, as follows:

Class A: Flame spread index 0-25; smoke-developed index 0-450

Class B: Flame spread index 26-75; smoke-developed index 0-450

Class C: Flame spread index 76-200; smoke-developed index 0-450

The interior finish class requirement (A, B or C) is based on occupancy type, location, and whether or not the building has sprinklers. See Section 803.5 and Table 803.5 (Figure 8-1). This flame spread index requirement applies to all occupancy types except Group U.

Interior wall and ceiling finish materials, other than textiles (cloth), can be tested to a different standard, NFPA 286, as described in Section 803.2. You can purchase this standard on the NFPA website at www.nfpa.org. Materials tested to NFPA 286, and meeting the acceptance criteria described in Section 803.2.1, can be used as Class A materials.

Measuring Flame Spread

A flame-spread rating isn't a fire-resistance rating or a combustible/noncombustible rating.

TABLE 803.5
INTERIOR WALL AND CEILING FINISH REQUIREMENTS BY OCCUPANCY

GROUP	SPRINKLERED[l]			NONSPRINKLERED		
	Exit enclosures and exit passageways[a,b]	Corridors	Rooms and enclosed spaces[c]	Exit enclosures and exit passageways[a,b]	Corridors	Rooms and enclosed spaces[c]
A-1 & A-2	B	B	C	A	A[d]	B[e]
A-3[f], A-4, A-5	B	B	C	A	A[d]	C
B, E, M, R-1, R-4	B	C	C	A	B	C
F	C	C	C	B	C	C
H	B	B	C[g]	A	A	B
I-1	B	C	C	A	B	B
I-2	B	B	B[h, i]	A	A	B
I-3	A	A[j]	C	A	A	B
I-4	B	B	B[h, i]	A	A	B
R-2	C	C	C	B	B	C
R-3	C	C	C	C	C	C
S	C	C	C	B	B	C
U	No restrictions			No restrictions		

For SI: 1 inch = 25.4 mm, 1 square foot = 0.0929 m^2.

a. Class C interior finish materials shall be permitted for wainscotting or paneling of not more than 1,000 square feet of applied surface area in the grade lobby where applied directly to a noncombustible base or over furring strips applied to a noncombustible base and fireblocked as required by Section 803.4.1.
b. In exit enclosures of buildings less than three stories in height of other than Group I-3, Class B interior finish for nonsprinklered buildings and Class C interior finish for sprinklered buildings shall be permitted.
c. Requirements for rooms and enclosed spaces shall be based upon spaces enclosed by partitions. Where a fire-resistance rating is required for structural elements, the enclosing partitions shall extend from the floor to the ceiling. Partitions that do not comply with this shall be considered enclosing spaces and the rooms or spaces on both sides shall be considered one. In determining the applicable requirements for rooms and enclosed spaces, the specific occupancy thereof shall be the governing factor regardless of the group classification of the building or structure.
d. Lobby areas in Group A-1, A-2 and A-3 occupancies shall not be less than Class B materials.
e. Class C interior finish materials shall be permitted in places of assembly with an occupant load of 300 persons or less.
f. For places of religious worship, wood used for ornamental purposes, trusses, paneling or chancel furnishing shall be permitted.
g. Class B material is required where the building exceeds two stories.
h. Class C interior finish materials shall be permitted in administrative spaces.
i. Class C interior finish materials shall be permitted in rooms with a capacity of four persons or less.
j. Class B materials shall be permitted as wainscotting extending not more than 48 inches above the finished floor in corridors.
k. Finish materials as provided for in other sections of this code.
l. Applies when the exit enclosures, exit passageways, corridors or rooms and enclosed spaces are protected by a sprinkler system installed in accordance with Section 903.3.1.1 or 903.3.1.2.

Figure 8-1 Interior wall and ceiling finish requirements

Flame-spread rating is a relative term. It compares the time it takes flame to spread on the surface of the material being tested with the time it takes the same flame to spread on untreated red oak. Red oak has been given an arbitrary rating of 100. Fiber cement board, at the other end of the scale, has been given a rating of 0. It's easy to see why fiber cement board is used for the 0 rating, but what's so special about red oak?

"Select" red oak is a fairly consistent grade of U.S. lumber that's available nationwide. But more important, it was chosen as the control material because of its uniform density and burning rate. Flame spread isn't the only factor measured in the flame spread test. The test also measures the density of the smoke produced. And, the smoke developed by burning red oak is more uniform than that of most other woods.

ASTM E 84-05

ASTM E 84 is the standard for the Flame Spread Index (FSI) and Smoke-Developed Index (SDI). It replaces the UL tunnel test used in the 1997 UBC.

ASTM E 84-05 describes the testing equipment and method for measuring flame spread. The fire test is conducted in a long, narrow chamber made of insulated masonry, with two

gas burners that distribute a flame evenly over the width of the sample's underside. One side of the chamber has observation windows so the entire test sample can be seen, and the technicians can record the time it takes for the flame front to advance down the chamber. A light beam and photocell positioned inside the chamber record the density of the smoke, particulate and other waste products generated.

The test chamber is calibrated, first using a test sample of red oak and then using a sample of fiber cement board. Then the test is conducted on the actual test material. The sample material being tested must be typical in size to what will be used in a real-life building. The distance the flame front travels over the sample is recorded every 30 seconds. The smoke test measuring the decrease in light registered by the photocell is recorded every 15 seconds.

FSI and SDI

The flame spread index, FSI, and the smoke-developed index, SDI, are determined using formulas given in the ASTM standards. Fortunately, you don't have to perform the test — but you *do* need to know that it's the accepted standard for classifying building materials. Knowing the FSI and SDI of building materials is essential in establishing which can safely be used in different occupancies and locations. The flame spread test is taken very seriously by the building inspector and the fire marshal; you need to take it seriously, too.

Just to review, the three classifications from IBC Section 803.1 are:

Class A: Flame spread index 0-25; smoke-developed index 0-450

Class B: Flame spread index 26-75; smoke-developed index 0-450

Class C: Flame spread index 76-200; smoke-developed index 0-450

This means that Class A materials have ¼ the FSI of red oak. Class B materials have between ¼ and ¾ of the red oak FSI. And Class C materials, which include red oak, have the highest flame spread index, with an FSI of 75 to 200.

Table 803.5 (refer back to Figure 8-1) gives the FSI requirements by occupancy group for finish materials in various locations (exits, enclosures and passageways, corridors and rooms) for both sprinklered and nonsprinklered buildings. Most wood products fall into Class C. So while it's OK to use wood paneling for the *room* walls of many types of sprinklered occupancies, it would *not* be OK for Groups I-2, hospitals, or I-4, day care facilities (outlined in Figure 8-1). For those, a minimum Class B interior finish material is required. There are some exceptions — see *notes,* "*h*" and "*i*" at the bottom of the table.

Other occupancies and locations, like exits or exit access corridors, usually need a higher FSI, as do nonsprinklered occupancies. Be sure to check the notes below Table 803.5 for other exceptions.

Wood is a common building material, especially in one- and two-family dwellings. For wood to be classified as fire retardant, it must have an FSI of less than 25. You can review Fire-Retardant Wood in IBC Section 2303.2, and Chapter 7 of this book.

Textiles as Wall Coverings

Textile wall and ceiling coverings provide an attractive finish. They also help in soundproofing. But they can pose a serious fire hazard. Consequently, they must have a Class A FSI and be protected by automatic sprinklers. This applies to all textiles that are:

- Materials with woven, nonwoven, napped, tufted, looped or similar surface
- Carpet and similar materials

If you need more information, see IBC Section 803.6.

Fire safety is important to everyone — building and fire inspectors, owners, contractors and occupants. We're spending a lot of time on these topics because lives are at stake in every structure we build.

Fire Resistance

We've looked at combustible/noncombustible factors and the flame spread and smoke-developed indexes. Now let's look at fire resistance. It's the third required element we must consider when selecting building materials — as far as fire prevention and suppression are concerned. Many of the materials contained in buildings are combustible, as we discussed earlier. This is especially true for one- or two-family dwellings. If a building catches fire, it's going to burn. And it can burn to the ground if nothing is done to stop the fire.

The main goal of addressing fire issues is to reduce the possibility of a fire starting in the first place. But if one *does* start, fire-resistant materials and assemblies can slow the fire's progress. That helps the building maintain its structural integrity long enough for people to escape.

Determining Fire Resistance

IBC Table 601 (look back to Chapter 4, Figure 4-4) gives the fire-resistance requirement (in number of hours) for a range of building elements under different construction types based on the ASTM E 119 standard, available at www.astm.org. Let's look at a brief summary of the test performed under this standard.

ASTM E 119-00a

ASTM E 119-00a uses a gas burner furnace to test the full sample. The furnace conditions are set so sensors record the temperatures on both the flame side and the unexposed side of the material over a period of 8 hours. During the test, the temperature will rise from room temperature to 1,260 degrees C (2,300 degrees F).

Immediately following the furnace test, a hose is used to direct a stream of water against the sample to simulate the effect of fire-fighting. The water pressure, distance from the sample, size of the nozzle and method of applying the water stream is strictly controlled.

The material/building component is rated as fire resistant for a specific period of time (1 hour, 1½ hours, 2 hours, etc.) if it passes both the fire-endurance test and the hose stream test.

The Test Sample

In order to get an accurate rating, the test sample must be built under the same conditions that are used in building construction and operation, or as close to that as possible. It has to conform to the construction being classified for fire resistance. This includes the materials, workmanship, and dimensions of the parts. Specific test sample requirements are given for the following types of building components:

- Nonbearing walls and partitions
- Load-bearing walls and partitions
- Columns
- Floors and roofs

Fire-Resistance-Rated Construction

IBC Chapter 7 covers Fire-Resistance-Rated Construction. It's one of the longest chapters in the code because of the wealth of detail included. The subjects covered are:

Exterior Walls, Section 704
Fire Walls, Section 705
Fire Barriers, Section 706
Shaft Enclosures, Section 707
Fire Partitions, Section 708
Smoke Barriers, Section 709
Smoke Partitions, Section 710
Horizontal Assemblies, Section 711
Penetrations, Section 712
Fire-Resistant Joint Systems, Section 713
Fire-Resistance Rating of Structural Members, Section 714
Opening Protectives, Section 715
Ducts and Air Transfer Openings, Section 716
Concealed Spaces, Section 717
Fire-Resistance Requirements for Plaster, Section 718
Thermal- and Sound-Insulating Materials, Section 719
Prescriptive Fire Resistance, Section 720
Calculated Fire Resistance, Section 721

TABLE 720.1(1)
MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR THE FOLLOWING FIRE-RESISTANCE PERIODS (inches)			
			4 hour	3 hour	2 hour	1 hour
1. Steel columns and all of primary trusses	1-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete, members 6″ × 6″ or greater (not including sandstone, granite and siliceous gravel).[a]	$2^1/_2$	2	$1^1/_2$	1
	1-1.2	Carbonate, lightweight and sand-lightweight aggregate concrete, members 8″ × 8″ or greater (not including sandstone, granite and siliceous gravel).[a]	2	$1^1/_2$	1	1
	1-1.3	Carbonate, lightweight and sand-lightweight aggregate concrete, members 12″ × 12″ or greater (not including sandstone, granite and siliceous gravel).[a]	$1^1/_2$	1	1	1
	1-1.4	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 6″ × 6″ or greater.[a]	3	2	$1^1/_2$	1
	1-1.5	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 8″ × 8″ or greater.[a]	$2^1/_2$	2	1	1
	1-1.6	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 12″ × 12″ or greater.[a]	2	1	1	1

For SI: 1 inch = 25.4 mm, 1 square inch = 645.2 mm^2, 1 cubic foot = 0.0283 m^3.
a. Reentrant parts of protected members to be filled solidly.

Figure 8-2 Minimum protection of structural parts based on time periods

Fire Resistance for Structural Parts

Prescriptive Fire Resistance, Section 720, contains three useful tables; 720.1(1), 720.1(2) and 720.1(3).

Table 720.1(1) (Figure 8-2), Minimum Protection of Structural Parts Based on Time Periods for Various Noncombustible Insulating Materials, is concerned with structural building components. Although only a portion of the table is shown here, you should become familiar with it in its entirety. Also, be sure to check all the footnotes. They may apply to your project.

Let's see how a general building inspector uses Table 720.1(1). Suppose he notices your plans have a 6-inch x 6-inch steel column encased in Grade A concrete (that's concrete that doesn't include sandstone, granite or siliceous gravel). Your specs say the concrete must be at least 2½ inches thick around the whole steel column. The inspector turns to Table 720.1(1) and finds the first item listed (outlined in the table). He sees that 2½ inches of concrete provides 4 hours of fire resistance. That's good enough for Type IA construction. Type IA calls for a minimum 3-hour fire-resistance rating (Table 601 back in Figure 4-4). The inspector looks at your specs and sees that the concrete complies. Your concrete-encased steel column qualifies for Type IA construction.

Of course, this doesn't just happen by accident. A good architect knows the code requirements and writes the specs to meet them. If your architect makes a mistake (maybe he only calls for 1½-inch-thick concrete), the inspector returns the plans for you or the architect to change.

Another thing the inspector could do is downgrade the construction type to IB. Then you'd only need a 2-hour fire-resistance rating, according to Table 601. But that could mean a much smaller building, with a proportionately smaller occupancy load. Consequently, it's usually not a practical option. The owner knows what occupancy type and load he wants. Remember, occupancy type and construction type determine the maximum floor area and number of stories. Each construction type calls

for a particular fire-resistance rating. It boils down to this: either the architect gets it right or the owner gets a new architect!

Fire Resistance for Walls and Partitions

IBC Table 720.1(2), Rated Fire-Resistance Periods for Various Walls and Partitions, does for walls and partitions what Table 720.1(1) does for the structural frame. Its purpose is to help you find the best wall or partition material and best construction for the fire-resistance rating you need. If you're designing the building, which material and construction should you use? That depends on a number of things.

First, identify the fire-resistance rating you need. Find the various combinations of material, construction and finished thickness from Table 720.1(2) that'll give you that rating. Then it's just a matter of choosing the best combination to meet the owner's requirements at the lowest cost. Simple, you say. But remember the code only requires the *minimum* rating. How much you exceed that rating is up to your client and his wallet.

Table 720.1(2) includes specific wall and partition assemblies. You can't make any substitutions if you intend to keep the fire-resistance rating, unless the combination is shown somewhere else in the table. Only the precise material, construction and face-to-face thickness combination defined in the table has the particular fire-resistance rating.

Fire Resistance for Floors and Roofs

Table 702.1(3), Minimum Protection for Floor and Roof Systems, is used the same way as the other two tables we just discussed.

Always read the notes following the tables if there's a note indicated next to your choice. The notes often contain information and exceptions that aren't specifically addressed elsewhere.

Be careful to follow the IBC when building floor and roof openings. All openings for mechanical and electrical equipment must be enclosed as described in Section 707, or protected with a penetration fire-stop system. Read Section 707 for important requirements to consider if your design calls for floor and roof openings.

Other Building Components

Let's discuss some other building components. Since there are often exceptions, you should thoroughly study the codes you're working under. The following sections will help you understand the IBC requirements.

Fire Walls

The IBC defines a fire wall as follows:

> ***Section 702*** *A fire-resistance-rated wall having protected openings, which restricts the spread of fire and extends continuously from the foundation to or through the roof, with sufficient structural stability under fire conditions to allow collapse of construction on either side without collapse of the wall.*

The fire-resistance-rating requirement for fire walls depends on the occupancy type; see Section 705.4. The minimum fire-resistance rating for fire walls for all occupancy types is shown in Table 705.4 (Figure 8-3).

Fire walls create separate buildings within an occupancy type, or between different occupancy types. When a firewall separates two different occupancy types, use the most restrictive rating of the two occupancies.

TABLE 705.4
FIRE WALL FIRE-RESISTANCE RATINGS

GROUP	FIRE-RESISTANCE RATING (hours)
A, B, E, H-4, I, R-1, R-2, U	3[a]
F-1, H-3[b], H-5, M, S-1	3
H-1, H-2	4[b]
F-2, S-2, R-3, R-4	2

a. Walls shall be not less than 2-hour fire-resistance rated where separating buildings of Type II or V construction.
b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.4 and 415.5.

Figure 8-3 Fire wall fire-resistance ratings

TABLE 715.4 FIRE DOOR AND FIRE SHUTTER FIRE PROTECTION RATINGS		
TYPE OF ASSEMBLY	REQUIRED ASSEMBLY RATING (hours)	MINIMUM FIRE DOOR AND FIRE SHUTTER ASSEMBLY RATING (hours)
Fire walls and fire barriers having a required fire-resistance rating greater than 1 hour	4 3 2 $1^1/_2$	3 3[a] $1^1/_2$ $1^1/_2$
Fire barriers having a required fire-resistance rating of 1 hour: Shaft, exit enclosure and exit passageway walls Other fire barriers	 1 1	 1 $^3/_4$
Fire partitions: Corridor walls Other fire partitions	 1 0.5 1 0.5	 $^1/_3$ [b] $^1/_3$ [b] $^3/_4$ $^1/_3$
Exterior walls	3 2 1	$1^1/_2$ $1^1/_2$ $^3/_4$
Smoke barriers	1	$^1/_3$ [b]

a. Two doors, each with a fire protection rating of $1^1/_2$ hours, installed on opposite sides of the same opening in a fire wall, shall be deemed equivalent in fire protection rating to one 3-hour fire door.
b. For testing requirements, see Section 715.3.3.

Figure 8-4 Fire door and fire shutter fire protection ratings

Fire Doors

Fire doors must have automatic or self-closing hardware. Automatic closing equipment must have heat-actuated devices on each side of the wall at the top of the opening. There's an additional requirement if the ceiling is more than 3 feet above the opening. The code requires a fusible link located at the ceiling on each side of the wall. IBC Section 715.4 says that fire door and shutter assemblies can be made of any material meeting specified test requirements and fire protection ratings shown in Table 715.4 (Figure 8-4).

Windows in Fire Doors

Two of the main requirements for windows in fire doors are discussed in Section 715.4.6. Basically, they must have wired glass, and conform to the area and dimensions shown in Table 715.5.3 (Figure 8-5).

The maximum fire-resistance rating for a fire door with a window is 1½ hours. The window can't be larger than 100 square inches (outlined in Figure 8-5). Tall narrow windows are allowed, but not wide horizontal ones. Windows in exit fire doors located in fire walls can't be more than 10 inches high.

There's one more thing you should be aware of regarding fire doors. If the Fire Marshall inspects your plans, he'll probably insist that all fire doors be marked "Fire Door — Do Not Obstruct." We'll take a closer look at fire safety in Chapter 9.

TABLE 715.5.3 LIMITING SIZES OF WIRED GLASS PANELS			
OPENING FIRE PROTECTION RATING	MAXIMUM AREA (square inches)	MAXIMUM HEIGHT (inches)	MAXIMUM WIDTH (inches)
3 hours	0	0	0
$1^1/_2$-hour doors in exterior walls	0	0	0
1 and $1^1/_2$ hours	100	33	10
$^3/_4$ hour	1,296	54	54
20 minutes	Not Limited	Not Limited	Not Limited
Fire window assemblies	1,296	54	54

For SI: 1 inch = 25.4 mm, 1 square inch = 645.2 mm^2.

Figure 8-5 Limiting sizes of wired glass panels

TABLE 715.5 FIRE WINDOW ASSEMBLY FIRE PROTECTION RATINGS		
TYPE OF ASSEMBLY	REQUIRED ASSEMBLY RATING (hours)	MINIMUM FIRE WINDOW ASSEMBLY RATINg (hours)
Interior walls:		
Fire walls	All	NP[a]
Fire barriers	> 1	NP[a]
Smoke barriers	1	$^3/_4$
and fire partitions	1	$^3/_4$
Exterior walls	> 1	$1^1/_2$
	1	$^3/_4$
Party wall	All	NP

NP = Not Permitted.
a. Not permitted except as specified in Section 715.2.

Figure 8-6 Fire window assembly fire protection ratings

Fire Windows

Section 715.5 and Table 715.5 (Figure 8-6) cover fire protection ratings for fire window assemblies.

Windows are not allowed in interior fire walls or barriers unless they're tested to the ASTM E 119 standard as a complete assembly (Section 715.2). Fire windows aren't allowed in party walls. What's a party wall, you ask? Well, it's got nothing to do with balloons and streamers. It's a wall built on a lot line and shared by two adjacent buildings. A party wall must be a fire wall with no openings. That creates two separate buildings, according to Section 705.1.1. The wall between adjacent townhouses is considered to be a party wall (see Townhouses, below). You really wouldn't want to build a window into the wall between two townhouses — the occupants could end up knowing their neighbors a little better than they wanted to.

Speaking of townhouses, let's take a look at the fire-resistance requirements for one- and two-family dwellings and townhouses.

One- and Two-Family Dwellings and Townhouses

The IRC spends a lot of time discussing fire resistance. Here are some of the most important points.

Exterior Walls

For elements of exterior walls for one- or two-family dwellings, refer to Section R302.1 and Table R302.1 (Figure 8-7). Included in their information are:

- Minimum fire-resistance ratings
- Minimum fire separation distances

If there's no exterior wall separation (such as the party wall in townhouses), the minimum fire-resistance-rating requirement is 1 hour for each "building" wall.

It's important to remember that connected townhouses are separated by fire walls and are considered "separate buildings." And, each "building" must have a 1-hour fire-resistant wall as part of the party wall.

When the separation between individual buildings is more than 5 feet, the exterior walls don't need a fire-resistance rating. There are exceptions for detached garages, tool sheds, playhouses and similar structures.

Exterior Wall Openings

Referring to Table R302.1 (Figure 8-7), you'll see that exterior wall openings aren't allowed if the separation between exterior walls is less than 3 feet. You certainly wouldn't want openings in a party wall between two-family dwellings or townhouses. If the wall separation is between 3 and 5 feet, you're allowed to build openings with areas up to 25 percent of the wall area. They don't need a fire-resistance rating. For separations more than 5 feet, "anything goes."

Dwelling Unit Separation

For more on required fire-resistance separation between separate units of two-family dwellings or townhouses, see IRC Section R317.

Two-Family Dwellings

Two-family dwelling units can be designed side-by-side, or stacked. Two-family dwelling party walls and any party wall/ceiling assembly must have at least a 1-hour fire-resistance rating, according to Section R317.1. If you want

TABLE R302.1 EXTERIOR WALLS			
EXTERIOR WALL ELEMENT		MINIMUM FIRE-RESISTANCE RATING	MINIMUM FIRE SEPARATION DISTANCE
Walls	(Fire-resistance rated)	1 hour with exposure from both sides	0 feet
	(Not fire-resistance rated)	0 hours	5 feet
Projections	(Fire-resistance rated)	1 hour on the underside	4 feet
	(Not fire-resistance rated)	0 hours	5 feet
Openings	Not allowed	N/A	< 3 feet
	25% Maximum of Wall Area	0 hours	3 feet
	Unlimited	0 hours	5 feet
Penetrations	All	Comply with Section R317.3	< 5 feet
		None required	5 feet

N/A = Not Applicable.

Figure 8-7 Exterior walls

to spend more money and install sprinklers, you can reduce the fire-resistance rating to ½ hour. This isn't very common, but sometimes you have no choice. Some jurisdictions require sprinklers in everything except Group R-3 occupancies. Floor/ceiling assemblies between stacked dwelling units must fit tightly to the exterior walls. That eliminates any fire gaps between the dwelling units.

In side-by-side designs, the party wall must extend all the way through the attic space to the roof sheathing. This completely separates the two dwelling units.

However, the wall doesn't need to extend to the roof sheathing in any one of the following situations:

- The ceiling is protected by Type X gypsum board.
- An attic draft stop is built (see IRC Section R502.12.1).
- The structural framing that supports the ceiling is protected by at least ½-inch gypsum board.

Townhouses

Each townhouse is considered a separate building, and must have its own 1-hour fire-resistant wall if the building separation is less than 5 feet. Obviously, adjoining townhouses have a separation of less than 5 feet — they're touching each other. In Figure 8-8, you can see a townhouse development in various stages of construction. As we discussed, a party wall must be made of two 1-hour fire-resistant walls, or one 2-hour wall.

In the three lower photographs of Figure 8-8, you can clearly see:

- Two 1-hour walls, through the floor framing separating the crawl space (b);
- ⅝-inch Type X gypsum and mineral wool fire-stop batts (c);
- The fire wall/party wall assembled (d).

The fire wall in (d) will be continued in the attic with identical 1-hour walls to the bottom of the roof sheeting, and capped by a Class A roofing material.

A 2-hour fire-resistant wall could have been substituted for the two 1-hour fire-resistant walls, but only if there was no plumbing, mechanical equipment, ducts or vents in the party wall cavity. Openings in a party wall (for electrical outlet boxes and similar items) are allowed only under strict conditions, shown in Section R317.3.

Chimneys and Fireplaces

Fireplaces and chimneys are common in one- and two-family dwellings. They're strictly

a b c d

Figure 8-8 Zero lot line townhouses and their fire wall elements under construction

regulated in the IRC, and code requirements are discussed in Chapter 10. We'll just discuss a few of them.

Masonry chimney walls must be at least 4 inches thick, and made of grouted, solid or hollow masonry units (IRC Section R1003.10).

Clearance between the chimney and anything combustible is critical. If any part of a masonry chimney is inside an exterior wall, there must be at least 2 inches of air space clearance. If the chimney is totally outside the exterior wall, that can be reduced to a minimum of 1 inch. This includes chimneys that pass through a soffit or cornice. Additional details and exceptions can be found in IRC Section R1003.18.

All spaces where chimneys pass through floors and ceilings must be fire-blocked with noncombustible material fixed securely in place. It's best to lay the material on strips of metal across the air space, as described in Section R1003.19.

TABLE R1001.1
SUMMARY OF REQUIREMENTS FOR MASONRY FIREPLACES AND CHIMNEYS

ITEM	LETTER[a]	REQUIREMENTS
Hearth slab thickness	A	4″
Hearth extension (each side of opening)	B	8″ fireplace opening < 6 square foot. 12″ fireplace opening ≥ 6 square foot.
Hearth extension (front of opening)	C	16″ fireplace opening < 6 square foot. 20″ fireplace opening ≥ 6 square foot.
Hearth slab reinforcing	D	Reinforced to carry its own weight and all imposed loads.
Thickness of wall of firebox	E	10″ solid brick or 8″ where a firebrick lining is used. Joints in firebrick $^1/_4$″ maximum.
Distance from top of opening to throat	F	8″
Smoke chamber wall thickness Unlined walls	G	6″ 8″
Chimney Vertical reinforcing[b]	H	Four No. 4 full-length bars for chimney up to 40″ wide. Add two No. 4 bars for each additional 40″ or fraction of width or each additional flue.
Horizontal reinforcing	J	$^1/_4$″ ties at 18″ and two ties at each bend in vertical steel.
Bond beams	K	No specified requirements.
Fireplace lintel	L	Noncombustible material.
Chimney walls with flue lining	M	Solid masonry units or hollow masonry units grouted solid with at least 4 inch nominal thickness.
Distances between adjacent flues	—	See Section R1003.13.
Effective flue area (based on area of fireplace opening)	P	See Section R1003.15.
Clearances: Combustible material Mantel and trim Above roof	R	 See Sections R1001.11 and R1003.18. See Section R1001.11, Exception 4. 3′ at roofline and 2′ at 10′.
Anchorage[b] Strap Number Embedment into chimney Fasten to Bolts	S	 $^3/_{16}$″ × 1″ Two 12″ hooked around outer bar with 6″ extension. 4 joists Two $^1/_2$″ diameter.
Footing Thickness Width	T	 12″ min. 6″ each side of fireplace wall.

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

NOTE: This table provides a summary of major requirements for the construction of masonry chimneys and fireplaces. Letter references are to Figure R1001.1, which shows examples of typical construction. This table does not cover all requirements, nor does it cover all aspects of the indicated requirements. For the actual mandatory requirements of the code, see the indicated section of text.

a. The letters refer to Figure R1001.1.

b. Not required in Seismic Design Category A, B or C.

Figure 8-9 Requirements for masonry fireplaces and chimneys

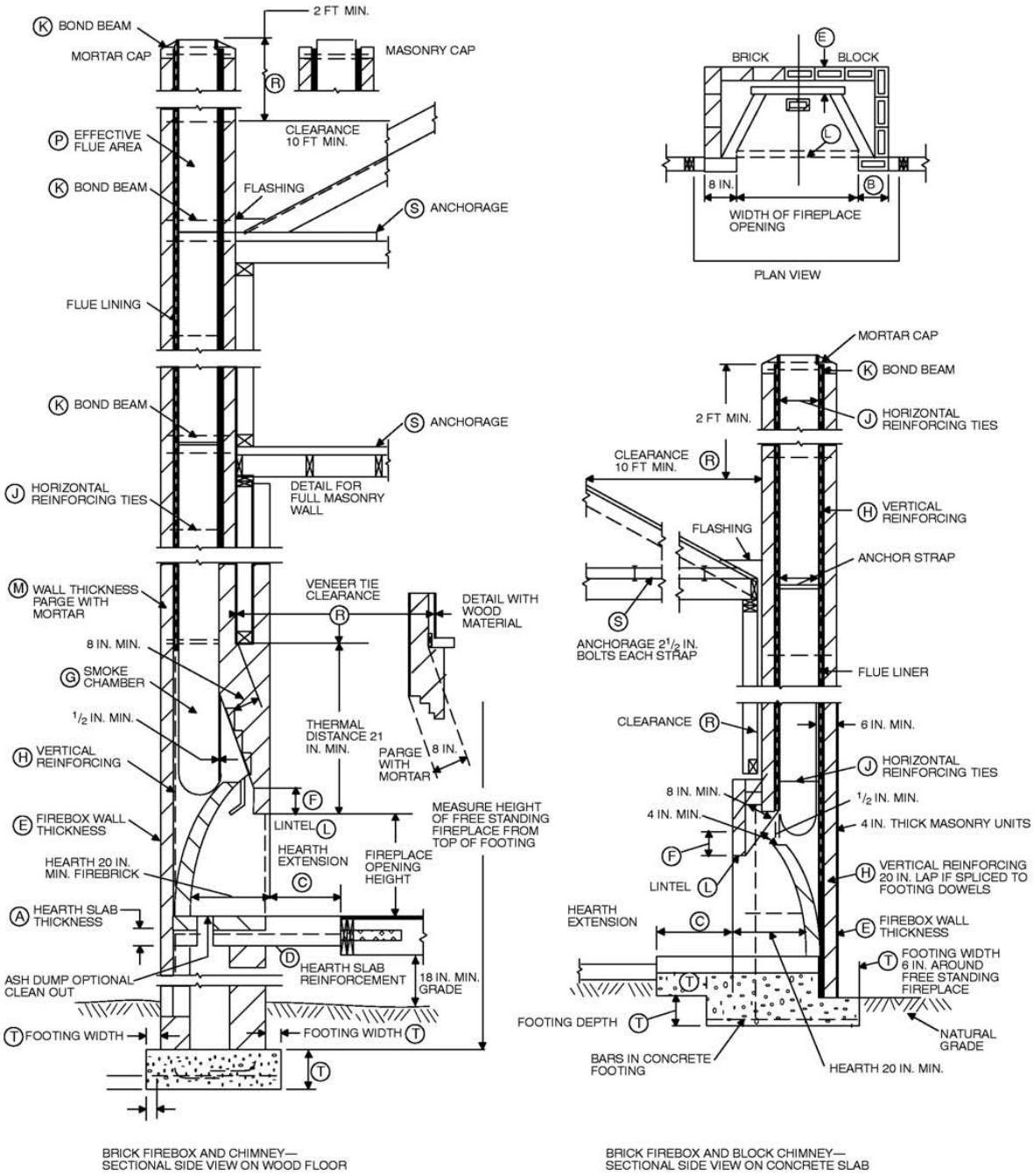
Fireplaces and chimneys must have concrete or solid masonry footings, at least 12 inches thick. They must extend at least 6 inches past the face of the fireplace or foundation wall on all sides. In frost-free areas, footings must be at least 12 inches below grade level. In frost-prone areas, they should be placed on natural, undisturbed earth or engineered fill below the frost depth (see Section R1003.2).

The clearance between the front face and sides of a masonry fireplace and combustible materials, such as wood beams, joists or studs, must be at least 2 inches. From the back of the fireplace, the clearance must be at least 4 inches, since that's where the heat is concentrated.

IRC Table R1001 (Figure 8-9) and Figure R1001.1 (Figure 8-10) summarize the requirements for masonry fireplaces and chimneys.

Chapters 18 (Chimneys and Vents) and 24 (Fuel Gas) of the IRC give information on fireplace- and chimney-related issues.

FIGURE R1001.1
FIREPLACE AND CHIMNEY DETAILS



For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

Figure 8-10 Fireplace and chimney details

Wall and Ceiling Coverings

IRC Section R315 covers flame spread and smoke density for wall and ceiling coverings in one- or two-family dwellings and townhouses. The main requirements are:

- Wall and ceiling finishes must have an FSI of no more than 200. However, there are exceptions for:

  Trim, such as picture molds, chair rails, baseboards and handrails

  Doors

  Windows

  Door and window frames

  Wall coverings less than $^1/_{28}$-inch thick cemented to walls or ceilings. These coverings must have an FSI no higher than the same thickness of paper cemented to a noncombustible backing. A $^1/_{28}$-inch-thick (about 1 mm) wall covering would be pretty thick, so the requirement for the FSI to be no more than 200 doesn't apply to most wall coverings.

- Wall and ceiling finishes must have a smoke-developed index of 450 or less.

- Material testing must be done to the ASTM E 84 standard; or materials can be tested to the NFPA 286 standard and meet alternate requirements; see Section R315.4.

In the next chapter we'll take a look at a related subject — fire protection systems.

Have I Got a Deal for You!

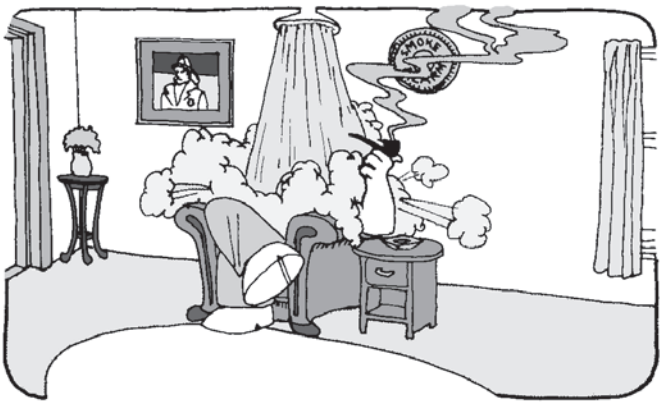
I guess I'm a little old fashioned. I get worried when I hear about some great new construction material. There are fads and fashions in construction just like in the garment industry. When a new material comes along, everyone wants to try it. Pretty soon they're all experts either at selling it, using it, or both. Never underestimate the enthusiasm of America's entrepreneurs. If there's a buck to be made, someone's reaching for it.

Roof coatings are a good example. A roofing truck pulls up in front of the house. Here's the spiel the homeowner gets: "Sir, I was just driving down the street and noticed that your roof isn't looking so good. I've been resurfacing roofs in this neighborhood and have enough extra time and material to resurface yours tomorrow afternoon. We use a new aerobic silicone polyester coating, the same stuff used to protect the skin of the space shuttle. It adds years to the life of your roof and costs pennies compared to a new roof."

The victim is often a senior citizen on a limited income, or someone worried about leaks when it rains next. This sales pitch seems like a stroke of good luck. So they sign up. The next day, the roofer applies a shiny aluminized coating and it really looks good. Except that, the first time it rains, the coating does a meltdown. And the roof leaks the same as before. What can be done now?

Don't bother looking for that smooth-talking roofer. He's miles away by now. What he did was coat the roof with an aluminum-colored distillate. It costs about $5.00 a gallon, and a gallon goes a long way. True, he charged less than the cost of a new roof. But all the homeowner got was a roof shine. Maybe if the homeowner had called the building inspector first . . .

Remember this the next time you decide to try a new building material. Building inspectors like to be consulted about new materials *before* you install them. And, you'll need to show proof of testing to defend any argument that the material may not stand up to the elements.



CHAPTER 9

Fire Protection Systems

No matter how hard the building industry tries to save lives, people still die in fires. No building is completely fire proof. The primary goals of the codes are to save lives and protect property. But people can make even the safest building hazardous. They misuse flammable materials. They panic in emergencies. They can become as dangerous to themselves and others as the fire that they're trying to escape.

The building codes reduce fire risks by showing contractors and designers how to make fire safety the goal of every project. Of course, safety comes at a price. Fire safe buildings usually cost more — but when the benefits are weighed, it's well-worth that price. That's the aim of the codes.

Proper construction is the first line of defense against fire destroying homes, buildings and lives. But there are two more aspects of major fire prevention:

- Fire detection and control systems (smoke alarms and automatic sprinklers)
- On-site fire-fighting equipment

These items can keep small fires from becoming big ones. Fire protection systems are covered in Chapter 9 of the IBC, and we'll discuss them in detail here.

Fire Detection and Fire-Extinguishing Systems

A number of fire detection and extinguishing systems are available, including:

- Basic residential smoke alarms (no fire extinguishing)
- Multiple interconnected smoke detectors for larger buildings
- Automatic sprinklers
- Wet and dry standpipes
- Fire-fighting teams

Of course, no system is 100 percent effective. Smoke detectors or alarms that warn the occupants of danger aren't effective if the occupants are disabled or locked up. They may be unable to put out a fire. Sensors trigger automatic sprinklers, but to be fully effective,

the sensors should be wired to the local fire station so professional fire-fighters can respond without delay. These are just some of the many things to think about when you're planning to install fire detection and extinguishing systems.

When there's a fire, it's hard to say which costs more to repair — fire damage or water damage, especially water from the fire-fighters' hoses. There's no alternative, though. To do nothing would mean the building's total destruction.

Standpipes provide water for fighting a fire, but can't put out a fire — for that you need properly trained in-house fire-fighting teams. But that's an expensive alternative. For instance, a large company involved in hazardous operations may have its own professional fire-fighters on-site. Their only job is to put out fires.

Smaller companies may have a team of employee volunteers who have had special fire-fighting classes. They'll be the first responders in case of fire.

Chapter 9 of the IBC goes into great detail and helps you address questions like, what happens if the city water is shut off to repair a line? Will your automatic sprinklers work in an emergency? Is there a backup system available? If your smoke detectors run on a main electricity source, what happens if there's a power outage? Is there a standby generator to operate the system? How about battery backup? Do the batteries automatically recharge when the power's on, or do they have to be changed regularly? If they have to be changed, what's the schedule and who's in charge of it?

Now we'll look at a few of these topics, using specific sections of the codes.

Automatic Sprinkler Systems

Automatic sprinkler systems are covered in IBC Section 903. There are three standards adopted by the IBC and the IFC (International Fire Code) available at www.iccsafe.org or www.nfpa.org:

1. NFPA 13 — applies to most buildings.
2. NFPA 13R — applies to Group R buildings up to and including four stories in height.
3. NFPA 13D — applies to one- and two-family dwellings and manufactured homes.

We looked at the Automatic Sprinkler Exception when we discussed NFPA 13R systems back in Chapter 4. But there are other situations where you don't need to install automatic sprinkler systems. Let's look at some of those now.

When Don't *You Need an Automatic Sprinkler System?*

The IRC only requires automatic sprinklers for one- and two-family dwellings and townhouses when Appendix P is adopted by the local jurisdiction. Section AP101 of Appendix P says:

> ***AP101 Fire sprinklers.*** *An approved automatic fire sprinkler system shall be installed in new one- and two-family dwellings and townhouses in accordance with Section 903.3.1 of the International Building Code.*

The IBC does not require automatic sprinklers for the following occupancy types:

- Group B
- Group F-2
- Group R-3 (if you can build to the IRC)
- Group U

The details for all other occupancy groups are in Section 903.2.

There are also some practical exceptions for the automatic sprinkler requirements. For example, telecommunications buildings are exempted from automatic sprinklers. Using water to put out a fire could seriously damage the equipment. This exemption only specifies telecommunications buildings, but it could apply to other buildings containing electronic or

computer equipment. You'll have to make a good case if you intend to use an alternate system, as you can see in item number 2, below. If you do get the OK, there are some special requirements to be met. The structures must:

- Have automatic fire detection systems
- Be separated from other areas of the building by at least 1-hour fire-resistance-rated walls and 2-hour fire-resistance-rated floor/ceiling assemblies

There's another exemption for automatic sprinklers in certain rooms or areas, but they still have to be protected by an approved automatic fire detection system; see IBC Section [F] 903.3.1.1.1. Four examples of such rooms or areas are:

1. Where water, or flames and water, constitutes a serious life or fire hazard;
2. Where sprinklers aren't advisable because of the contents (this has to be approved by the fire code official);
3. Rooms containing generators and/or transformers. These must be separated from the rest of the building by walls and floor/ceiling or roof/ceiling assemblies with a fire-resistance rating of at least 2 hours;
4. Rooms or areas constructed of noncombustible materials with all contents noncombustible.

Omitting sprinklers isn't a decision you alone can make. You have to get the fire official's approval. You can't decide not to install them using the excuse that there's electrical equipment in the area, you're using fire-resistant construction, or the area's already damp!

Alternatives to Automatic Sprinkler Systems

There are also alternate ways to put out fires, noted in IBC Section 904, Alternative Automatic Fire-Extinguishing Systems. In the unlikely event there's an accidental activation of the fire-extinguishing system, these systems don't cause water damage.

These include:

- Wet and dry chemical
- Foam systems
- Carbon dioxide
- Halon
- Clean-agent systems

Where You Do Need an Automatic Sprinkler System

IBC Section 903.2 describes automatic sprinkler system requirements for the different occupancy groups. They're listed below.

Group A-1

Group A-1 includes theaters, concert halls, TV studios, etc. Automatic sprinklers must be installed in Group A-1 occupancies in any of the following situations:

- The fire area is larger than 12,000 square feet.
- The fire area has an occupant load of 300 or more.
- The fire area is on a floor other than the exit discharge level.
- The fire area contains a multiplex theater complex.

Group A-2

Group A-2 includes restaurants, banquet halls, bars, night clubs, etc. Automatic sprinklers must be installed in Group A-2 occupancies in any of the following situations:

- The fire area is larger than 5,000 square feet.
- The fire area has an occupant load of 100 or more.
- The fire area is on a floor other than the exit discharge level.

Group A-3

Group A-3 includes churches, libraries, community halls, exhibition halls, dance halls, bowling alleys, gymnasiums, indoor tennis courts without spectator seating, etc. Automatic sprinklers must be installed in Group A-3 occupancies in any of the following situations:

- The fire area is larger than 12,000 square feet.
- The fire area has an occupant load of 300 or more.
- The fire area is on a floor other than the exit discharge level.

There's an exception made for participant-only sports areas where the main floor is on the same level as the main entrance and exit.

Group A-4

Group A-4 includes arenas, skating rinks, swimming pools, etc., with spectator seating. Automatic sprinklers must be installed in Group A-4 occupancies in any of the following situations:

- The fire area is larger than 12,000 square feet.
- The fire area has an occupant load of 300 or more.
- The fire area is on a floor other than the exit discharge level.

There's the same exception for Group A-4 as for A-3 in participant-only sports areas where the main floor is on the same level as the main entrance and exit.

Group A-5

Group A-5 includes stadiums, grandstands, bleachers, etc. Automatic sprinklers must be installed in Group A-5 occupancies in concession stands, retail areas, press boxes and similar areas larger than 1,000 square feet.

Group E

Group E includes educational occupancies for six or more people, through the 12th grade. Automatic sprinklers must be installed in Group E occupancies:

- Where the fire area is larger than 20,000 square feet.
- In all parts of the building below the exit level, unless every classroom below exit level has an outside exit door at ground level.

Group F-1

Group F-1 includes factories for moderate-hazard manufacturing processes or products. Automatic sprinklers must be installed in Group F-1 occupancies in any of the following situations:

- The fire area is larger than 12,000 square feet.
- The fire area is more than three stories above grade.
- The total fire area on all floors, including any mezzanines, is larger than 24,000 square feet.

Group H

Group H includes five separate high-hazard occupancies. Automatic sprinklers must be installed in all Group H occupancies (IBC Sections 903.2.4.2 and 903.2.4.3).

Group I

Group I includes four different institutional occupancies — residential care facilities (I-1), hospitals (I-2), prisons (I-3), and day care facilities (I-4). Automatic sprinklers must be installed in all Group I occupancies. NFPA 13R- or NFPA 13D-type can be used in Group I-1. But NFPA 13-type must be used in Groups I-2, I-3 and I-4.

Group M

Group M includes department stores, retail or wholesale stores, sales rooms, etc. Automatic sprinklers must be installed in Group M occupancies in any of the following situations:

- The fire area is larger than 12,000 square feet.
- The fire area is more than three stories above grade.

- The total fire area on all floors, including any mezzanines, is larger than 24,000 square feet.
- Stored merchandise is piled high, or on racks.

Group R

Group R includes four different residential occupancies — hotels (R-1), apartment houses (R-2), permanent residences for fewer than six unrelated people (R-3), and permanent residences for six to 16 unrelated people (R-4). Automatic sprinklers must be installed in all Group R occupancies. (R-3 occupancies are exempt if they can be built to the IRC.)

Group S-1

Group S-1 includes buildings for the storage of moderate-hazard materials. Automatic sprinklers must be installed in Group S-1 occupancies in any of the following situations:

- The fire area is larger than 12,000 square feet.
- The fire area is more than three stories above grade.
- The total fire area on all floors, including any mezzanines, is larger than 24,000 square feet.

There are special requirements for repair garages (IBC Section 903.2.8.1) and for buildings storing tires (Section 903.2.8.2).

Group S-2

Group S-2 includes buildings storing low-hazard materials. This group includes both open and enclosed parking garages. Automatic sprinklers are only required in Group S-2 occupancies that are:

- Parking garages, either classified as enclosed (which simply means they can't be classified as open; see IBC Section 406.4), or under buildings designated for other occupancy groups.
- Commercial truck or bus storage buildings with a fire area larger than 5,000 square feet.

Windowless Stories

Automatic sprinklers are required for windowless stories of all occupancy groups where the floor area is greater than 1,500 square feet and specific openings are not provided. Details are given in the subsections of IBC Section 903.2.10. Also, some exceptions are listed for Groups R-3 and U.

Types of Automatic Sprinkler Systems

There are four types of automatic sprinkler systems:

- Wet pipe
- Dry pipe
- Pre-action
- Deluge

In a wet-pipe system, the sprinkler pipe work is always full of water. Localized heat activates one or more sprinkler heads, allowing water to flow through just those activated sprinkler heads.

In a dry-pipe system, the pipe work is filled with compressed air, not water. Activation of one or more sprinkler heads by local heat releases the compressed air which then activates a remote flow-valve. This releases water to flow through just the activated sprinkler heads.

A pre-action system is a double-valve system. Under normal conditions, there's no water in the sprinkler pipes. In the event of a fire, a remote fire detector activates a valve which releases water to the sprinkler pipes. Then when local heat activates one or more sprinkler heads, the water flows through just those heads.

In a deluge system, there's no water in the sprinkler pipe work and all the sprinkler heads in a particular zone are open all the time. In the event of a fire, a remote fire detector activates a flow-valve which releases water to all the sprinkler heads in that zone simultaneously. This creates a deluge of water, not just a flow from one or more sprinklers located near the actual fire. We've all seen movies where someone holds a cigarette up to a fire sprinkler and suddenly water sprays from all the sprinkler

Figure 9-1 Tenting keeps blown insulation away from sprinkler piping

heads. In real life that doesn't happen. A deluge system is tripped by a remote fire detector, not a local sprinkler head. However, deluge systems aren't very common and, if used at all, it's only in special occupancies or for special hazards.

Which Sprinkler Systems Do You Need?

For buildings in areas where temperatures drop below freezing, you need a dry fire sprinkler system, such as a dry-pipe or pre-action system. Otherwise, you'll most likely have frozen pipes in cold weather. Dry systems must be installed with the pipes at a minimum slope, and with low-point drains for the water to be drained off. That's how the system is returned to a dry state after use or testing.

Sometimes antifreeze can be used in cold areas to prime the lines. But be careful! Spraying antifreeze could do more harm than the fire it's intended to put out.

Even in moderate climates, the sprinkler system needs to be protected from freezing. This is typically done by keeping the sprinkler piping inside the insulation envelope. Figure 9-1 shows *tenting* over residential sprinkler pipes to prevent blown insulation from getting between the pipe and the building's warmth.

Sprinklers are supposed to contain a fire before it really gets going, and give the occupants time to get out. That's why sprinklers aren't required in some occupancy groups where the occupant load is below a certain number. Under normal circumstances, if there are only a small number of occupants, they should be able to get out of the building quickly and easily.

Sometimes automatic sprinklers are enough to put out a fire. In an ideal situation, the fire is out before fire-fighters arrive. But what about a flash-fire, like an explosion? The sprinklers may work — but will they work in time? Check the occupancy type and area separations. Make sure you separate people from the high-danger fire areas.

In almost every city or town, you'll see old residential areas where small homes have been replaced by mini-mansions. There are lots of reasons why people want these palatial homes. The area could be desirable and a draw for the "upwardly-mobile" who want to show off their success. And property values are most likely on the rise there. But these neighborhoods might

not have adequate accessibility for fire trucks. Old water mains may need updating. What will happen to your beautiful new house if there isn't sufficient water pressure for the fire-fighters to combat a fire effectively? There *is* an alternative. Consider installing an automatic sprinkler system as part of any new construction. It's been estimated that adding an automatic sprinkler system adds no more than 1 to 1½ percent to the total building cost. And there's usually enough water pressure available for a 1-inch or 1½-inch sprinkler system, even when there isn't enough pressure for a fire truck to be fully effective.

If you're unsure about installing an automatic sprinkler system, check out the alternative automatic fire-extinguishing systems in IBC Section 904. And you'll find information on portable fire extinguishers in Section 906.

What about a smoldering fire that doesn't set off sprinklers but fills the room with toxic fumes? That's the reason that most occupancy groups require smoke detectors, fire detection and alarm systems, and automatic sprinklers.

Fire Detection and Alarm Systems

Fire detection and alarm systems are critical to fire safety. The complete list of requirements for all occupancy groups is in IBC Section 907. I'll just cover the basics here.

Make sure you submit construction documents describing your proposed fire detection and alarm systems for review and approval before starting an installation. If you subcontract the job, be sure the review is done before any work is started, or the contractor may have to rip out the whole system and start over again. There's a list of the documents that need to be reviewed in Section 907.1.1.

A fire detection and alarm system (either manual, automatic or manual, or fully automatic) must be installed in most new buildings in accordance with the IBC and the NFPA 72, National Fire Alarm Code®, available at www.nfpa.org. The alarm must sound when there's a fire; see Section 907.9. Automatic fire detector systems usually use smoke detectors for activation. One exception to that type of system would be if conditions like dust or steam make a smoke detector unsuitable, since either of those could set off false alarms. Automatic heat detectors or rate-of-rise detectors might be required in these situations, but not if an automatic sprinkler system is installed and connected to the building fire alarm system.

Group A

Group A occupancies of 300 people or more must have a manual fire alarm system. If the occupant load is 1,000 or more, activation of the fire alarm system must initiate a signal using an emergency voice/alarm communications system in accordance with NFPA 72. See IBC Section 907.2.1.1.

Group B

Group B occupancies of 500 people or more must have a manual fire alarm system. It's also required if there are more than 100 people above or below the lowest exit level. Manual fire alarm boxes aren't needed if an automatic sprinkler system is installed and connected to an occupant fire alarm.

Group E

Group E occupancies of 50 people or more must have a manual fire alarm system. When installed, automatic sprinkler systems or smoke detectors must be connected to the building fire alarm system. Manual fire alarm boxes aren't required in either of the following cases:

- The six specific sets of conditions in IBC Section 907.2.3 are met.
- An automatic sprinkler system is installed and connected to an occupant fire alarm, and manual activation can be done from a station that's normally manned.

Group E occupancy areas for assembly purposes must have a fire alarm system; see Section 907.2.1.

Group F

Group F occupancies two or more stories high, with an occupant load of 500 or more above or below the lowest exit level, must have a manual fire alarm system. Again, manual fire alarm boxes aren't required if an automatic sprinkler system is installed and connected to an occupant fire alarm.

Group H

Group H-5 occupancies, and areas where organic coatings are made, must have manual fire alarm systems. Automatic smoke detector systems are required where highly toxic gases, organic peroxides and oxidizers are used, as described in Chapters 37, 39 and 40 of the International Fire Code.

Group I

A manual fire alarm system and an automatic fire detection system are usually needed for Group I occupancies. There are lots of conditions and special requirements for Group I occupancies. Study IBC Sections 907.2.6.1 through 907.2.6.3 carefully if you're building for Group I-1, I-2 or I-3 occupancy.

Group M

Group M occupancies for 500 or more people, or with more than 100 people above or below the lowest exit level, must have a manual fire alarm system. Manual fire alarm boxes must be installed to notify the occupants when there's a fire. As an alternative, an automatic sprinkler system can be installed, provided it has an alarm.

Group R-1

A manual fire alarm system must be installed in Group R-1 occupancies. There's an exception if the building is two stories high or less, and all individual sleeping units and attic and crawl spaces are separated from each other and from public or common areas by at least 1-hour rated fire partitions. Also, each individual sleeping unit must have an exit directly onto a public way, exit court or yard.

Multiple manual fire alarm boxes aren't required if an automatic sprinkler system is installed and connected to an occupant fire alarm, but at least one manual fire alarm box must be provided in an approved location. This is usually a check-in desk that's always manned.

An automatic fire alarm system must be installed in all interior corridors leading to sleeping units. This doesn't apply to buildings like motels that don't have interior corridors serving sleeping units, and where each sleeping unit has its own outside exit.

Group R-2

A manual fire alarm system must be installed in Group R-2 occupancies with more than 16 units, where any unit is three or more stories above the exit level, or more than one story below the highest exit level.

Again, there's an exception if the building is two stories high or less, and all individual dwelling units and attic and crawl spaces are separated from each other and from public or common areas by at least 1-hour rated fire partitions. Also, every individual sleeping unit must have its own exit directly onto a public way, exit court or yard.

Manual fire alarm boxes aren't required if an automatic sprinkler system is installed and connected to an occupant fire alarm.

A fire alarm system isn't required in buildings that have no interior corridors serving dwelling units. Each sleeping unit must have its own outside exit and the building must have an automatic sprinkler system.

Other Situations

The IBC also covers many other cases where fire detection and alarm systems may be required. Check the list below. If your building

occupancy type falls in any of these classes, see the code for details.

Special amusement buildings, Section 907.2.11

High-rise buildings, Section 907.2.12

Atriums connecting more than two stories, Section 907.2.13

High-piled combustible storage areas, Section 907.2.14

Delayed egress locks, Section 907.2.15

Aerosol storage uses, Section 907.2.16

Lumber, plywood and veneer mills, Section 907.2.17

Underground buildings with a smoke exhaust system, Section 907.2.18

Underground buildings, Section 907.2.19

Covered mall buildings, Section 907.2.20

Residential aircraft hangars, Section 907.2.21

Airport traffic control towers, Section 907.2.22

Battery rooms, Section 907.2.23

Smoke Detectors and Alarms

Fire detection and alarm systems usually use smoke detectors to indicate the presence of fire. Smoke detectors must meet the requirements of NFPA 72, the National Fire Alarm Code®, available on the NFPA website, www.nfpa.org. The IBC discusses the systems as they apply to group occupancies.

Group I-1

IBC Section 907.2.10.1.2 requires smoke alarms to be installed and maintained in Group I-1 occupancies, regardless of occupant load, at all of the following locations:

- In each room used for sleeping purposes;
- On the ceiling or wall outside of each separate sleeping area close to bedrooms;
- On each story of a dwelling unit, including basements. If there are split levels less than a full story, a smoke alarm on the upper story meets the code requirements.

Section 907.2.6.1 states that an electrically supervised, automatic smoke detection system is required in Group I-1 corridors, habitable spaces other than sleeping units, and kitchens and waiting areas that are open to corridors.

You don't need to install smoke alarms if the building has an automatic sprinkler system throughout. Smoke alarms aren't required on exterior balconies.

Group I-3

An automatic smoke detection system must be installed in all inmate housing areas (Section 907.2.6.3.3). These include sleeping areas, day rooms, group activity rooms and other common use spaces. Sleeping areas in jails and prisons are inmate cells. In situations where inmates are likely to tamper with the smoke detectors, alternate smoke detection installations are allowed. Smoke detectors may be installed in cell exhaust ducts or behind protective guards. There's an exception for smoke detectors in sleeping units in Group I-3. They're not required if inmates are able to move freely between sleeping areas and common use areas. If inmates are restricted to individual cells, smoke detectors are required.

Group R-1

According to Section 907.2.10.1.1, smoke alarms must be installed at the following locations:

- In sleeping areas. If the building doesn't have an automatic sprinkler system, these smoke alarms must be connected to an emergency electrical system. The system must notify building personnel, at an area that's always manned (like the front

desk of a hotel), which sleeping unit smoke alarm has been activated (see Section 907.2.8.3). They can then activate the building fire alarm system and evacuate the affected sleeping unit(s).

- In every room in the path from the door of the sleeping area to the building exit.
- On each story of a dwelling unit, including basements. If there are split levels less than a full story, a smoke alarm on the upper story meets code.

Groups R-2, R-3 and R-4

Section 907.2.10.1.2 says that smoke alarms must be installed at the following locations, no matter what the occupant load:

- In each room used for sleeping;
- On the ceiling or wall outside of each separate sleeping area close to bedrooms;
- On each story of a dwelling unit, including basements. If there are split levels less than a full story, a smoke alarm on the upper story satisfies the code.

You don't need to install smoke alarms if the building has an automatic fire detection system throughout, as specified in Section 907.2.6.

Section 907.2.10.1.2 says that smoke alarms must be *installed and maintained*. Of course, it's not up to you to maintain the smoke alarm system. That's the owner's responsibility, so be sure to point that out to him. This differs from the IRC, which has no code requirement for the owner of a one- or two-family dwelling to maintain the smoke alarm system. However, it's in the owner's best interest to do so. This is another one of those enforcement issues. It's fairly easy to enforce smoke alarm maintenance in Group R occupancy buildings. But it's almost impossible in one- or two-family dwellings. That's up to the homeowner.

Home Day Care, Group R-3

Appendix M is new to the 2006 IRC. It covers exits and smoke detectors in Group R-3 occupancies used for home day care. Study Appendix M carefully if you're planning on building a home day care facility.

One- or Two-Family Dwellings

The IRC now has more smoke alarm requirements for new buildings than it used to. Section R313 says that NFPA 72 smoke alarms must be installed in the following locations:

- In each sleeping room;
- Outside each separate sleeping area close to the bedrooms;
- On each additional habitable story of the dwelling, including basements. If there are split levels less than a full story, a smoke alarm on the upper story meets code.

If there's more than one smoke alarm in a single dwelling unit, they all must be interconnected, so when one alarm goes off, the others must sound off as well.

Section R313.3 requires that smoke alarms get their primary power directly from the main power supply, and must have a battery backup in case the power goes out. Smoke alarms that are solely battery-activated are no longer acceptable in new construction.

Standpipes

Standpipes are used for fire hose connection. Not many homes have them, but most large apartment buildings and office buildings do. IBC Sections 905.4, 905.5 and 905.6 give the required locations of Class I, Class II and Class III standpipes, respectively. Let's look at how a standpipe system works and what the differences are in Class I, II and III systems.

Standpipe Systems

A standpipe system is a wet or dry system of piping, valves, outlets, and related equipment. The system's sole use is for fighting fires. Wet systems are filled with water all the time, and provide water to fire-fighters at specified pressures. So how does a dry standpipe system work? It's usually filled with pressurized air that lets water into the piping automatically when a hose valve is opened. In older buildings, dry systems can be simple pipes going from the ground floor to the upper floors. The fire-fighters connect a fire hose to the ground floor standpipe so they don't have to carry a full hose while climbing flights of stairs. Hoses are heavy and extremely hard to handle. In an emergency, there's no time to be wasted hauling full hoses up the stairs.

Dry standpipes are recommended in areas that experience very cold weather. Winter temperatures could freeze the water in a wet standpipe, making it useless for fighting a fire in the middle of a cold spell. And, believe me, when the temperature drops, there are a lot of fires caused by portable heaters that aren't used correctly.

Standpipe System Classes

Class I is a standpipe system with 2½-inch outlets. They're only for use by fire departments and trained personnel.

Class II is a 1½-inch hose station to be used by building occupants or the fire department during the first response to a fire.

Class III is a system that combines the two elements:

1. 1½-inch hose station to be used by building occupants;
2. 2½-inch hose connection to be used by fire departments and trained personnel.

Standpipe Class I System Locations

IBC Section 905.4 states that Class I standpipe hose connections must be provided in any of the following locations:

- On the intermediate floor landing between each floor level for all required stairways, above and below grade.
- On each side of the wall next to the opening of a horizontal exit. There's an exception if the area can be reached from an exit stairway standpipe by a nozzle connected to 100 feet of hose projecting a 30-foot stream of water.
- In every exit passageway at the entrance from the passageway to other areas of the building.
- In covered malls, next to every mall entrance and by each entrance from an exit passageway to the mall.
- Where the roof of the building has a slope less than 1 in 3. Each standpipe must have a hose connection either on the roof or at the highest landing of any stairway with access to the roof. An additional hose connection must be provided at the highest standpipe for testing purposes.
- Where the most remote part of a nonsprinklered floor or story is more than 150 feet from a hose connection.

If the most remote part of a *sprinklered* floor or story is 200 feet or more from a hose connection, the fire code official can require additional hose connections in specific locations.

Standpipe Class II System Locations

According to IBC Section 905.5, accessible Class II standpipe hose connections must be provided so that all parts of a building are reachable by 100 feet of hose projecting a 30-foot stream of water.

In Group A-1 and A-2 occupancies with occupant loads of more than 1,000 people, Class II hose connections must be located at all of the following:

- On each side of any stage
- On each side of the rear of the auditorium
- On each side of the balcony
- On each level of dressing rooms

Standpipe Class III System Locations

IBC Section 905.6 says that Class III standpipe systems must be installed throughout buildings that have:

- floor levels higher than 30 feet above the *lowest* level of fire department vehicle access;
- the floor level of the lowest story more than 30 feet below the *highest* level of fire department access;
- a theater stage more than 1,000 square feet. A Class III standpipe must be located on each side of the stage. There's an exception if the building has an automatic sprinkler system throughout. Then, a Class I standpipe can be installed.

One problem with standpipes is that occupants sometimes try to use them to put out a fire before calling the fire department. That's a really bad idea — the first minutes after a fire starts are critical. In any fire, the very first thing the occupants should do is call the fire department. Then they should try to keep the fire from spreading.

Of course, it's different if the building occupants are organized and trained to fight a fire. As we discussed earlier in this chapter, many large buildings and industrial plants have their own trained fire-fighting teams. In that case, the fire department should only be called if they're needed in addition to those teams.

What Should Be Done?

Here's how one joker defined a truly fire safe building: It's made of reinforced concrete, has no doors or windows, is completely sprinklered, has smoke detectors, has nothing stored in it, and has no occupants! That would be fire safe, all right. But I don't think you'll be building any of them. There has to be a balance of practicality, cost and fire safety.

City officials — usually the fire marshal and the building official — should take a good look at their city and ask themselves some hard questions:

- Does the city have enough water to make fire sprinklers effective in case of a major catastrophe?
- Does the city have a fire and police communication system that can handle all the calls in a real emergency? San Diego County didn't. The brush fires in 2003 destroyed over 1,000 homes and even threatened the city of San Diego itself. The county/city officials had to re-evaluate their entire emergency-response communications system.
- Have there been numerous fires in the city's past? Was anything learned from them? Were changes made to help handle future fires?
- If the city adopted stronger fire safety rules, would it reduce the number of fire deaths without significantly increasing building costs or making it cheaper to build in another city? Or even in another country? Outsourcing and the global economy have made this an option for many companies.
- Are most buildings in the city fairly new? New buildings are usually more fire resistant. Finally, what can be done to make older buildings more fire safe?

Consider Future Needs

Fire extinguishing systems are expensive, and in order to work correctly, they must be installed correctly. If you're building anything other than a residential building, you can't be sure how it will be used in the future. The system you install today might not be adequate in 10 years for a different occupancy.

What if your building is a borderline size for requiring an automatic sprinkler system, with low-hazard occupancy? Should you install sprinklers now, or wait? You can't foretell the future. There could be a change in building

occupancy. You'll have to make a business decision, and that's not something you'll find in the code.

Automatic sprinkler systems usually pay for themselves in five to 10 years. Insurance rates are lower for sprinklered buildings. In fact, savings on insurance during the first seven years will usually pay for most fire protection systems. Spec builders try to make as much profit as they can on the smallest initial investment, so they usually don't install sprinklers unless they're required. But those buildings are going to be used for many years. The code is written to protect them.

Many communities have adopted ordinances requiring automatic sprinklers in all structures other than one- or two-family dwellings. And other local jurisdictions have adopted Appendix P of the IRC, requiring automatic sprinklers in one- or two-family dwellings and townhouses as well (see Section AP101).

Automatic sprinklers could be required soon in all new construction, so be sure to get the lowdown from your local fire code official.

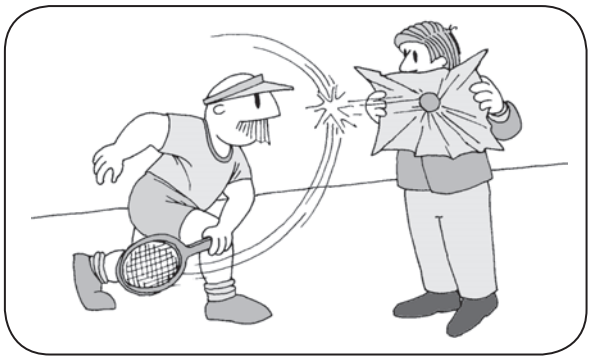
Construction is Just a Start

By ensuring you have code-compliant construction, uncluttered employee work areas and well-informed occupants — as well as minimizing stored combustible material — you can help control fire danger. Exits must be designed to give building occupants the quickest and most direct route to safety. The codes assume that not everyone knows where the exits are. And people respond unpredictably in an emergency. So buildings have to be designed for people to get out quickly and easily. Chapter 16 of this book, Exits/Means of Egress, covers exits in detail.

The building code's influence is limited. Once the owner has the keys to the building, it's his baby. Even the best fire suppression system isn't as effective as fire prevention.

The building's management should have regular fire drills so that everyone knows what to do in case of an emergency. Fire drill requirements are usually spelled out in the building's insurance policy — read the fine print. If there's a fire, and it's discovered that the fire drill requirements weren't fulfilled, the policy might be voided.

It can't be repeated enough: The primary goal of any fire control or fire safety system is saving lives. Second to that is reducing property damage. In a hot fire, almost all materials and building components will burn, melt or soften to the point that they're no longer structurally sound. A fire-resistant building and good fire suppression equipment can delay a fire's progress long enough for people to exit safely.



Who Are You Going to Trust?

I think an inspector should always be willing to answer questions about the code. When a contractor asks for advice, the inspector should do his or her best to help. After all, being a building inspector isn't a guessing game: "I have the answer but you have to guess what it is." It's everyone doing what they can to construct safe, practical buildings at a reasonable cost.

Of course, I know inspectors who would rather be hung by their thumbs than give a contractor free advice. I think that's wrong, but I can understand why they do it. They're afraid of getting sued. If you give bad advice and somebody follows it, you're at fault.

A city manager once accused me of being too friendly with contractors. So what? I enjoy working with the contractors I know. I hope every building inspector does. And I think knowing something about the people who apply for permits is part of an inspector's job. The code may be written in black ink on white paper — but the answer to every code question isn't a matter of black and white.

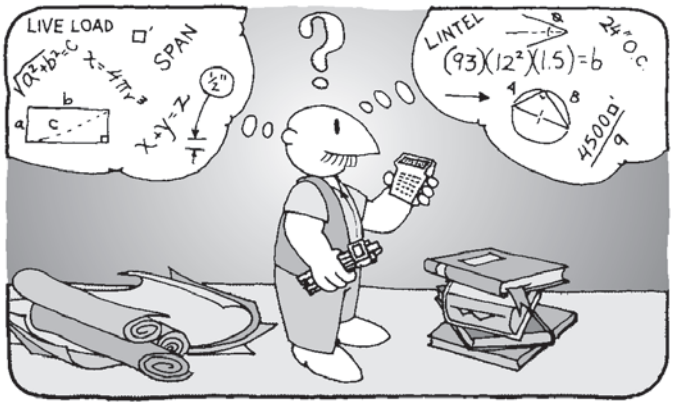
I've had people apply for permits with little more than a rough sketch. No plans — just an idea, a few notes and a line of chatter. What do I do? Well, first, I listen. If the project is a carport or something simple, and they know what they're doing, I usually send them off with a permit. That saves days or weeks of paperwork and probably some money, too. But if an applicant obviously isn't prepared, I suggest he or she draw up some plans. Maybe that's discriminatory. Maybe it wouldn't work in a large office handling hundreds of projects a week for hundreds of different contractors. But it works for me.

A lawyer once came into my office wanting a permit for a small office building. He had sketched the plans himself on scratch paper. I looked them over and turned him down, suggesting he hire an architect. He wasn't willing to take no for an answer. So I asked him a question: "I've got this pain in my wrist, right here. Do you think I should give up tennis?"

"How should I know? I'm a lawyer, not a doctor." he answered.

"True, you're not a doctor. And you're not an architect either. I'll find a doctor for my wrist and you find an architect for your building."

Like I said, he wouldn't take no for an answer. He found a way to outsmart me. Back then, our county hadn't adopted building codes, so you didn't need a permit outside the city limits. He decided to build his office just outside the city limits. The basement turned out okay, but then work came to a standstill. He couldn't get any subcontractors to bid the rest of the job from his scratch-paper sketches.



C H A P T E R 1 0

Engineering and Design Requirements

Engineering is pretty complex, and it's a subject best left to trained professionals. But you should understand some of the formulas in the code's engineering and design sections. You don't need to know how or why the formulas were developed; you just need to understand the code's principles. I'm going to help you with the basics. The rest you can leave to the experts.

It's not difficult to determine engineering requirements — they're spelled out in the code. The most important thing you need to recognize is when you need professional help.

Loads and Loading

Engineering is first mentioned in Chapter 16 of the IBC:

> ***IBC 1601 Scope.*** *The provisions of this chapter shall govern the structural design of buildings, structures and portions thereof regulated by this code.*

Section 1602 goes right to the heart of the matter: loads and loading. This section defines the types of loads, including dead loads and live loads.

> ***Dead Loads.*** *The weight of materials of construction incorporated into the building, including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and the weight of fixed service equipment, such as cranes, plumbing stacks and risers, electrical feeders, heating, ventilating and air-conditioning systems and fire sprinkler systems.*

> ***Live Loads.*** *Those loads produced by the use and occupancy of the building or other structure and do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load or dead load.*

Live Loads (Roof). *Those loads produced (1) during maintenance by workers, equipment and materials; and (2) during the life of the structure by movable objects such as planters and by people.*

Dead Loads

Dead loads are permanent or fixed — they're static loads, exerting force by reason of weight alone without motion. They're calculated by taking the actual weights of construction materials used. This includes fixed service equipment. If actual figures aren't available, you can make an estimate, but it must be approved by the building official. Dead loads are covered by IBC Section 1606. Weights of typical construction materials can be found in Table C3-1 of Minimum Design Loads for Buildings and Other Structures, known as ASCE 7. ASCE 7-05 is the referenced standard for loads in the IBC.

Live Loads

Live loads are everything that goes into the building during its use, including the furnishings, non-fixed equipment and occupants. They're dynamic, changeable loads — and they can vary depending on how the building is used. Live loads are covered in Section 1607. Minimum live loads for various uses and occupancies are shown in Table 1607.1 (Figure 10-1). Live loads may be uniformly distributed or concentrated; see Sections 1607.3 and 1607.4.

What are uniformly distributed live loads? They're the maximum loads expected for the intended use of the building. And they're assumed to be the same (uniform) throughout the building, unless particular sections of the building are singled out for a different load in Table 1607.1. Looking at Table 1607.1 in Figure 10-1, you'll see that a bowling alley (item 6) has a single uniform load factor, as does a dance hall (item 8) and a gymnasium (item 19). But note that for many uses, the uniform load factor varies within the building depending upon the use of the section considered. For example, in office buildings (item 26) there are different load factors for the offices themselves (50 psf), the lobby and first floor corridors (100 psf), and the corridors above the first floor (80 psf). However, the uniform load for any occupancy can never be less than the minimum load given in Table 1607.1.

Concentrated live loads are usually calculated by assuming the load is uniformly distributed over an area 2½ feet by 2½ feet, rather than the entire building or a building section. Floors and similar surfaces must be constructed to support either the uniformly distributed load prescribed in Section 1607.3 or the concentrated live load given in Table 1607.1, whichever produces the greater load effect. For example, office floors must support either the 50 psf uniformly distributed load of the expected furnishings and workers or a 2,000 pound concentrated load, whichever is greater.

In addition to dead and live load, the IBC also prescribes various environmental load effects that must be considered, such as snow, wind and earthquake loads.

Calculating Live Loads

Designers use both the minimum uniform and the concentrated live load values shown in IBC Table 1607.1 to plan floors and foundations that will support the intended loads for the building. As we discussed earlier, uniform live loads are those loads that will be distributed throughout the building, or in specific areas of the building, like the office furniture in offices. If a building use will include a few pieces of heavy equipment or machinery that's different from the other furnishings or equipment, those would fall under the category of concentrated live loads. The building must be designed to support the governing load condition (the greater load) from distributed or concentrated loads.

A common type of concentrated load is a vehicle parked in a residential garage. The load is concentrated on four points — one under each wheel of the vehicle. Large SUVs have very heavy concentrated loads. According to item 17 of Table 1607.1, the garage floor must be designed to carry a uniform load of 40 psf. But the vehicle load is concentrated on four points. So Note "*a*" says that garage floors must be designed for the uniformly distributed live load of Table 1607.1 (i.e. 40 psf) *or* for the concentrated load of 3,000 pounds acting on an area 4½ inches by 4½ inches. This only applies to garages for vehicles with a capacity of nine passengers or less, which covers most private vehicles.

TABLE 1607.1
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS AND MINIMUM CONCENTRATED LIVE LOADS[G]

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)
1. Apartments (see residential)	—	—
2. Access floor systems		
Office use	50	2,000
Computer use	100	2,000
3. Armories and drill rooms	150	—
4. Assembly areas and theaters		
Fixed seats (fastened to floor)	60	
Follow spot, projections and control rooms	50	—
Lobbies	100	
Movable seats	100	
Stages and platforms	125	
5. Balconies	100	
On one- and two-family residences only, and not exceeding 100 sq ft	60	—
6. Bowling alleys	75	—
7. Catwalks	40	300
8. Dance halls and ballrooms	100	—
9. Decks	Same as occupancy served[h]	—
10. Dining rooms and restaurants	100	—
11. Dwellings (see residential)	—	—
12. Cornices	60	—
13. Corridors, except as otherwise indicated	100	—
14. Elevator machine room grating (on area of 4 in^2)	—	300
15. Finish light floor plate construction (on area of 1 in^2)	—	200
	—	
16. Fire escapes	100	—
On single-family dwellings only	40	
17. Garages (passenger vehicles only)	40	Note a
Trucks and buses	See Section 1607.6	
18. Grandstands (see stadium and arena bleachers)	—	—
19. Gymnasiums, main floors and balconies	100	—
20. Handrails, guards and grab bars	See Section 1607.7	
21. Hospitals		
Corridors above first floor	80	1,000
Operating rooms, laboratories	60	1,000
Patient rooms	40	1,000
22. Hotels (see residential)	—	—
23. Libraries		
Corridors above first floor	80	1,000
Reading rooms	60	1,000
Stack rooms	150[b]	1,000
24. Manufacturing		
Heavy	250	3,000
Light	125	2,000
25. Marquees	75	—
26. Office buildings		
Corridors above first floor	80	2,000
File and computer rooms shall be designed for heavier loads based on anticipated occupancy	—	—
Lobbies and first-floor corridors	100	2,000
Offices	50	2,000
27. Penal institutions		
Cell blocks	40	—
Corridors	100	
28. Residential		
One- and two-family dwellings		
Uninhabitable attics without storage[i]	10	
Uninhabitable attics with limited storage[j, k]	20	
Habitable attics and sleeping areas	30	
All other areas except balconies and decks	40	—
Hotels and multiple-family dwellings		
Private rooms and corridors serving them	40	
Public rooms and corridors serving them	100	
29. Reviewing stands, grandstands and bleachers	Note c	
30. Roofs		
All roof surfaces subject to maintenance workers		300
Awnings and canopies		
Fabric construction supported by a lightweight rigid skeleton structure	5 nonreduceable	
All other construction	20	
Ordinary flat, pitched, and curved roofs	20	
Primary roof members, exposed to a work floor		
Single panel point of lower chord of roof trusses or any point along primary structural members supporting roofs:		
Over manufacturing, storage warehouses, and repair garages		2,000
All other occupancies		300
Roofs used for other special purposes	Note 1	Note 1
Roofs used for promenade purposes	60	
Roofs used for roof gardens or assembly purposes	100	

Figure 10-1 Minimum uniformly distributed and concentrated live loads

TABLE 1607.1 (CONTINUED)
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS AND MINIMUM CONCENTRATED LIVE LOADS[G]

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)
31. Schools		
Classrooms	40	1,000
Corridors above first floor	80	1,000
First-floor corridors	100	1,000
32. Scuttles, skylight ribs and accessible ceilings	—	200
33. Sidewalks, vehicular driveways and yards, subject to trucking	250[d]	8,000[e]
34. Skating rinks	100	—
35. Stadiums and arenas		
Bleachers	100[c]	—
Fixed seats (fastened to floor)	60[c]	
36. Stairs and exits		Note f
One- and two-family dwellings	40	
All other	100	
37. Storage warehouses (shall be designed for heavier loads if required for anticipated storage)		
Heavy	250	
Light	125	
38. Stores		
Retail		
First floor	100	1,000
Upper floors	75	1,000
Wholesale, all floors	125	1,000
39. Vehicle barriers	See Section 1607.7.3	
40. Walkways and elevated platforms (other than exitways)	60	—
41. Yards and terraces, pedestrians	100	—

For SI: 1 inch = 25.4 mm, 1 square inch = 645.16 mm^2,
1 square foot = 0.0929 m^2,
1 pound per square foot = 0.0479 kN/m^2, 1 pound = 0.004448 kN,
1 pound per cubic foot = 16 kg/m^3

a. Floors in garages or portions of buildings used for the storage of motor vehicles shall be designed for the uniformly distributed live loads of Table 1607.1 or the following concentrated loads: (1) for garages restricted to vehicles accommodating not more than nine passengers, 3,000 pounds acting on an area of 4.5 inches by 4.5 inches; (2) for mechanical parking structures without slab or deck which are used for storing passenger vehicles only, 2,250 pounds per wheel.

b. The loading applies to stack room floors that support nonmobile, double-faced library bookstacks, subject to the following limitations:
   1. The nominal bookstack unit height shall not exceed 90 inches;
   2. The nominal shelf depth shall not exceed 12 inches for each face; and
   3. Parallel rows of double-faced bookstacks shall be separated by aisles not less than 36 inches wide.

c. Design in accordance with the ICC *Standard on Bleachers, Folding and Telescopic Seating and Grandstands.*

d. Other uniform loads in accordance with an approved method which contains provisions for truck loadings shall also be considered where appropriate.

e. The concentrated wheel load shall be applied on an area of 20 square inches.

f. Minimum concentrated load on stair treads (on area of 4 square inches) is 300 pounds.

g. Where snow loads occur that are in excess of the design conditions, the structure shall be designed to support the loads due to the increased loads caused by drift buildup or a greater snow design determined by the building official (see Section 1608). For special-purpose roofs, see Section 1607.11.2.2.

h. See Section 1604.8.3 for decks attached to exterior walls.

i. Attics without storage are those where the maximum clear height between the joist and rafter is less than 42 inches, or where there are not two or more adjacent trusses with the same web configuration capable of containing a rectangle 42 inches high by 2 feet wide, or greater, located within the plane of the truss. For attics without storage, this live load need not be assumed to act concurrently with any other live load requirements.

j. For attics with limited storage and constructed with trusses, this live load need only be applied to those portions of the bottom chord where there are two or more adjacent trusses with the same web configuration capable of containing a rectangle 42 inches high by 2 feet wide or greater, located within the plane of the truss. The rectangle shall fit between the top of the bottom chord and the bottom of any other truss member, provided that each of the following criteria is met:
   i. The attic area is accessible by a pull-down stairway or framed opening in accordance with Section 1209.2, and
   ii. The truss shall have a bottom chord pitch less than 2:12.
   iii. Bottom chords of trusses shall be designed for the greater of actual imposed dead load or 10 psf, uniformly distributed over the entire span.

k. Attic spaces served by a fixed stair shall be designed to support the minimum live load specified for habitable attics and sleeping rooms.

l. Roofs used for other special purposes shall be designed for appropriate loads as approved by the building official.

Figure 10-1 Minimum uniformly distributed and concentrated live loads (continued)

But vehicles move into and out of a garage, changing these points into paths. And the paths are wide because vehicles use different lines of entry. So any area of the garage floor where the vehicle could be driven must be designed for this concentrated load. A standard 4-inch slab on grade will support most vehicles. But what if it will garage an 8,000 pound Hummer or a motor home? That's when slab thickness becomes a factor. You have no control over the vehicle a future owner will drive into the garage, so you need to plan for a heaviest-use scenario. This also applies to the driveway.

In addition to concentrated loads, the IBC includes requirements for:

Partition loads, Section 1607.5

Truck and bus garages, Section 1607.6

Loads on handrails, guards, grab bars and vehicle barriers, Section 1607.7

Impact loads, Section 1607.8

Read these sections carefully if they apply to the building you're constructing.

Design Methods

IBC Section 1604 makes it clear that buildings must be designed to support the loads prescribed by the code.

> ***1604.1 General.*** *Building, structures and parts thereof shall be designed and constructed in accordance with strength design, load and resistance factor design, allowable stress design, empirical design or conventional construction methods, as permitted by the applicable material chapters.*

The code provides more information than we can cover here. But there are a few things we'll look at in detail, one of which is roof load. The roof is usually the first part of the building that fails. If the roof is destroyed in a storm or a hurricane, the rest of the building and everything inside could be damaged or destroyed as well.

Roof Loads and Design

People sometimes think more about the loading inside a building than the load on the roof. They worry about the floor collapsing under the weight of a grand piano, but not what could happen if 2 feet of snow collects on the roof. That's a serious oversight. The live load on a building floor is relatively easy to figure, and it's not going to change that much. Code prescribed roof live load is also relatively easy to calculate; but environmental live loads on roofs, which are often temporary and unpredictable, are more complicated.

IBC Section 1607.11 covers roof loads in detail. It says that roofs and marquees must resist wind, and where applicable, snow and earthquake loads. That's in addition to the dead load of construction and any live loads on the roof, like workmen and their equipment. On sloping roofs, live loads are assumed to act vertically on the horizontal projection of the roof. That means that the entire live load (weight) of a workman on the sloped surface of the roof is transmitted straight down at the spot where he's standing. Flat roofs are sometimes used as roof gardens, so their live load could also include sun bathers or party guests, canopies, awnings, and planters with shrubs and flowers, etc. These are covered in item 30 of Table 1607.1 (see Figure 10-1).

Section 1607.11.1 covers the distribution of roof loads, and Section 1607.11.2 deals with any reduction in roof live loads, which are only allowed under special circumstances.

There are four important environmental loads that affect a building's exterior, especially the roof:

1. Wind loads
2. Rain loads
3. Snow loads
4. Uplift loads

Calculating these loads can get pretty technical, for obvious reasons. Wind and snow are the two most import loads affecting the roof. These loads are zero most of the time — but not always. Designers must be aware of the potential weather-related problems in the area

where they're intending to build and take them into consideration. Builders in Los Angeles need not be too concerned about snow loads, but they'd better factor in the powerful Santa Ana winds common to Southern California.

Wind Loads

Because wind speeds can vary greatly, you need good advice from an engineer when designing a roof. You may think that certain parts of the country hardly ever have high winds, while others have Category 5 hurricanes. That assumption is wrong. For design purposes, the minimum wind speed out West is 85 mph. For most of the country, it's 90 mph. For the East and Gulf Coasts it's considerably higher.

IBC Section 1609 explains wind load requirements in detail. Since you probably don't have a background in engineering, we'll keep it simple.

> ***1609.1 Applications.*** *Buildings, structures and parts thereof shall be designed to withstand the minimum wind loads prescribed herein. Decreases in wind loads shall not be made for the effect of shielding by other structures.*

Usually, ordinary wind loads aren't a problem for residences and small commercial structures. Most wood-frame and masonry buildings designed according to code are strong enough to take whatever Mother Nature dishes out. But in some areas, you may have to build beyond the minimums. Find out if the area you're building in is subject to unusually high wind loads. Also, some land features can cause wind patterns that are stronger than in nearby areas. It isn't easy to determine without specific information.

IBC Figure 1609, shown in Figure 10-2, is the basic wind speed (3-second gust) map of the U.S. It shows the wind speeds, in both miles-per-hour and meters-per-second, at 33 feet above the ground for Exposure category C. Before we look at the map more closely, let's define Exposure category. The IBC states:

> ***1609.4 Exposure category.*** *For each wind direction considered, an exposure category that adequately reflects the characteristics of ground surface irregularities shall be determined for the site at which the building or structure is to be constructed.*

Surface Roughness and Exposure Categories

The ground surface features affect the velocity of winds. The more obstructed or rough the terrain, the less probability of high-speed winds. There are three Surface Roughness categories: B, C and D; and three Exposure categories: B, C and D (A is no longer used).

Category B

Surface Roughness B is described as urban, suburban, wooded areas, or other terrain with closely-spaced obstructions the size of a single-family dwelling or larger. Exposure B category applies when the ground roughness condition, explained above, prevails in the upwind direction for a distance of at least 2600 feet, or 20 times the height of the planned building, whichever is greater. For buildings with a mean roof height of 30 feet or less, the upwind distance can be reduced to 1,500 feet.

Category C

Surface Roughness C is open terrain with only scattered obstructions, usually less than 30 feet high. These areas include flat open country, grasslands, and water surfaces in hurricane-prone regions. Exposure C applies whenever Exposures B and D don't.

Exposure C should be the assumed exposure unless the area specifically meets one of the other two conditions. Most engineering plans submitted for review assume Exposure B. But if the engineer is wrong, the plan will be rejected. Before your plans are prepared, ask your building department for guidance on which exposure category to use. This could save you time and money in the long run.

Category D

Surface Roughness D is flat, unobstructed land and water surfaces outside hurricane-prone areas. These include smooth mud flats, salt flats and unbroken ice. Some lakefront or

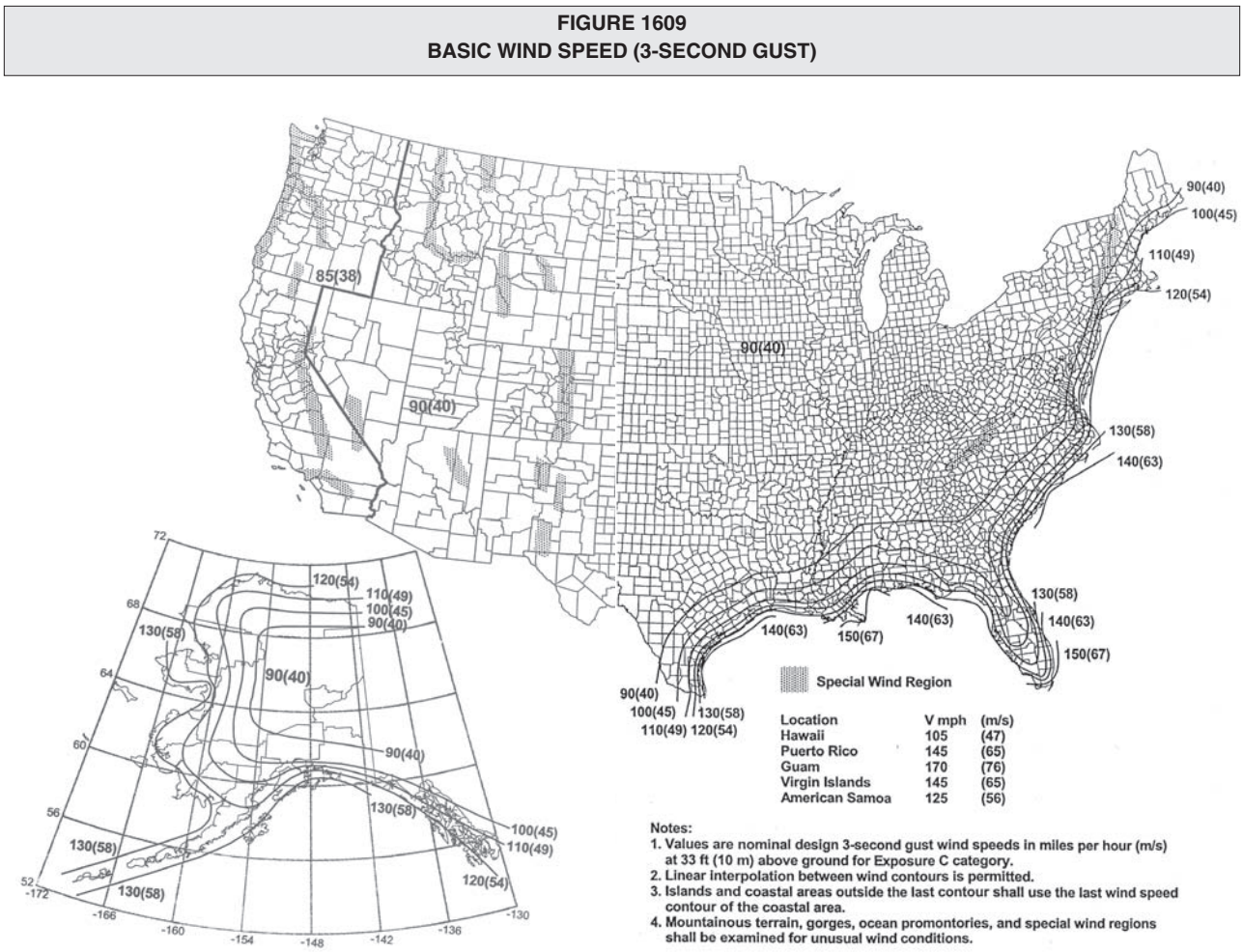


Figure 10-2 Basic wind speed (3-second gust)

bayside property may qualify as category D. Exposure D applies where the surface roughness described above prevails in the upwind distance for 5,000 feet or 20 times the height of the building planned, whichever is greater. It goes inland from the shoreline for at least 600 feet, or 20 times the height of the building planned.

Hurricane Regions

The basic wind speed map in IBC Figure 1609 has three additional maps not provided in this book. They show the hurricane-prone regions of the country in more detail than on the map in Figure 10-2. These regions include:

Western Gulf of Mexico Hurricane Coastline

Eastern Gulf of Mexico and Southeastern U.S. Hurricane Coastline

Mid- and Northern Atlantic Hurricane Coastline

These areas may also be subject to wind-borne debris requirements, as stated in IBC Section 1609.2. Note that the shorelines in the hurricane-prone regions are considered Exposure C, not D. Hawaii, Puerto Rico, Guam, the Virgin Islands and American Samoa are also considered hurricane-prone regions.

Wind Load Calculation

The code once had many pages on wind load calculations. Now, IBC Section 1609 refers you and your engineer or architect to the ASCE 7 standard.

IBC Section 1609.5.1 says that your building's roof deck must be designed to withstand wind pressures determined using ASCE 7, the American Society of Civil Engineers standard for Minimum Design Loads for Buildings and Other Structures. The latest standard, ASCE 7-05, is available from www.pubs.asce.org or from the ICC at www.iccsafe.com.

Wind Loads on Tile Roof Coverings

Section 1609.5.3 shows how to calculate wind loads on rigid tile roof coverings. It also covers design and installation requirements for roof tiles, as follows:

- Roof tiles must be installed on solid sheathing designed as components and cladding.
- An underlayment must be installed according to IBC Chapter 15.
- Roof tiles must be either loose laid on battens, mechanically fastened, mortar set or adhesive set.
- Tiles must be single lapped interlocking with a minimum head lap of at least 2 inches.
- Tile length must be between 12 and 21 inches.
- Exposed width of tile must be between 8 and 15 inches.
- Maximum thickness of the tail of the tile can't exceed $1^1/_3$ inches.
- Roof tiles using mortar-set or adhesive-set systems must have at least two-thirds of the area of the tile free of mortar or adhesive contact.

Rain Loads

Rain loads can cause just as much damage as wind loads. How many times have you seen your local news team reporting the collapse of a supermarket roof during a heavy rainstorm? It was probably caused by blocked roof drains. But the basic roof design could also have been at fault. Roof design for rain loads is covered in IBC Section 1611.1. First and foremost, roof design should take into account that the primary drainage system could become blocked, and plan for that possibility. The system is then designed for roof live load, roof snow load, or roof rain load, whichever regulation is applicable.

Accumulated Rainwater

A roof must be capable of holding the load caused by rainwater accumulating, if the primary drainage system is blocked. If blocked, and the rainwater rises to the inlet level of the secondary drainage system, that system takes over. But the accumulated rain load will remain constant up to the secondary drain inlet level.

Rain load, R, is calculated using IBC Equation 16-36:

$$R = 5.2(d_s + d_h)$$

In this equation:

R is the rain load in pounds per square foot (psf).

d_s is the depth of water, in inches, that would build up on the roof to the inlet level of the secondary drainage system if the primary drainage system is blocked. That's called the static head.

d_h is the additional depth of water, in inches, that could build up above the inlet level of the secondary drainage system inlet (at the flow rate it's designed to discharge), during the worst possible circumstances. That's called the hydraulic head.

You also have to be aware of ponding on roofs with a slope of less than ¼ inch in 1 foot. Ponding makes an area of the roof sag (deflect). This increases the ponding, which makes the sagging even worse, and in time leads to a progressive collapse. Ponding instability is covered in IBC Section 1611.2 and Section 8.4 of ASCE 7.

Snow Loads

Snow falls over a good portion of the U.S., so snow loads are something you need to consider. Again, much of the information on snow load calculations has been taken out of the code.

FIGURE 1608.2
GROUND SNOW LOADS, P_G, FOR THE WESTERN UNITED STATES (PSF)

Figure 10-3 Ground snow loads for the western U.S.

Now, IBC Section 1608 refers you and the engineer or architect to the ASCE 7 standard. The roof must be designed for the governing load, roof snow load, or roof live load.

You can use the ground snow load information in IBC Figure 1608.2 (Figure 10-3) or Table 1608.2 for Alaska, which is not shown on the map. The map usually has two numbers for mountainous areas. For example, in northwestern Montana, outlined in Figure 10-3, they're (4000) and 20. The first number (shown in parentheses) is the elevation up to which the second figure, the snow load (20 psf in this case), can be used. Above that elevation, site-specific case studies must be made and the results approved. This also applies to the areas on the map marked CS (for case studies). In the flatter parts of the country, only one figure is shown, the ground snow load, given in psf.

Do you know what your local snow load is? If you get a lot of snow, you probably do. But if your work spans several different areas, each job might have a different snow load. For example, in the state of Washington, counties vary in elevation from sea level to over 8,000 feet. At sea level, there isn't a lot of snow. There may be just a few inches that hardly settle, with little or no freezing. But in the mountains of Washington, the snow depth can reach 15 feet or more and stay on the ground from October to June. Is the entire county considered a snow area? Yes, of course. But how do you find snow loads for each community in the county? Where do you draw the line? When do you have a 10 psf, a 15 psf or a 20 psf load? You can't always depend on elevation, because snowfall varies even at the same elevation, as do freezing and thawing conditions. This is another case where it's wise to consult your local building official before preparing your plans.

I once asked the Snohomish County building official about this problem. Here's what he told me: "In Snohomish County it only snows back of the section line. On one side of the section line you get one rating; on the other side it's something completely different."

His opinion was based on years of experience and observation. If you don't have official reference data, the local inspector's opinion may be your best guide. If it's based on experience and good judgment, it's probably right. If you don't agree, then it's up to you to prove that you have more accurate information.

Uplift Loads

Ever hear of uplift loads? If you haven't, don't worry. Nearly everyone thinks loads are caused by gravity pulling things down.

But roofs can experience uplift loads from wind pressure just like airplane wings. A roof with a parapet wall is extremely vulnerable. Winds can cause a vortex that creates a vacuum (negative pressure) on the roof behind the wall. Large sections of roofing have been literally sucked off by uplift pressure. High-rise buildings with large glass windows can also have heavy negative loads. The only defense is a design that takes negative wind load into consideration.

Gable roofs can also fall victim to this type of load. Winds blowing over the roof cause negative pressure on the leeward side of the roof (the side away from the wind). Large patches of shingles can tear off and go flying. If your chimney is too short or in the wrong place, the same force can cause draft problems and smoky fires.

Although we understand the wind's effect, conditions vary considerably from place to place. Be aware of any conditions that may create uplift loads on your building. If you think you can depend on trees or other buildings nearby to reduce the wind load, think again. They may disappear in the next windstorm, leaving your building vulnerable and at the mercy of the storm.

Roofs of unenclosed buildings, roof overhangs, architectural projections, eaves, canopies, cornices, marquees, etc. have to be designed and built to withstand wind pressures. Listen when the inspector tells you to bolt your patio or carport cover to the concrete slab. He's just trying to keep it out of the neighbor's yard!

You'll find more information on wind uplift forces in IBC Section 2308.10.1, and on required fastenings for conventional wood frame buildings in Tables 2308.10.1 (Figure 10-4) and 2304.9.1 (Figure 10-5).

> ***Section 2308.10.1.*** *Roof assemblies shall have rafter and truss ties to the wall below. Resultant uplift loads shall be transferred to the foundation using a continuous load path. The rafter or truss to wall connection shall comply with Tables 2304.9.1 and 2308.10.1.*

The top part of Table 2308.10.1 (Figure 10-4) shows an example of a 28-foot roof span in a 100-mph wind speed (outlined). The required rating of approved uplift connectors is negative 305 pounds. You must also take into account the exposure category and the mean roof height of the building, as shown in the second table. So if your building is 35 feet high and in Exposure C (outlined in the lower section of Figure10-4), you have to multiply the negative 305 pounds by 1.45. This gives you a total figure of negative 442 pounds.

Note "*b*" under the Table is important. It states that these numbers are based on framing spaced 24 inches on center. If the spacing is 16 inches on center, the table numbers can be reduced by one third. Remember, there are important details in the footnotes, so read them carefully.

Other Loads

IBC Table 2304.9.1 (a portion of which is in Figure 10-5) gives a listing of wood members to be fastened and the *minimum* number and size of fasteners for conventional wood-frame buildings. Remember, you can always exceed the minimum number.

TABLE 2308.10.1
REQUIRED RATING OF APPROVED UPLIFT CONNECTORS (POUNDS)[A,B,C,E,F,G,H]

BASIC WIND SPEED (3-second gust)	ROOF SPAN (feet)							OVERHANGS (pounds/feet)[d]
	12	20	24	28	32	36	40	
85	-72	-120	-145	-169	-193	-217	-241	-38.55
90	-91	-151	-181	-212	-242	-272	-302	-43.22
100	-131	-281	-262	-305	-349	-393	-436	-53.36
110	-175	-292	-351	-409	-467	-526	-584	-64.56

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 mile per hour = 1.61 km/hr; 1 pound = 0.454 Kg, 1 pound/foot = 14.5939 N/m.

a. The uplift connection requirements are based on a 30-foot mean roof height located in Exposure B. For Exposure C or D and for other mean roof heights, multiply the above loads by the adjustment coefficients below.

	Mean Roof Height (feet)									
EXPOSURE	15	20	25	30	35	40	45	50	55	60
B	1.00	1.00	1.00	1.00	1.05	1.09	1.12	1.16	1.19	1.22
C	1.21	1.29	1.35	1.40	1.45	1.49	1.53	1.56	1.59	1.62
D	1.47	1.55	1.61	1.66	1.70	1.74	1.78	1.81	1.84	1.87

b. The uplift connection requirements are based on the framing being spaced 24 inches on center. Multiply by 0.67 for framing spaced 16 inches on center and multiply by 0.5 for framing spaced 12 inches on center.

c. The uplift connection requirements include an allowance for 10 pounds of dead load.

d. The uplift connection requirements do not account for the effects of overhangs. The magnitude of the above loads shall be increased by adding the overhang loads found in the table. The overhang loads are also based on framing spaced 24 inches on center. The overhang loads given shall be multiplied by the overhang projection and added to the roof uplift value in the table.

e. The uplift connection requirements are based upon wind loading on end zones as defined in Figure 6-2 of ASCE 7. Connection loads for connections located a distance of 20 percent of the least horizontal dimension of the building from the corner of the building are permitted to be reduced by multiplying the table connection value by 0.7 and multiplying the overhang load by 0.8.

f. For wall-to-wall and wall-to-foundation connections, the capacity of the uplift connector is permitted to be reduced by 100 pounds for each full wall above. (For example, if a 500-pound rated connector is used on the roof framing, a 400-pound rated connector is permitted at the next floor level down).

g. Interpolation is permitted for intermediate values of basic wind speeds and roof spans.

h. The rated capacity of approved tie-down devices is permitted to include up to a 60-percent increase for wind effects where allowed by material specifications.

Figure 10-4 Required rating of approved uplift connectors

So far, we've only talked about the loads that affect roof design: wind, rain, snow and uplift loads. But there are loads that affect other parts, or all, of the building structure. Some of them are:

- Earthquake loads
- Flood loads
- Soil lateral loads

Generally, these loads apply only to certain parts of the country or to specific locations. It's best to let the experts deal with them, so consult an engineer familiar with the local conditions.

Always make sure the building inspector confirms that your plans comply with the code before you begin construction.

Earthquake Loads

Parts of the U.S. have minimal earthquake load effects. But people in areas of seismic activity take earthquakes very seriously. Earthquake damage can be substantial. Unlike hurricanes, earthquakes don't give any warning to allow people to evacuate a building. The code no longer covers this subject in depth. Now IBC Section 1613 refers you and your engineer or architect to the ASCE 7 standard.

Flood Loads

Always check with your local building official to see if your building location is in a designated flood hazard area. IBC Section 1612.3 requires the governing body to establish a flood hazard map showing areas of special flood hazard, as identified by the Federal Emergency Management Agency (FEMA).

If your building is in a flood hazard area, ***Section 1612.1*** says that …*all new construction of buildings, structures and portions of buildings and structures, including substantial improvement and restoration of substantial damage to buildings and structures, shall be designed and constructed to resist the effects of flood hazards and flood loads.*

TABLE 2304.9.1 FASTENING SCHEDULE		
CONNECTION	**FASTENING[a,m]**	**LOCATION**
1. Joist to sill or girder	3 - 8d common ($2^1/_2$″ × 0.131″) 3 - 3″ × 0.131″ nails 3 - 3″ 14 gage staples	toenail
2. Bridging to joist	2 - 8d common ($2^1/_2$″ × 0.131″) 2 - 3″ × 0.131″ nails 2 - 3″ 14 gage staples	toenail each end
3. 1″ × 6″ subfloor or less to each joist	2 - 8d common ($2^1/_2$″ × 0.131″)	face nail
4. Wider than 1″ × 6″ subfloor to each joist	3 - 8d common ($2^1/_2$″ × 0.131″)	face nail
5. 2″ subfloor to joist or girder	2 - 16d common ($3^1/_2$″ × 0.162″)	blind and face nail
6. Sole plate to joist or blocking	16d ($3^1/_2$″ × 0.135″) at 16″ o.c. 3″ × 0.131″ nails at 8″ o.c. 3″ 14 gage staples at 12″ o.c.	typical face nail
Sole plate to joist or blocking at braced wall panel	3″ - 16d ($3^1/_2$″ × 0.135″) at 16″ 4 - 3″ × 0.131″ nails at 16″ 4 - 3″ 14 gage staples per 16″	braced wall panels
7. Top plate to stud	2 - 16d common ($3^1/_2$″ × 0.162″) 3 - 3″ × 0.131″ nails 3 - 3″ 14 gage staples	end nail
8. Stud to sole plate	4 - 8d common ($2^1/_2$″ × 0.131″) 4 - 3″ × 0.131″ nails 3 - 3″ 14 gage staples	toenail
	2 - 16d common ($3^1/_2$″ × 0.162″) 3 - 3″ × 0.131″ nails 3 - 3″ 14 gage staples	end nail
9. Double studs	16d ($3^1/_2$″ × 0.135″) at 24″ o.c. 3″ × 0.131″ nail at 8″ o.c. 3″ 14 gage staple at 8″ o.c.	face nail
10. Double top plates	16d ($3^1/_2$″ × 0.135″) at 16″ o.c. 3″ × 0.131″ nail at 12″ o.c. 3″ 14 gage staple at 12″ o.c.	typical face nail
Double top plates	8-16d common ($3^1/_2$″ × 0.162″) 12-3″ × 0.131″ nails 12-3″ 14 gage staples	lap splice
11. Blocking between joists or rafters to top plate	3 - 8d common ($2^1/_2$″ × 0.131″) 3 - 3″ × 0.131″ nails 3 - 3″ 14 gage staples	toenail
12. Rim joist to top plate	8d ($2^1/_2$″ × 0.131″) at 6″ o.c. 3″ × 0.131″ nail at 6″ o.c. 3″ 14 gage staple at 6″ o.c.	toenail
13. Top plates, laps and intersections	2 - 16d common ($3^1/_2$″ × 0.162″) 3 - 3″ × 0.131″ nails 3 -3″ 14 gage staples	face nail
14. Continuous header, two pieces	16d common ($3^1/_2$″ × 0.162″)	16″ o.c. along edge
15. Ceiling joists to plate	3 - 8d common ($2^1/_2$″ × 0.131″) 5 - 3″ × 0.131″ nails 5 - 3″ 14 gage staples	toenail
16. Continuous header to stud	4 - 8d common ($2^1/_2$″ × 0.131″)	toenail

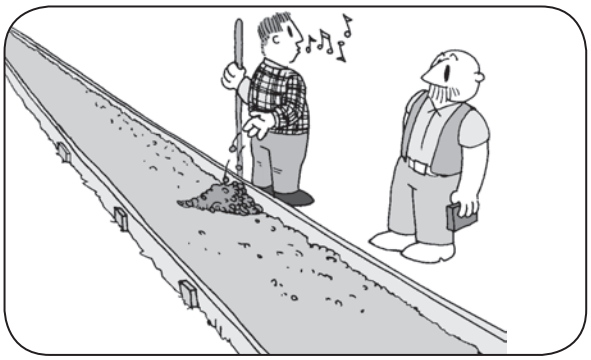
Figure 10-5 Fastening schedule

In this case, you or your engineer will need to consult the American Society of Civil Engineers standard for Flood Resistant Design and Construction, (ASCE 24). The latest standard, ASCE 24-05, is available at www.pubs.asce.org.

Soil Lateral Loads

Basement, foundation and retaining walls must be designed to resist any lateral loads from soil pressure, based on soil type and moisture conditions. We'll spend some time looking at lateral loads when we discuss foundations in Chapter 12 of this book.

We've covered the basics of the design and engineering topics you should be aware of. It's time to start looking at the building itself. In the next two chapters, we'll focus on the code requirements for concrete, followed by foundation details.



Sidewalks Anyone?

Everybody knows how important a good sidewalk is to kids — and their parents! It gives the kids a smooth, safe surface to ride bikes, skate, skate board, play hopscotch, jump rope, and walk to school. From a professional viewpoint, curbs and sidewalks reduce dust and debris in a neighborhood — but more important — they increase pedestrian safety. My town, Kennewick, had no curbs or sidewalks. So, one day a while ago, the Kennewick city engineer and I sat down to try to make life better for the kids and easier for housekeepers and homeowners. We decided to revise our public works ordinance. Anyone building a new house or doing substantial remodeling would need a sidewalk in front of the home. If they didn't already have one, they'd have to build one. The city council agreed, and our draft became law.

That created quite a stir. Contractors were against it. Some homeowners were against it. But the city council stood by their guns.

About a year later I had a contractor breeze into my office insisting that he built the best houses around. And he also insisted that a sidewalk wasn't needed in front of the new house he wanted to build. It would be the only house on the block with a sidewalk and a curb — and that just seemed ridiculous to him. As it was located on a corner lot, he'd have to install a lot of sidewalk and curbing. Of course, the cost of that part of the job was probably the main cause of his complaint.

After I'd inspected his plans, I issued him a permit for a new residence — and a sidewalk to go with it.

He built the house and I did the final inspection, including a check of his curb and sidewalk forms. His forms checked out perfectly, so I signed off the inspection and left for the next job.

About an hour later, I realized that I'd forgotten to make the final plumbing inspection for the property. I drove back to the job just in time to find him filling in part of the sidewalk forms with gravel. I guess he was still mad about spending those extra bucks for a curb and sidewalk. Anyhow, he had the decency to turn red with embarrassment, and started digging out the forms again.

"I'm curious," I said. "About how much concrete did you expect to save by partially filling in the forms with gravel?"

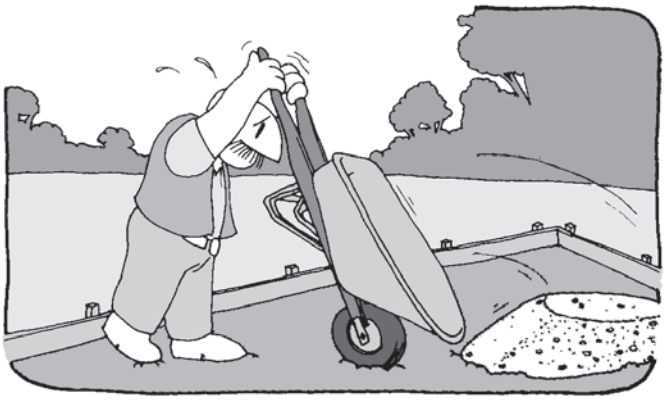
"Oh, maybe twenty or thirty dollars worth," he replied.

"What do you figure your time is worth?" I asked.

He stared at me until it dawned on him. Then he started to grin. "Wasn't going to save very much, was I?"

"Guess not," I agreed. "Let's see how long it takes you to dig out all that extra gravel. I'll sit right here and time you while you're digging. Then, when you get ready to pour the concrete, I'll come back to keep track of your time on that as well." And that's exactly what I did.

I passed by that home a few months later. Sidewalks and curbs stretched up and down both sides of the street. The city completed the stretches where sidewalks hadn't been installed. But my ordinance (and a little arm twisting) had done the job. I'm sure the kids will appreciate growing up in a neighborhood with good sidewalks. I wish I'd had the same advantage. And, judging by the current asking prices for homes on that street, the sidewalks haven't done the homeowners any harm, either. Funny thing, I don't hear contractors complaining about my sidewalk ordinance any more. I guess as people get comfortable with one code change, they find other, newer changes to complain about!



CHAPTER 11

Concrete

When you're building homes, apartments or small commercial buildings, you probably don't need to know much about concrete. After all, it's delivered on-site already mixed and ready to use. But the bigger the job, the more you need to know. You don't want to break up a freshly-poured foundation because it didn't pass inspection. Knowing your stuff and doing it right the first time will help prevent that from happening.

What Is Concrete?

There's a difference between concrete and cement. Though the terms are often used interchangeably by people who aren't in the building trades, they aren't the same thing. Cement is the powdered limestone-based mixture used to make concrete. Cement is usually made by heating a crushed mixture of limestone and clay or slag to a very high temperature. Large, glassy cinders called *clinkers* are formed. The clinkers are then ground into the fine powder we know as cement. There are actually four different types of cement, each made from different silicate and aluminate materials. We'll discuss them in a little more detail later in the chapter.

Concrete is a mixture made up of one of those cement types, large and small aggregates, and water. Its strength is determined by the amount and type of cement in the mix, the size of the aggregate used, and the amount of water added. A chemical reaction between the cement and the water, called *hydration*, binds the mixture together. During the hydration process, the mixture hardens into concrete. Cement alone is just a powder. Add water, and you have a paste. Add aggregates into the mix, and you have concrete. But to have good concrete, you need to use good materials.

The materials, quality control, design and construction of concrete used for building are covered in Chapter 19 of the IBC. These requirements are mostly based on the American Concrete Institute (ACI) standard, Building Code Requirements for Structural Concrete and Commentary (ACI 318). It's available for purchase at the ACI website, www.aci-int.org or from the ICC at www.iccsafe.org.

Concrete Terms

Let's define concrete and a few of the materials used with concrete.

Concrete: *A mixture of cement, fine aggregate, coarse aggregate and water, with or without admixtures.*

Admixture: *A material other than water, aggregate or cement, used as an ingredient of concrete and added before or during mixing to change the concrete's properties.*

Aggregate: *A granular material, like sand, gravel, crushed stone or blast-furnace slag, used with cement to form a hydraulic cement concrete or mortar.*

Deformed Reinforcement: *Deformed means "not smooth." The reinforcing materials have ribs or an irregular shape so they can be held firmly by the concrete or mortar. These materials must conform to ACI 318, Section 3.5.3. Reinforcement comes in several forms. They are:*

Deformed bars, usually called rebar

Bar mats

Deformed wire

Welded plain wire fabric

Welded deformed wire fabric

Hydraulic Cement: *Cement that hardens when water is added.*

Plain Concrete: *Structural concrete with no reinforcement, or with less reinforcement than the required minimum for reinforced concrete.*

Portland Cement: *A generic term for hydraulic cement. In 1824, a British stonemason, Joseph Aspdin, patented a new kind of cement. He made it by heating a mixture of finely-ground limestone and clay on his kitchen stove. Then he ground the mixture into a powder. He named it portland cement because it looked like stone quarried on the Isle of Portland, off the coast of southern England.*

Precast Concrete: *A structural concrete element cast in other than its final position in the structure.*

Prestressed Concrete: *Reinforced concrete in which internal stresses have been introduced to reduce potential tensile stresses in the concrete resulting from loads.*

Reinforced Concrete: *Structural concrete reinforced with at least the minimum amounts of prestressing steel or nonprestressed reinforcement given in ACI 318.*

Structural Concrete: *Concrete used for structural purposes. It includes plain and reinforced concrete.*

Materials

Concrete is probably one of the most abused of all construction materials. It's been mismatched, mixed incorrectly, and watered down. Products are added to speed up or slow down hardening. But in spite of all this, it's one of the most reliable building materials in use today. Weather will eventually erode it, but it won't rust or rot. Even bad mixes usually last longer than the framing, wiring, and other parts of a residential building.

Concrete block is another durable and versatile building material. It can be adapted to nearly any design or building application. It'll also support greater loads than most other building products. Concrete block masonry is discussed in depth in Chapter 13 of this book.

Materials used for concrete production must meet the applicable requirements in Chapter 3 of the ACI 318 standard. Here are a few of the sections for you to refer to:

- Cement, Section 3.2
- Aggregates, Section 3.3
- Water, Section 3.4
- Admixtures, Section 3.6

You can see by its contents that ACI 318 is an important reference. If you're going to be working with concrete, you should have a copy.

Types of Concrete

Concrete has been used for construction since before the Roman era, so we have a lot of information about its qualities and composi-

tion. What make concrete mixes different are the ingredients — the various types of cement and the combinations of aggregate and admixtures.

As we mentioned earlier, there are four basic types of cement, made from four different silicate and aluminate materials:

1. Tricalcium silicate (alite)
2. Dicalcium silicate (belite)
3. Tricalcium aluminate
4. Tetracalcium aluminoferrite

You can get free information on Cementitious Materials for Concrete, ACI Education Bulletin E3-01, at www.aci-int.org/general/fE3-01.pdf.

There are eight types of concrete commonly used in construction. E3-01 lists the cement compositions for each of the eight different types. Each type has characteristics that make it useful in particular applications. Check the specs for your job to know which concrete to use.

- Type I: Used in general concrete construction when the special properties specified for Types II, III, IV, and V aren't required
- Type IA: Same applications as Type I, but where air-entrainment is required
- Type II: Used in general concrete construction that will be exposed to moderate sulfate action, or where moderated heat of hydration is desired
- Type IIA: Same applications as Type II, but where air-entrainment is required
- Type III: Used when high early strength is desired
- Type IIIA: Same applications as Type III, but where air-entrainment is required
- Type IV: Used when a low heat of hydration is required
- Type V: Used when high sulfate resistance is required

Type I concrete is the most-commonly used. Unless your specs call for a specific concrete type, use Type I concrete. If the job requires something out of the ordinary, check with your concrete supplier. The engineer designing the job will have the final say.

You also need to know the right type of cement and the proportions to use. This information should be in the job specs. There'll probably be three figures, like 1-3-5. This means: 1 sack cement, 3 cubic feet of sand, and 5 cubic feet of aggregate. Finally, you'll add the amount of water necessary to get the slump required by the slump test specs (which we'll cover shortly).

The aggregate must be clean and free of foreign material and pollutants. It can't contain ash, dirt, grease, oil or wood chips. The nominal maximum size of the aggregate should be no larger than one of the following:

- $^1/_5$ of the narrowest dimension between the sides of the form
- $^1/_3$ the depth of the slab
- $^3/_4$ of the minimum clear spacing between reinforcing steel

Check the mix's workability and consolidation methods. Make sure the finished concrete has no honeycombs or voids. It should still be plastic — not too runny and not too stiff to be workable.

Use clean water that's free of oil, acids, alkalis, salts or organic materials which could affect either the concrete or the reinforcing steel. As a rule of thumb, if you wouldn't drink the water, you shouldn't use it for concrete.

Durability Requirements

The concrete durability requirement depends on two things:

1. How it's being used
2. The environmental conditions over its lifetime

Durability is controlled by:

- Water/cementitious material ratio; see IBC Section 1904.1 and ACI 318, Section 4.1
- The mixing process

What if concrete is exposed to freezing and thawing? In that case, it has to meet certain air-entrainment requirements. See ACI 318, Section 4.2.1. This requirement applies to most areas of the U.S.

TABLE 1904.2.2 MINIMUM SPECIFIED COMPRESSIVE STRENGTH			
TYPE OR LOCATION OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH (f'_c at 28 days, psi)		
	Negligible exposure	Moderate exposure	Severe exposure
Basement walls[c] and foundations not exposed to the weather	2,500	2,500	2,500[a]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[a]
Basement walls[c], foundation walls, exterior walls and other vertical concrete surfaces exposed to the weather	2,500	3,000[b]	3,000[b]
Driveways, curbs, walks, patios, porches, carport slabs, steps and other flatwork exposed to the weather, and garage floor slabs	2,500	3,000[b, d]	3,500[b, d]

For SI: 1 pound per square inch = 0.00689 MPa.

a. Concrete in these locations that can be subjected to freezing and thawing during construction shall be of air-entrained concrete in accordance with Section 1904.2.1.

b. Concrete shall be air entrained in accordance with Section 1904.2.1.

c. Structural plain concrete basement walls are exempt from the requirements for exposure conditions of Section 1904.2.2 (see Section 1909.6.1).

d. For garage floor slabs where a steel trowel finish is used, the total air content required by Section 1904.2.1 is permitted to be reduced to not less than 3 percent, provided the minimum specified compressive strength of the concrete is increased to 4,000 psi.

Figure 11-1 Minimum specified compressive strength

There are also special requirements in ACI 318, Section 4.2.2 for:

- Concrete with low permeability in wet conditions
- Concrete exposed to freezing and thawing in a moist condition, or exposed to deicing chemicals
- Concrete with reinforcement where the concrete is exposed to chlorides from deicing chemicals, salt, salt water, brackish water, seawater or spray from these sources. Concrete exposed to deicing chemicals must also meet the requirements of ACI 318, Section 4.2.3.

There are also special requirements in IBC Section 1904.3 and ACI 318, Section 4.3, for concrete exposed to sulfate-containing solutions or soils.

For Group R occupancies less than four stories high, including one- or two-family dwellings and townhouses, Section 1904.2.2 says that the concrete used . . . *shall comply with the requirements of Table 1904.2.2* (Figure 11-1), *based on the weathering classificatio*n (freezing and thawing) determined from *IBC Figure 1904.2.2* Figure 11-2).

Testing Concrete

Concrete is difficult, if not impossible, to inspect properly after it's poured and cured. That's why the inspector can require any tests he thinks are necessary. Inspection can take place during the placement of reinforcing bars, the concrete mixing, and the pouring phase. The requirement for these tests and their time lines should be in the job specs, so you'll know in advance when they're scheduled. But be aware that if the inspector thinks the tests in the specs are inadequate, he can ask for more specific tests. Most on-site concrete testing is easily done. The requirement for special inspections is covered in IBC Section 1704. The special inspections and verifications of concrete construction are spelled out in Section 1704 and Table 1704.4 (Figure 11-3).

The following are some of the exceptions to the special inspection requirements of Table 1704.4:

- Isolated spread concrete footings of buildings three stories high or less, fully supported on earth or rock.
- Continuous concrete footings supporting walls of buildings three stories high or less, fully supported on earth or rock, where:

FIGURE 1904.2.2
WEATHERING PROBABILITY MAP FOR CONCRETE

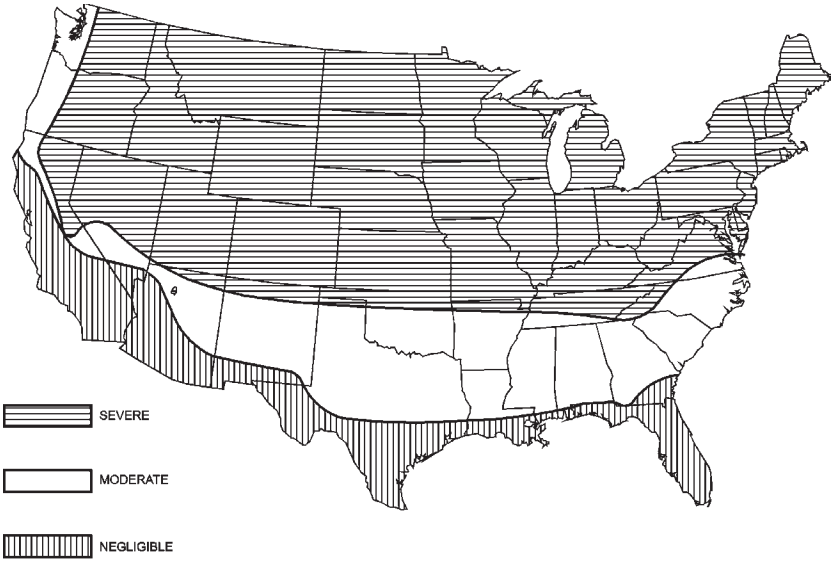


FIGURE 1904.2.2
WEATHERING PROBABILITY MAP FOR CONCRETE[a, b, c]

a. Lines defining areas are approximate only. Local areas can be more or less severe than indicated by the region classification.
b. A "severe" classification is where weather conditions encourage or require the use of deicing chemicals or where there is potential for a continuous presence of moisture during frequent cycles of freezing and thawing. A "moderate" classification is where weather conditions occasionally expose concrete in the presence of moisture to freezing and thawing, but where deicing chemicals are not generally used. A "negligible" classification is where weather conditions rarely expose concrete in the presence of moisture to freezing and thawing.
c. Alaska and Hawaii are classified as severe and negligible, respectively.

Figure 11-2 Weathering probability map for concrete

1. The footings support walls of light-frame construction;

Or

2. The footings are designed to meet the requirements of IBC Table 1805.4.2;

Or

3. The structural design of the footing is based on a specified compressive strength, f'_c, no greater than 2,500 psi, regardless of the compressive strength specified in the construction documents or used in the footing construction.

- Nonstructural concrete slabs supported directly on the ground, including prestressed slabs on grade, where the effective prestress in the concrete is less than 150 psi.
- Concrete foundation walls meeting the requirements of Table 1805.5(5).
- Concrete patios, driveways and sidewalks constructed on grade.

These exceptions include buildings of three stories or less, so they exempt special inspections for concrete footings for most one- and two-family dwellings and townhouses. They also exclude patios, driveways and sidewalks. These exceptions mean that you'll need minimal concrete testing if you only build small residential buildings. High-rises are another story, so be sure you know the job specs in case some of the special inspections need to be made.

Two of the most common concrete tests are:

- Slump test
- Compression, or compressive fracture, test

TABLE 1704.4 REQUIRED VERIFICATION AND INSPECTION OF CONCRETE CONSTRUCTION				
VERIFICATION AND INSPECTION	CONTINUOUS	PERIODIC	REFERENCED STANDARD[a]	IBC REFERENCE
1. Inspection of reinforcing steel, including prestressing tendons, and placement.	—	X	ACI 318: 3.5, 7.1-7.7	1913.4
2. Inspection of reinforcing steel welding in accordance with Table 1704.3, Item 5b.	—	—	AWS D1.4 ACI 318: 3.5.2	—
3. Inspect bolts to be installed in concrete prior to and during placement of concrete where allowable loads have been increased.	X	—	—	1911.5
4. Verifying use of required design mix.	—	X	ACI 318: Ch. 4, 5.2-5.4	1904.2.2, 1913.2, 1913.3
5. At the time fresh concrete is sampled to fabricate specimens for strength tests, perform slump and air content tests, and determine the temperature of the concrete.	X	—	ASTM C 172 ASTM C 31 ACI 318: 5.6, 5.8	1913.10
6. Inspection of concrete and shotcrete placement for proper application techniques.	X	—	ACI 318: 5.9, 5.10	1913.6, 1913.7, 1913.8
7. Inspection for maintenance of specified curing temperature and techniques.	—	X	ACI 318: 5.11-5.13	1913.9
8. Inspection of prestressed concrete: a. Application of prestressing forces. b. Grouting of bonded prestressing tendons in the seismic-force-resisting system.	 X X	—	 ACI 318: 18.20 ACI 318: 18.18.4	—
9. Erection of precast concrete members.	—	X	ACI 318: Ch. 16	—
10. Verification of in-situ concrete strength, prior to stressing of tendons in posttensioned concrete and prior to removal of shores and forms from beams and structural slabs.	—	X	ACI 318: 6.2	—
11. Inspect formwork for shape, location and dimensions of the concrete member being formed.	—	X	ACI 318: 6.1.1	—

For SI: 1 inch = 25.4 mm.
a. Where applicable, see also Section 1707.1, Special inspection for seismic resistance.

Figure 11-3 Required verification and inspection of concrete construction

Testing samples are taken from the mixed concrete, and can be done either right before or during the pouring process. If the specs call for the testing to be done during the pour, one sample is taken just after the first 10 percent of the pour has been placed, and a second sample just before the final 10 percent. The two samples should be taken no more than 15 minutes apart. The samples are blended to form a composite sample for testing. For full sampling details see the American Society for Testing and Materials standards, Standard Practice for Sampling Freshly Mixed Concrete (ASTM C172) and Standard Practice for Making and Curing Concrete Test Specimens in the Field (ASTM C31). ASTM standards can be purchased at www.astm.org or from the ICC at www.icccsafe.org.

Other concrete tests that may be called for are:

- Air content tests for concretes with dense aggregate (Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method, ASTM C231-04)
- Air content tests for concretes with lightweight, porous aggregates (Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method, ASTM C173/C173M-01)
- Temperature tests (Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete, ASTM C1064/C1064M-05)

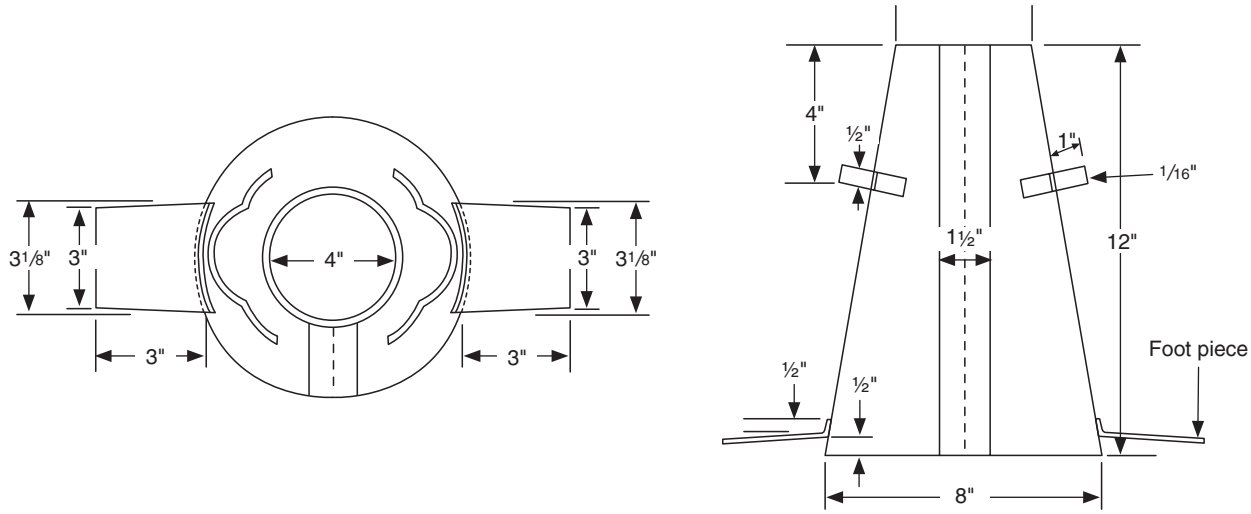


Figure 11-4 Details of cone used for slump test

- Unit weight, yield and gravimetric air content (Standard Test Method for Density [Unit Weight], Yield, and Air Content [Gravimetric] of Concrete, ASTM C138/C138M-01)

If the specs call for any of these tests, check the referenced ASTM standards. Now, let's take a closer look at the slump test and the compressive fracture test.

Slump Test

The slump test is conducted as specified in ASTM C143, and is probably the easiest concrete test to perform. It's used for testing concrete containing coarse aggregate up to 1½ inches in size. If the coarse aggregate is larger than 1½ inches, this method is only applicable when it's performed on the concrete *that passes through a 1½-inch sieve*.

The test uses a seamless, cone-shaped device, 12 inches high with an 8-inch diameter base. The cone is open at the top and bottom. Figure 11-4 shows the dimensions in detail.

Begin the test by dampening the inside of the cone and placing it on a flat surface, with the narrow end up. Make sure the cone is held down firmly as you fill it with the composite concrete sample. Pour the concrete in three equal layers, tamping each layer 25 times with a steel rod. (The rod is ⅝ inch in diameter and approximately 24 inches long, with a half-circle-shaped rounded tip on the tamping end.)

Distribute the strokes uniformly over the cross-section of each layer. Pierce the second layer so that it just penetrates into the first layer. Do the same with the third layer. Overfill the top layer to prevent it from falling below the top of the cone as it settles during the rodding process. Add more concrete if necessary. After rodding the top layer, remove the excess concrete using the tamping rod as a screed. Clean any extra concrete from around the base of the cone.

Now, carefully lift off the cone without disturbing the integrity of the concrete sample. This entire process, from filling the cone to its removal, should take roughly 2½ minutes. Immediately measure the height of the sample to the nearest quarter-inch. The difference between this measurement and the 12-inch height of the cone is the amount of slump.

You'll usually perform three slump tests and take an average of the results. The inspector will compare this average with the slump figure allowed by the job specs. If the result isn't within the allowed range, the inspector can reject the batch of concrete.

Concrete with a slump of less than ½ inch may not be plastic enough. Concrete with a slump of more than about 9 inches may not be

Figure 11-5 Slump test being performed

cohesive enough for the test to have any significance. The specs will generally call for a slump midway between these two extremes, along with an acceptable range on either side of this. Use caution when you interpret the results of a test with a slump of more than 9 inches. That's generally not a good result. Figure 11-5 shows a slump test being performed.

One of the best things about the slump test is that it can be done before the concrete is even poured into the forms if you or the inspectors suspect that the delivery might not meet the specs. Then, if the concrete fails the test, it can be rejected before it's actually placed. But, even if you take the samples during the pour, and the concrete fails the slump test, it's a lot easier to remove wet concrete from the forms than concrete that's cured and hardened.

Compressive Fracture Test

The compression test (ASTM C31/C31M) begins in the field and ends in the lab. It's an after-the-pour test, usually performed in an accredited laboratory a few days after the concrete is poured and cured. That makes it a confirmation test, rather than a go, no-go test like the slump test.

Test samples are taken from the mix on-site. Again, you can't take samples from the first or last 10 percent of the pour. A number of samples are taken and blended, and the mixture is poured into open-ended test cylinders, 6 inches in diameter by 12 inches long. You may also use 4- by 8-inch cylinders, if that's what's called for in the job specs. The cylinders are usually made of steel, but cast iron or another nonabsorbent material can also be used.

The samples are poured into the test cylinders in three separate layers, with each layer being roughly the same the volume. A tamping rod or vibrator is used to settle each layer before the next layer is added. For a 6-inch test cylinder, the tamping rod is ⅝ inch in diameter by 20 inches long. Each layer is rodded 25 times with the tamping rod. This mixes the layers together and settles the sample. For more details on the rodding technique, see the ASTM test specification. If an internal vibrator is used, it should have a vibration frequency of at least 7,000 vibrations per minute.

After rodding is completed, the cylinders should be stored on-site for 48 hours during the initial set-up and cure. The samples should be kept in an environment that will prevent moisture loss. The easiest way to do this is to place the samples inside sealed plastic bags. The storage temperature should be between 60 and 80 degrees F (16 and 27 degrees C). For mixtures with a specified strength of 6,000 psi or more, the initial curing temperature must be between 68 and 78 degrees F (20 to 26 degrees C).You can read the details of the test procedure in the ASTM test specifications.

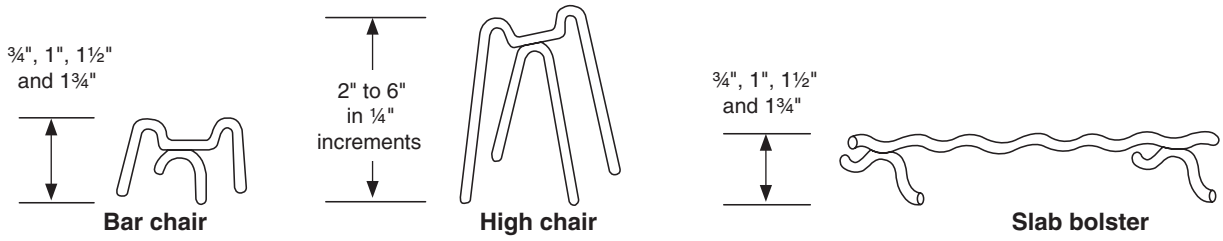


Figure 11-6 Chairs for supporting reinforcing steel

After initial curing, the test samples are taken to the lab and removed from the cylinders for final curing. During this time, free water must be maintained on the sample surfaces at all times, and the temperature kept at 73 degrees F, plus or minus 3 degrees (23 degrees C, plus or minus 2 degrees). Water storage tanks or moist rooms work well for the final cure.

The cured concrete samples are then tested using a compression or breaking press to measure their compressive fracture strength. The press applies the set amount of pressure to the sample that's called for in the specifications. The tests are conducted after different curing periods, usually 24 hours, 7 days, and 28 days. Several samples are tested each time, and the results are checked against the job specs. This test confirms the compressive fracture strength of the poured and cured concrete. Your pour must pass this test.

Most transit-mix companies run ongoing compressive tests on their concrete. The plant may produce an occasional bad batch, but most problems occur after the mix arrives at the job site.

Concrete Reinforcement

Always use rebar that meets the job specs, and place it according to the plans. IBC Section 1907 and ACI 318 give the type of hooks to use, minimum bend diameters, bending techniques and surface condition of reinforcement bars. Rebar made from steel will rust, so it's important to check the surface condition of the bars before pouring concrete. Section 1907.4 says the surface condition of reinforcement must comply with ACI 318, Section 7.4.

Before you install rebar, make sure it has no mud, oil or other nonmetallic coating. Rust, mill scale, or a combination of the two is acceptable — except for prestressing steel.

The clear distance between parallel rebar in a layer should be at least the same as the nominal diameter of the bars, but not less than 1 inch. The spacing limits for reinforcement are covered in IBC Section 1907.6 and ACI 318, Section 7.6. If two or more parallel layers of rebar are used, the bars in the upper layer must be put right above the bars in the lower layer. The distance between the two layers can't be less than 1 inch.

Bundled bars must be held together with stirrups or ties. No more than four parallel bars can be bundled to make a single unit. Bars larger than No. 11 can't be bundled in beams.

You can use lap splices on bars up to 1.41 inches in diameter. (We'll cover more on splicing in Chapter 13.) There's an exception that allows you to lap splice larger bars if they're used as dowels in footings. You can also use welded splices. A full welded splice has bars that are butted together and welded to develop a bond at least 125 percent of the specified yield strength of the bar.

Be sure to support all reinforcement. For vertical work, secure it so it won't touch the sides of the forms or other reinforcement, unless it's designated in the construction of the bundles or mats. For horizontal work like slabs for floors or roofs, place reinforcement on chairs to keep it from touching the ground or the form below. Chairs are metal devices usually made of heavy-gauge wire designed to support the rebar. Figure 11-6 shows some typical chair designs.

Some concrete workers have a nifty shortcut for placing rebar in a slab. They just lay the rebar

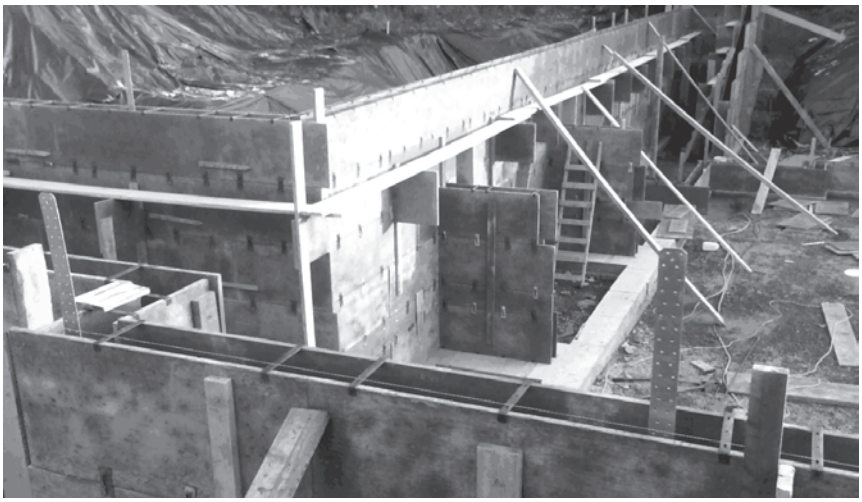


Figure 11-7 Foundation wall forms ready for concrete to be pumped in

or mats on the ground and pour the concrete on top. After the pour, the finisher hooks the steel and pulls it up into the concrete. *This is not acceptable.* Most of the steel won't be centered in the slab using that technique, and the job won't pass inspection. Watch that your workers or subs don't try this shortcut.

Placing Concrete in Forms

You can't place concrete without knowing how to build forms correctly. Forms have to hold concrete in the shape shown on the plans until hardened, and be strong enough to hold the weight of wet concrete without collapsing or leaking. I've worked on jobs where the forms weren't braced correctly. It's not only frustrating to see concrete seeping out where it shouldn't; it could also mean reforming and pouring all over again.

The code requirements for the construction of formwork are covered in IBC Section 1906 and ACI 318, Section 6.1. Forms must be:

- Designed and built to conform to the required dimensions of the construction documents, keeping in mind the pour rate, construction loads and the requirements for special shapes;
- Braced and tied well enough to maintain their original position under the load of the poured concrete;
- Strong and tight enough to prevent leakage;
- Designed to prevent any damage to existing structures.

Figure 11-7 shows a formed-up foundation wall. The metal clips that you can see under, between, and on top of the forms keep the boards from spreading. Forms for prestressed members must allow for any movement of the member without damaging the form.

Try to create an accessible arrangement for the ready-mix truck to reach your forms. It's easiest if the truck can pour concrete directly into the forms. Otherwise you'll have to carry the concrete to the forms. This can be done by pump, wheelbarrow, or even by bucket and crane, but that'll cost you extra time and money.

However you do it, don't let the concrete fall more than 48 inches from the chute to the form. If the distance is more than 48 inches, use an extension chute. You can buy prefabricated metal chute extensions, but it's cheaper to make your own from scrap wood at the job site. Just be careful to keep the mix from separating while you pour.

The concrete pour must completely cover reinforcement materials to prevent their contact

with earth, elements and harmful chemicals. Concrete reinforcement protection is covered in IBC Section 1907, and ACI 318, Section 7.7.1 for nonprestressed concrete and ACI 318, Section 7.7.2 for prestressed concrete.

ACI 318, Section 7.7.1 says that for nonprestressed concrete, the minimum reinforcement coverage for earth-cast concrete must be at least 3 inches. For concrete exposed to earth or weather, the coverage depends on the size of reinforcement bars used. The concrete coverage for rebar No. 6 (¾ inch in diameter) through No. 18 (2¼ inches in diameter) must be at least two inches. Number 5 bar (⅝ inch in diameter) and W31 or D31 wire or smaller must be covered with at least 1½ inches of concrete.

For concrete not exposed to weather or contact with the ground, the required reinforcement coverage is 1½ inches for No. 14 (1.693 inches) or larger bars, and ¾ inch for No. 11 (1.41 inches) or smaller. Coverage for beams, columns, shells and folded plate members are also given.

You must keep these coverage requirements in mind when placing the rebar in the forms. The rebar must be centered in the pour to provide the needed concrete strength, and there must be enough concrete above the rebar to satisfy the rebar coverage required.

When you're ready to remove the forms, be careful not to damage the green concrete. Details for removal of forms, shores and reshores are given in IBC Section 1906.2 and ACI 318, Section 6.2. You can usually start removing the forms after 24 hours. However, a major factor in when forms can be removed is whether or not the concrete is cast on the ground, like concrete slabs on grade. For concrete *not* cast on the ground, the code requirements are much stricter. You may need to add supports or leave the forms on longer. The only load allowed on unshored parts of the concrete during construction is that of the concrete itself. No construction can be supported by the new work until the concrete is strong enough. This usually takes from 3 to 28 days.

Settling or Consolidating the Concrete

The amount of slump in the mix is related to the amount of settling (or consolidation) required. A high slump mix needs little consolidation. There are two ways of consolidating — hand spading or mechanical vibration. Mechanical vibrators, as you would expect, make settling the mix much less work than hand spading. They also allow for stiffer mixes. But if you *can* hand-spade the mix, do it. Vibrators can make the concrete separate too much. That's why you shouldn't use vibrators to move concrete horizontally.

Curing

Time is of the essence when you're pouring concrete. Concrete additives can delay or increase the curing time. In about 24 hours, the concrete will reach over half its full strength. By the end of seven days, it'll have about 90 percent of its design strength. Concrete usually doesn't reach full strength until 28 days after pouring.

Let's say you've just poured a basement for a simple structure. You could work around the area for a day or two while the concrete hardens. But you can't build on a newly-poured surface. You'd be treading on green concrete, and I doubt that the inspector would allow it.

IBC Section 1905.11 and ACI 318, Section 5.11 require general purpose concrete to be maintained above 50 degrees F (10 degrees C), in a moist environment, for at least the first seven days. There's an exception if an accelerated curing procedure is used. And for high-early-strength concrete (Type III), it's the first three days, which can be reduced still further if an accelerated curing procedure is used.

ACI 318, Section 5.11.3 approves certain ways to accelerate curing time. These include:

- High-pressure steam
- Steam at atmospheric pressure
- Heat and moisture
- Other accepted processes

The accelerated curing process must make the concrete at least as strong as it would be if produced by a nonaccelerated process.

How do you know when the concrete has reached proper strength? Remember those test cylinders we talked about earlier? The test samples were from the same batch of concrete. The curing process for the samples and the site concrete should be the same. So when the test samples are determined to be strong enough, the concrete used in the work should be, too.

Cold Weather Pours

What should you do if you need to pour concrete in the fall and winter, when temperatures drop below 50 degrees F? Cover the wet concrete. The water, cement and other chemicals in the concrete interact during the cure, and this chemical reaction creates internal heat. In cold weather, you can cover fresh concrete with a layer of straw, sawdust, or even polyethylene film. If extremely cold weather is expected, use blankets. This keeps the heat in and maintains the temperature of the surface layer of the concrete. The low heat conductivity of concrete also helps keep the body of the concrete at a high enough temperature to cure well.

The code requirements for cold weather concrete placement are covered in Section 1905.12 and ACI 318, Section 5.12. The IBC says that if you pour concrete during freezing or near-freezing weather, you must:

- Provide equipment to heat and protect the concrete
- Make sure the concrete materials, rebar, forms, and any earth the concrete will come in contact with are free of frost
- Not use any frozen materials or materials containing ice

ACI has recommendations for cold weather concreting in Standard Specification for Cold Weather Concreting (ACI 306.1-90).

Hot Weather Pours

There are also things you need to know about placing concrete during hot and dry weather. You don't want the concrete get too hot, and you must watch out for water evaporation. Either could have serious effects on the concrete's strength and serviceability.

That's about all IBC Section 1905.13 and ACI 318, Section 5.13 say about hot weather concreting. They don't say how hot is *hot*. The air temperature controls the concrete temperature and water evaporation rate. And these conditions change depending on the relative humidity, wind speed, and amount of solar radiation. The important factor is preventing rapid evaporation of water from the fresh concrete.

The speed of evaporation changes depending on humidity. If you're in a humid part of the country, you use one set of rules. In a dry climate, you have another. The Portland Cement Association has some useful information. If the relative humidity drops from 90 percent to 50 percent, the evaporation rate increases five times. If the humidity falls another 10 percent, the evaporation rate increases nine times. You can see how crucial it is to stay on top of humidity!

Evaporation rates also increase when it's windy. If wind speed changes from 0 to 10 mph, the evaporation rate increases four times. It's *nine* times greater when wind speed increases to 25 mph.

Using cool materials and protecting the work from direct sunlight helps slow evaporation. So does spraying the concrete with a fine mist. For more details on the effects of temperature, humidity, wind speed and solar radiation, get a copy of Hot Weather Concreting, ACI publication 305R-99, available on the ACI website www.concrete.org.

Interrupting the Pour

Don't interrupt your pour if at all possible. But if it's unavoidable, be aware that the IBC *does* allow it. The requirements for joining the old pour with the new using a construction joint are given in IBC Section 1906.4 and ACI 318, Section 6.4. The main requirements are that:

- Joints must be cleaned and any laitance (described below) removed.

- Joints must be wetted and any standing water removed immediately before new concrete is placed.
- Joints in floors must be in the middle third of the span. Other details for beams, girders, drop panels, and capitals are given in ACI 318, Section 6.4.

It's very hard to get a good seal or bond between old and new concrete. Have you ever tried to put a thin concrete layer over an existing one? Perhaps you've run into this trying to raise the height of a stair or sidewalk. It's not easy, and usually something you want to avoid if you can. You can't just pour new concrete over old. You have to prepare the existing surface first. There are ways to do this correctly, and products that will make the job easier. Ask your concrete supplier about the materials you'll need and how to use them.

As just mentioned, ACI 318, Section 6.4 requires you to remove all laitance and standing water before making joints in concrete. What is laitance and how is it formed? When there's too much water in the concrete mix, the excess water rises to the surface and collects on the top. This water brings up with it a mix of impurities, small amounts of cement, dust and other foreign matter. When the water evaporates, it leaves a dusty, grayish-brown film on the concrete's surface. That's *laitance*.

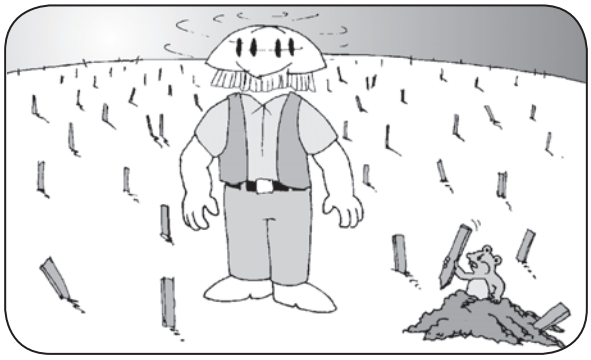
On flat slabs, where the surface is worked down and smoothed as part of the finishing process, laitance is usually insignificant. Most of the laitance is worked off in prefinishing, and the rest is worked back into the concrete. But on formwork, laitance can be a real problem. It prevents bonding. If a pour is interrupted, the laitance must be removed before proceeding, usually with sandblasting equipment.

Summary

Concrete has been very well researched, since it's been around for so long. Even though it's a basic material, it should be highly respected. It's an essential building material that's stood the test of time. There are many concrete structures built during the Roman Empire that are still standing today. One of the most spectacular is the Pantheon in Rome, built between AD 118 and 126. The dome is 142 feet in diameter — almost half the length of a football field. It was the largest self-supporting dome for over 1,400 years. That's pretty amazing architecture!

A more modern, yet still spectacular, use of concrete is the Hoover Dam in Nevada. It was built as a public works project during the Depression. Over a two-year period, beginning in 1933, 3.25 million cubic yards of concrete weighing 6.6 million tons were poured. That's a lot of concrete! But one of the real engineering feats of this structure was its internal cooling system. If the dam had been set as a single block of concrete, it may have taken a thousand years for all of the heat to escape. So the dam was cast in separate vertical columns and the heat was removed by putting over 582 miles of steel pipe in the columns and circulating ice-cold water through the pipework. You can see why concrete is such a valuable material — used effectively, it's immensely strong and durable.

This chapter has given you a basic understanding of concrete, its properties, and some of the factors you have to consider when using it. We've also covered important information about mixing, pouring, curing and testing concrete. In the next chapter, we'll look at concrete foundations.



Misplaced Stake – Misplaced House

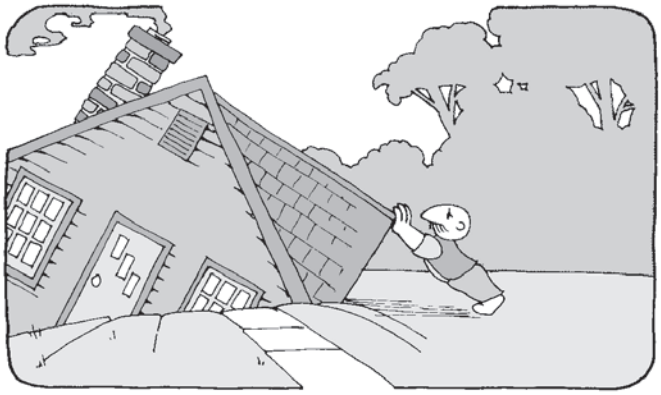
Most lots and plats have been surveyed, mapped, and staked at least once before the contractor arrives. Surveyors set stakes for streets and walks, sewers, water lines, underground power and phone lines. Stakes for these site improvements are usually uprooted, replanted, and generally kicked around while the site work is being done. Not only that, but kids have a natural attraction to survey stakes. They make great swords.

By the time you get to the site, there's no telling where the survey stakes might have wandered off to. That's why I always recommended a new survey when I issued a permit for a building. A new survey won't cost much — usually less than $500. That's cheap insurance. Many jurisdictions now *require* a survey before placing concrete.

I once issued a permit with the usual warning about surveys and such.

"Yeah, yeah," the contractor said.

I suspected he'd ignore my suggetion. And I was right. When I inspected the foundation, something looked wrong. I called the contractor and suggested he get a survey before doing any more work. When he finally hired a surveyor, he found that the foundation not only violated the setback requirements, but part of it was on the neighbor's lot!



CHAPTER 12

Foundations

So far in this book we've discussed occupancies, construction types for different occupancies, the fire resistance of materials, design and engineering, and the fine points of concrete. It's time to look at the building itself — starting with the foundation. But first, we should consider the building site.

Site Considerations

Here are some things you'll want to check for at the site:

- Is there a water problem — too much or too little?
- Is the land stable? Does it have too much slope? If so, what's too much?
- Will you need to move dirt before building the structure? If so, compacting will be needed. Make sure you plan that into your project's time frame.
- What are you going to do with any cut banks? Will sloping do, or will you have to build retaining walls?
- Will there be excess dirt after backfilling is finished? What are you going to do with it?

Answering any of these questions will require an understanding of the building code. For example, suppose you have too much water at the building site due to a high water table. What does that have to do with the building code? Well, one of the first questions the inspector will want answered is just how much water you have and what your plans are for dealing with it.

You have to know if and how your specifications cover this situation, and whether the plan requirements will also satisfy the code requirements for your area. Do the plans show a sump pump or drainage system to carry the water to a lower part of the property? Or do they specify another method of draining the water? Most cities won't let you dump it into

a sanitary sewer. But diverting it into a storm drain would be okay. Maybe the plans call for leaving the water where it is and waterproofing the basement. What if the building doesn't have a basement? In that case, will your building sit on piles or on a fill? Will you have a post and beam floor or a slab on grade? What does the code require under these circumstances? These are some of the first questions you'll need to consider — because the inspector will be sure to ask these questions, and more.

Do Your Homework

Before any site work is begun, make sure you know exactly where the property lines are. The corners must be properly staked and set by a surveyor. This costs a little more, but it's money well spent. I've seen houses that encroached on the legal setback area and others that actually extended over the property line. I even met one contractor who built on the wrong lot! Funny? Sure it is, but not if you're the one who did it. It's not only embarrassing, but fixing it is awfully expensive. Hiring a surveyor is your best insurance against problems like these.

Be sure you have all documents and reports, such as land and geological surveys and engineering reports, in writing and signed by the proper authority. And make sure it *is* the proper authority. A signature isn't worth the paper it's written on if the person signing doesn't have the authority to give that permission in the first place. Claiming that you contacted the county engineer won't fly when there's a dispute; you need to prove it. If you end up in court without proper documentation to back your claim, you're going to lose. So remember: forewarned is forearmed.

Soils Classification and Geology

Chapter 18 of the IBC covers Soils and Foundations. Excavation is necessary at almost every building site, both to level the site and install the footings. If not done correctly, the initial excavation can cause problems that snowball throughout construction. Some problems may even surface months after the project is complete. We'll see later in this chapter that many problems start during backfill and compaction.

But, it isn't always the fill material or its placement and compaction that cause problems. Sometimes the problem is what's under the fill. Here are what IBC Sections 1802.3.1 and 1802.2.2 have to say about soil:

> ***1802.3.1 General.*** *For the purposes of this chapter, the definition and classification of soil materials for use in Table 1804.2 shall be in accordance with ASTM D 2487.*

ASTM D 2487 is the basic reference for the Unified Soil Classification System (USC) and includes the description and group symbol for 15 different soil types:

1. Well-graded gravel, fine to coarse (GW)
2. Poorly-graded gravel (GP)
3. Silty gravel (GM)
4. Clayey gravel (GC)
5. Well-graded sand, fine to coarse (SW)
6. Poorly-graded sand (SP)
7. Silty sand (SM)
8. Clayey sand (SC)
9. Inorganic silt (ML)
10. Inorganic lean clay (CL)
11. Organic silt, organic clay (OL)
12. Inorganic elastic silt (MH)
13. Inorganic fat clay (CH)
14. Organic clay, organic silt (OH)
15. Peat (PT)

Soil or aggregate material that contains too much water (resulting in expansive soil) may be unsuitable to build on. Expansive soil expands and contracts depending on the amount of water present. In dry periods, the soil will contract and in wet periods, if the water penetrates the soil, it will expand putting substantial stress on the building. The soil must always be able to support the weight of the structure, both dead and live loads. IBC Table 1804.2 (Figure 12-1) shows the allowable pressure, in pounds per square foot, for foundations built on various types of soils.

TABLE 1804.2 ALLOWABLE FOUNDATION AND LATERAL PRESSURE				
			LATERAL SLIDING	
CLASS OF MATERIALS	ALLOWABLE FOUNDATION PRESSURE (psf)[d]	LATERAL BEARING (psf/f below natural grade)[d]	Coefficient of friction[a]	Resistance (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and/or gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500[c]	100	—	130

For SI: 1 pound per square foot = 0.0479 kPa, 1 pound per square foot per foot = 0.157 kPa/m.
a. Coefficient to be multiplied by the dead load.
b. Lateral sliding resistance value to be multiplied by the contact area, as limited by Section 1804.3.
c. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.
d. An increase of one-third is permitted when using the alternate load combinations in Section 1605.3.2 that include wind or earthquake loads.

Figure 12-1 Allowable foundation and lateral pressure

> ***1802.2.2 Expansive soils.*** *In areas likely to have expansive soil, the building official shall require soil tests to determine where such soils do exist.*

If the inspector suspects expansive soil, you'll have to hire a soils geologist or geotechnical engineer. He'll take core samples or run some tests on the soil. IRC Section 1802.3.2 gives him a choice of tests. He can either check the Expansion Index (EI) of the soil using a consolidometer and a test detailed in ASTM D 4829, or perform three other tests — all of which the soil must pass. If the Expansion Index is 20 or less, or the soil passes the other tests, the soil is *not* considered expansive.

If the soil is found to be expansive, the remedy can be very expensive. You may have to excavate the area and haul in good fill. Or, worst-case scenario, you may have to have your architect and engineer modify the design of the structure. Fortunately, this usually won't happen unless you're working on large jobs, or where you have borderline soil conditions.

Soil Inspections

In any situation where you have to excavate down to stable soil, bring in fill, or there's a question about the stability of the existing soil, you may have to arrange for special inspections. Special inspection for site soil conditions may be set up at various stages of the excavation, material placement and compaction to ensure that the materials below the footings and foundation are adequate to meet the load-bearing requirements for the structure. See IBC Section 1704.7, and Table 1704.7 (Figure 12-2).

These inspections are intended to answer the question, "Is the soil of the intended building site stable?" Section 1802.2.1 of the IBC states:

> ***1802.2.1 Questionable soil.*** *Where the classification, strength, or compressibility of the soil are in doubt or where a load-bearing value superior to that specified in this code is claimed, the building official shall require that the necessary investigation be made. Such investigation shall comply with the provisions of Sections 1802.4 through 1802.6.*

The building official may let you use the load-bearing values (allowable foundation pressure) shown in the second column of Table 1804.2 (see Figure 12-1). However, if you're working to the IRC and the building inspector suspects poor soil conditions, you may be required to do test boring and soil sampling. R401.4 of the IRC states:

> ***R401.4 Soil tests.*** *In areas likely to have expansive, compressible, shifting*

TABLE 1704.7 REQUIRED VERIFICATION AND INSPECTION OF SOILS		
VERIFICATION AND INSPECTION TASK	CONTINUOUS DURING TASK LISTED	PERIODICALLY DURING TASK LISTED
1. Verify materials below footings are adequate to achieve the design bearing capacity.	—	X
2. Verify excavations are extended to proper depth and have reached proper material.	—	X
3. Perform classification and testing of controlled fill materials.	—	X
4. Verify use of proper materials, densities and lift thicknesses during placement and compaction of controlled fill.	X	—
5. Prior to placement of controlled fill, observe subgrade and verify that site has been prepared properly.	—	X

Figure 12-2 Required verification and inspection of soils

or other unknown soil characteristics, the building official shall determine whether to require a soil test to determine the soil's characteristics at a particular location. This test shall be made by an approved agency using an approved method.

If the topsoil or subsoil is compressible or shifts easily, you must remove enough to ensure stability. You can't reuse this removed soil as fill or attempt to stabilize it, as stated in R401.4.2.

Drainage

Another major factor in site preparation is drainage. IRC Section R401.3 says that surface drainage must be diverted to a storm drain or other approved point. Lots must be graded to divert surface water away from the foundation walls. The grade must have a minimum fall of 6 inches in the first 10 feet. If 10 feet of slope is not available due to lot lines, walls or other physical barriers, the final slope away from the foundation must be at least 5 percent. Direct the water to a drain or swale (open drain) with a minimum slope of 2 percent. Any watertight surfaces, like patios, within 10 feet of the building must be sloped away from the building using at least a 2 percent grade.

Excavation

You may need a grading permit before you begin excavation and grading. A permit is required by Appendix J, Section J103 of the IBC. However, the appendix chapters of the code(s) aren't mandatory unless specifically adopted by the local jurisdiction. You need to check the requirements in your area. But even if your jurisdiction has adopted Appendix J, there are a few exceptions where a grading permit isn't required:

- If the construction of the building has already been permitted
- In isolated, self-contained areas, where grading won't adversely affect adjacent properties and there's no danger to the public
- For exploratory excavations for design purposes, but *not* as a means of starting construction before a permit is issued
- For wells or for trenches for utilities
- For cemetery graves, refuse disposal or mining or quarrying activities

Excavation, grading and fill operations related to foundations are covered in IBC Section 1803. Again, always check with your local authority before starting excavation. Local grading and drainage requirements may be different from one jurisdiction to the next.

Excavating Cut Slopes

IBC Section 3304.1.1 and Appendix Section J106 say you can't make the cut slopes for a permanent site excavation steeper than 2 in 1 (2 horizontal units of measure to 1 vertical unit).

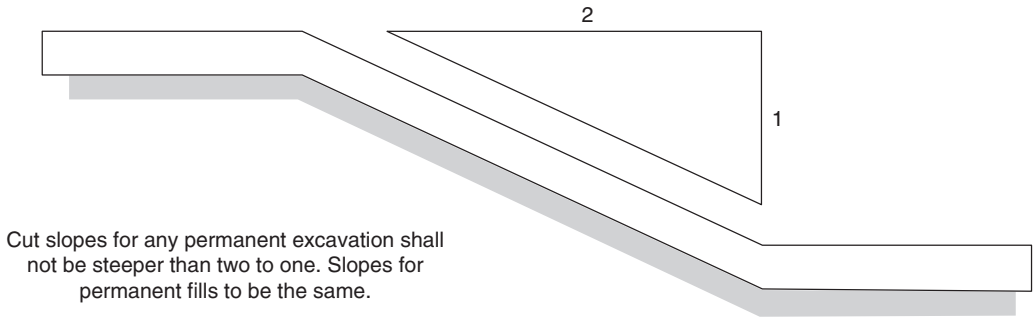


Figure 12-3 Cut slope dimensions for excavations

See the illustration in Figure 12-3. The same applies to slopes for permanent fill. Whether you're measuring in feet, inches or yards, the ratio is the same.

Appendix J, Section J106 provides some exceptions to this rule:

- A slope greater than 2 in 1 may be allowed if you provide a soil report justifying a steeper slope.
- A surface cut into bedrock may be as steep as 1 in 1.
- A cut surface slope as steep as 1½ in 1 may be allowed if *all* four of the following requirements are met:
  1. The slope is *not* intended to support structures or surcharges.
  2. The slope is adequately protected against erosion.
  3. The slope is not more than 8 feet high.
  4. The slope is approved by a building official.

Excavating Near Footings and Foundations

IBC Section 1803.1 states that any excavation you do must not remove lateral support for footings or foundations without first underpinning or protecting the footings or foundation from settlement or lateral movement. That seems very sensible, but it's often overlooked.

Worker safety is a very important aspect of temporary cuts and fills. Almost any inspector will flag a job or call the workplace safety folks if they see unsafe conditions. Remember, a worker can't be in a trench more than 5 feet deep unless the sides are shored or the trench is sloped. Many people don't consider excavating for a house the same as working in a pipe trench or ditch. But it is. Safe cut and fill slopes are just as important when the exposure is temporary. In many places, your job will be stopped if there's less than a 1 in 1 cut, more than 3 feet deep, with workers exposed. Sometimes you'll need to get a soils engineer to decide what the slope should be for safe working conditions.

Cut-Slope Setbacks

The codes require a building to be set back from the top of a cut or the toe of a fill. Look at IRC Section R403.1.7 and Figure R403.1.7.1 (in Figure 12-4) or Section 1805.3 and Figure 1805.3.1 of the IBC.

The following conditions only apply near slopes steeper than 3 in 1 (3 horizontal units of measure to 1 vertical unit).

Ascending Slopes

Buildings must be set back far enough from ascending slopes to protect against slope drainage, erosion, and shallow failures.

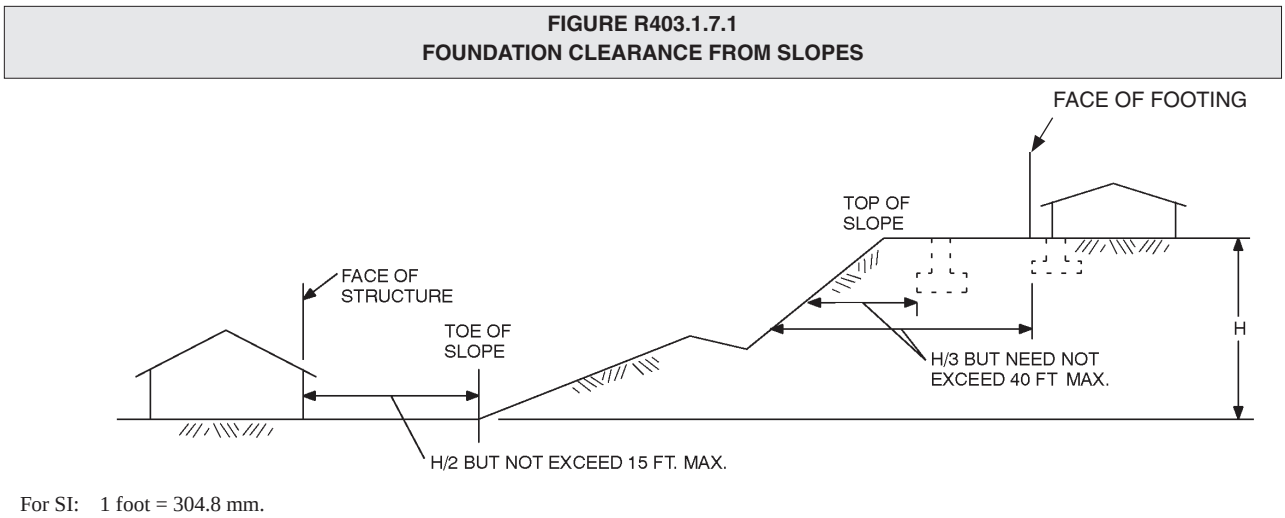


Figure 12-4 Foundation clearance from slopes

The codes say the following circumstances provide adequate protection:

- The distance from the toe of the slope to the building face is at least half the height of the slope (as designated by H in Figure 12-4), or 15 feet, whichever is less.
- A retaining wall is built at the bottom of the slope. In this case, the height of the slope is taken as the height from the top of the wall to the top of the slope. This means your building can be constructed closer to the toe of the slope.
- An alternate setback is approved by a building official.

For slopes steeper than 1 in 1, the toe of the slope is taken as the point where a line drawn horizontally from the top of the foundation intersects with the line of the slope. That means that your building must be constructed farther away from the toe of the slope.

Descending Slopes

Footings next to descending slopes must be put where they'll provide good vertical and lateral support to protect against settlement.

The codes say this protection is adequate under the following conditions:

- The distance from the face of the footing to the line of the slope is at least 1/3 the height of the slope, or 40 feet, whichever is less.
- An alternate setback is approved by a building official.

For slopes steeper than 1 in 1, the line of the slope is taken as a line drawn at 45 degrees from the *toe* of the slope instead of the actual line of the slope. That means your building must be constructed farther away from the actual top of the slope.

The building official may require a greater setback than what's shown in Figure 12-4. This is usually based on the recommendation of a soils engineer, or from his own knowledge of the area.

Retaining Walls

Information on retaining walls begins in IBC Section 1806.1, as follows:

> ***1806.1 General.*** *Retaining walls shall be designed to ensure stability against overturning, sliding, excessive foundation pressure and water uplift. Retaining walls shall be designed for a safety factor of 1.5 against lateral sliding and overturning.*

TABLE 1610.1 SOIL LATERAL LOAD			
DESCRIPTION OF BACKFILL MATERIAL[c]	UNIFIED SOIL CLASSIFICATION	DESIGN LATERAL SOIL LOAD[a] (pound per square foot per foot of depth)	
		Active pressure	At-rest pressure
Well-graded, clean gravels; gravel-sand mixes	GW	30	60
Poorly graded clean gravels; gravel-sand mixes	GP	30	60
Silty gravels, poorly graded gravel-sand mixes	GM	40	60
Clayey gravels, poorly graded gravel-and-clay mixes	GC	45	60
Well-graded, clean sands; gravelly sand mixes	SW	30	60
Poorly graded clean sands; sand-gravel mixes	SP	30	60
Silty sands, poorly graded sand-silt mixes	SM	45	60
Sand-silt clay mix with plastic fines	SM-SC	45	100
Clayey sands, poorly graded sand-clay mixes	SC	60	100
Inorganic silts and clayey silts	ML	45	100
Mixture of inorganic silt and clay	ML-CL	60	100
Inorganic clays of low to medium plasticity	CL	60	100
Organic silts and silt clays, low plasticity	OL	Note b	Note b
Inorganic clayey silts, elastic silts	MH	Note b	Note b
Inorganic clays of high plasticity	CH	Note b	Note b
Organic clays and silty clays	OH	Note b	Note b

For SI: 1 pound per square foot per foot of depth = 0.157 kPa/m, 1 foot = 304.8 mm.

a. Design lateral soil loads are given for moist conditions for the specified soils at their optimum densities. Actual field conditions shall govern. Submerged or saturated soil pressures shall include the weight of the buoyant soil plus the hydrostatic loads.

b. Unsuitable as backfill material.

c. The definition and classification of soil materials shall be in accordance with ASTM D 2487.

Figure 12-5 Soil lateral load

IBC Section 1610.1 gives a general outline of the design requirements for retaining walls.

> ***1610.1 General.*** *Basement, foundation and retaining walls shall be designed to resist lateral soil loads. Soil loads specified in Table 1610.1 (Figure 12-5) shall be used as the minimum design lateral soil loads unless specified otherwise in a soil investigation report approved by the building official. Basement walls and other walls in which horizontal movement is restricted at the top shall be designed for at-rest pressure. Retaining walls free to move and rotate at the top are permitted to be designed for active pressure. Design lateral pressure from surcharge loads shall be added to the lateral earth-pressure load. Design lateral pressure shall be increased if soils with expansion potential are present at the site.*

You'll see the phrase *"Design lateral pressure from surcharge loads…"* used in Section 1610.1. So what are surcharge loads? In the case of retaining walls, the main load is the lateral load from the soil that the retaining wall is supporting. Surcharge loads come from a building or other item close to a retaining wall. A swimming pool, or a driveway on which heavy vehicles are parked, will exert an additional lateral load (surcharge load) on the retaining wall.

Retaining walls should be engineered to determine the thickness and reinforcing steel needed to sustain the loads they must support.

If wood is used in the construction of a retaining wall, it must comply with IBC Section 2304.11.7. The wood has to be treated with a preservative according to AWPA U1.

Retaining walls are also included in Group U occupancies, so requirements for Group U also apply to retaining walls.

Retaining Wall Permit

The grading permit you get when you're planning a retaining wall does *not* automatically include a permit to build a retaining wall, according to IBC Section J103.1.

> ***J103.1 Permits required.*** *. . . A grading permit does not include the construction of retaining walls or other structures.*

However, you'll remember from Chapter 1 of this book, IBC Section 105.2 and IRC Section R105.2 state that a retaining wall up to 4 feet high is exempt from a permit. But note that Section 105.2 also says that exemption from permit requirements of the code does not mean that the work can be done in a manner in violation of the provisions of the code or any other laws or ordinances.

Remember that the height of the retaining wall is measured from the bottom of the footing to the top of the wall. So if the footing is 18 inches deep, that only leaves a 2½-foot-high retaining wall above ground if you want it to be exempt from a permit. That's not a very high wall!

Most inspectors want the bottom of the footing of a retaining wall to be at least 12 inches deep, or at or below the frost line, whichever is greater. This requirement is the same as for any footing.

Backfilling and Compaction

Backfilling and compaction are subjects that many contractors know too little about. That's a problem, because, if done improperly, they can destroy good construction.

You've probably seen steps that have pulled away from a house, or shrubbery around a building that looks like it has sunk. That usually happens when the backfill around a basement area wasn't sufficiently compacted. If backfilling is done without proper supervision, only a density test can show if it has had adequate compaction.

There are three important factors in proper backfilling: the ground surface preparation, the placement procedure and the intermediate compaction required. Section J107 of Appendix J in the IBC shows the requirements for fill.

Ground Surface Preparation

If you're building on a site that requires fill to bring it up to grade, you must prepare the ground surface before filling. Remove plants and other vegetation, as well as topsoil and any other unsuitable material. The cleared ground must be *scarified* to break up the surface and provide a good bond with the fill material.

Surface preparation on a slope requires special consideration. Where the existing grade is greater than 5 in 1 (5 horizontal feet to 1 vertical foot), and the depth of the fill exceeds 5 feet, you must bench the slope to provide a tie-in to the natural grade. Benching is cutting steps into the existing slope. You also need to provide a key at the base of the slope that's 10 feet wide and 2 feet deep. These benching details are shown in Figure J107.3 from Appendix J (Figure 12-6).

Placing Fill

IBC Section 1803.2 covers the placement of backfill. Soil used for backfilling excavation inside and outside the foundations must not contain organic or frozen material, cobbles, boulders, or construction debris. Only clean soil or a controlled, low-strength material, defined by the code as a *self-compacted, cementitious material* can be used as backfill (IBC Chapter 2, Definitions).

Backfill must be placed in layers, or *lifts*, and each layer compacted before the next one is placed. You get better compaction when you compact in layers. The placing and compacting must be done carefully to avoid damage to footings or foundations or any attached waterproofing or damp-proofing material.

The slope of a filled surface can't exceed 2 in 1 (2 horizontal units of measure to 1 vertical unit). Fill slopes steeper than that must be justified with soil reports and engineering data.

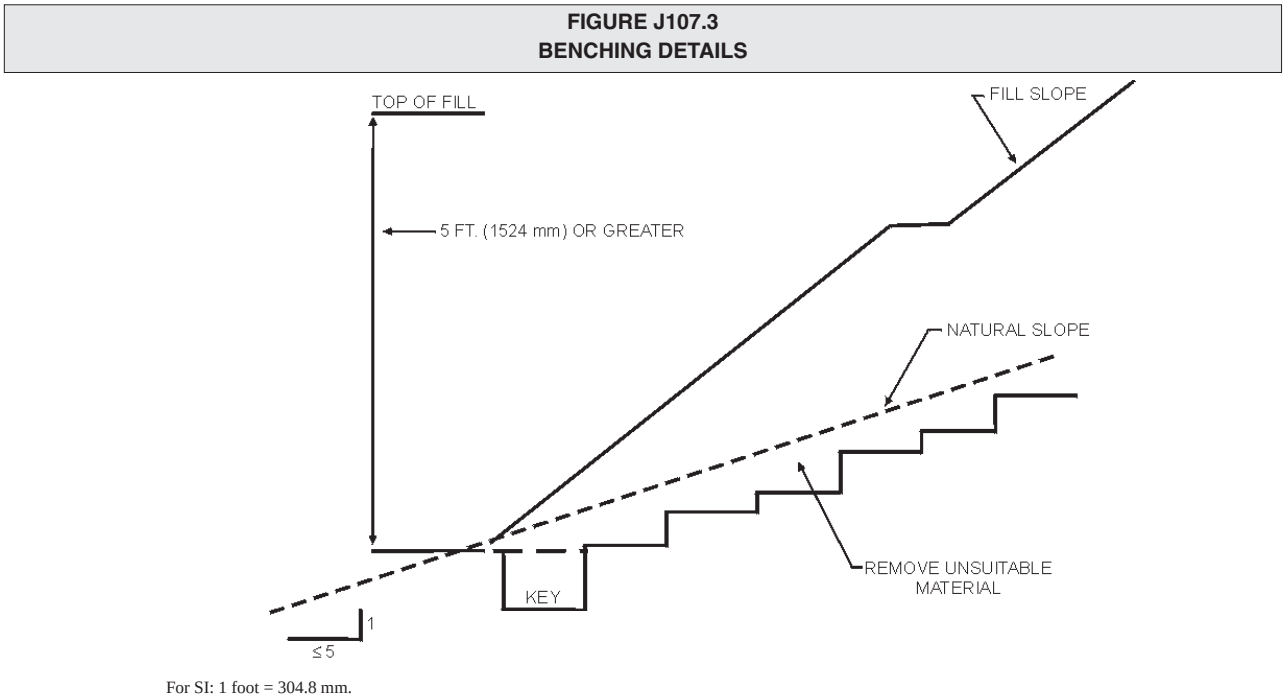


Figure 12-6 Benching details

Compaction

Details on compaction are given in IBC Section 1803.5. Where footings will bear on compacted fill material, the fill must comply with the provisions of an approved report, containing the following information:

1. Site preparation specs
2. Fill material specs
3. Test method to be used to determine the maximum dry density and optimum moisture content of the fill material
4. Maximum allowable thickness of each layer of fill before compaction of that layer
5. Field test method for determining the in-place dry density of the compacted fill
6. Minimum acceptable in-place dry density expressed as a percentage of the maximum dry density, determined according to the test in item 3
7. Number and frequency of field tests required to comply with testing procedure in item 6

An exception to the report approval is made if the compacted fill material is less than 12 inches deep, as long it has been compacted to a minimum of 90 percent and approved by the building inspector.

Compaction to 90 percent of maximum density is called for in IBC Appendix Section J107.5, in accordance with the ASTM D1557 standard. But in dry climates, it's difficult to get 90 percent. Dry soil packs loosely. Never use a tractor to compact soil. When a tractor passes over soil, only the top few inches get compacted. It just doesn't work! Remember, when backfilling trenches, the fill must be placed and compacted in lifts or only the top 6 to 10 inches of soil get compacted.

When soil is dry, water-settling can be a good way to compact soil. Saturate a layer of fill, wait until it dries, add more fill and saturate again. Be careful to always allow the water to completely soak in. Too much water will fill voids and not allow adequate compaction. This

takes time, so most builders don't do it. The problem with compaction is that if you don't do it right, over time, Mother Nature will do it for you. If that happens, who knows what the result will be. Remember our example where the front steps separated from the house? That homeowner won't be happy with your work. If you value your reputation, take the time to do the job right.

For proper compaction, place the fill in layers no more than 12 inches deep and compact each layer separately. A small vibratory plate compactor does a good job on small areas. Sprinkle the soil with a little water if it's dry. The deeper the excavation, the more layers and compaction needed. Plan your time and equipment usage carefully. It'll take a lot longer to compact a 7-foot-deep sewer trench than a 3-foot-deep trench for a water line. For bigger jobs, you may want to use a handheld rammer-tamper powered by a small gasoline engine.

IBC Section 3304.1.2 says that no fill or surcharge loads can be placed next to a building unless the building is capable of withstanding those loads. We talked about surcharge loads earlier in regard to retaining walls — but they apply to backfilling and compacting against structures as well. You need to be especially careful in placing loads against new concrete. The usual curing time for concrete in basement walls is about seven days. That's the minimum amount of time you need to wait. I recommend waiting another week if possible, just to be sure.

Compaction tests are rarely required for single residences unless the home is built on a large fill in a new area. But tests may be required for subdivisions in hilly areas where deep cuts and fills were necessary.

Most building departments aren't equipped to make compaction tests. That's one reason why compaction is sometimes overlooked by inspectors. But if the inspector thinks there's a problem, he can order tests — at the owner's expense. Soil-testing companies charge a lot for these tests. And, sometimes they have to travel a long distance to do the tests, because many jurisdictions don't have a soil-testing company nearby.

Foundations

Now we're ready to look at the foundation itself. Foundations can be made from wood, masonry, poured concrete or precast concrete. If you're using wood, pay special attention to treatment of the wood and the fasteners used below grade.

Wood Foundations

IRC Section R402.1.2 covers the subject of wood treatment.

All wood products used in foundations must be treated according to the American Wood-Preservers' Association, AWPA, Standard U1. You don't need to be familiar with the standard. Just make sure that the wood you use is labeled as properly treated.

If you cut or drill holes in the treated wood, you'll expose fresh surfaces. Treat the newly-exposed surfaces with a Copper Napthenate wood preservative. Continue treating the wood until it won't absorb any more of the preservative. Copper Napthenate is available under the trade names Cuprinol or CuNap-8™. You can get more information on this preservative at www.merichem.com.

IRC Section R402.1.1 describes wood fasteners. Below grade, you must use stainless steel fasteners (either Type 304 or 316) to attach plywood to the exterior side of exterior basement or crawlspace wall studs. Above grade, you can use stainless steel, silicon bronze, copper, hot-dipped or hot-tumbled galvanized steel nails, but *not* electro-galvanized steel nails or galvanized steel staples.

Concrete Foundations

Concrete foundations may be either poured or precast; see IRC Sections R402.2 and R402.3.

Poured Concrete

Foundation concrete must meet the requirements of Table R402.2 (Figure 12-7). They include the various types and locations

TABLE R402.2
MINIMUM SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE

TYPE OR LOCATION OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH[a] (f'_c) Weathering Potential[b]		
	Negligible	Moderate	Severe
Basement walls, foundations and other concrete not exposed to the weather	2,500	2,500	2,500[c]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[c]
Basement walls, foundation walls, exterior walls and other vertical concrete work exposed to the weather	2,500	3,000[d]	3,000[d]
Porches, carport slabs and steps exposed to the weather, and garage floor slabs	2,500	3,000[d,e,f]	3,500[d,e,f]

For SI: 1 pound per square inch = 6.895 kPa.
a. Strength at 28 days psi.
b. See Table R301.2(1) for weathering potential.
c. Concrete in these locations that may be subject to freezing and thawing during construction shall be air-entrained concrete in accordance with Footnote d.
d. Concrete shall be air-entrained. Total air content (percent by volume of concrete) shall be not less than 5 percent or more than 7 percent.
e. See Section R402.2 for maximum cementitious materials content.
f. For garage floors with a steel troweled finish, reduction of the total air content (percent by volume of concrete) to not less than 3 percent is permitted if the specified compressive strength of the concrete is increased to not less than 4,000 psi.

Figure 12-7 Minimum specified compressive strength of concrete

of concrete construction and the weathering potential. The weathering potential for your building location will be found in column 4 of the local jurisdiction's publication of IRC Table R301.2(1) (look back to Figure 1-1 of this book). You can get a copy of this completed table from your local building official.

Be sure and read the Notes at the bottom of Table R402.2. You may be required to use air-entrained concrete in certain weather conditions and locations (see Notes *"c"* and *"d"*). Air-entrained concrete is made by using air-entraining cement or admixtures. Both of these components produce billions of tiny air cells in the concrete. These cells relieve internal pressure on the concrete caused by water expansion during freezing. Yes, water first expands when it freezes — before it starts to contract as the temperature falls further. Air-entrained concrete is very resistant to severe frost action and cycles of freezing and thawing.

Weather exposure may also require a change in the type or size of aggregate used in concrete. Section 4.2.3 of ACI 318 gives the permitted amounts of different aggregates for garage floor slabs and exterior slabs that will be exposed to deicing chemicals. Exterior slabs include porches, carport slabs and steps.

Precast Concrete

The only code requirement for precast concrete foundations is that they be designed and installed according to the manufacturer's instructions. See IRC Section R402.3.

Footings

Footings get lots of attention in both the IRC and the IBC. That's not surprising. They're the very basis of any building. If they're not constructed correctly, what's placed on top of the footings won't be satisfactory. We'll discuss some of the important items here, but take the time to read and fully understand all of this section of the code. Footings are covered in IRC Section R403 and IBC Section 1805. R403.1 says:

> ***R403.1 General.*** *All exterior walls shall be supported on continuous solid or fully grouted masonry or concrete footings, wood foundations, or other approved structural systems which shall be of sufficient design to accommodate all loads according to Section R301 and to transmit the resulting loads to the soil*

TABLE R403.1 MINIMUM WIDTH OF CONCRETE OR MASONRY FOOTINGS (INCHES)				
	LOAD-BEARING VALUE OF SOIL (psf)			
	1,500	2,000	3,000	≥4,000
Conventional light–frame construction				
1-story	12	12	12	12
2-story	15	12	12	12
3-story	23	17	12	12
4-inch brick veneer over light frame or 8-inch hollow concrete masonry				
1-story	12	12	12	12
2-story	21	16	12	12
3-story	32	24	16	12
8-inch solid or fully grouted masonry				
1-story	16	12	12	12
2-story	29	21	14	12
3-story	42	32	21	16

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 0.0479 kPa.

a. Where minimum footing width is 12 inches, use of a single wythe of solid or fully grouted 12-inch nominal concrete masonry units is permitted.

Figure 12-8 Minimum width of concrete or masonry footings

within the limitations as determined from the character of the soil. Footings shall be supported on undisturbed natural soils or engineered fill.

In the IRC, the minimum size of concrete and masonry footings is given in Section R403.1.1, Table R403.1 (Figure 12-8) and Figure R403.1(1) (Figure 12-9).

The minimum footing width, W in Figure 12-9, is based on the load-bearing value of the soil. This is shown in IRC Table R401.4.1, which is the same as the first two columns of IBC Table 1804.2 (refer back to Figure 12-1). The minimum footing thickness is 6 inches, no matter the number of stories. See Section R403.1.1. Spread footings must also be at least 6 inches thick. Footing projections, P, in Figure 12-9, must be at least 2 inches wide, but not more than the thickness of the footing.

In the IBC, the minimum width and thickness for footings in light-frame construction, used mostly for one- or two-family dwellings, is given in Table 1805.4.2 (Figure 12-10).

Typical footings and foundation wall requirements are shown in Figure 12-11. The minimum requirements for wood footings are given in IRC Section R403.2 and Figures R403.1(2) and R403.1(3).

Excavation for the foundation must go down at least 12 inches below the ground's surface, and include the removal of all stumps and roots. When you're finished building, be sure to remove all form material and wood scraps from under the house. And don't bury any wood in the backfill. You'll be providing a breeding ground for termites (see Termites, below).

Frost Protection

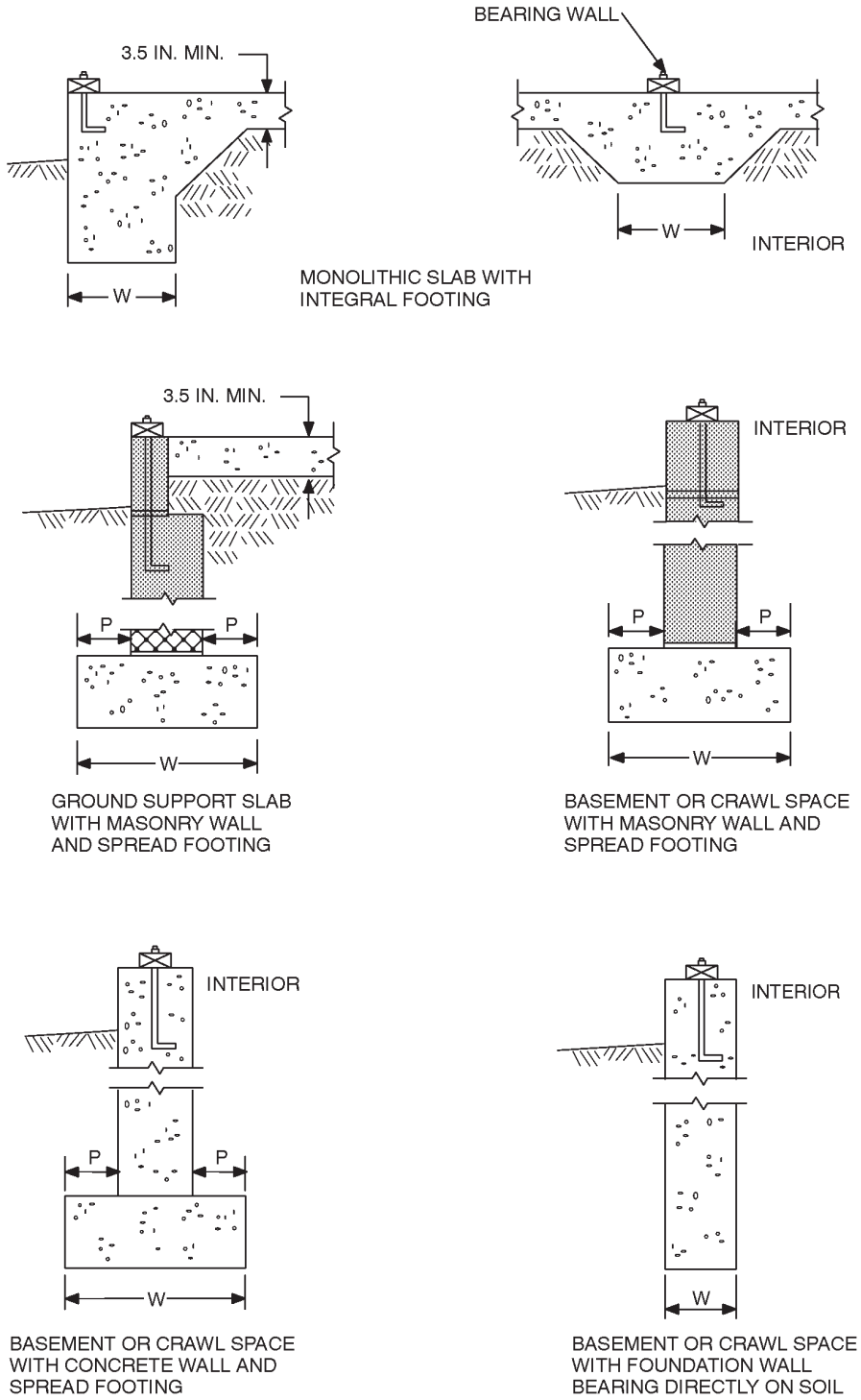
The *frost line depth* is different for every climate. In Kennewick, Washington, the frost depth is figured at 24 inches for building purposes. All footings and water lines must be at least that deep. But the city requires that water lines be run 36 inches below ground level. That way the water lines come in below the foundation, if there's no basement.

There are many places in the country that aren't as cold in the winter as eastern Washington. You may be lucky enough to live and work in one of them. So, we need to look at the frost line situation in other parts of the country as well.

IRC Section R403.1.4 says that all exterior footings must be placed at least 12 inches below the undisturbed ground surface. Also, footings must be protected from frost by one of the following four methods:

1. By extending below the frost line specified by the local jurisdiction in Table R301.2(1), column 5 (again, refer back to Figure 1-1).
2. By building according to Section R403.3. This applies to buildings with mean monthly temperatures maintained at a minimum of 64 degrees F.
3. By building a Frost-Protected Shallow Foundation, FPSF, according to the American Society of Civil Engineers standard ASCE 32.

FIGURE R403.1(1)
CONCRETE AND MASONRY FOUNDATION DETAILS



For SI: 1 inch = 25.4 mm.

Figure 12-9 Concrete and masonry foundation details

TABLE 1805.4.2 FOOTINGS SUPPORTING WALLS OF LIGHT-FRAME CONSTRUCTION		
NUMBER OF FLOORS SUPPORTED BY THE FOOTING[f]	WIDTH OF FOOTING (inches)	THICKNESS OF FOOTING (inches)
1	12	6
2	15	6
3	18	8[g]

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Depth of footings shall be in accordance with Section 1805.2.
b. The ground under the floor is permitted to be excavated to the elevation of the top of the footing.
c. Interior-stud-bearing walls are permitted to be supported by isolated footings. The footing width and length shall be twice the width shown in this table, and footings shall be spaced not more than 6 feet on center.
d. See Section 1908 for additional requirements for footings of structures assigned to Seismic Design Category C, D, E or F.
e. For thickness of foundation walls, see Section 1805.5.
f. Footings are permitted to support a roof in addition to the stipulated number of floors. Footings supporting roof only shall be as required for supporting one floor.
g. Plain concrete footings for Group R-3 occupancies are permitted to be 6 inches thick.

Figure 12-10 Footings supporting walls of light-frame construction

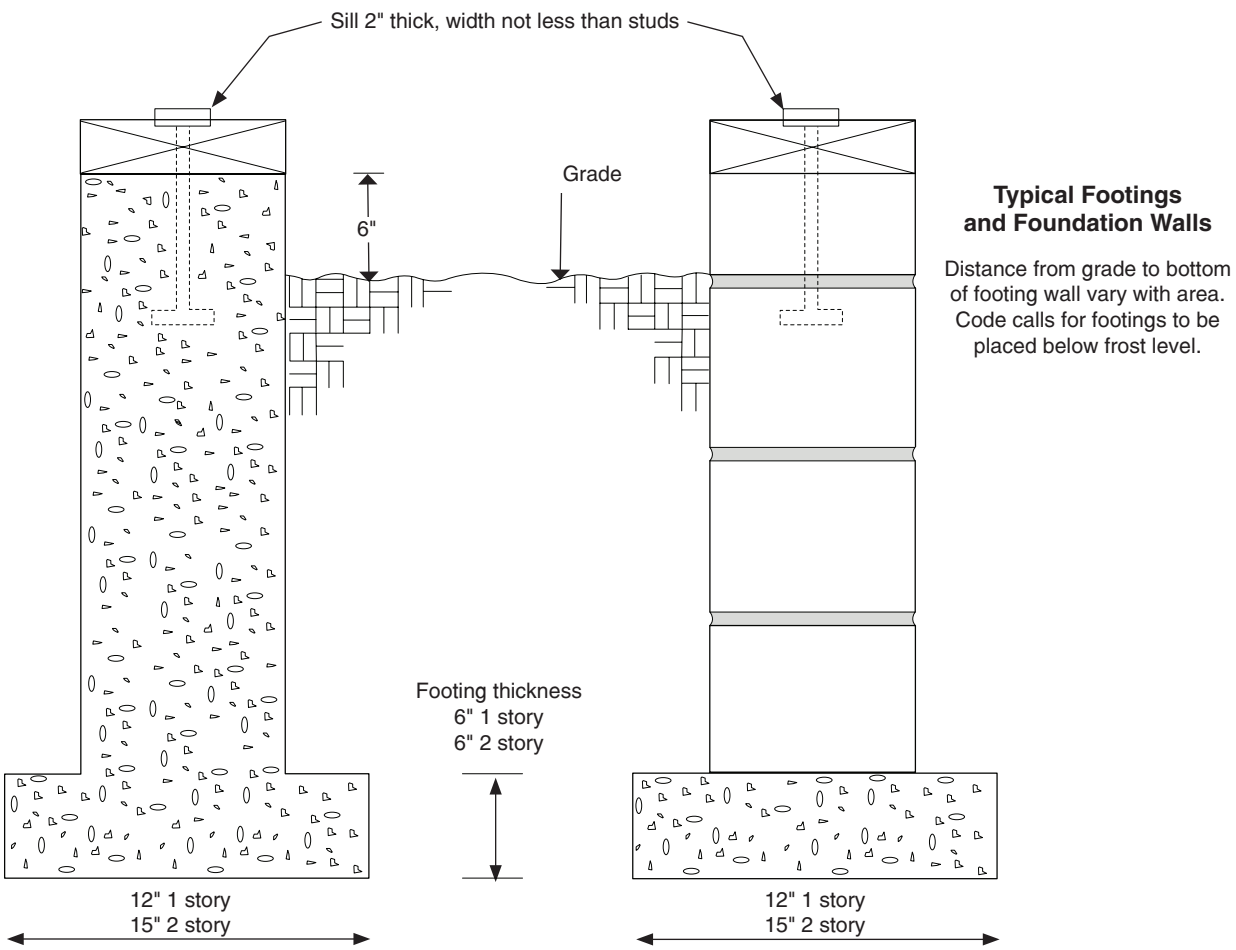


Figure 12-11 Foundation requirements

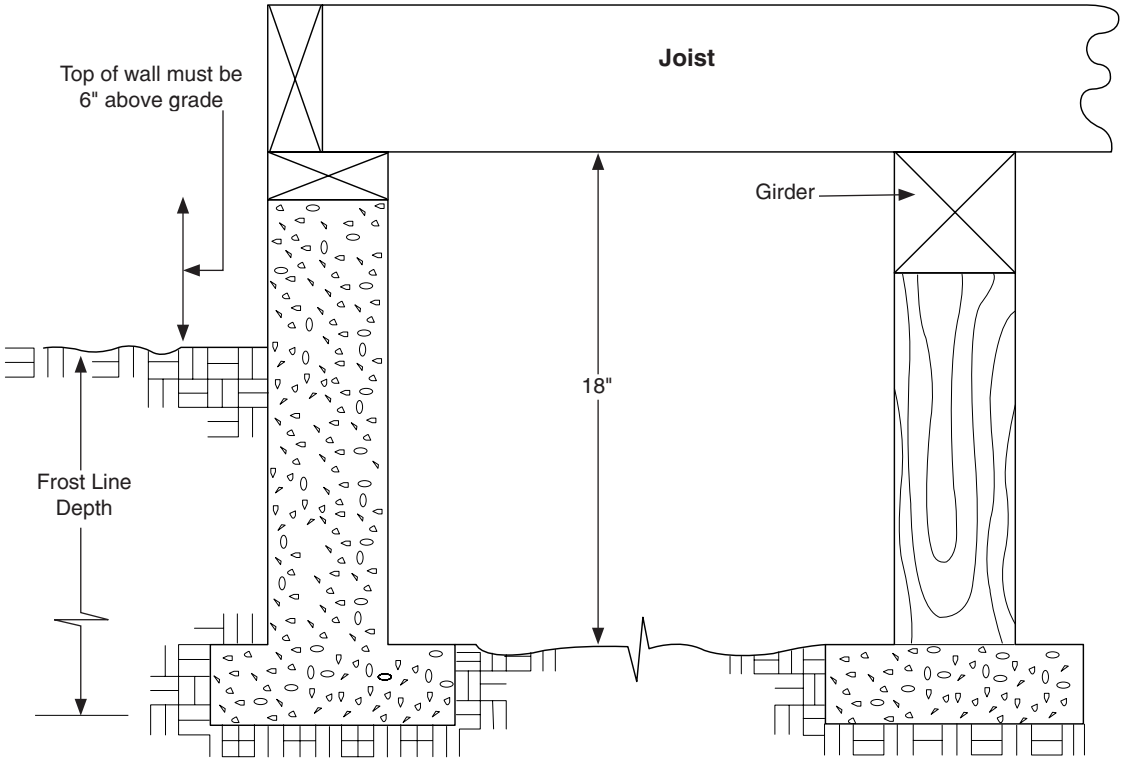


Figure 12-12 Residential foundations

You can buy the standard at the ASCE bookstore at www.pubs.asce.org. You'll also find useful information at www.toolbase.org. Just type ASCE 32 into the Search box.

4. By building the foundations on solid rock.

Footings can't be put on frozen soil unless the soil is frozen all the time. Do you build in northern Alaska? If you do, then I guess you'll need to protect the frozen soil from thawing! Remember, climates change.

Are there any times when frost protection isn't needed for footings? Yes, for freestanding accessory structures, if the structure is 400 square feet or less and has an eave height of 10 feet or less. Footings for decks not supported by a dwelling don't need to be frost-protected, either.

IBC Section 1805.2.1 cites exceptions a little differently. Buildings don't need frost-protected footings if they are:

- agricultural facilities, certain temporary facilities or minor storage facilities, and
- no more than 600 square feet in area (400 feet for light-frame construction), with an eave height of no more than 10 feet.

It isn't always necessary to excavate for footings. If your lot is in a low area and you plan to fill after the house is constructed, form the footings on the surface and excavate only enough so that the footing will be level. Just make sure that when the house is finished and the fill material is brought in, the footings are at or below the frost line. I'm talking about the bottom of the footing pad — not the bottom of the foundation wall. Figure 12-12 shows this measurement and other footing and foundation requirements.

When you dig footings down to the frost line, leave 18 inches of crawlspace below the joists, as shown in Figure 12-12. If wood joists

or the bottom of a wood structural floor are closer than 18 inches to the exposed ground in crawlspaces, they must be protected from decay. This can be done by using a naturally durable wood or wood that's treated with a preservative in accordance with AWPA U1. See IRC Section R319.1. The same goes for wood girders closer than 12 inches to the exposed ground.

Access to a crawlspace must be a minimum of 18 inches by 24 inches if it's through the floor. If it's through a perimeter wall, it must be at least 16 inches by 24 inches (see IRC Section R408.4).

Under-Floor Ventilation

Whenever you have an under-floor crawlspace that's not a basement or a usable space, you need to provide adequate ventilation. One way is to cut vent holes in the foundation walls. Or you could put in a fan — but that's more expensive.

Vent Holes

Vent holes must be covered to keep out bugs and critters that might see the crawl space as a prospective home. Corrosion-resistant wire mesh with an opening dimension of at least ⅛ inch, but not more than ¼ inch, is a good material. You can use different vent coverings, as long as the least dimension of any opening is no more than ¼ inch. Some good materials to use are:

- Perforated sheet metal plates, at least 7/100 inch thick
- Expanded sheet metal plates, at least 4.7/100 inch thick
- Cast iron grilles or grating
- Extruded load-bearing brick vents
- Hardware cloth of 3.5/100 inch wire or heavier

Size the foundation vent holes according to IRC Section R408. The minimum total net free area of vent holes must be at least 1 square foot for every 150 square feet of under-floor space. And remember, the net *free* area is used in this calculation. Screen usually reduces your vent area by 10 percent, but cast iron grills and brick vents will be much more restrictive. As a result, you can't just count the number of vents and multiply by the rough size. Most manufactured vent covers will list the net free area on the product. There also must be a vent hole within 3 feet of each corner of the building. To prevent dry rot, arrange the vent holes to give cross ventilation to all areas of the crawlspace.

Mechanical Ventilation

If vent holes to under-floor spaces aren't provided, you must cover the exposed earth with a vapor retarder. Be sure to provide continuous mechanical ventilation using a fan-based or air conditioner-based system at a rate of 1 cfm for each 50 square feet of crawlspace floor area (see IRC Section R408.3 for details).

Under-Floor Appliances

If you're going to install an under-floor furnace or other appliance, you'll need some additional space. You'll also need a light, a receptacle and an access hole big enough so the equipment can be removed or serviced without taking it apart. The access hole can't measure less than 30 inches high by 20 inches wide. Also, if the access is by a passageway, it can't be longer than 20 feet. See IRC Section M1305.1.4 for more specific details. Finally, pipes and ducts can't interfere with access to, or access inside, any crawlspace.

Dampproofing and Waterproofing

Water seepage through retaining walls and walls that enclose interior spaces below grade can be a serious problem. Not only is the

Figure 12-13 Sealing emulsion in an approved waterproofing and drainage system

water where it's not wanted, it can also cause erosion. IBC Section 1807 is devoted entirely to dampproofing and waterproofing. Let me emphasize Section 1807.2.2.

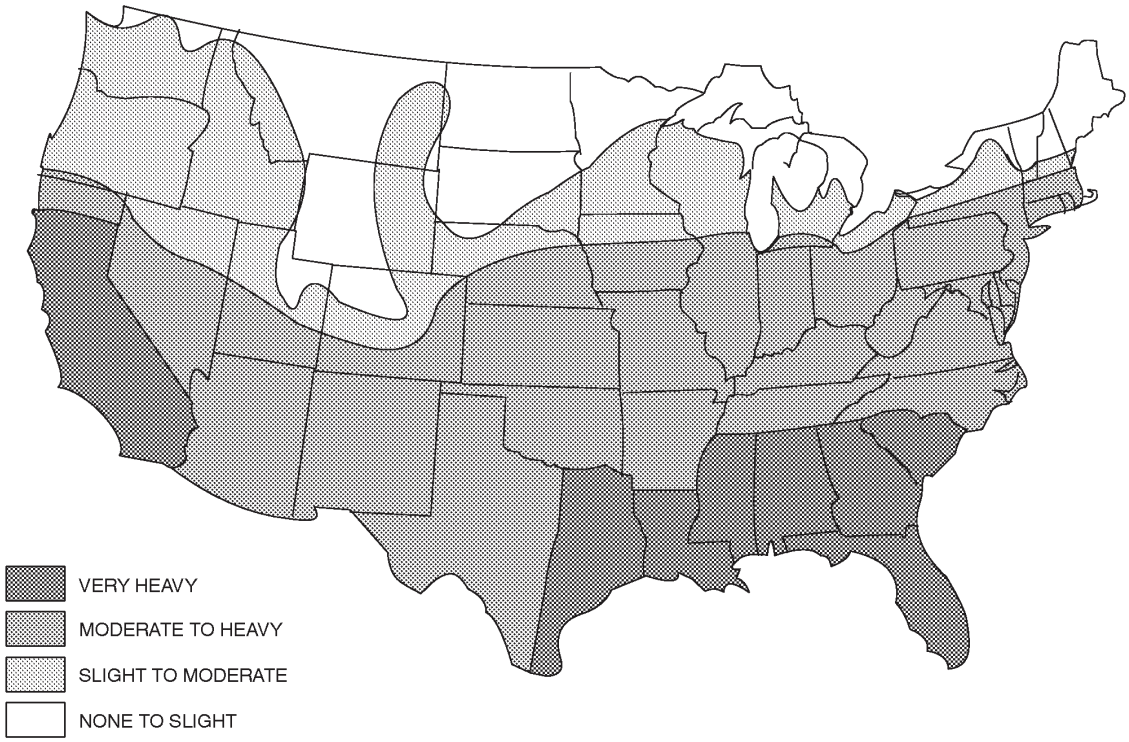
> ***1807.2.2 Walls.*** *Dampproofing materials for walls shall be installed on the exterior surface of the wall, and shall extend from the top of the footing to above ground level.*
>
> *Dampproofing shall consist of a bituminous material, 3 pounds per square yard (16 N/m^2) of acrylic modified cement, 0.125 inch (3.2 mm) coat of surface-bonding mortar complying with ASTM C 887, any of the materials permitted for waterproofing by Section 1807.3.2 or other approved methods or materials.*

Dampproofing and waterproofing should always be done on the outside of the wall, as shown in Figure 12-13. The wall in this photograph has been coated with a waterproof emulsion, then covered by an approved water protection/drainage material (in this case, Delta®-Drain manufactured by Cosella-Dörken Products, Inc. with Typar® geotextile fabric). This will protect the waterproof emulsion while backfilling is completed and divert any water away from the foundation wall.

Dampproofing and waterproofing must be done before excavations are backfilled. It's almost impossible to stop water seeping through a wall by coating the inside of the wall. There are some coating materials that supposedly do this. But I recommend using them only as a last resort. The best way to stop water seepage through a wall is to keep it out in the first place.

New materials and products for dampproofing and waterproofing become available all the time. If there's a method you want to use that isn't currently recognized by your building officials, have the listing information and the manufacturer's cut-sheet or the *ICC-ES (Evaluation Services)* paperwork in hand before you ask for approval. I can't stress this enough. Before you ask for any approval, have everything you'll need in hand!

FIGURE R301.2(6)
TERMITE INFESTATION PROBABILITY MAP



NOTE: Lines defining areas are approximate only. Local conditions may be more or less severe than indicated by the region classification.

Figure 12-14 Termite infestation probability map

Termites

Termites are a serious problem in many parts of the country. IRC Section R320 covers the code requirements. You can see if termites are trouble in your area by checking column 6 of Table R301.2(1) (see Figure 1-1 in the beginning of this book), the *climatic and geographic design criteria* list provided by your jurisdiction.

Section R320.1 requires that wood in any area where there could be termite damage must be protected by one or a combination of the following:

- Treatment of both soil and wood with a chemical termite killer according to the manufacturer's instructions
- Baiting of termites according to the manufacturer's instructions
- Use of wood treated to the AWPA U1 standard, mentioned above
- Use of naturally termite-resistant wood, like redwood heartwood and eastern red cedar
- Use of physical barriers, like metal or plastic sheeting; see Section R320.4

The only exceptions to these requirements are:

- For noncombustible materials
- For pressure-treated wood
- Where foam plastic protection is used
- On interior side of basement walls

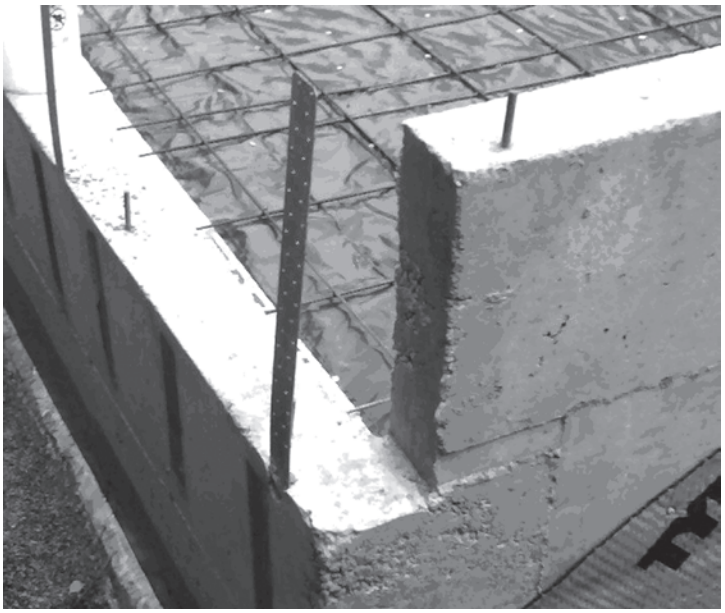


Figure 12-15 Foundation bolts and hold-down straps cast in place

Areas where the possibility of termite damage is considered *very heavy* are shown in Figure R301.2(6) (Figure 12-14). In these regions, foam plastic protection must be provided *on the exterior face or under interior or exterior foundation walls or slab foundations located below grade* (Section R320.5).

Foundation Plates

On the top of the foundation wall is a wooden member called a foundation sill plate. This is required whether the foundation is a footing with a slab on grade, or a foundation wall surrounding a crawlspace or a basement. But it's not required if the rest of the structure is masonry.

The sill plate must at least be a 2 x 4 (as per IRC Section R404.3). It's common to see a 2 x 6 or even a 2 x 8. The sill plate is drilled and fastened to the foundation wall with anchor bolts cast in wet concrete, as shown in Figures 12-9 and 12-11. IRC Section R319 says that all plates, sills, and sleepers must be pressure-treated wood or foundation-grade redwood, black locust or cedar. These types of wood also must be used for any wood joists or the bottoms of wood floors that are closer than 18 inches to exposed ground in crawlspaces; or for wood girders closer than 12 inches to exposed ground in crawlspaces. These types of wood reduce the hazards of termite damage and decay.

Sill plates must be anchored to the foundations according to IRC Section R403.1.6. You'll need at least ½-inch diameter steel bolts set a minimum of 7 inches deep in concrete or masonry foundations to bolt the foundation sill plate to the foundation wall. Place bolts a maximum of 6 feet apart (or 4 feet for light-frame wood construction buildings over two stories high). There must be at least two bolts in each piece of plate material. One bolt must be no more than 12 inches, and no less than 7 bolt diameters, from the end of each sill plate section. That means that an 8-foot sill plate would need two anchor bolts, but a 9-foot piece would need three. Figure 12-15 and the sketch in Figure 12-11 show typical anchor bolt installations. A nut and washer must be tightened on each bolt. See Section R403.1.6 for further details.

In seismic design categories D_0, D_1, and D_2, and wood light-frame townhouses in seismic design category C, you need to install plate

Figure 12-16 Sill plates with both a hold-down and anchor bolts with plate washers

washers that are at least 3 inches square and 0.229 inches thick between the foundation sill plate and the nut (see IRC Section R602.11.1). Anchor bolts resist shear, but a qualified engineer may decide you need to add hold-downs to resist uplift and overturning. Figure 12-16 shows both a hold-down and anchor bolts with plate washers.

Bolts that are set wrong can be a major problem. Let's say the bolts are set assuming a continuous 26-foot piece of sill plate material. If the framers splice the plate, using one piece 14 feet long and one piece 12 feet long, the anchor bolt spacing won't meet code. Some builders keep extra plate material on hand for the framing subcontractors — to ensure there won't be a need for splicing.

Anchor bolts are supposed to keep a house anchored to the foundation. That isn't a sure thing, though. I have many photos of what used to be homes in earthquake and tornado zones. The anchor bolts and sill plates are still in place — but the houses are gone. Today, there are many types of hold-downs and straps that can be used in addition to anchor bolts, but they need professional structural design. Even professionals have a hard time designing anything — short of a concrete bunker — that will withstand the full force of a tornado. Earthquake-prone areas also have specific problems. Depending on your location, you may need an engineer to decide if wind or seismic forces will dominate the design.

These anchorage requirements apply to seismic design categories D_0, D_1 and D_2, which are in the middle range of the seven seismic categories (A, B, C, D_0, D_1, D_2 and E). You can see the locations of the various seismic areas if you check the maps in IRC Figure R301.2(2).

One- or two-family dwellings built in seismic design categories A, B, and C are actually exempt from the seismic requirements of the IRC (see Section R301.2.2). However, townhouses

in category C aren't exempt. But following the seismic anchorage requirements is good practice. So, most builders follow them.

If you're building in an area with seismic design category E, you'll need professional help. Category E only applies if you're building on the West Coast, Alaska, South Carolina, Missouri, Arkansas, or on the big island of Hawaii.

Pile Foundations

There are types of foundations you can use to overcome building problems associated with multistory structures, unusual soil categories, or areas of extreme climate conditions. Using *foundation piles* is an accepted method of creating a stable base to support structural loads in different types and conditions of soils. These include:

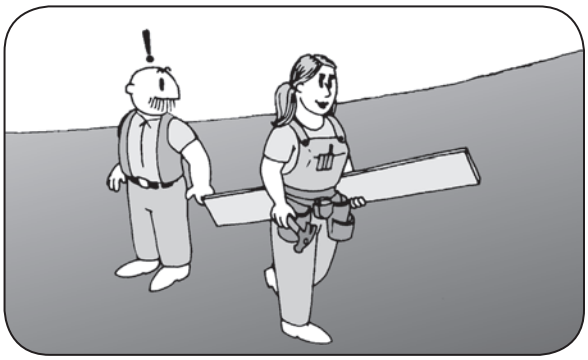
- Round wood piles
- Uncased cast-in-place concrete piles
- Metal-cased concrete piles
- Precast concrete piles
- Precast and prestressed concrete piles
- Structural steel piles
- Concrete-filled steel pipe piles

These piles are usually driven or placed in the ground and covered by slabs. Mathematical formulas determine the size of the pile, its depth in the ground, and the number of piles required. The type of pile you use depends on the soil type and condition, and the load to be carried.

Most small contractors never have to deal with these kinds of foundations. If you do, have a structural engineer design them based on geotechnical recommendations. This eliminates problems, and helps you get plan approval from the building inspector.

This was only a brief review of foundation work. There's much more on the subject in the codes that you can and should study. Let's face it, if your foundations are no good, anything you build on top won't be any good either.

In the next chapter we'll move on to the subject of masonry walls.



A Woman's Place

Many years ago a young woman contractor came into my office to apply for a permit. She said she'd drawn the plans herself. She'd done a real good job, and got her permit.

We didn't talk again until I made the final inspection. I was curious about how she got into the construction business. "My dad was a carpenter in Arkansas," she told me, "and I worked a lot with him. When my kids were old enough for school, I looked around for something to do. I had three choices: Stay home and do housework, get an office job and sit at a computer all day, or build houses. I like building houses."

At the next home builders' association meeting I took a little good-natured kidding. What was I doing issuing a permit to a woman? Some of the newer contractors there didn't understand that many of my applicants were women — but usually contractor's wives helping out with the paperwork. There weren't that many female contractors back then. It was mostly a man's business, and I suppose that's the way some of my contractor friends liked it. Maybe they couldn't take the competition.

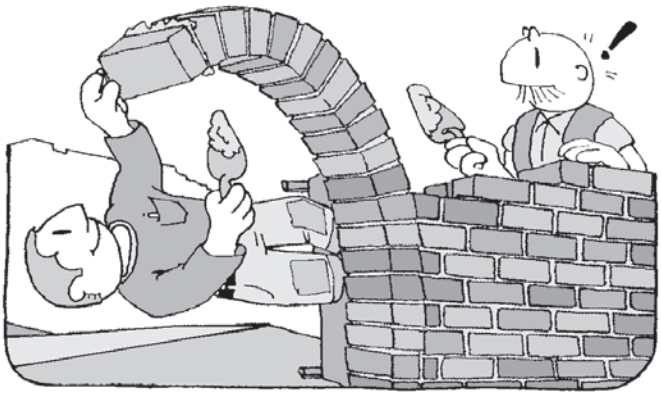
Anyhow, the woman I'm talking about eventually moved away from the area. But while she was here, she designed and built some fine houses. And I never had any code enforcement problems with her. She was as professional and capable as any contractor I know.

When you think about it, there's nothing in construction contracting that keeps a woman from being every bit as good as a man — or better, in some cases. You don't have to be 6'2" and weigh 225 to make it in this business.

Of course, there are far more male contractors than female. And I don't expect that will change any time soon. But if you're a woman (and I hope at least a few of my readers are), let me encourage you with this note:

I've checked the building code very carefully, from cover to cover. I haven't found a single section, not a single word, not a shred of a trace of anything that gives a preference to men.

So ladies, feel free to be the best you can. This industry can always use one more dedicated professional, male or female.



CHAPTER 13

Masonry Walls

After the foundation is poured and cured, you're ready to put up the walls. Most residential walls are either masonry or wood frame. In Chapter 14, we'll cover the requirements for frame walls. Here, however, we'll focus on masonry walls.

Masonry walls are discussed in Chapter 21 of the IBC and Chapter 6 of the IRC. The first part of Chapter 21, Section 2102, is dedicated to definitions. Most are only of interest to designers, but the following are a few definitions you'll need to know:

Area, Bedded: *The area of the surface of a masonry unit that is in contact with mortar in the plane of the joint.*

Bed Joint: *The horizontal layer of mortar on which a masonry unit is laid.*

Bond Beam: *A horizontal grouted element within masonry in which reinforcement is embedded.*

Cell: *A void space having a gross cross-sectional area greater than 1½ square inches.*

Collar Joint: *Vertical longitudinal joint between wythes of masonry or between masonry and backup construction that is permitted to be filled with mortar or grout.*

Head Joint: *Vertical mortar joint placed between masonry units within the wythe at the time the masonry units are laid.*

Header (Bonder): *A masonry unit that connects two or more adjacent wythes of masonry.*

Mean Daily Temperature: *The average of the daily temperature extremes predicted by a local weather bureau for a 24-hour period.*

Plastic Hinge: *The zone in a structural member in which the yield moment is anticipated to be exceeded under loading combinations that include earthquakes.*

Prism: *An assemblage of masonry units and mortar, with or without grout, used as a test specimen for determining properties of the masonry.*

Running Bond: *The placement of masonry units such that head joints in successive courses are horizontally offset at least one-quarter the unit length.*

Shell: *The outer portion of a hollow masonry unit as placed in masonry.*

Stack Bond: *The placement of masonry units in a bond pattern is such that head joints in successive courses are vertically aligned. For the purpose of this code, requirements for stack bond shall apply to masonry laid in other than running bond.*

Tie, Lateral: *Loop of reinforcing bar or wire enclosing longitudinal reinforcement.*

Tie, Wall: *A connector that connects wythes of masonry walls together.*

Wall: *A vertical element with a horizontal length-to-thickness ratio greater than three, used to enclose space.*

Cavity Wall: *A wall built of masonry units or of concrete, or a combination of these materials, arranged to provide airspace within the wall, and in which the inner and outer parts of the wall are tied together with metal ties.*

Composite Wall: *A wall built of a combination of two or more masonry units bonded together, one forming the backup and the other forming the facing elements.*

Dry-Stacked, Surface-Bonded Wall: *A wall built of concrete masonry units where the units are stacked dry, without mortar on the bed or head joints, and where both sides of the wall are coated with a surface-bonding mortar.*

Masonry-Bonded Hollow Wall: *A wall built of masonry units so arranged as to provide airspace within the wall, and in which the facing and backing of the wall are bonded together with masonry units.*

Web: *An interior solid portion of a hollow-masonry unit as placed in masonry.*

Wythe: *Each continuous, vertical section of a wall, one masonry unit in thickness.*

Types of Masonry

The codes no longer list the different masonry types, but I've listed them for you, strongest to weakest, based primarily on their compressive strength.

1. Brick made with sand-lime
2. Brick made of clay or shale
3. Concrete building blocks
4. Structural clay floor tile
5. Solid load-bearing concrete masonry units
6. Unburned clay

You can always use a stronger material instead of a weaker one, but not the other way around. Not *all* stronger materials are necessarily good substitutes for *all* weaker materials.

Masonry Grades

The grade of masonry units is very important. Building bricks made of clay or shale are graded SW, MW, and NW. The ones made of sand-lime come in only two of these grades: SW and MW. Here's what the grades mean:

SW (Severe Weathering): *These bricks have a high resistance to frost. Use them in areas where the brick is exposed to the elements, and could freeze when wet. These bricks are a good choice for foundation courses and retaining walls in frost-prone areas.*

MW (Medium Weathering): *These bricks are good anywhere temperatures dip below freezing, but where the material won't be exposed to water. These bricks have only moderate and nonuniform resistance to frost. Use them in the face of a wall above ground, where they're not exposed to constant moisture.*

NW (Nonweathering): *These bricks may be used for interior masonry. You can use them in exposed areas with no frost, or colder areas where the annual rainfall is less than 20 inches.*

Bond Beams

A bond beam is a block cast with three sides and no ends, so it forms an open U. It's laid into a course with the open side up, which is then filled with concrete. Lintel blocks, used to build lintels over doors, windows, and other openings, are a variation of the bond beam. I think lintel blocks are easier to use and look

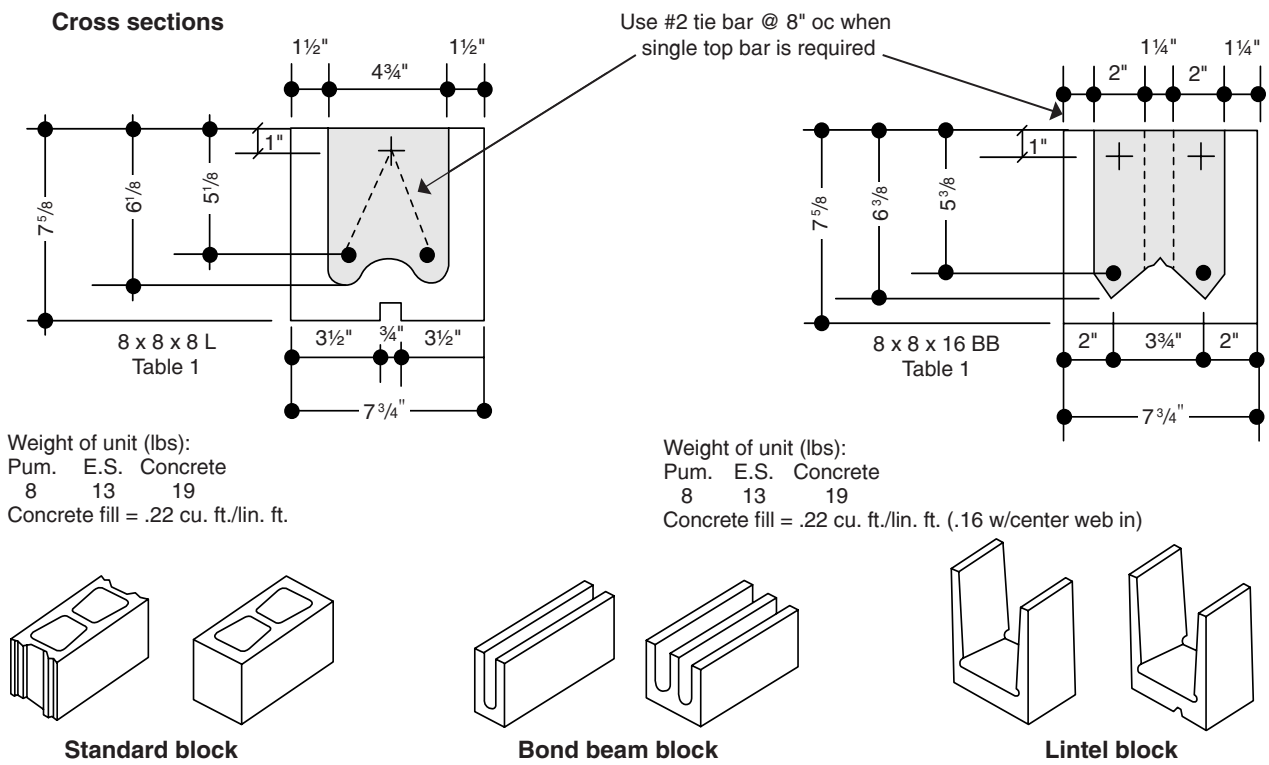


Figure 13-1 Concrete block and lintel block reinforcing

nicer than a cast-in-place concrete lintel. Make sure the door frame is in place before the lintel block is installed.

In both bond beam and lintel blocks, the amount of reinforcing used in the cavity depends on the strength required. Figure 13-1 shows several types of concrete block, bond beam block and lintel block reinforcing.

Bond beams are often used in chimney design, shown in the fireplace and chimney details of IRC Figure R1001.1 (Look back to Figure 8-10 in Chapter 8). They're also used when masonry is laid in stack bond (See IRC Section R608.2.2).

Used Brick

Used materials must conform to the same standards as new materials (IBC Section 2103.7). Used bricks must be sound, free from cracks and other defects, and all the old mortar must be removed before use. That's very important. There's a revival today in facing homes with "olde" brick. Shiploads of old bricks are coming from Europe to satisfy this growing U.S. market.

Naturally, the requirement for conformity is difficult for inspectors to enforce. It's hard to tell anything about used masonry, other than how it looks on the surface. It's a safe bet that new masonry meets current code requirements. But were the standards the same when the used material was produced? Probably not, especially since the "olde" bricks could be over 100 years old. All you can do is see if the bricks look sound. If they don't, don't use them.

Face Brick and Veneer Anchorage

The most common use of brick is as face veneer. Brick veneer can be used over:

- Wood frame
- Concrete block
- Cold-formed steel backing
- Stone walls

These are clay building bricks, not concrete blocks. The materials are quite different, even though some people use the terms brick and block interchangeably.

Most masons anchor face brick to a concrete block wall with mortar having a high cement ratio. This produces a tight, secure bond. However, ties are also required. Ties can be made of either strand wire or strips of corrugated sheet metal. They're used to anchor the veneer to the block wall. On a frame building, the ties are nailed to the exterior sheathing and bent outward to lay between the brick courses (IRC Section R703.7.4). The main requirements are as follows:

- Metal ties must be corrosion resistant.
- Strand wire ties must be at least No. 9 U.S. gauge wire with a hook embedded in the mortar joint.
- Corrugated sheet metal ties must be at least No. 22 U.S. gauge by ⅞ inch wide.
- Space each tie no more than 24 inches apart, either horizontally or vertically.
- Each tie can support no more than 2⅔ square feet of wall area. So, for instance, each 8 square feet of wall area must have at least three ties.
- When using corrugated sheet metal ties to anchor brick veneer to wood sheath backing, the distance between the veneer and the sheathing material can't be more than 1 inch.
- When using metal strand wire ties to anchor brick veneer to wood sheath backing, the distance between the veneer and the sheathing material can't be more than 4½ inches.

Ties are often installed improperly. The two most common mistakes are not using enough ties, and placing ties at random. If someone isn't keeping an eye on the job, there's a good chance that the ties won't be installed correctly. A good mason will use the appropriate number of ties and place them according to the code. Make sure it's done correctly on your jobs.

Figure 13-2 Rebar for masonry wall construction

Masonry Usually Means Block

Concrete blocks and cinder blocks are the most popular units of masonry used today. Not many buildings have walls made entirely of brick. The brick you see in homes is usually a veneer that covers either concrete block or wood frame walls.

With concrete block walls, there's no need for a sill plate on top of the foundation. In fact, you don't even need a concrete foundation. You can just build with masonry from the footing right up to the roof line.

Placing Rebar

If you're using masonry block for the foundation, you'll probably need to put iron reinforcing dowels in the footing when it's poured. Space these dowels every 4 feet, as shown in Figure 13-2. When the blocks are in place, fill every cell having a dowel with concrete grout.

These reinforcing dowels don't have to run continuously the full height of the wall. There's a practical reason for that. Masons don't like having to lift and drop blocks over reinforcing dowels when they're 10 to 15 feet high. It takes too long and it breaks a lot of blocks. Rebar doesn't have to be continuous, but its strength must be continuous. You can achieve this by tying shorter pieces together.

Since inspectors don't watch every block being laid, some masons may not bother to tie rebar joints. They may just jam rebar into the grout in each cell and hope that nobody notices. Poor workmanship like this is hidden as soon as the next layer of blocks is laid. It's impossible to tell, after the fact. Don't let the masons get away with that on your jobs. Insist that rebar joints are spliced to meet the code requirements in IBC Section 2107. This section discusses lap splices, welded splices and mechanical splices. Section 2107 refers you to the American Concrete Institute standard ACI 530, a copy of which is available on the ACI website at www.aci-int.org.

Many jurisdictions require a special inspector, approved by the building official, to monitor the following tasks:

- Placement and splicing of reinforcement
- Mixing of mortar
- Grouting of cells and bond beams in structural masonry

Splicing Rebar

In most cases, rebar joints are made by lap splicing and wiring, not welding. So we're going to concentrate on lap splicing. If you need to weld rebar joints, see the ACI standards for details and requirements.

Bars that have been spliced should be as strong as an unspliced bar. This is achieved by lapping bars at least 40 bar diameters, but not less than 12 inches, wherever bars join. For example, if you're using No. 4 bar (½ inch), the lap must be 20 inches. If you're using No. 5 bar (⅝ inch), lap the bars 25 inches. For No. 6 bar (¾ inch), lap the bars 30 inches. If you're using epoxy-coated rebar, increase the splice distance by 50 percent. Figure 13-3 shows a good rebar splice.

Can you just stick the rebar anywhere in the cell? Not according to the code. Joint reinforcement must have at least ¾ inch of grout coverage surrounding No. 11 (1.41-inch diameter) or smaller reinforcement bar to protect it from exposure to the environment.

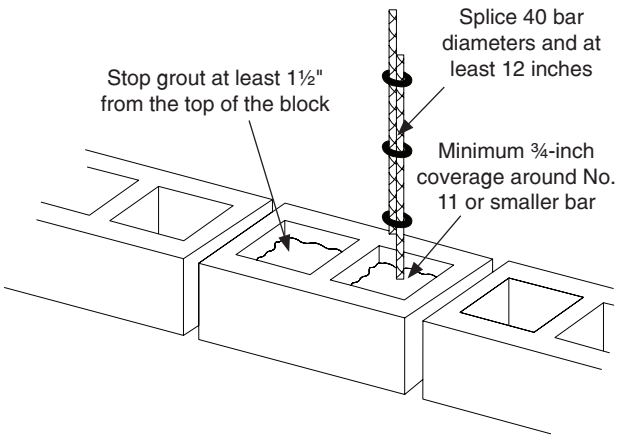


Figure 13-3 Properly spliced rebar

Running Pipes or Conduit Through Masonry

Let's say you're building a concrete block basement, and you want to put electrical outlets in the exterior wall. There shouldn't be any problem with that as long as you don't reduce the structural stability of the wall itself. You can run pipe or conduit through masonry, using a sleeve large enough to pass any hub or coupling on the pipeline. You can use multiple sleeves when the block must be core-filled, or where rebar will be installed, but make sure they're at least 3 inches apart. Pipe or conduit placed in the unfilled cores of hollow unit masonry isn't considered embedded.

General Masonry Requirements

How thick does the wall have to be? If you're building to the IRC, you'll find guidelines in Section R606.2.1. They're summarized as follows:

- Solid masonry walls of single-story dwellings or garages no greater than 9 feet high must be at least 6 inches thick.
- The height can be extended to 15 feet at the peak of the gable for single-story gable construction.
- Solid masonry walls more than a single-story must be at least 8 inches thick.

TABLE R606.9 SPACING OF LATERAL SUPPORT FOR MASONRY WALLS	
CONSTRUCTION	MAXIMUM WALL LENGTH TO THICKNESS OR WALL HEIGHT TO THICKNESS[a,b]
Bearing walls:	
Solid or solid grouted	20
All other	18
Nonbearing walls:	
Exterior	18
Interior	36

For SI: 1 foot = 304.8 mm.

a. Except for cavity walls and cantilevered walls, the thickness of a wall shall be its nominal thickness measured perpendicular to the face of the wall. For cavity walls, the thickness shall be determined as the sum of the nominal thicknesses of the individual wythes. For cantilever walls, except for parapets, the ratio of height to nominal thickness shall not exceed 6 for solid masonry, or 4 for hollow masonry. For parapets, see Section R606.2.4.

b. An additional unsupported height of 6 feet is permitted for gable end walls.

Figure 13-4 Spacing of lateral support for masonry walls

Providing Lateral Support

Masonry walls may need lateral support, depending on their length, thickness and height. That support can be provided in either the horizontal or vertical direction. IRC Table R606.9 (Figure 13-4) gives the maximum allowed spacing between lateral supports. This is expressed as a ratio. Horizontally, the maximum distance between lateral supports for solid grouted bearing walls is given as a ratio of the wall length to thickness of 20 (dotted outline in Figure 13-4). So if the wall is 6 inches thick, the distance between lateral supports can be a maximum of 120 inches (6 × 20 = 120), or 10 feet. For interior nonbearing walls, the ratio is 36 (dashed outline in Figure 13-4). So for a nonbearing interior wall 6 inches thick, the maximum distance between lateral supports is 216 inches (6 × 36 = 216), or 18 feet.

There are different ways to provide lateral support. When the maximum spacing is measured horizontally, the support can be provided by cross walls, pilasters, buttresses or structural frame members. When it's measured vertically, support can be provided by floors or roofs.

Thickness-to-Height Ratio

For buildings other than one- and two-family dwellings and townhouses, you must use the IBC to calculate your thickness-to-height ratio, and it's pretty complex. Before the 1985 edition of the UBC, the code had a table of thickness-to-height ratios for both reinforced and unreinforced masonry. But since these were simply rules of thumb and not code requirements, they were often misinterpreted. In 1985, the authors added text to explain the table — which, in my opinion, didn't help much. The 1991 edition replaced that explanation with text that was even harder to understand. This was mostly for design purposes; its usefulness in the field was limited.

Now the IBC helps designers deal with earthquake loads. Code recommendations for thickness-to-height ratios may not apply in all parts of the country, although earthquakes can occur just about anywhere. Only an engineer designing a particular building for a certain risk is qualified to decide what's adequate and what isn't.

Most people without an engineering degree won't be able to understand the section on thickness-to-height ratios. And not all building departments have plans examiners or inspectors on their staffs who can interpret these code sections for you. So if you're constructing buildings to the IBC using masonry, you'll need an engineer.

In a nutshell, here's what you need to know about Chapter 21 of the IBC. *All masonry must be reinforced.* There's no exception, unless it's been permitted by a licensed engineer and you have it in writing. That's the long and the short of it. This is over-simplified, of course, but it's a good beginning point for your planning.

Use of Mass

Anytime you build a wall higher, it has to be built stronger. And the easiest way to make it stronger is to make it thicker. Adding mass adds strength. Architects have known that for centuries. It's called a *principle of empirical design*. This means that we know it will work even before we start trying to prove that it will.

New York City once had a building code that stated the rule very simply. It required that brick walls for buildings be 12 inches thick for single-story buildings, and an additional 4 inches thick for each additional floor. So a two-story building had to have first floor walls 16 inches thick. The practical limit on the height of masonry walls was about 10 stories, because

then the wall on the ground floor had to be 4 feet thick. The rules are a lot more complex today, but at least 10-story buildings don't require 4-foot-thick walls anymore!

Ties, Anchors and Wire Fabric

Metal ties, anchors and wire fabric must conform to IRC Section R606.15. This section refers you to six different ASTM standards. They cover the requirements for:

1. Steel wire
2. Steel rods
3. Carbon structural steel
4. Masonry joint reinforcement
5. Copper-clad steel wire
6. Stainless steel wire

Section R606.15.1 covers corrosion protection, and refers you to another set of ASTM standards. You can be relatively confident that any anchors and ties you buy from a regular supplier will meet these standards. Metal ties and anchors must be corrosion resistant unless they're fully embedded in mortar or grout.

IRC R607.3 gives the details for installing wall ties, as follows:

- The ends of wall ties must be embedded in mortar joints.
- For hollow masonry units, the ends of wall ties must engage the face shell by at least ½ inch.
- For solid masonry units or solid grouted hollow units, wire wall ties must be embedded into the mortar bed at least 1½ inches.
- Wall ties must not be bent after being embedded in mortar or grout.

Bonding with Wall Ties

The correct ties to use for multiple wythe masonry, and how to use them, is found in IRC Section R608.1.2. This section covers the use of wall ties, adjustable wall ties and prefabricated joint reinforcement. We'll just cover bonding with wall ties (Section R608.1.2.1), since that's what's used most often. You can get the details for adjustable wall ties and prefabricated joint reinforcement in Sections R608.1.2.2 and R608.1.2.3.

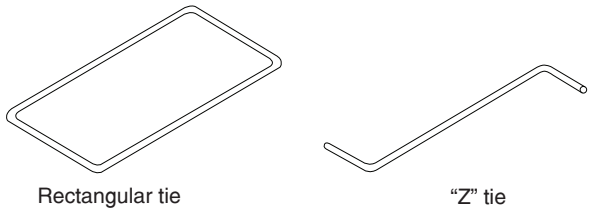


Figure 13-5 Rectangular and Z-shaped wall ties

The main IRC requirements for bonding adjacent wythes of masonry walls with wall ties are:

- Use $^{3}/_{16}$-inch-diameter wall ties embedded in the horizontal mortar joints.
- Use rectangular-shaped wire ties (Figure 13-5) with hollow masonry units laid with the cells set vertically.
- In other walls, use Z-shaped wall ties (Figure 13-5) with the ends of the ties bent at 90-degree angles for at least 2 inches.
- Use at least one metal tie for each 4½ square feet of wall area.
- Stagger ties in alternate courses.
- Space ties no more than 24 inches vertically.
- Space ties no more than 36 inches horizontally.
- At all openings, provide additional bonding ties, spaced no more than 36 inches apart and within 12 inches of the opening.

Mortar

Mortar must be applied properly to ensure a wall will have the strength intended. First, all units must be laid with a full head and bed joint. Second, all interior joints designed to be mortared need to be filled.

IBC TABLE 2103.8(1)
MORTAR PROPORTIONS

MORTAR	TYPE	PROPORTIONS BY VOLUME (cementitious materials)								AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
		Portland cement[a] or blended cement[b]	Masonry cement[c]			Mortar cement[d]			HYDRATED LIME[e] OR LIME PUTTY	
			M	S	N	M	S	N		
Cement-lime	M	1	—	—	—	—	—	—	$^1/_4$	Not less than $2^1/_4$ and not more than 3 times the sum of the separate volumes of cementitious materials
	S	1	—	—	—	—	—	—	over $^1/_4$ to $^1/_2$	
	N	1	—	—	—	—	—	—	over $^1/_2$ to $1^1/_4$	
	O	1	—	—	—	—	—	—	over $1^1/_4$ to $2^1/_2$	
Mortar cement	M	1	—	—	—	—	—	1	—	
	M	—	—	—	—	1	—	—	—	
	S	$^1/_2$	—	—	—	—	—	1	—	
	S	—	—	—	—	—	1	—	—	
	N	—	—	—	—	—	—	1	—	
	O	—	—	—	—	—	—	1	—	
Masonry cement	M	1	—	—	1	—	—	—	—	
	M	—	1	—	—	—	—	—	—	
	S	$^1/_2$	—	—	1	—	—	—	—	
	S	—	—	1	—	—	—	—	—	
	N	—	—	—	1	—	—	—	—	
	O	—	—	—	1	—	—	—	—	

a. Portland cement conforming to the requirements of ASTM C 150.
b. Blended cement conforming to the requirements of ASTM C 595.
c. Masonry cement conforming to the requirements of ASTM C 91.
d. Mortar cement conforming to the requirements of ASTM C 1329.
e. Hydrated lime conforming to the requirements of ASTM C 207.

Figure 13-6 Mortar proportions

The mortar mix itself is also critical. There are four types of mortar used in masonry construction:

1. *Type N* is the normal, general purpose mortar mix. It's for above-grade work in both exterior and interior load-bearing installations.
2. *Type M* is for below-grade, load-bearing masonry work. It's also used for chimneys and brick manholes.
3. *Type S* is for below-grade work and in areas like masonry foundation walls, brick manholes, retaining walls and sewers. It's also used for brick walkways, brick pavement and brick patios.
4. *Type O* is a lime-rich mortar. It's usually called "pointing" mortar. It's also used in above-grade, nonbearing situations in both interior and exterior environments.

Mix proportions are given in both IRC Table R607.1 and IBC Table 2103.8(1). The IBC Table is shown in Figure 13-6.

IRC Table R606.5 (Figure 13-7), provides the allowable working stresses for unreinforced unit masonry. Figures 13-6 and 13-7 will help you choose the right mortar and the proper mix for most masonry work. The proportions of cement, lime and aggregate (sand) are by volume, not weight.

The other ingredient used to make mortar doesn't get a lot of attention, but it should. It's water. The water used in mortar or grout should be the same quality as the water used in concrete. ASTM C 270 says that the water for mortar must be clean and free of organic materials, oils, acids, alkalis, salts, and any other substances that could damage mortar or any metal in the wall. Again, if you wouldn't drink it, you shouldn't use it in mortar or grout.

Most mortar is mixed at the job, making it easier to control the quality of the mix. IRC Section R607.1 and IBC Section 2103.8 say that mortar should be mixed according to ASTM C270. But there's one major drawback to these two sections. The requirements apply to every job, whether big or small. You'll have to decide if it's practical on small jobs. The main requirements are:

TABLE R606.5 ALLOWABLE COMPRESSIVE STRESSES FOR EMPIRICAL DESIGN OF MASONRY		
CONSTRUCTION; COMPRESSIVE STRENGTH OF UNIT, GROSS AREA	ALLOWABLE COMPRESSIVE STRESSES[a] GROSS CROSS-SECTIONAL AREA[b]	
	Type M or S mortar	Type N mortar
Solid masonry of brick and other solid units of clay or shale; sand-lime or concrete brick:		
8,000 + psi	350	300
4,500 psi	225	200
2,500 psi	160	140
1,500 psi	115	100
Grouted[c] masonry, of clay or shale; sand-lime or concrete:		
4,500+ psi	225	200
2,500 psi	160	140
1,500 psi	115	100
Solid masonry of solid concrete masonry units:		
3,000+ psi	225	200
2,000 psi	160	140
1,200 psi	115	100
Masonry of hollow load-bearing units:		
2,000+ psi	140	120
1,500 psi	115	100
1,000 psi	75	70
700 psi	60	55
Hollow walls (cavity or masonry bonded[d]) solid units:		
2,500+ psi	160	140
1,500 psi	115	100
Hollow units	75	70
Stone ashlar masonry:		
Granite	720	640
Limestone or marble	450	400
Sandstone or cast stone	360	320
Rubble stone masonry:		
Coarse, rough or random	120	100

For SI: 1 pound per square inch = 6.895 kPa.

a. Linear interpolation shall be used for determining allowable stresses for masonry units having compressive strengths that are intermediate between those given in the table.

b. Gross cross-sectional area shall be calculated on the actual rather than nominal dimensions.

c. See Section R608.

d. Where floor and roof loads are carried upon one wythe, the gross cross-sectional area is that of the wythe under load; if both wythes are loaded, the gross cross-sectional area is that of the wall minus the area of the cavity between the wythes. Walls bonded with metal ties shall be considered as cavity walls unless the collar joints are filled with mortar or grout.

Figure 13-7 Allowable compressive stresses for masonry

- Mortar must meet ASTM standard C270 (see subject following).
- The proportion specs for mortar must conform to IBC Table 2103.8(1) or IRC Table 607.1.
- Mortar properties must meet the specs of IBC Table 2103.8(2) (Figure 13-8).
- Unused mortar must be thrown away no more than 2½ hours after initial mixing.
- If you're laying glass unit masonry, other conditions apply (see IBC Section 2103.8).

ASTM C270 — Standard Specification for Mortar for Unit Masonry

ASTM C270 says that mortar must be mixed for three to five minutes. It should be done in a mechanical batch mixer, with the maximum amount of water needed to produce a workable texture. Hand-mixing of mortar is also permitted if you have the written approval of the person specifying the hand-mixing procedure — which could be a bother.

ASTM C270 calls for the *maximum* amount of water to be used to produce a workable texture, not the minimum amount. Water content might be the most misunderstood factor of masonry mortar. Maybe it's because of the difference in water requirements between mortar and concrete. A low water/cement ratio is good when mixing concrete. But mortar should have as much water as possible, and still remain workable.

Since water is lost through evaporation, especially in hot weather, mortar may need to be retempered. This means adding more water to maintain optimum consistency. But you can't retemper after the mortar has started to set. That's why mortar should be used as soon as possible, and discarded if not used within 2½ hours of the original mixing.

Another serious problem with ASTM C270 is that an inspector would have to be present the entire time masons are working to ensure that the mortar is mixed correctly. That just isn't practical. However, if an inspector calls for special tests on the mortar, or a special inspector is required, it's at the contractor's expense.

TABLE 2103.8(2)
MORTAR PROPERTIES

MORTAR	TYPE	AVERAGE COMPRESSIVE[b] STRENGTH AT 28 DAYS minimum (psi)	WATER RETENTION minimum (%)	AIR CONTENT maximum (%)
Cement-lime	M	2,500	75	12
	S	1,800	75	12
	N	750	75	14[c]
	O	350	75	14[c]
Mortar cement	M	2,500	75	12
	S	1,800	75	12
	N	750	75	14[c]
	O	350	75	14[c]
Masonry cement	M	2,500	75	18
	S	1,800	75	18
	N	750	75	20[d]
	O	350	75	20[d]

For SI: 1 inch = 25.4 mm, 1 pound per square inch = 6.895 kPa.
a. This aggregate ratio (measured in damp, loose condition) shall not be less than $2^1/_4$ and not more than 3 times the sum of the separate volumes of cementitious materials.
b. Average of three 2-inch cubes of laboratory-prepared mortar, in accordance with ASTM C 270.
c. When structural reinforcement is incorporated in cement-lime or mortar cement mortars, the maximum air content shall not exceed 12 percent.
d. When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall not exceed 18 percent.

Figure 13-8 Mortar properties

Masonry Joints

There are strict tolerances for structural masonry joints. They don't apply to nonbearing masonry walls or to masonry veneers, but they can serve as guidelines.

Your first bed joint (on top of the foundation wall) should be between ¼ and ¾ inch thick. The rest of the joints must be as specified in IRC Section R607.2.1 or IBC 2104.1.2.1, as follows:

- Bed joint: ⅜ inch, + ⅛, - 0 (between ⅜ and ½ inch)
- Head joint: ¼ inch, + ⅜, - 0 (between ¼ and ⅝ inch)
- Collar joints: ¼ inch, + ⅜, - 0, (between ¼ and ⅝ inch)

Most masonry is put up in lifts (individual increments of wall height). Lifts are usually limited to 4 feet high. Although the codes don't stipulate a lift height, this is a good rule of thumb. If a lift is higher than 4 feet, the weight of the succeeding courses may squeeze the wet mortar out of lower course joints before the mortar sets. So, each 4-foot lift should be laid, grouted and allowed to set before the next lift is started.

Always build walls in lifts when you're grouting, especially when grouting around rebar. Remember, the grout should not be level with the top of the block, except on the last course. It should stop at least 1½ inches below the top (see Figure 13-3). If both the grout joint and the wall bed joint fall at the same level, it will create a weak point in the wall. When you're using bond beams, the grout should stop ½ inch below the beam.

Any chases or recesses you're building into the wall should be small enough so they don't reduce the strength or fire-resistance of the wall.

Sometimes you'll come across masonry walls to be built with a stack bond. A stack bond is where the blocks are placed directly over each other without the lapped joint used on most masonry work. Walls built with a stack bond must have horizontal reinforcement. The minimum area of reinforcement in the bed joints must be at least 0.0003 times the vertical cross-sectional area of the wall (in inches); see IBC Section 2109.6.5.2. If the wall area is 20 feet by 10 feet, you'll have 200 square feet or 28,800 square inches (240 inches × 120 inches = 28,800 square inches). So, the cross-sectional area of reinforcement in the bed joints must be at least 8.64 square inches (28,800 × 0.0003 = 8.64).

Typically you'll use reinforcing wire with a cross-sectional area of 0.017 square inch, laying two wires close to each other in a bed joint. Dividing the 8.64 square inches of cross-sectional area reinforcement you need for your

20- by 10-foot wall by 0.017, means you'll need about 42 feet of reinforcing wire (8.64 ÷ 0.017 = 508 inches ÷ 12 = 42.33 feet). Install the wires horizontally between courses, but not more than 16 inches apart.

Active earthquake zones have stricter requirements. If you're planning to build in an earthquake zone, you'll need to consult an engineer for advice.

Corbelling

If you work with masonry, you certainly know about corbelling. Webster's dictionary says that a corbel is an architectural member that projects from within a wall and supports a weight. Corbels are usually stepped upward and outward from a vertical surface. Figure 13-9 illustrates corbelling in masonry construction.

The code requirements for corbelling are given in IRC Section R606.3 and IBC Section 2104.2.

The main points of Section R606.3 are:

- Use only solid masonry units for corbelling.
- The maximum projection of a corbel, from the face of the wall, must not be more than half of the wall thickness; see Figure 13-9.
- For hollow (two-wythe) walls, the maximum corbel projection must not be more than half of the one-wythe thickness.
- The maximum projection of one masonry unit must not be more than one-third of the wall or wythe thickness or half of the unit height, whichever is less; see Figure 13-9.
- When a corbel is used to support a floor or roof structure, the top course of the corbel must be a header course. Or, the bed joint of the top course must be tied to the vertical wall. The hollow space behind the corbel must be filled with mortar or grout.

Section 2104.2 has additional provisions:

- The maximum corbel from the face of the wall for multiwythe walls can be as much as half of the wall thickness provided the wythes are bonded by mortar or grout and wall ties or masonry headers.
- The maximum corbel from the face of the wall for single-wythe walls, hollow walls bonded with masonry, multiwythe walls with open collar joints, and veneer walls can't be more than half of the wythe thickness.
- The back surface of the corbelled section must remain within 1 inch of plane.

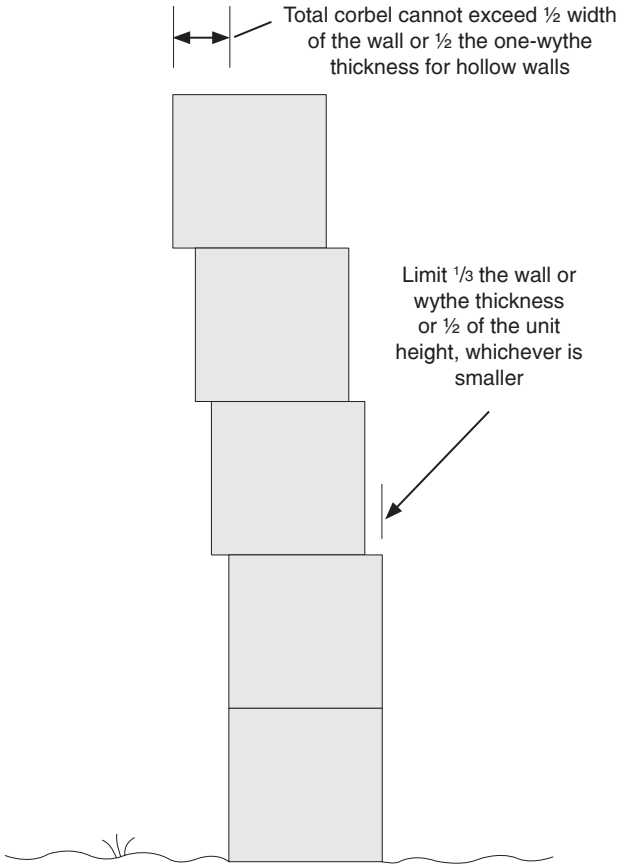


Figure 13-9 Corbelling in masonry construction

Be careful when building corbels in earthquake zones. The IBC has stricter regulations. Officials in some seismic-prone areas are actually requiring owners to remove corbels and cornices that might fall on people in the event of an earthquake.

Laying Masonry in Cold Weather

Can you lay masonry units in any kind of weather? Not unless you take specific steps to protect the strength of the wall. Review IBC Section 2104.3 if you plan on laying masonry units when temperatures fall below 40 degrees F.

Preparation

2104.3.1 Preparation.

1. *Temperatures of masonry units shall not be less than 20 degrees F (-7 degrees C) when laid in the masonry. Masonry units containing frozen moisture, visible ice or snow on their surface shall not be laid.*
2. *Visible ice and snow shall be removed from the top surface of existing foundations and masonry to receive new construction. These surfaces shall be heated to above freezing, using methods that do not result in damage.*

Construction

2104.3.2.1 Construction requirements for temperatures between 40 degrees F (4 degrees C) and 32 degrees F (0 degrees C). *The following construction requirements shall be met when the ambient temperature is between 40 degrees F (4 degrees C) and 32 degrees F (0 degrees C):*

1. *Glass unit masonry shall not be laid.*
2. *Water and aggregates used in mortar and grout shall not be heated above 140 degrees F (60 degrees C).*
3. *Mortar sand or mixing water shall be heated to produce mortar temperatures between 40 degrees F (4 degrees C) and 120 degrees F (49 degrees C) at the time of mixing. When water and aggregates for grout are below 32 degrees F (0 degrees C), they shall be heated.*

The following IBC sections cover construction requirements if the ambient temperature drops below 32 degrees F:

Section 2104.3.2.2 covers temperatures between 32 degrees F and 25 degrees F.

Section 2104.3.2.3 covers temperatures between 25 degrees F and 20 degrees F.

Section 2104.3.2.4 covers temperatures below 20 degrees F.

The colder it gets, the more requirements there are.

New requirements were added in the 2006 IBC for Autoclaved Aerated Concrete (AAC) block masonry units. You must heat AAC blocks to 40 degrees F before laying them on thin-bed mortar in temperatures between 32 degrees F and 25 degrees F. You can get more information on this fairly new product at the Autoclaved Aerated Concrete Products Association (AACPA) website at www.aacpa.org.

Protection

All masonry work must be protected after installation during cold weather construction, as described in IBC Section 2104.3.3. The length of time depends on the expected minimum daily temperature (for grouted masonry) and the expected mean daily temperature (for ungrouted masonry). Section 2104.3.3.3 gives the protection requirements for temperatures between 40 degrees F and 25 degrees F.

2104.3.3.3 Protection requirements for temperatures between 40 degrees F (4 degrees C) and 25 degrees F (-4 degrees C). *When the temperature is between 40 degrees F (4 degrees C) and 25 degrees F (-4 degrees C), newly constructed masonry shall be covered with a weather-resistive membrane for 24 hours after being completed.*

The protection required for other temperature ranges are given in:

Section 2104.3.3.4, for temperatures between 25 degrees F and 20 degrees F

Section 2104.3.3.5, for temperatures below 20 degrees F

For AAC masonry, Section 2104.3.3.2 requires the temperature be kept above 32 degrees F for the first four hours after thin-bed mortar application.

If you live in a cold climate, you've probably seen buildings under construction shrouded in giant plastic cocoons. These cocoons are heated

and inflated (like a balloon) during construction. The heat must be kept in for 24 hours after laying masonry in Type III portland cement, and for 48 hours after laying masonry in Type I portland cement.

Laying Masonry in Hot Weather

You also need to be concerned about laying masonry in hot weather. This is covered in IBC Section 2104.4.

Preparation

2104.4.1 Preparation. *The following requirements shall be met prior to conducting masonry work.*

2104.4.1.1 Temperature. *When the ambient temperature exceeds 100 degrees F (38 degrees C), or exceeds 90 degrees F (32 degrees C) with a wind velocity greater than 8 mph (3.5 m/s):*

1. *Necessary conditions and equipment shall be provided to produce mortar having a temperature below 120 degrees F (49 degrees C).*
2. *Sand piles shall be maintained in a damp, loose condition.*

If the ambient temperature is over 115 degrees F, or 105 degrees F with an 8 mph or greater wind, all materials and mixing equipment must be shaded from direct sunlight.

Construction

2104.4.2.1 Temperature. *When the ambient temperature exceeds 100 degrees F (38 degrees C), or exceeds 90 degrees F (32 degrees C) with a wind velocity greater than 8 mph (3.5 m/s):*

1. *The temperature of mortar and grout shall be maintained below 120 degrees F (49 degrees C).*
2. *Mixers, mortar transport containers and mortar boards shall be flushed with cool water before they come into contact with mortar ingredients or mortar.*
3. *Mortar consistency shall be maintained by retempering with cool water.*
4. *Mortar shall be used within 2 hours of initial mixing.*
5. *Thin-bed mortar shall be spread no more than 4 feet (1219 mm) ahead of AAC masonry units.*
6. *AAC masonry units shall be placed within one minute after spreading thin-bed mortar.*

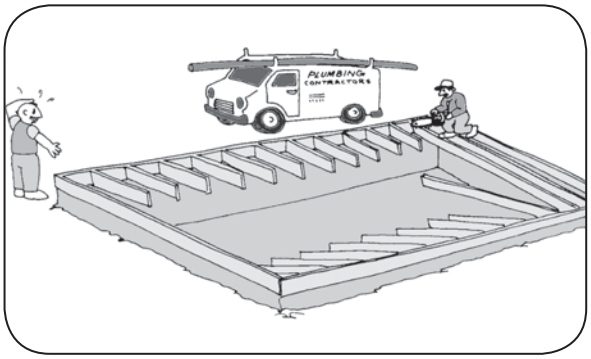
If the ambient temperature is over 115 degrees F, or 105 degrees F with an 8 mph or greater wind, you must mix the mortar with cool water. You can cool the water with ice, but make sure there's no ice left in the water when you mix the mortar.

Protection

Laid masonry must be protected from very high temperatures; see Section 2104.4.3.

2104.4.3 Protection. *When the mean daily temperature exceeds 100 degrees F (38 degrees C), or exceeds 90 degrees F (32 degrees C) with a wind velocity greater than 8 mph (3.5 m/s), newly constructed masonry shall be fog sprayed until damp at least three times a day until the masonry is three days old.*

That's it for masonry walls. However, most residential construction is still done with frame walls. So in the next chapter, we'll look at the code requirements for frame wall construction.



Who's Going to Header That Hole?

Every subcontractor makes mistakes. But mistakes made by framing subs can be the worst. I can say that, since I was a framer once. Anything a framer leaves out is probably very important.

Framers make their living with high production: Get the foundation sill down; install the joists; get it plated; tilt up the walls, and so on. The sooner the framing is done, the bigger the profit, and the sooner we get paid.

Framers generally have excuses for most anything bad that happens, but usually the root of their problems is lack of planning. For instance, the lumber truck dumps the load at the south side of the lot. So Joe Framer starts setting floor joists right there, on the south side, working north, at 16-inch centers. That's the quickest way to do it. In a few minutes he's nailing on rim joists and is almost ready for decking. This is going as slick as a whistle.

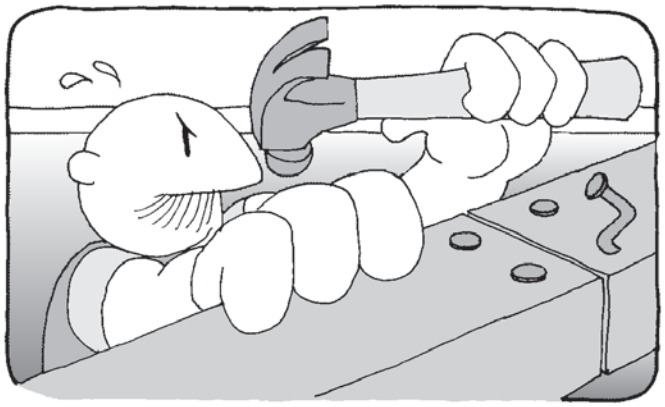
Framer finishes in just a few days. And no wonder. He didn't waste a minute, especially in checking the plans. But he's overlooked a few things. Like where plumbing lines have to run through his precious framing. Certainly Sam Plumber will notice.

Speaking of Sam Plumber, here he comes. He discovers there's a joist in the way of the closet bend for his toilet. And another goes right through where the middle of the bathtub drain trap will come down. Of course, there isn't a carpenter anywhere in sight. So he falls back on "Plan B." He drags out his trusty chain saw and whacks off several feet of perfectly good joist, leaving it dangling like a limb on a tree.

The writers of the code, in their wisdom, decided that the ends of joists have to be supported by something solid. So guess what happens when I come along to inspect the job?

"This hole will have to be headed," I say. "What hole is that?" the foreman asks, wearing his most innocent expression. I point it out. "But I didn't cut that hole. It must have been the plumber." True enough. But code is code, so it's got to be done.

The whole problem could have been avoided if Joe Framer had been as quick at reading plans as he was at driving nails. For this job, floor joists should have been laid out starting from the north side of the foundation, where the plumbing fixtures were. That's probably what the architect had in mind in the first place. But don't blame the architect. The framer should know his business. And part of that is planning for work by other trades.



CHAPTER 14

Wood Frame Walls and Floors

The intent of the IBC and IRC is the same for frame walls as for masonry walls: to produce a sturdy building that stays warm and dry. In the IRC, Chapter 6 covers wood wall construction and Chapter 5 discusses floors. In the IBC, Chapter 23 covers wood construction in general. So you need to know something about lumber and what the codes require for its use.

Lumber Grading

Lumber grades indicate the lumber's strength. Grade marks must be clearly visible on all pieces of framing lumber. Unfortunately, a grade stamp isn't a promise that every piece is going to be the same strength. Lumber mill grades are based on the judgment of the person grading the lumber. Almost all framing lumber is graded by eye — and the human eye can't see every defect.

The IRC requires all load-bearing lumber to be identified; see Section R602.1. Load-bearing lumber must have the grade mark of a grading or inspection agency. The agency has to be approved by an organization complying with the American Softwood Lumber Standard, DOC PS 20. It's published by the National Institute of Standards and Technology (NIST). The standard is available at the NIST website, www.nist.gov. If load-bearing lumber doesn't have a grade mark, a certificate of inspection from the grading or inspection agency is acceptable.

You don't have to accept all the lumber that's delivered to your job site. Just because a piece of wood has a grade mark or a certificate doesn't mean that it's good lumber. If it looks like poor quality to you, reject it. If the dealer won't take it back, stop doing business there. There are plenty of lumber companies that will work with you. Unless you bought the lumber from a stack of bargain material, you should be able to return it. Most dealers want to keep your business. They're not going to risk losing it for a few pieces of lumber.

What if the lumber isn't good enough to use for framing, but not bad enough to return? You can use it for blocking or backing; someplace where it won't matter what it looks like or how strong it is. But be careful using questionable lumber — the inspector can reject flawed lumber if he finds it on your job. And if it's already installed, he can make you replace it.

Suppose you have a floor joist with a knot that's the maximum size allowed for a particular joist. Then your plumber comes along and notches the joist near enough to this knot to weaken the entire piece. This will almost certainly catch the inspector's eye. The inspector has the following options:

- He can ask you to replace it.
- He can have you cut it back and header it in.
- He can ask you to brace it with a post or by scabbing another piece to it.

If you don't want to do any of these, the inspector can make you hire a testing agency — at your expense. And that won't be cheap. They'll sandbag the floor and test it for deflection. If it passes, they'll certify to the inspector that the assembly has the required strength. You'll have proven to the inspector that you were right, but it would have been much cheaper and faster to have just scabbed on another piece.

Well, that's what the inspector *can* do. It's better to avoid the situation by anticipating the problem and bracing the joist before the inspector ever sees it. Once the inspector finds one problem you didn't fix on your own, he'll assume that you'll accept substandard work and he'll look even harder to find more. That's just human nature — and the inspector's job.

Determining Wood Strength

The building industry uses standard formulas to determine the strength of wood, wood joints, and other wood assemblies. Since most of these formulas apply only to large structures, we'll leave them for the engineers and designers. If you're an average contractor you'll find almost all the design information you need in the span tables in IRC Chapter 5, Floors, and Chapter 6, Wall Construction, as well as in IBC Chapter 23.

The structural design of timber is a complex subject. But if you're framing houses and building to the IRC, you don't have to know anything about timber engineering. If you're building to the IBC, you may need to know more than the joist and rafter tables show. If that's the case, consult a design engineer.

Allowable Spans for Floor Joists

IRC Sections R502.3 and R502.3(2), as well as Table R502.3.1(1) (Figure 14-1), give information to help you choose the type and grade of wood you need for floor joists. The table lists the four most common types and grades of lumber. Use the figure and tables in these sections to find the lumber species, grade, joist size and joist spacing you need for different floor joist spans.

The information in Table R502.3.1(1) is for residential sleeping areas where the live load doesn't exceed 30 psf. Table R502.3.1(2) is for residential living areas where the live load doesn't exceed 40 psf. In either case, the design dead load shouldn't exceed 10 psf.

Let's look briefly at an example using Table R502.3.1(1) in Figure 14-1. Say you have a 20-foot span in a residential sleeping area with a dead load of 10 psf. What wood species, grade, joist size and spacing can you use? Any combination of species, grade, joist size, and spacing which shows a span distance greater than 20 feet will work. You'll notice that the thicker the joist and the closer the spacing, the more choices you have. For most species, you'll need 2 x 12 joists, either 12- or 16-inch joist spacing, and the higher grade of lumber. But let's say you want to use 2 x 10 joists. No problem. I've outlined your choices. You'll use 12-inch joist spacing and either Douglas Fir-Larch or Southern Pine in Select Structural or No. 1 grade. If you want to use 16-inch joist spacing, you'll have to use 2 x 12 joists, but you have a wider choice of wood species and grade.

What if you don't find the wood species or grade you'd like to use, or you have different loading conditions? You can always use the American Wood and Paper Association (AWPA)

TABLE R502.3.1(1)
FLOOR JOIST SPANS FOR COMMON LUMBER SPECIES

(RESIDENTIAL SLEEPING AREAS, LIVE LOAD = 30 PSF, L/Δ = 360)[a]

JOIST SPACING (inches)	SPECIES AND GRADE		DEAD LOAD = 10 psf				DEAD LOAD = 20 psf			
			2×6	2×8	2×10	2×12	2×6	2×8	2×10	2×12
			Maximum floor joist spans							
			(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)	(ft - in.)
12	Douglas fir-larch	SS	12- 6	16- 6	21- 0	25- 7	12- 6	16- 6	21- 0	25- 7
	Douglas fir-larch	#1	12- 0	15-10	20- 3	24- 8	12- 0	15- 7	19- 0	22- 0
	Douglas fir-larch	#2	11-10	15- 7	19-10	23- 0	11- 6	14- 7	17- 9	20- 7
	Douglas fir-larch	#3	9- 8	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
	Hem-fir	SS	11-10	15- 7	19-10	24- 2	11-10	15- 7	19-10	24- 2
	Hem-fir	#1	11- 7	15- 3	19- 5	23- 7	11- 7	15- 2	18- 6	21- 6
	Hem-fir	#2	11- 0	14- 6	18- 6	22- 6	11- 0	14- 4	17- 6	20- 4
	Hem-fir	#3	9- 8	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
	Southern pine	SS	12- 3	16- 2	20- 8	25- 1	12- 3	16- 2	20- 8	25- 1
	Southern pine	#1	12- 0	15-10	20- 3	24- 8	12- 0	15-10	20- 3	24- 8
	Southern pine	#2	11-10	15- 7	19-10	24- 2	11-10	15- 7	18- 7	21- 9
	Southern pine	#3	10- 5	13- 3	15- 8	18- 8	9- 4	11-11	14- 0	16- 8
	Spruce-pine-fir	SS	11- 7	15- 3	19- 5	23- 7	11- 7	15- 3	19- 5	23- 7
	Spruce-pine-fir	#1	11- 3	14-11	19- 0	23- 0	11- 3	14- 7	17- 9	20- 7
	Spruce-pine-fir	#2	11- 3	14-11	19- 0	23- 0	11- 3	14- 7	17- 9	20- 7
	Spruce-pine-fir	#3	9- 8	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
16	Douglas fir-larch	SS	11- 4	15- 0	19- 1	23- 3	11- 4	15- 0	19- 1	23- 0
	Douglas fir-larch	#1	10-11	14- 5	18- 5	21- 4	10- 8	13- 6	16- 5	19- 1
	Douglas fir-larch	#2	10- 9	14- 1	17- 2	19-11	9-11	12- 7	15- 5	17-10
	Douglas fir-larch	#3	8- 5	10- 8	13- 0	15- 1	7- 6	9- 6	11- 8	13- 6
	Hem-fir	SS	10- 9	14- 2	18- 0	21-11	10- 9	14- 2	18- 0	21-11
	Hem-fir	#1	10- 6	13-10	17- 8	20- 9	10- 4	13- 1	16- 0	18- 7
	Hem-fir	#2	10- 0	13- 2	16-10	19- 8	9-10	12- 5	15- 2	17- 7
	Hem-fir	#3	8- 5	10- 8	13- 0	15- 1	7- 6	9- 6	11- 8	13- 6
	Southern pine	SS	11- 2	14- 8	18- 9	22-10	11- 2	14- 8	18- 9	22-10
	Southern pine	#1	10-11	14- 5	18- 5	22- 5	10-11	14- 5	17-11	21- 4
	Southern pine	#2	10- 9	14- 2	18- 0	21- 1	10- 5	13- 6	16- 1	18-10
	Southern pine	#3	9- 0	11- 6	13- 7	16- 2	8- 1	10- 3	12- 2	14- 6
	Spruce-pine-fir	SS	10- 6	13-10	17- 8	21- 6	10- 6	13-10	17- 8	21- 4
	Spruce-pine-fir	#1	10- 3	13- 6	17- 2	19-11	9-11	12- 7	15- 5	17-10
	Spruce-pine-fir	#2	10- 3	13- 6	17- 2	19-11	9-11	12- 7	15- 5	17-10
	Spruce-pine-fir	#3	8- 5	10- 8	13- 0	15- 1	7- 6	9- 6	11- 8	13- 6
19.2	Douglas fir-larch	SS	10- 8	14- 1	18- 0	21-10	10- 8	14- 1	18- 0	21- 0
	Douglas fir-larch	#1	10- 4	13- 7	16- 9	19- 6	9- 8	12- 4	15- 0	17- 5
	Douglas fir-larch	#2	10-1	12-10	15- 8	18- 3	9- 1	11- 6	14- 1	16- 3
	Douglas fir-larch	#3	7- 8	9- 9	11-10	13- 9	6-10	8- 8	10- 7	12- 4
	Hem-fir	SS	10- 1	13- 4	17- 0	20- 8	10- 1	13- 4	17- 0	20- 7
	Hem-fir	#1	9-10	13- 0	16- 4	19- 0	9- 6	12- 0	14- 8	17- 0
	Hem-fir	#2	9- 5	12- 5	15- 6	17-1	8-11	11- 4	13-10	16- 1
	Hem-fir	#3	7- 8	9- 9	11- 10	13- 9	6-10	8- 8	10- 7	12- 4
	Southern pine	SS	10- 6	13-10	17- 8	21- 6	10- 6	13-10	17- 8	21- 6
	Southern pine	#1	10- 4	13- 7	17- 4	21- 1	10- 4	13- 7	16- 4	19- 6
	Southern pine	#2	10- 1	13- 4	16- 5	19- 3	9- 6	12- 4	14- 8	17- 2
	Southern pine	#3	8- 3	10- 6	12- 5	14- 9	7- 4	9- 5	11- 1	13- 2
	Spruce-pine-fir	SS	9- 10	13- 0	16- 7	20- 2	9-10	13- 0	16- 7	19- 6
	Spruce-pine-fir	#1	9- 8	12- 9	15- 8	18- 3	9- 1	11- 6	14- 1	16- 3
	Spruce-pine-fir	#2	9- 8	12- 9	15- 8	18- 3	9- 1	11- 6	14- 1	16- 3
	Spruce-pine-fir	#3	7- 8	9- 9	11-10	13- 9	6-10	8- 8	10- 7	12- 4
24	Douglas fir-larch	SS	9-11	13- 1	16- 8	20- 3	9-11	13- 1	16- 2	18- 9
	Douglas fir-larch	#1	9- 7	12- 4	15- 0	17- 5	8- 8	11- 0	13- 5	15- 7
	Douglas fir-larch	#2	9- 1	11- 6	14- 1	16- 3	8- 1	10- 3	12- 7	14- 7
	Douglas fir-larch	#3	6-10	8- 8	10- 7	12- 4	6- 2	7- 9	9- 6	11- 0
	Hem-fir	SS	9- 4	12- 4	15- 9	19- 2	9- 4	12- 4	15- 9	18- 5
	Hem-fir	#1	9- 2	12- 0	14- 8	17- 0	8- 6	10- 9	13- 1	15- 2
	Hem-fir	#2	8- 9	11- 4	13-10	16- 1	8- 0	10- 2	12- 5	14- 4
	Hem-fir	#3	6-10	8- 8	10- 7	12- 4	6- 2	7- 9	9- 6	11- 0
	Southern pine	SS	9- 9	12-10	16- 5	19-11	9- 9	12-10	16- 5	19-11
	Southern pine	#1	9- 7	12- 7	16- 1	19- 6	9- 7	12- 4	14- 7	17- 5
	Southern pine	#2	9- 4	12- 4	14- 8	17- 2	8- 6	11- 0	13- 1	15- 5
	Southern pine	#3	7- 4	9- 5	11- 1	13- 2	6- 7	8- 5	9-11	11-10
	Spruce-pine-fir	SS	9- 2	12- 1	15- 5	18- 9	9- 2	12- 1	15- 0	17- 5
	Spruce-pine-fir	#1	8-11	11- 6	14- 1	16- 3	8- 1	10- 3	12- 7	14- 7
	Spruce-pine-fir	#2	8-11	11- 6	14- 1	16- 3	8- 1	10- 3	12- 7	14- 7
	Spruce-pine-fir	#3	6-10	8- 8	10- 7	12- 4	6- 2	7- 9	9- 6	11- 0

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa.

NOTE: Check sources for availability of lumber in lengths greater than 20 feet.

a. Dead load limits for townhouses in Seismic Design Category C and all structures in Seismic Design Categories D_0, D_1 and D_2 shall be determined in accordance with Section R301.2.2.2.1.

Figure 14-1 Floor joist spans for common lumber species

Span Tables for Joists and Rafters. Get a copy at the American Wood Council website, www.awc.org/technical/spantables/index.html. There's also some useful information on *Understanding Loads and Using Span Tables*, at www.awc.org/technical/spantables/tutorial.htm.

Wouldn't a calculator that can help you determine which species and grade you should use come in handy for this job? Well, there's good news. The *Maximum Span Calculator for Joists & Rafters* is available at www.awc.org/calculators/span/calc/timbercalcstyle.asp. You can plug in the following choices:

Species	Select from 29 different species
Size	2 x 4, 2 x 6, 2 x 8, 2 x 10 or 2 x 12
Grade	SS, #1, #2, #3, Stud, Construction, Standard or Utility
Member type	Floor joists, Ceiling joists, Rafters (snow load) or Rafters (roof live-load)
Deflection limit	L/720, L/600, L/480, L/360, L/240 or L/180
Spacing (inches)	12, 16, 19.2 or 24
Wet service conditions	Yes or No
Incised lumber	Yes or No
Live load (psf)	30, 40, 50, 60, 70, 80, 90 or 100
Dead load (psf)	5, 7, 10, 15 or 20

The calculator computes the maximum span that your selection can cover. All you do is adjust your selection to get the correct combination for the span you need. Nothing could be easier. No more calculations. No more looking up tables. And you can change your selection and get an updated answer in milliseconds!

You need to keep one thing in mind. Unless specified, the calculator and these tables always give the acceptable *minimums*. They'll slide past the inspector, but will you get the quality you want? Remember, there's another person you have to satisfy — the owner. Ultimately, he's even more important than the inspector. Squeaky floors can be annoying. If you comply with the code using the minimum requirements and you end up with an unhappy customer, what does that do for your reputation? Good will is even harder to build than good floors. Why risk it? Going to a slightly higher joist size may serve you better. In this case, the extra cost would be a good investment. I'm not saying that using the minimums will give you a squeaky floor every time. It won't. But you don't leave yourself much room for error in construction or workmanship, either.

If you're using a plan prepared by an engineer, the drawings will show the size of the joists, the spacing, and the direction of run. They should also identify the lumber species and grade.

Floor Joists and Joist Problems

There's more to joists than just knowing sizes and loading. You can't just lay floor joists out on top of the foundation plate. They need lateral support with solid blocking at the ends and support points. You can nail the joist ends to a header, band or rim joist, or an adjoining stud. Solid blocking must be at least 2 inches thick and the full depth of the joist (See IBC Section 2308.8.2).

No cross-bridging or blocking is required between the ends of the joists. But there are some exceptions in Section 2308.8.2. Notice that I said "between" the ends of joists. The ends themselves must still be solid blocked. Here's what Section 2308.8.2 says about blocking:

> ***2308.8.2 Framing details.*** *Joists shall be supported laterally at the ends and at each support by solid blocking except where the ends of the joists are nailed to a header, band or rim joist or to an adjoining stud or by other means. Solid blocking shall not be less than 2 inches (51 mm) in thickness and the full depth of the joist. Notches on the ends of joists shall not exceed one-fourth the joist depth. Holes bored in joists shall not be within 2 inches (51 mm) of the top or bottom of the joist, and the diameter of any such hole shall not exceed one-third the depth of the joist. Notches in the top or bottom of joists shall not exceed one-sixth the depth and shall not be located in the middle third of the span.*

Joist framing from opposite sides of a beam, girder or partition shall be lapped at least 3 inches (76 mm) or the opposing joists shall be tied together in an approved manner.

Joists framing into the side of a wood girder shall be supported by framing anchors or on ledger strips not less than 2 inches by 2 inches (51 mm by 51 mm).

Joists running parallel under bearing partitions must be doubled.

If the header's span exceeds 4 feet, double the header joists. Or use lumber that's the same cross-section as a doubled header. The ends of header joists longer than 6 feet must be supported by framing anchors or joist hangers, unless the header joists are bearing on a beam. This means you only need a single header if your opening is less than 4 feet. In any case, it must be as wide as the joist it supports.

Framing Floors

First let's look at subflooring. Squeaky, noisy floors usually begin with bad subfloors. I once owned a house that had squeaking floors in the hall and bathroom. The bathroom tiles kept popping up. Finally, I tore up the floor to see what the trouble was. The subfloor was nothing but scrap lumber laid on the joists. It wasn't even nailed or laid tight. I had to replace the entire floor from the joists up.

Laying Subfloor

IRC Section R503 tells all you need to know about floor sheathing. R503.1 states that the maximum allowable spans for lumber used as floor sheathing must meet the requirements of Tables R503.1, R503.2.1.1(1) and R503.2.1.1(2).

Table R503.1 (Figure 14-2) gives you the minimum thickness of lumber you can use for floor sheathing. Remember these are *minimum* numbers. You might want to use thicker lumber if it's not substantially more expensive.

TABLE R503.1
MINIMUM THICKNESS OF LUMBER FLOOR SHEATHING

JOIST OR BEAM SPACING (inches)	MINIMUM NET THICKNESS	
	Perpendicular to joist	Diagonal to joist
24	$^{11}/_{16}$	$^{3}/_{4}$
16	$^{5}/_{8}$	$^{5}/_{8}$
48[a]	$1^{1}/_{2}$ T & G	N/A
54[b]		
60[c]		

For SI: 1 inch = 25.4 mm, 1 pound per square inch = 6.895 kPa.

a. For this support spacing, lumber sheathing shall have a minimum F_b of 675 and minimum E of 1,100,000 (see AF&PA/NDS).

b. For this support spacing, lumber sheathing shall have a minimum F_b of 765 and minimum E of 1,400,000 (see AF&PA/NDS).

c. For this support spacing, lumber sheathing shall have a minimum F_b of 855 and minimum E of 1,700,000 (see AF&PA/NDS).

Figure 14-2 Minimum thickness of lumber floor sheathing

Nearly all structural panel type floor or roof sheathing (plywood or OSB) will have a "Span Rating" stamped right on the panel. Table R503.2.1.1(1) (Figure 14-3) gives you the allowable spans for wood structural panel floor and roof sheathing.

Table R503.2.1.1(2) (Figure 14-4) is a little tricky. Do you see the column called *Species group*? You'll have to investigate further to find out which woods are in each species group before you can use this table to select the thickness of material you need for your joist spacing.

To find that information, refer to Classification of Species, Voluntary Product Standard PS 1-95 (Figure 14-5), from Construction and Industrial Plywood, published by the U.S. Department of Commerce. You can also find it on the Internet at http://ts.nist.gov/Standards/Conformity/upload/ps1-95.pdf.

Details for using wood structural panel (usually OSB) or particleboard for floor sheathing are given in IRC Sections R503.2 and R503.3, respectively.

Joints in subflooring should all be made over joists, unless you're using end-matched lumber (tongue-and-groove). When properly installed, end-matched lumber acts as one continuous piece. Each piece must rest on at least two joists, as stated in IRC Section R503.1.1. No subflooring is needed if the joist spacing is 16 inches or less and a 1-inch-thick tongue-and-groove wood strip floor is laid across the joists.

TABLE R503.2.1.1(1)
ALLOWABLE SPANS AND LOADS FOR WOOD STRUCTURAL PANELS FOR ROOF AND SUBFLOOR SHEATHING AND COMBINATION SUBFLOOR UNDERLAYMENT[a,b,c]

SPAN RATING	MINIMUM NOMINAL PANEL THICKNESS (inch)	ALLOWABLE LIVE LOAD (psf)[h, l]		MAXIMUM SPAN (inches)		LOAD (pounds per square foot, at maximum span)		MAXIMUM SPAN (inches)
		SPAN @ 16" o.c.	SPAN @ 24" o.c.	With edge support[d]	Without edge support	Total load	Live load	
Sheathing[e]				Roof[f]				Subfloor[j]
12/0	$^5/_{16}$	—	—	12	12	40	30	0
16/0	$^5/_{16}$	30	—	16	16	40	30	0
20/0	$^5/_{16}$	50	—	20	20	40	30	0
24/0	$^3/_8$	100	30	24	20[g]	40	30	0
24/16	$^7/_{16}$	100	40	24	24	50	40	16
32/16	$^{15}/_{32}$, $^1/_2$	180	70	32	28	40	30	16[h]
40/20	$^{19}/_{32}$, $^5/_8$	305	30	40	32	40	30	20[h,i]
48/24	$^{23}/_{32}$, $^3/_{48}$	—	175	48	36	45	35	24
60/32	$^7/_8$	—	305	60	48	45	35	32
Underlayment, C-C plugged, single floor[e]				Roof[f]				Combination subfloor underlayment[k]
16 o.c.	$^{19}/_{32}$, $^5/_8$	100	40	24	24	50	40	16[i]
20 o.c.	$^{19}/_{32}$, $^5/_8$	150	60	32	32	40	30	20[i,j]
24 o.c.	$^{23}/_{32}$, $^3/_4$	240	100	48	36	35	25	24
32 o.c.	$^7/_8$	—	185	48	40	50	40	32
48 o.c.	$1^3/_{32}$, $1^1/_8$	—	290	60	48	50	40	48

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 0.0479 kPa.

a. The allowable total loads were determined using a dead load of 10 psf. If the dead load exceeds 10 psf, then the live load shall be reduced accordingly.
b. Panels continuous over two or more spans with long dimension perpendicular to supports. Spans shall be limited to values shown because of possible effect of concentrated loads.
c. Applies to panels 24 inches or wider.
d. Lumber blocking, panel edge clips (one midway between each support, except two equally spaced between supports when span is 48 inches), tongue-and-groove panel edges, or other approved type of edge support.
e. Includes Structural 1 panels in these grades.
f. Uniform load deflection limitation: $^1/_{180}$ of span under live load plus dead load, $^1/_{240}$ of span under live load only.
g. Maximum span 24 inches for $^{15}/_{32}$-and $^1/_2$-inch panels.
h. Maximum span 24 inches where $^3/_4$-inch wood finish flooring is installed at right angles to joists.
i. Maximum span 24 inches where 1.5 inches of lightweight concrete or approved cellular concrete is placed over the subfloor.
j. Unsupported edges shall have tongue-and-groove joints or shall be supported with blocking unless minimum nominal $^1/_4$-inch thick underlayment with end and edge joints offset at least 2 inches or 1.5 inches of lightweight concrete or approved cellular concrete is placed over the subfloor, or $^3/_4$-inch wood finish flooring is installed at right angles to the supports. Allowable uniform live load at maximum span, based on deflection of $^1/_{360}$ of span, is 100 psf.
k. Unsupported edges shall have tongue-and-groove joints or shall be supported by blocking unless nominal $^1/_4$-inch-thick underlayment with end and edge joints offset at least 2 inches or $^3/_4$-inch wood finish flooring is installed at right angles to the supports. Allowable uniform live load at maximum span, based on deflection of $^1/_{360}$ of span, is 100 psf, except panels with a span rating of 48 on center are limited to 65 psf total uniform load at maximum span.
l. Allowable live load values at spans of 16" o.c. and 24" o.c taken from reference standard APA E30, APA Engineered Wood Construction Guide. Refer to reference standard for allowable spans not listed in the table.

Figure 14-3 Allowable spans and loads for structural panels for roof and subfloor

Plank and Beam — Post and Beam

These two types of construction aren't the same, even though some people use the terms interchangeably. A plank and beam system has planks covering the beams (5-quarter plywood can be substituted for planks).

Post and beam floors must meet the same general specs as other types of floors. But while other floor types use 2-inch-thick joists on edge and ⅝- or ¾-inch subflooring, post and beam floors use 2-inch-thick planks or decking with heavier beams and greater spans. End-matched lumber has the same requirements. You don't have to position the joints on joists as you would if using plain unmatched planks.

When using the normal 5-quarter or 4-for-1 plywood, check IRC Table R503.2.1.1(1) in Figure 14-3. If you lay these panels with the long edges across the joists, unsupported spans of 48 inches are permitted. But that makes a spongy floor if it has to support heavier loads like a water bed or a piano. Most builders prefer using 32-inch spacing in their floor beams. And the extra cost is minimal.

TABLE R503.2.1.1(2) ALLOWABLE SPANS FOR SANDED PLYWOOD COMBINATION SUBFLOOR UNDERLAYMENT[a]			
	SPACING OF JOISTS (inches)		
IDENTIFICATION	16	20	24
Species group[b]	—	—	—
1	$^1/_2$	$^5/_8$	$^3/_4$
2, 3	$^5/_8$	$^3/_4$	$^7/_8$
4	$^3/_4$	$^7/_8$	1

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 0.0479 kPa.

a. Plywood continuous over two or more spans and face grain perpendicular to supports. Unsupported edges shall be tongue-and-groove or blocked except where nominal $^1/_4$-inch-thick underlayment or $^3/_4$-inch wood finish floor is used. Allowable uniform live load at maximum span based on deflection of $^1/_{360}$ of span is 100 psf.

b. Applicable to all grades of sanded exterior-type plywood.

Figure 14-4 Allowable spans for combination subfloor underlayment

TABLE 1 CLASSIFICATION OF SPECIES, VOLUNTARY PRODUCT STANDARD PS 1-95					
Group 1	Group 2		Group 3	Group 4	Group 5
Apitong[a, b] Beech, American Birch Sweet Yellow Douglas-fir[c] Kapur[a] Keruing[a, b] Larch, Western Maple, Sugar Pine Caribbean Ocote Pine, Southern Loblolly Longleaf Shortleaf Slash Tanoak	Cedar, Port Orford Cypress Douglas-fir[c] Fir Balsam California Red Grand Noble Pacific Silver White Hemlock, Western Lauan Almon Bagtikan Mayapis Red Lauan Tangile White Lauan	Maple, Black Mengkulang[a] Meranti, Red[a, d] Mersawa[a] Pine Pond Red Virginia Western White Spruce Black Red Sitka Sweetgum Tamarack Yellow Poplar	Alder, Red Birch, Paper Cedar, Alaska Fir, Subalpine Hemlock, Eastern Maple, Bigleaf Pine Jack Lodgepole Ponderosa Spruce Redwood Spruce Engelmann White	Aspen Bigtooth Quaking Cativo Cedar Incense Western Red Cottonwood Eastern Black (Western Poplar) Pine Eastern White Sugar	Basswood Poplar, Balsam

(a) Each of these names represents a trade group of woods consisting of a member of closely related species.

(b) Species from the genus Dipterocarpus marked collectively: Apitong if originating in the Philippines, Keruing if originating in Malaysia or Indonesia.

(c) Douglas-fir from trees grown in the states of Washington, Oregon, California, Idaho, Montana, Wyoming, and the Canadian Provinces of Alberta and British Columbia shall be classified as Douglas-fir No. 1. Douglas-fir from trees grown in the states of Nevada, Utah, Colorado, Arizona, and New Mexico shall be classified as Douglas-fir No. 2.

(d) Red Meranti shall be limited to species having a specific gravity of 0.41 or more based on green volume and oven dry weight.

From PS 1-95, Construction and Industrial Plywood, National Institute of Standards and Technology

Figure 14-5 Classification of species

Diaphragms and Framing

If you want stronger framing, nail plywood sheathing to your wood framing. This type of reinforcement is called a wood diaphragm. It's actually any assembly of lumber and plywood designed to resist horizontal and vertical pressures and loads. Some bending or curving is allowable, as long as the diaphragm is still able to support the load or resist the forces without danger to the structure or its occupants.

A diaphragm can be incorporated into the design for roof, floor, or wall framing. You can find the allowable shear capacities needed to design typical wood structural panel diaphragms of plywood, composite, or oriented strand board (OSB) panels in IBC Table 2306.3.1. Diaphragms are designed to resist horizontal or lateral forces from winds or seismic loading. The IBC table also includes drawings of some typical diaphragms.

A diaphragm is lightweight and strong because the framing holds the sheathing flat in the strength plane. But what happens when you need to put a hole in it? Openings in a structural diaphragm for windows, doors, stairs and skylights, have to be constructed to transfer lateral stresses. This is done using framing and mechanical connectors, which transfer stress to other panels around the opening and then to the foundation.

Shear walls are covered in IBC Sections 2305.3.4 through 2305.3.8. There's a dimension ratio (slenderness factor) to consider. IBC Figure 2305.3.5 gives information needed to calculate the shear resistance of a perforated shear wall.

Figure 14-6 shows a perforated shear wall assembly. Oriented strand board (OSB) has been used in place of plywood for the exterior wall and roof sheathing. As you can see in the photograph, proper care wasn't taken when the hold-down straps were cast into the foundation. The hold-down strap under the left side of the window is in the wrong position, and the one on the right has been cast at an angle. Because the straps don't line up with the window framing, an engineer will have to decide what kind of hold-downs must be added. This is one of the most common mistakes caught at inspection.

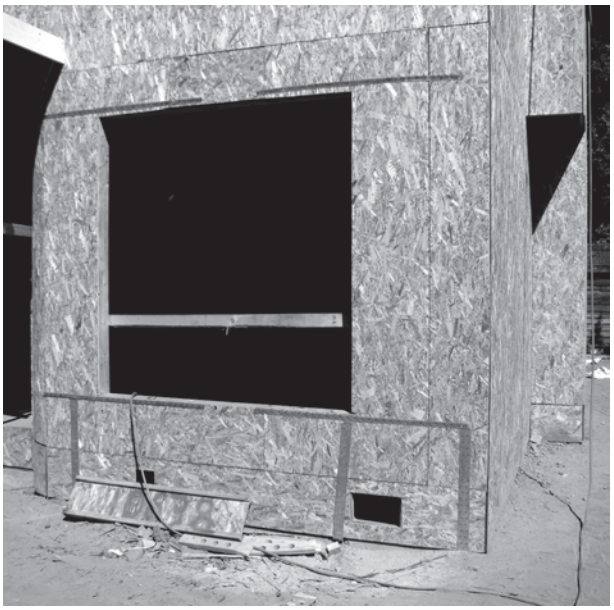


Figure 14-6 Perforated shear wall with OSB sheathing

Framing Walls

After the subfloor is installed, the next step is to get the studding up. Studs (usually 2 x 4s or 2 x 6s) form the building's walls. Siding and wallboard are hung from the studs. The second floor and roof are also supported by wall studs. Studs are an important part of every wood-frame building.

In addition to the lay-out studs, whether they're spaced 16 or 24 inches on center, you must add studs or posts under every concentrated load (point load). Figure 14-7 shows typical framed walls with temporary braces to hold the stud walls straight and plumb until the roof and wall sheathing are installed.

Stud Spacing

Studs supporting floors above them must be spaced 16 inches on center or less. But 2 x 4 studs supporting only a ceiling and a roof can be spaced up to 24 inches on center. You can also use 24-inch spacing for nonbearing interior walls.

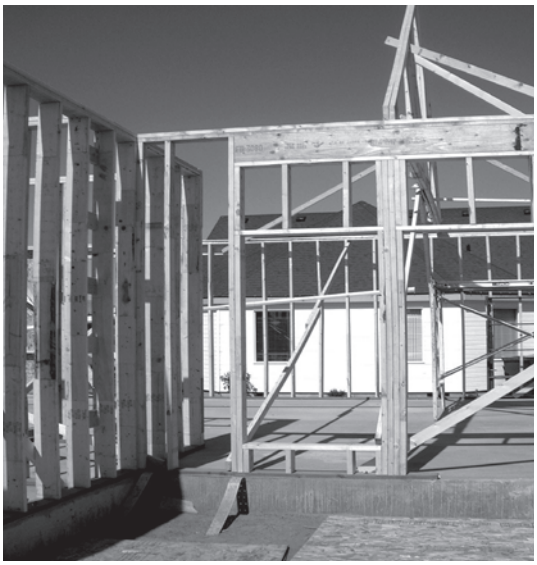


Figure 14-7 Framed stud walls ready for trusses

TABLE R602.3(5)
SIZE, HEIGHT AND SPACING OF WOOD STUDS[a]

STUD SIZE (inches)	BEARING WALLS					NONBEARING WALLS	
	Laterally unsupported stud height[a] (feet)	Maximum spacing when supporting roof and ceiling only (inches)	Maximum spacing when supporting one floor, roof and ceiling (inches)	Maximum spacing when supporting two floors, roof and ceiling (inches)	Maximum spacing when supporting one floor only (inches)	Laterally unsupported stud height[a] (feet)	Maximum spacing (inches)
2 × 3[b]	—	—	—	—	—	10	16
2 × 4	10	24	16	—	24	14	24
3 × 4	10	24	24	16	24	14	24
2 × 5	10	24	24	—	24	16	24
2 × 6	10	24	24	16	24	20	24

For SI: 1 inch = 25.4 mm.

a. Listed heights are distances between points of lateral support placed perpendicular to the plane of the wall. Increases in unsupported height are permitted where justified by analysis.

b. Shall not be used in exterior walls.

Figure 14-8 Size, height and spacing of wood studs

With 24-inch spacing, center the roof trusses directly over the studding. This transfers the vertical roof load directly through the studding to the foundation. Stud size, height and spacing are described in IRC Section R602.3.1 and Table R602.3(5), shown in Figure 14-8. Make sure your carpenters place the studs with the wide dimension of the timber at right angles to the wall.

You can use utility grade studs only under the following conditions:

- You limit your framing to 16-inch spacing.
- Your building has only one story, with just a ceiling and a roof.
- The exterior and other load-bearing walls are 8 feet high or less.

Interior nonbearing walls can use utility grade studs up to 10 feet high.

The maximum stud height covered in R602.3(5) (Figure 14-8) is 10 feet. If you want to use studs higher than that, check Table R602.3.1.

I once inspected a job where exterior stud spacing varied from 10 to 16 inches on center. The interior walls were even worse — the spacing varied up to 24 inches on center. I'd never seen anything like it. But checking my code book, I found that I had to pass the project. The spacing didn't exceed the code maximums. And the codes don't require evenly-spaced studs. I pity the drywall crew on that job. Finding studs to nail the drywall had to be a nightmare.

Top Plates

Wood stud walls are usually capped with a double top plate. See IRC Section R602.3.2 and Figure R602.3(2) (Figure 14-9). Here's more of what Section R602.3.2 says:

- Top plates must be at least 2 inches thick and at least as wide as the studs.
- Individual top plates must overlap at corners and at intersections with bearing partitions.
- End joints in top plates must be offset at least 24 inches.
- Joints in plates don't have to be positioned over studs.

A single top plate can be used in stud walls if the plate is tied at joints, corners and intersecting walls. If you use this method, see the exception to Section R602.3.2 for installation details. Also, there's no need for a top plate over lintels (headers) if the lintel is fastened to the adjacent wall with steel plates, or their equivalent, as described in the exception just noted.

The IRC doesn't require double top plates on nonbearing interior partitions. But since studs are sold in bundles precut to length, many contractors use double plates even on interior partitions. That saves ordering two different sizes of studs for the job.

Wall Bracing

All exterior walls must be braced. The easiest way to accomplish this is to simply place plywood panels at each corner. Another method uses a 1- x 4-inch brace notched into (let-in) the studs. This angle brace runs from the bottom plate to the top plate at an angle between 45 and 60 degrees. The full description is given in IRC Section R602.10.3, Item 1. The illustration in the bottom left of Figure 14-9 shows you the placement of the 1 x 4, but doesn't show the actual let-in.

Today's homes are complex and complicated to build. They're not simple boxes with four walls any more. They have many different wall lines, angles and offsets. IRC Section R602.10.3 has eight alternative materials and methods of bracing. But before you buy any material, check with the inspector to make sure it's acceptable. Verify that your brand has been approved and find out how it should be installed. Table R602.10.1 tells you how much bracing you'll need, and where you'll need it, based on your seismic or wind speed category. The IRC even tells you how many nails to use — see Tables R602.3(1) and R602.3(2).

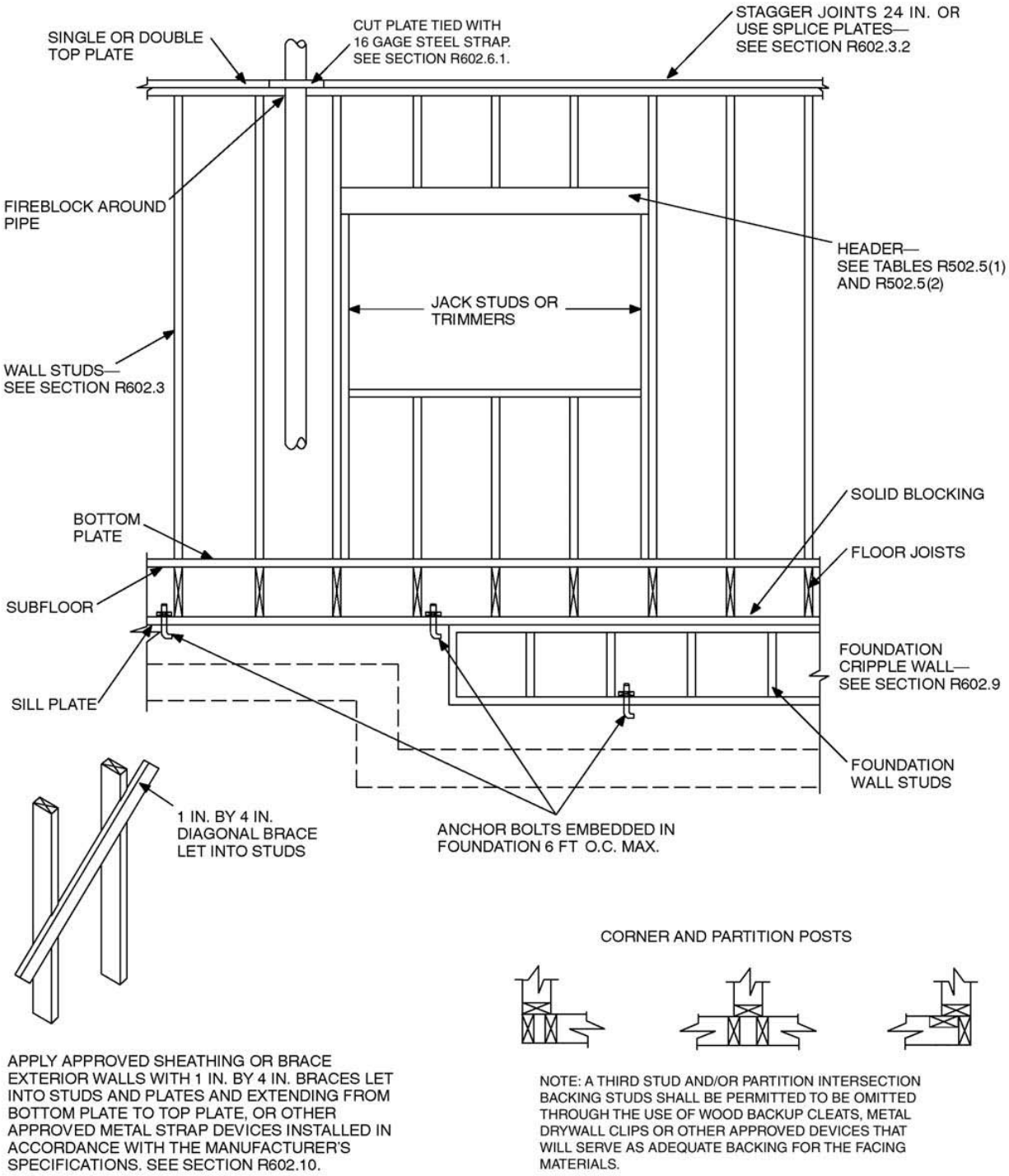
Most modern houses use mechanical hold-down hardware and steel straps to complete the frame bracing and shear flow path. Figure 14-10 shows a building with plywood sheathing and galvanized steel strap shear connections.

All Openings

It used to be easy to know the right headers to use for wall openings. If you were only supporting a roof, openings 4 feet or less needed double 2 x 4s, on edge. For each additional 2 feet of opening over 4 feet, you had to increase the lumber size by 2 inches. In other words, you could use two 2 x 4s over a 4-foot opening, two 2 x 6s over a 6-foot opening, two 2 x 8s over an 8-foot opening, and so on. This is still true most of the time, but check IRC Table R502.5(1) for exterior walls and Table R502.5(2) for interior walls to make sure you're meeting the code.

IRC Section R602.7.1 tells you that wood structural panel (usually plywood or OSB) box headers must be built to meet Table R602.7.2 (Figure 14-11) and Figure R602.7.2 (Figure 14-12) requirements.

FIGURE R602.3(2)
FRAMING DETAILS



For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

Figure 14-9 Framing details

Figure 14-10 Plywood siding with galvanized steel strap shear connections

TABLE R602.7.2
MAXIMUM SPANS FOR WOOD STRUCTURAL PANEL BOX HEADERS[a]

HEADER CONSTRUCTION[b]	HEADER DEPTH (inches)	HOUSE DEPTH (feet)				
		24	26	28	30	32
Wood structural panel—one side	9	4	4	3	3	—
	15	5	5	4	3	3
Wood structural panel—both sides	9	7	5	5	4	3
	15	8	8	7	7	6

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.
a. Spans are based on single story with clear-span trussed roof or two-story with floor and roof supported by interior-bearing walls.
b. See Figure R602.7.2 for construction details.

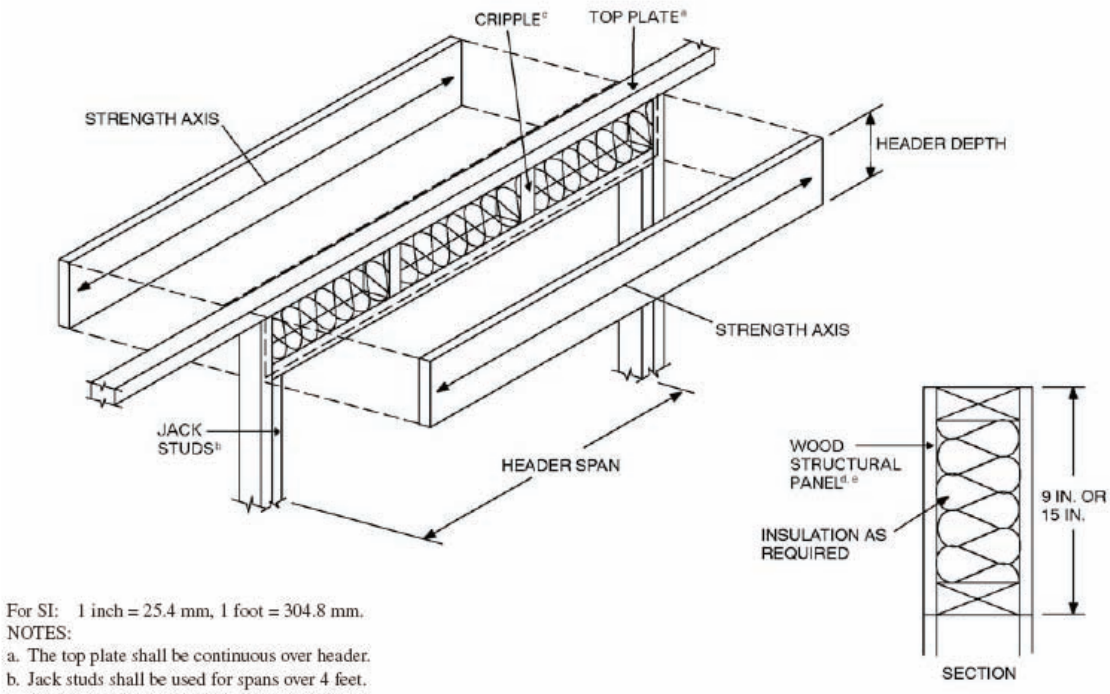
Figure 14-11 Maximum spans for wood headers

You don't have to use a load-bearing header for either interior or exterior nonbearing walls. You can use a single 2 x 4 for all openings up to 8 feet. But the vertical distance to the parallel nailing surface above can't be more than 24 inches (IRC Section R602.7.2). In this case, you don't need any cripples or blocking above the header.

Cripples and Cripple Walls

When you frame window openings, you'll usually insert short studs (called cripples) under the lower side of the opening. Cripples double up the stud where the lower framing cross member touches the studs at the sides of the opening. This gives extra support to that

FIGURE R602.7.2
TYPICAL WOOD STRUCTURAL PANEL BOX HEADER CONSTRUCTION



For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.
NOTES:
a. The top plate shall be continuous over header.
b. Jack studs shall be used for spans over 4 feet.
c. Cripple spacing shall be the same as for studs.
d. Wood structural panel faces shall be single pieces of $^{15}/_{32}$-inch-thick Exposure 1 (exterior glue) or thicker, installed on the interior or exterior or both sides of the header.
e. Wood structural panel faces shall be nailed to framing and cripples with 8d common or galvanized box nails spaced 3 inches on center, staggering alternate nails $^{1}/_{2}$ inch. Galvanized nails shall be hot-dipped or tumbled.

Figure 14-12 Typical wood structural header construction

member. Even though the IRC doesn't always require it, I recommend using cripples. There's nothing wrong with having a stronger wall. Or you can double-stud the sides of the opening with jack studs or trimmers, as shown in Figure R602.3(2) (Figure 14-9 earlier in this chapter).

IRC Section R602.9 gives more information on cripple walls:

- Foundation cripple walls must be framed with studs at least the size of the studding above.
- Foundation cripple walls higher than 4 feet must be framed with studs sized for an additional story.
- Cripple walls with stud height less than 14 inches must be sheathed on at least one side.
- Cripple walls can be constructed with solid blocking.
- Cripple walls must be supported on a continuous foundation.

Fireblocking

Fireblocking is defined in IRC Section R202, as ... *Building materials installed to resist the free passage of flame to other areas of the building through concealed spaces.*

Fireblocks are installed between studs to form a barrier to air, smoke and flame movement in the framing and between floors. Most framing has enough fire stops without adding any extra blocks. But there are a few areas, such as those described in IRC Section R602.8, which might need additional fireblocks.

R602.8 Fireblocking required. *Fireblocking shall be provided to cut off all concealed draft openings (both vertical and horizontal) and to form an effective fire barrier between stories, and between a top story and the roof space. Fireblocking shall be provided in wood-frame construction in the following locations.*

1. *In concealed spaces of stud walls and partitions, including furred spaces and parallel rows of studs or staggered studs; as follows:*
   - *1.1. Vertically at the ceiling and floor levels.*
   - *1.2. Horizontally at intervals not exceeding 10 feet (3048 mm).*
2. *At all interconnections between concealed vertical and horizontal spaces such as occur at soffits, drop ceilings and cove ceilings.*
3. *In concealed spaces between stair stringers at the top and bottom of the run. Enclosed spaces under stairs shall comply with Section R311.2.2.*
4. *At openings around vents, pipes, ducts, cables and wires at ceiling and floor level, with an approved material to resist the free passage of flame and products of combustion.* [See the callout for fireblocking around the pipe in the upper left hand corner of IRC Figure R602.3(2) (Figure 14-9)].
5. *For the fireblocking of chimneys and fireplaces, see Section R1003.19.*
6. *Fireblocking of cornices of a two-family dwelling is required at the line of dwelling unit separation.*

You'll find acceptable fireblocking materials listed in IRC Section R602.8.1. Here are some of them:

- Wood panel
- Particleboard
- Gypsum board
- Millboard
- Mineral wood
- Glass fiber batts or blankets

Loose-fill insulation material is prohibited. However, if it passes a test specifically for the form and manner in which it's used, an exception will be granted.

The requirements for chimney fireblocking, mentioned in Item 5 above, are given in IRC Section R1003.19:

R1003.19 Chimney fireblocking. *All spaces between chimneys and floors and ceilings through which chimneys pass shall be fireblocked with noncombustible material securely fastened in place. The fireblocking of spaces between chimneys and wood joists, beams or headers shall be self-supporting or be placed on strips of metal or metal lath laid across the spaces between combustible material and the chimney.*

Drilling and Notching

When your framing is in place you may need to drill it or notch it to pass wiring or piping through the framing members for electrical and plumbing runs. The size and location of holes and notches must be strictly limited so that the framing isn't weakened.

Studs

Drilling and notching studs is permitted by the code, but only under certain conditions. Here's what IRC Section R602.6 says:

R602.6 Drilling and notching — studs. *Drilling and notching of studs shall be in accordance with the following:*

1. *Notching. Any stud in an exterior wall or bearing partition may be cut or notched to a depth not exceeding 25 percent of its width. Studs in nonbearing partitions may be notched to a depth not to exceed 40 percent of a single stud width.*
2. *Drilling. Any stud may be bored or drilled, provided that the diameter of the resulting hole is no more than 60 percent of the stud width, the edge*

FIGURE R602.6(1)
NOTCHING AND BORED HOLE LIMITATIONS FOR EXTERIOR WALLS AND BEARING WALLS

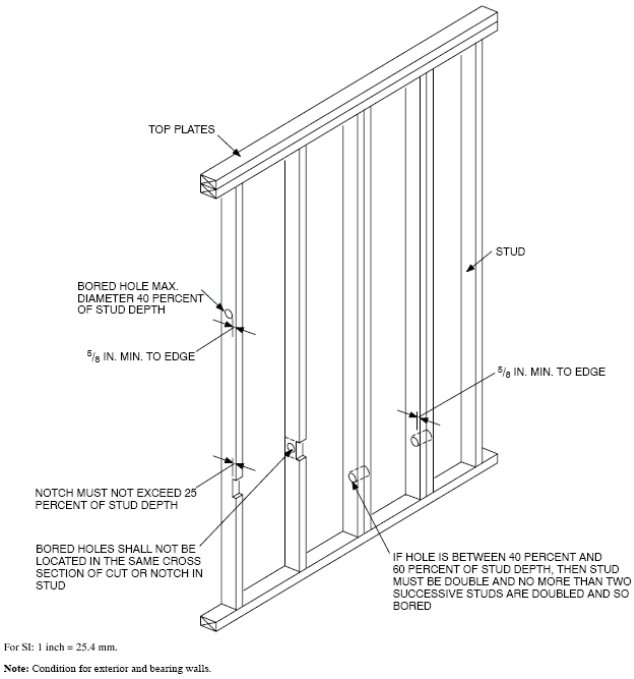


Figure14-13 Hole limitations for exterior walls and bearing walls

FIGURE R602.6(2)
NOTCHING AND BORED HOLE LIMITATIONS FOR INTERIOR NONBEARING WALLS

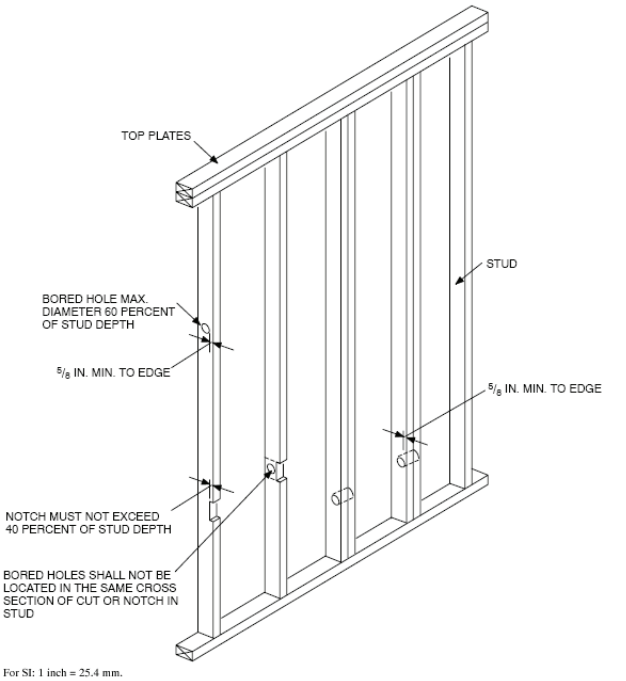


Figure 14-14 Hole limitations for interior nonbearing walls

> *of the hole is no more than ⅝ inch (16 mm) to the edge of the stud, and the hole is not located in the same section as a cut or notch. Studs located in exterior walls or bearing partitions drilled over 40 percent and up to 60 percent shall also be doubled with no more than two successive doubled studs bored. See Figures R602.6(1)* (Figure 14-13) *and R602.6(2)* (Figure 14-14).

There's an exception to Section R602.6 that allows the use of stud shoes (manufactured shaped reinforcing brackets) if they're installed according to the manufacturer's instructions. Figure 14-15 shows an example of where you might use stud shoes to correct a problem with over-drilled studs. The king stud and cripples have been drilled for plumbing vent pipes, hot and cold water supply, and electric wiring — and clearly no longer meet the requirements of Section R602.6. Problems like this are commonly seen at kitchen window framing. This wall should have had 2 x 6 framing. The steel plates for nail protection that you see in Figure 14-15 will have to be replaced with stud shoes that wrap

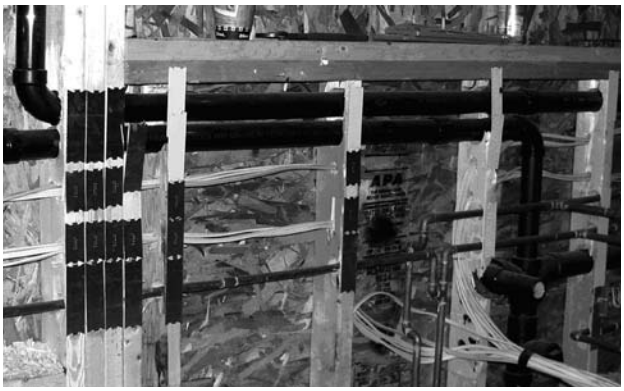
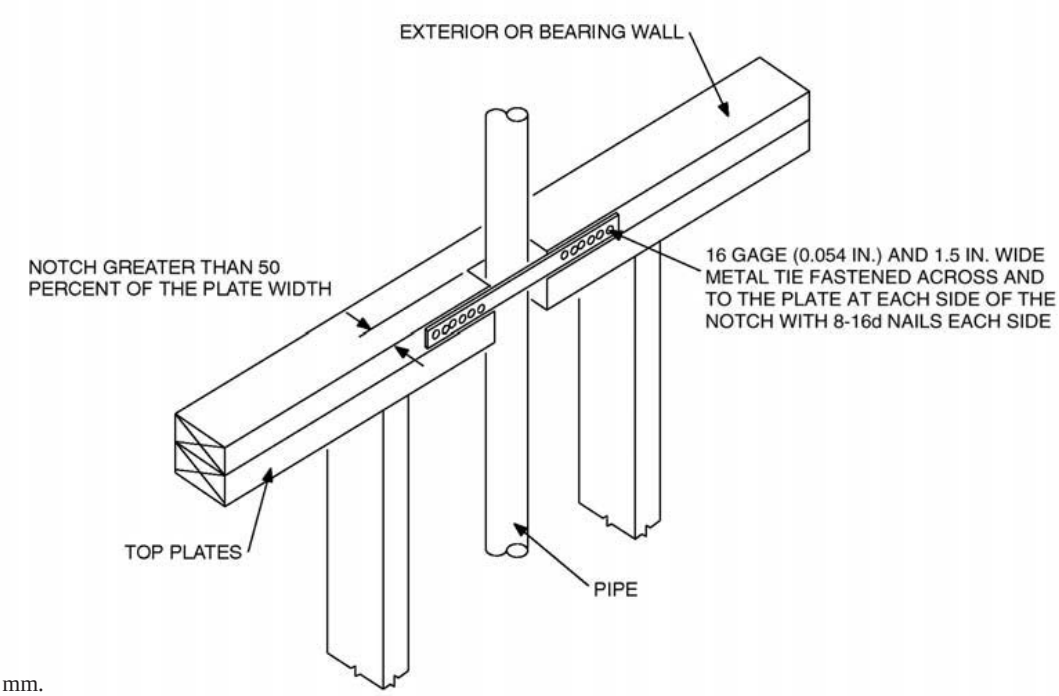


Figure 14-15 Example of noncompliant stud drilling

FIGURE R602.6.1
TOP PLATE FRAMING TO ACCOMMODATE PIPING



For SI: 1 inch = 25.4 mm.

Figure 14-16 Top plate framing to accommodate piping

the face and sides of the over-drilled studs. The pipes will also need to be rearranged because stud shoes are only intended to wrap one pipe. Another solution to this problem would be to replace these studs, then reroute the plumbing pipes around the studs and conceal them in a cabinet.

The most important information you need to know about drilling and notching is how much is allowed, and where!

Top Plates

Wall top plates give a wall strength and continuity and tie the building together. They can be drilled and notched provided you comply with IRC Section 602.6.1.

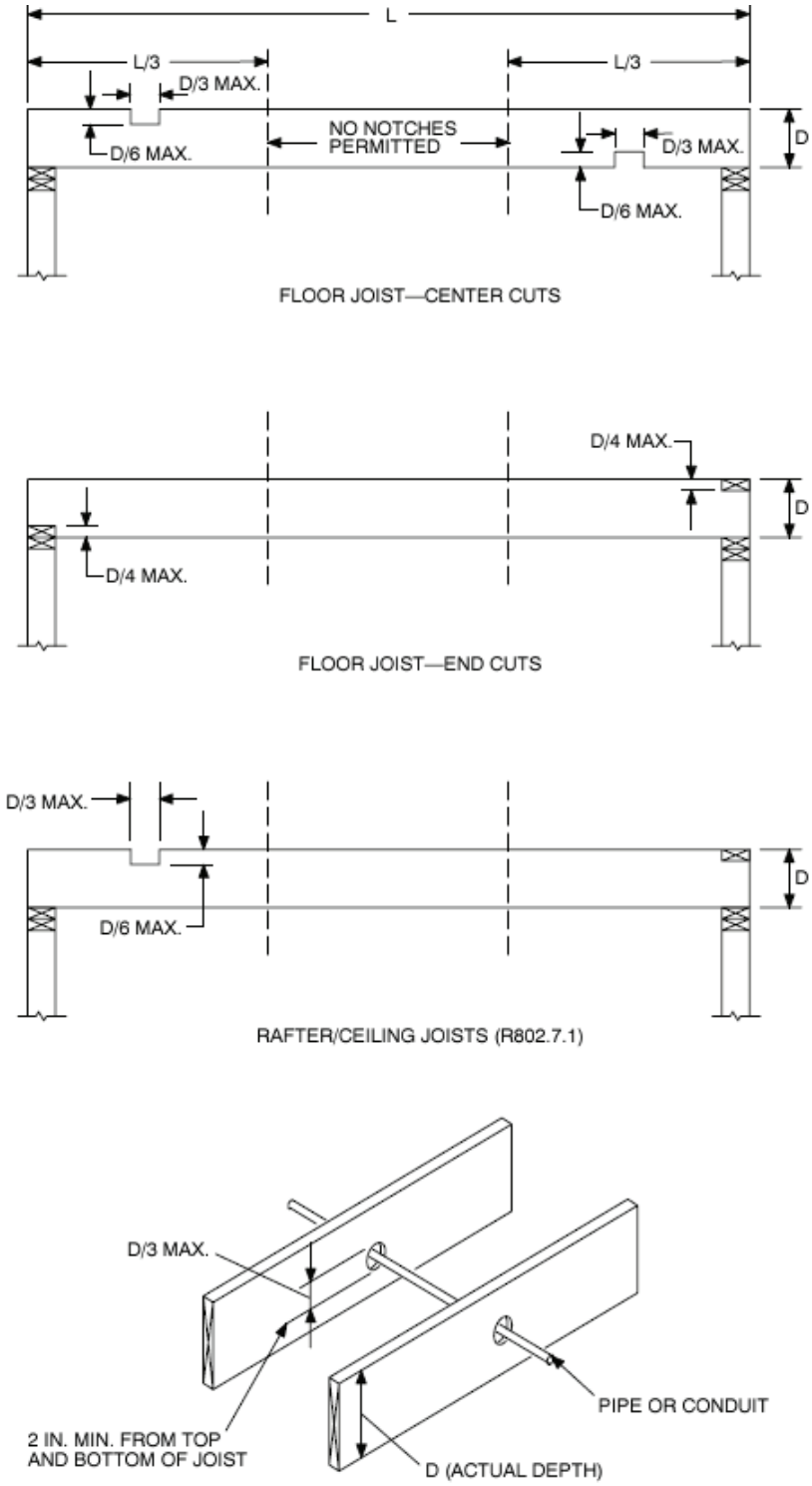
> ***R602.6.1 Drilling and notching of top plate.*** *When piping or ductwork is placed in or partly in an exterior wall or interior load-bearing wall, necessitating cutting, drilling or notching of the top plate by more than 50 percent of its width, a galvanized metal tie of not less than 0.054 inch thick (1.37 mm) (16 ga) and 1½ inches (38 mm) wide shall be fastened across and to the plate at each side of the opening with not less than eight 16d nails at each side or equivalent. See Figure R602.6.1 (Figure 14-16).*

There's an exception that allows you to omit the galvanized metal tie when drilling or notching an exterior wall or an interior shear wall with panel sheathing. In this case, the sheathing holds it all together.

Beams and Joists

Drilling and notching of beams and joists is permitted only under certain conditions. IRC Section R502.8 and Figure R502.8 (Figure 14-17) give the following requirements for notching and boring joists, rafters and beams.

FIGURE R502.8
CUTTING, NOTCHING AND DRILLING



For **SI:** 1 inch = 25.4 mm.

Figure 14-17 Cutting, notching and drilling

Notches in solid lumber joists, rafters and beams must *never* be:

- Deeper than one-sixth the depth of the joist, or one-quarter the depth, if at the ends of the joist;
- Longer than one-third the depth of the joist;
- Cut in the middle third of the span;
- Cut in the tension side of the joist if the joist is thicker than 4 inches, except at the ends of the joist.

Holes bored in solid lumber joists, rafters and beams must not be larger than one-third the depth of the member. Nor may they be closer than 2 inches to the top or bottom of the member, to any other hole, or to any notch.

In most cases, engineered wood products like *trusses, laminated veneer lumber, glued-laminated members or I-joists* can't be cut, notched or drilled. The only exception is if it's permitted by the manufacturer or designed into the plan by a professional engineer.

What do you think a plumber will do if he needs to install a bathroom pipe where a joist exists? He'll get out his saw and make a few alterations! Plumbers have been known to cut away any framing that's in their way, especially in bathrooms. The next thing you know, the inspector is knocking on your door. He'll want you to fix the problem by installing a header. By this time, the pipes are already in place and the plumber is off on another job. Adding a header at this point isn't exactly easy.

Of course, a good framer would have seen the problem and solved it before the plumber even arrived. Just beginning the joist layout from the other side of the foundation might have worked. In most cases, the problem boils down to lack of experience and supervision. If your framer isn't experienced, go over the layout in detail before he cuts any lumber. Show him exactly where pipe chases and cutouts should be, and how to header them. This is why most bathroom walls with pipe are framed with 2 x 6s — to allow room for the hub of the pipe.

When it comes down to it, the owner is the one responsible for choosing a good general contractor. The general contractor has to find good subcontractors. And the subs have to hire people who can do the work right. Make sure you fulfill your obligation in this chain of command.

Figure 14-18 Pipes through stud blocking

What Should You Do About Holes?

We've talked about cutting holes in joists for pipe, conduit, or wires — but there's more to it than that. We need to discuss size. Holes should be a little bigger than the size of the pipe or conduit that will go through them. That helps the wire-puller or the plumber install the pipe. Help is good, but if the holes are too big, they can create a fire hazard by allowing a space where fire can spread. See IRC Section R602.8, Item 4, regarding fireblocks at both ceiling and floor level.

> ***Section R602.8. Fireblocking required.*** *...Fireblocking shall be provided in wood-frame construction in the following locations.*
>
> > *4. At openings around vents, pipes, ducts, cables and wires at ceiling and floor level, with an approved material to resist the free passage of flame and products of combustion.*

Figure 14-18 shows pipes running through stud blocking. There's approximately ⅝ inch from the edge of the block to the edge of the hole and the galvanized plates on the edge of the

blocking. Remember, the edge of the bored hole can't be closer than ⅝ inch from the edge of the stud, and if there's already a cut or a notch in a section of stud, you can't bore another.

Practice preventive construction. The ⅛-inch plate and the ⅝-inch setback from the edge serve a purpose. They keep sheetrock nails and screws from puncturing the water lines. Obviously, this is important. If a nail or screw tip punctures a water line, it might not show up right away. But normal vibration and shrinkage after a couple of months can loosen the nail in the hole. Then you have a leak that's hard to find and expensive to repair. It could do a lot of damage before it's found and fixed.

Exterior Covering

Before you install an exterior veneer to your framed building, IRC Section R703.1 says you must apply a weather-resistant barrier.

Weather-Resistive Barriers

> ***R703.1 General.*** *Exterior walls shall provide the building with a weather-resistant exterior wall envelope. The exterior wall envelope shall include flashing as described in Section R703.8. The exterior wall envelope shall be designed and constructed in such a manner as to prevent the accumulation of water within the wall assembly by providing a water-resistant barrier behind the exterior veneer as required by Section R703.2 and a means of draining water that enters the assembly to the exterior. Protection against condensation in the exterior wall assembly shall be provided in accordance with Chapter 11 of this code.*

You'll need to hang a layer of No. 15 asphalt felt, or another approved water-resistive barrier, over studs or wood base sheathing. Section R703.2 says the water-resistive barrier must be:

- In compliance with ASTM D 226 for Type 1 felt (ASTM D 226, Standard Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing, is available at www.astm.org);
- Free from holes and breaks;
- Applied horizontally, with the upper layer lapped over the lower layer by at least 2 inches;
- Lapped at least 6 inches where joints occur;
- Continuous to the top of walls;
- Terminated at penetrations and building appendages so as to meet the requirements of Section R703.1 above.

You don't need the water-resistant barrier:

- Over masonry or concrete walls designed to comply with IRC Chapter 6, and flashed as required in IRC Sections R703.7 or R703.8;
- For detached accessory buildings with no human occupancy;
- Under paper-backed stucco lath, if the paper backing is approved weather-resistive sheathing paper;
- Under masonry veneer over wood sheathing, if a 1-inch air space is provided between the veneer and the sheathing. But if the 1-inch space is filled with mortar, a water-resistant barrier is required. See note "l" in Table R703.4 (Figure 14-19).

There are many changes to Table R703.4 in the 2006 IRC, especially in column 4, requirements for a *Water-Resistive Barrier*. So look over the table closely.

Siding

There are many different siding materials now available, as you can see in IRC Table R703.4 (Figure 14-19). This table also shows:

- The minimum thicknesses allowed
- Whether or not a water-resistant barrier is required
- The type of support material and fasteners needed

Make sure you read Note "a." It tells you that the nominal thicknesses of siding materials are based on stud spacing 16 inches on center. Remember, the IRC now allows the maximum

TABLE R703.4
WEATHER-RESISTANT SIDING ATTACHMENT AND MINIMUM THICKNESS

SIDING MATERIAL		NOMINAL THICKNES[a] (inches)	JOINT TREATMENT	WATER-RESISTIVE BARRIER REQUIRED	TYPE OF SUPPORTS FOR THE SIDING MATERIAL AND FASTENERS[b,c,d]					
					Wood or wood structural panel sheathing	Fiberboard sheathing into stud	Gypsum sheathing into stud	Foam plastic sheathing into stud	Direct to studs	Number or spacing of fasteners
Horizontal aluminum[e]	Without insulation	0.019[f]	Lap	Yes	0.120 nail $1\frac{1}{2}''$ long	0.120 nail $2''$ long	0.120 nail $2''$ long	0.120 nail[y]	Not allowed	Same as stud spacing
		0.024	Lap	Yes	0.120 nail $1\frac{1}{2}''$ long	0.120 nail $2''$ long	0.120 nail $2''$ long	0.120 nail[y]	Not allowed	
	With insulation	0.019	Lap	Yes	0.120 nail $1\frac{1}{2}''$ long	0.120 nail $2\frac{1}{2}''$ long	0.120 nail $2\frac{1}{2}''$ long	0.120 nail[y]	0.120 nail $1\frac{1}{2}''$ long	
Brick veneer[z] Concrete masonry veneer[z]		2 2	Section R703	Yes (Note l)	See Section R703 and Figure R703.7[g]					
Hardboard[k] Panel siding-vertical		$\frac{7}{16}$	—	Yes	Note n	Note n	Note n	Note n	Note n	$6''$ panel edges $12''$ inter. sup.[o]
Hardboard[k] Lap-siding-horizontal		$\frac{7}{16}$	Note q	Yes	Note p	Note p	Note p	Note p	Note p	Same as stud spacing 2 per bearing
Steel[h]		29 ga.	Lap	Yes	0.113 nail $1\frac{3}{4}''$ Staple–$1\frac{3}{4}''$	0.113 nail $2\frac{3}{4}''$ Staple–$2\frac{1}{2}''$	0.113 nail $2\frac{1}{2}''$ Staple–$2\frac{1}{4}''$	0.113 nail[y] Staple[y]	Not allowed	Same as stud spacing
Stone veneer		2	Section R703	Yes (Note l)	See Section R703 and Figure R703.7[g]					
Particleboard panels		$\frac{3}{8}$ – $\frac{1}{2}$	—	Yes	6d box nail ($2'' \times 0.099''$)	6d box nail ($2'' \times 0.099''$)	6d box nail ($2'' \times 0.099''$)	box nail[y]	6d box nail ($2'' \times 0.099''$), $\frac{3}{8}$ not allowed	$6''$ panel edge, $12''$ inter. sup.
		$\frac{5}{8}$	—	Yes	6d box nail ($2'' \times 0.099''$)	8d box nail ($2\frac{1}{2}'' \times 0.113''$)	8d box nail ($2\frac{1}{2}'' \times 0.113''$)	box nail[y]	6d box nail ($2'' \times 0.099''$)	
Plywood panel[i] (exterior grade)		$\frac{3}{8}$	—	Yes	0.099 nail–$2''$	0.113 nail–$2\frac{1}{2}''$	0.099 nail–$2''$	0.113 nail[y]	0.099 nail–$2''$	$6''$ on edges, $12''$ inter. sup.
Vinyl siding[m]		0.035	Lap	Yes	0.120 nail $1\frac{1}{2}''$ Staple–$1\frac{3}{4}''$	0.120 nail $2''$ Staple–$2\frac{1}{2}''$	0.120 nail $2''$ Staple–$2\frac{1}{2}''$	0.120 nail[y] Staple[y]	Not allowed	Same as stud spacing
Wood[j] rustic, drop		$\frac{3}{8}$ Min	Lap	Yes	Fastener penetration into stud–$1''$				0.113 nail–$2\frac{1}{2}''$ Staple–$2''$	Face nailing up to $6''$ widths, 1 nail per bearing; $8''$ widths and over, 2 nails per bearing
Shiplap		$\frac{19}{32}$ Average	Lap	Yes						
Bevel		$\frac{7}{16}$								
Butt tip		$\frac{3}{16}$	Lap	Yes						
Fiber cement panel siding[r]		$\frac{5}{16}$	Note s	Yes Note x	6d corrosion-resistant nail[t]	6d corrosion-resistant nail[t]	6d corrosion-resistant nail[t]	6d corrosion-resistant nail[t, y]	4d corrosion-resistant nail[u]	$6''$ o.c. on edges, $12''$ o.c. on intermed. studs
Fiber cement lap siding[r]		$\frac{5}{16}$	Note v	Yes Note x	6d corrosion-resistant nail[t]	6d corrosion-resistant nail[t]	6d corrosion-resistant nail[t]	6d corrosion-resistant nail[t, y]	6d corrosion-resistant nail[w]	Note w

For SI: 1 inch = 25.4 mm.

a. Based on stud spacing of 16 inches on center where studs are spaced 24 inches, siding shall be applied to sheathing approved for that spacing.
b. Nail is a general description and shall be T-head, modified round head, or round head with smooth or deformed shanks.
c. Staples shall have a minimum crown width of $\frac{7}{16}$-inch outside diameter and be manufactured of minimum 16 gage wire.
d. Nails or staples shall be aluminum, galvanized, or rust-preventative coated and shall be driven into the studs for fiberboard or gypsum backing.
e. Aluminum nails shall be used to attach aluminum siding.
f. Aluminum (0.019 inch) shall be unbacked only when the maximum panel width is 10 inches and the maximum flat area is 8 inches. The tolerance for aluminum siding shall be +0.002 inch of the nominal dimension.
g. All attachments shall be coated with a corrosion-resistant coating.
h. Shall be of approved type.

(continued)

Figure 14-19 Weather-resistant siding attachment

Footnotes to Table R703.4—continued

i. Three-eighths-inch plywood shall not be applied directly to studs spaced more than 16 inches on center when long dimension is parallel to studs. Plywood $^1/_2$-inch or thinner shall not be applied directly to studs spaced more than 24 inches on center. The stud spacing shall not exceed the panel span rating provided by the manufacturer unless the panels are installed with the face grain perpendicular to the studs or over sheathing approved for that stud spacing.
j. Wood board sidings applied vertically shall be nailed to horizontal nailing strips or blocking set 24 inches on center. Nails shall penetrate $1^1/_2$ inches into studs, studs and wood sheathing combined, or blocking. A weather-resistive membrane shall be installed weatherboard fashion under the vertical siding unless the siding boards are lapped or battens are used.
k. Hardboard siding shall comply with AHA A135.6.
l. For masonry veneer, a weather-resistive sheathing paper is not required over a sheathing that performs as a weather-resistive barrier when a 1-inch air space is provided between the veneer and the sheathing. When the 1-inch space is filled with mortar, a weather-resistive sheathing paper is required over studs or sheathing.
m. Vinyl siding shall comply with ASTM D 3679.
n. Minimum shank diameter of 0.092 inch, minimum head diameter of 0.225 inch, and nail length must accommodate sheathing and penetrate framing $1^1/_2$ inches.
o. When used to resist shear forces, the spacing must be 4 inches at panel edges and 8 inches on interior supports.
p. Minimum shank diameter of 0.099 inch, minimum head diameter of 0.240 inch, and nail length must accommodate sheathing and penetrate framing $1^1/_2$ inches.
q. Vertical end joints shall occur at studs and shall be covered with a joint cover or shall be caulked.
r. Fiber cement siding shall comply with the requirements of ASTM C 1186.
s. See Section R703.10.1.
t. Minimum 0.102″ smooth shank, 0.255″ round head.
u. Minimum 0.099″ smooth shank, 0.250″ round head.
v. See Section R703.10.2.
w. Face nailing: 2 nails at each stud. Concealed nailing: one 11 gage $1^1/_2$ galv. roofing nail (0.371″ head diameter, 0.120″ shank) or 6d galv. box nail at each stud.
x. See Section R703.2 exceptions.
y. Minimum nail length must accommodate sheathing and penetrate framing $1^1/_2$ inches.
z. Adhered masonry veneer shall comply with the requirements in Sections 6.1 and 6.3 of ACI 530/ASCE 5/TMS-402.

Figure 14-19 Weather-resistant siding attachment (continued)

TABLE R602.3(3)
WOOD STRUCTURAL PANEL WALL SHEATHING

PANEL SPAN RATING	PANEL NOMINAL THICKNESS (inch)	MAXIMUM STUD SPACING (inches)	
		Siding nailed to:[a]	
		Stud	Sheathing
12/0, 16/0, 20/0, or wall —16 o.c.	$^5/_{16}$, $^3/_8$	16	16[b]
24/0, 24/16, 32/16 or wall—24 o.c.	$^3/_8$, $^7/_{16}$, $^{15}/_{32}$, $^1/_2$	24	24[c]

For SI: 1 inch = 25.4 mm.
a. Blocking of horizontal joints shall not be required.
b. Plywood sheathing $^3/_8$-inch thick or less shall be applied with long dimension across studs.
c. Three-ply plywood panels shall be applied with long dimension across studs.

Figure 14-20 Wood structural panel wall sheathing

stud spacing to be 24 inches for single-story exterior walls. If you do use 24-inch stud spacing, you might need to use thicker sheathing underneath the siding. It depends on the panel span rating in the first column of IRC Table R602.3(3) (Figure 14-20).

Details for various types of siding are given in the following IRC sections:

- Wood, hardboard and wood structural panel siding, Section R703.3
- Wood shakes and shingles, Section R703.5
- Exterior plaster, Section R703.6
- Stone and masonry veneer, general, Section R703.7
- Fiber cement siding, Section R703.10
- Vinyl siding, Section R703.11

Bevel Siding

Bevel siding must be at least $^7/_{16}$ inch thick on the butt and $^3/_{16}$ inch thick on the tip. You might be able to use thinner siding, so check with your local inspector.

Unless you're putting the siding over sheathing, joints must fall over the framing members. They must be covered with a continuous wood batt, lapped horizontally. You can waterproof it some other way, like with caulking or flashing, as long as the inspector is satisfied.

Shingle or Shake Siding

There are strict requirements for wood shake and wood shingle siding. These types of siding aren't very popular today because of their flammable reputation. You can find the full details for their grading rules, attachment and weather exposure in IRC R703.5.

Shingles or shakes — whether they're made of wood, asbestos cement or other approved materials — have their own set of rules. They can be applied over:

- Wood sheathing
- Furring strips over non-wood sheathing
- Approved fiberboard shingle backer

If fiberboard backing is used, the shingles or shakes must be attached with corrosion-resistant annular grooved nails.

Aluminum Siding

What about aluminum siding? There's not much about it in the IRC, even though it's lightweight and maintenance-free. The only mentions in the IRC are in notes "e" and "f" of Table R703.4 (Figure 14-19), which say that:

- Aluminum siding can be applied unbacked only when the maximum panel width is 10 inches and the maximum flat area is 8 inches;
- The thickness tolerance for 0.019- and 0.024-inch aluminum siding is +0.002 inch, -0.00 inch;
- Aluminum nails must be used to attach aluminum siding.

IBC Section 1404.5.1 adds that aluminum siding must conform to the American Architectural Manufacturer Association standard, AAMA 1402, Standard Specifications for Aluminum Siding, Soffit and Fascia. You can buy a copy of the standard from the AAMA website at www.aamanet.org.

Siding Attachment

IRC Section R703.4 says that all wall coverings must be securely fastened. Table R703.4 (Figure 14-19) gives the details. What's most important is that the fasteners are approved and corrosion-resistant.

All weatherboarding or siding must be nailed securely to each stud. Use at least one nail every 6 inches on the edges, and every 12 inches on the field. For conventional siding, there should be at least one nail per stud. Conventional siding installed over 1-inch nominal sheathing or ½-inch plywood sheathing must be fastened with nails spaced not more than 24 inches on center in each piece.

Fastening Requirements

General fastening requirements for most carpentry joints used in residential construction are given in IRC Table R602.3(1) (Figure 14-21).

Nails

Table R602.3(1) also spells out the spacing for nails. If you have to bore holes for nails to prevent splitting, make the hole much smaller in diameter than the nail you'll use, or the amount of grip you'll end up with will be just about worthless.

Notice the length and diameter of the fasteners in parenthesis in the middle column of the table. Now, besides the traditional box or common *penny weight*, the physical properties of the fasteners are listed to show equivalence with most popular gun nails for your pneumatic (air) nail gun.

Staples

Staples are popular with many tradesmen. They make the work easier and save time, as well as being very effective. Automatic nailers are also fast and efficient. If there's a problem with a nailer or a staple gun, it's usually the operator's fault. (No matter how well a tool is designed and built, there's always someone who can foul it up!)

TABLE R602.3(1) FASTENER SCHEDULE FOR STRUCTURAL MEMBERS		
DESCRIPTION OF BUILDING ELEMENTS	NUMBER AND TYPE OF FASTENER[a,b,c]	SPACING OF FASTENERS
Joist to sill or girder, toe nail	3-8d (2-$^1/_2$″ × 0.113″)	—
1″ × 6″ subfloor or less to each joist, face nail	2-8d (2$^1/_2$″ × 0.113″) 2 staples, 1$^3/_4$″	— —
2″ subfloor to joist or girder, blind and face nail	2-16d (3$^1/_2$″ × 0.135″)	—
Sole plate to joist or blocking, face nail	16d (3$^1/_2$″ × 0.135″)	16″ o.c.
Top or sole plate to stud, end nail	2-16d (3$^1/_2$″ × 0.135″)	—
Stud to sole plate, toe nail	3-8d (2$^1/_2$″ × 0.113″) or 2-16d (3$^1/_2$″ × 0.135″)	—
Double studs, face nail	10d (3″ × 0.128″)	24″ o.c.
Double top plates, face nail	10d (3″ × 0.128″)	24″ o.c.
Sole plate to joist or blocking at braced wall panels	3-16d (3$^1/_2$″ × 0.135″)	16″ o.c.
Double top plates, minimum 24-inch offset of end joints, face nail in lapped area	8-16d (3$^1/_2$″ × 0.135″)	—
Blocking between joists or rafters to top plate, toe nail	3-8d (2$^1/_2$″ × 0.113″)	—
Rim joist to top plate, toe nail	8d (2$^1/_2$″ × 0.113″)	6″ o.c.
Top plates, laps at corners and intersections, face nail	2-10d (3″ × 0.128″)	—
Built-up header, two pieces with $^1/_2$″ spacer	16d (3$^1/_2$″ × 0.135″)	16″ o.c. along each edge
Continued header, two pieces	16d (3$^1/_2$″ × 0.135″)	16″ o.c. along each edge
Ceiling joists to plate, toe nail	3-8d (2$^1/_2$″ × 0.113″)	—
Continuous header to stud, toe nail	4-8d (2$^1/_2$″ × 0.113″)	—
Ceiling joist, laps over partitions, face nail	3-10d (3″ × 0.128″)	—
Ceiling joist to parallel rafters, face nail	3-10d (3″ × 0.128″)	—
Rafter to plate, toe nail	2-16d (3$^1/_2$″ × 0.135″)	—
1″ brace to each stud and plate, face nail	2-8d (2$^1/_2$″ × 0.113″) 2 staples, 1$^3/_4$″	— —
1″ × 6″ sheathing to each bearing, face nail	2-8d (2$^1/_2$″ × 0.113″) 2 staples, 1$^3/_4$″	— —
1″ × 8″ sheathing to each bearing, face nail	2-8d (2$^1/_2$″ × 0.113″) 3 staples, 1$^3/_4$″	— —
Wider than 1″ × 8″ sheathing to each bearing, face nail	3-8d (2$^1/_2$″ × 0.113″) 4 staples, 1$^3/_4$″	— —
Built-up corner studs	10d (3″ × 0.128″)	24″o.c.
Built-up girders and beams, 2-inch lumber layers	10d (3″ × 0.128″)	Nail each layer as follows: 32″ o.c. at top and bottom and staggered. Two nails at ends and at each splice.
2″ planks	2-16d (3$^1/_2$″ × 0.135″)	At each bearing
Roof rafters to ridge, valley or hip rafters: toe nail face nail	 4-16d (3$^1/_2$″ × 0.135″) 3-16d (3$^1/_2$″ × 0.135″)	 — —
Rafter ties to rafters, face nail	3-8d (2$^1/_2$″ × 0.113″)	—
Collar tie to rafter, face nail, or 1$^1/_4$″ × 20 gage ridge strap	3-10d (3″ × 0.128″)	—

(continued)

Figure 14-21 Fastener schedule for structural members

TABLE R602.3(1) CONTINUED FASTENER SCHEDULE FOR STRUCTURAL MEMBERS			
DESCRIPTION OF BUILDING MATERIALS	DESCRIPTION OF FASTENER[b, c, e]	SPACING OF FASTENERS	
		Edges (inches)[i]	Intermediate supports[c,e] (inches)
Wood structural panels, subfloor, roof and wall sheathing to framing, and particleboard wall sheathing to framing			
$^5/_{16}$″-$^1/_2$″	6d common (2″ × 0.113″) nail (subfloor, wall) 8d common (2$^1/_2$″ × 0.131″) nail (roof)[f]	6	12[g]
$^{19}/_{32}$″ -1″	8d common nail (2$^1/_2$″ × 0.131″)	6	12[g]
1$^1/_8$″-1$^1/_4$″	10d common (3″ × 0.148″) nail or 8d (2$^1/_2$″ × 0.131″) deformed nail	6	12
Other wall sheathing[h]			
$^1/_2$″ structural cellulosic fiberboard sheathing	1$^1/_2$″ galvanized roofing nail 8d common (2$^1/_2$″ × 0.131″) nail; staple 16 ga., 1$^1/_2$″ long	3	6
$^{25}/_{32}$″ structural cellulosic fiberboard sheathing	1$^3/_4$″ galvanized roofing nail 8d common (2$^1/_2$″ × 0.131″) nail; staple 16 ga., 1$^3/_4$″ long	3	6
$^1/_2$″ gypsum sheathing[d]	1$^1/_2$″ galvanized roofing nail; 6d common (2″ x 0.131″) nail; staple galvanized 1$^1/_2$″ long; 1$^1/_4$″ screws, Type W or S	4	8
$^5/_8$″ gypsum sheathing[d]	1$^3/_4$″ galvanized roofing nail; 8d common (2$^1/_2$″ × 0.131″) nail; staple galvanized 1$^5/_8$″ long; 1$^5/_8$″ screws, Type W or S	4	8
Wood structural panels, combination subfloor underlayment to framing			
$^3/_4$″ and less	6d deformed (2″ × 0.120″) nail or 8d common (2$^1/_2$″ × 0.131″) nail	6	12
$^7/_8$″-1″	8d common (2$^1/_2$″ × 0.131″) nail or 8d deformed (2$^1/_2$″ × 0.120″) nail	6	12
1$^1/_8$″-1$^1/_4$″	10d common (3″ × 0.148″) nail or 8d deformed (2$^1/_2$″ × 0.120″) nail	6	12

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 mile per hour = 0.447 m/s; 1ksi = 6.895 MPa.

a. All nails are smooth-common, box or deformed shanks except where otherwise stated. Nails used for framing and sheathing connections shall have minimum average bending yield strengths as shown: 80 ksi for shank diameter of 0.192 inch (20d common nail), 90 ksi for shank diameters larger than 0.142 inch but not larger than 0.177 inch, and 100 ksi for shank diameters of 0.142 inch or less.

b. Staples are 16 gage wire and have a minimum $^7/_{16}$-inch on diameter crown width.

c. Nails shall be spaced at not more than 6 inches on center at all supports where spans are 48 inches or greater.

d. Four-foot-by-8-foot or 4-foot-by-9-foot panels shall be applied vertically.

e. Spacing of fasteners not included in this table shall be based on Table R602.3(2).

f. For regions having basic wind speed of 110 mph or greater, 8d deformed (2$^1/_2$″ × 0.120) nails shall be used for attaching plywood and wood structural panel roof sheathing to framing within minimum 48-inch distance from gable end walls, if mean roof height is more than 25 feet, up to 35 feet maximum.

g. For regions having basic wind speed of 100 mph or less, nails for attaching wood structural panel roof sheathing to gable end wall framing shall be spaced 6 inches on center. When basic wind speed is greater than 100 mph, nails for attaching panel roof sheathing to intermediate supports shall be spaced 6 inches on center for minimum 48-inch distance from ridges, eaves and gable end walls; and 4 inches on center to gable end wall framing.

h. Gypsum sheathing shall conform to ASTM C 79 and shall be installed in accordance with GA 253. Fiberboard sheathing shall conform to ASTM C 208.

i. Spacing of fasteners on floor sheathing panel edges applies to panel edges supported by framing members and required blocking and at all floor perimeters only. Spacing of fasteners on roof sheathing panel edges applies to panel edges supported by framing members and required blocking. Blocking of roof or floor sheathing panel edges perpendicular to the framing members need not be provided except as required by other provisions of this code. Floor perimeter shall be supported by framing members or solid blocking.

Figure 14-21 Fastener schedule for structural members (continued)

As you can see in IRC Table R602.3(1), staples are sometimes an acceptable replacement for nails. However, it's important to use the right staple size for the job to ensure the end result is as strong as nailing. You wouldn't staple down a roof with an ordinary office stapler. Well, using the wrong staple, even in the right gun, can have the same effect. Once the job is finished and the paint is on, it's hard to tell what you used. But the owner will know the difference as soon as the first storm of the season hits.

Special Fastening Requirements

There are additional fastening requirements for exterior exit balconies, stairs and similar exit facilities in IRC Section R311, *Means of Egress.* You must use positive anchoring; in other words, fasteners not subject to withdrawal. The attachment must be anchored to the primary structure to resist both vertical and lateral forces (Section R311.2.1). Without positive anchoring, egress (exit) may be impeded or impossible in the event of an emergency. You can't exit from a second-story stairway or balcony if it's fallen away from the building!

There are also some areas in the U.S. with extra fastening requirements, such as earthquake and high wind hazard (hurricane) zones. If you're building light-frame structures in those areas, your plans will probably have to be approved by an engineer. Check with your building department.

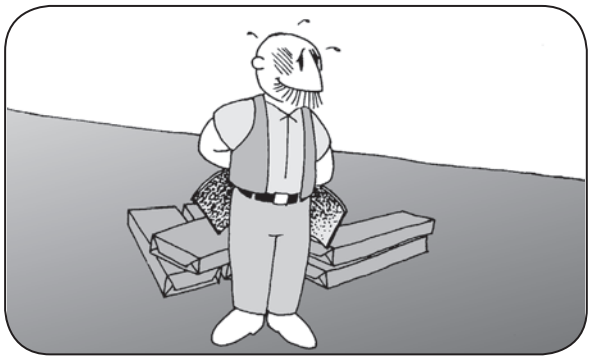
Crawl Spaces

Earlier in this book, I mentioned crawl-spaces and crawl holes. Remember that crawl space access holes have to be at least 18 inches by 24 inches. Even if you have only a partial basement, you still must have a crawl hole or access to the unexcavated portion. Pipes or heat ducts can't reduce the size of the crawl space access hole.

Plans often call for beams set in pockets made in the foundation wall. Just remember to leave at least ½ inch of clearance at the tops, sides and ends of the beams to prevent rot or decay. There's an exception if you're using either treated wood or an approved wood that resists decay. The only woods that I know of with a natural resistance to decay are the heartwood of redwood, black locust, or cedar.

We've discussed foundation ventilation, so you already know that framing material must be 6 inches from any earth, unless separated by at least 3 inches of concrete. But what about planter boxes installed next to wood framing? These are usually masonry boxes built on the ground. To protect the framing from rot or infestation, a planter box must have at least 2 inches of space between it and the wall next to it. And the wall must have flashing if it's within 6 inches of the planter.

This should help get you through the rough carpentry. Most jurisdictions allow an exterior nailing or "shear" inspection so that you can proceed with siding or the exterior finish while the inside is being completed and services roughed in. You won't get a framing inspection until plumbing, gas piping, mechanical, electrical, and all the other services have passed. Similarly, the nailing of the roof sheathing can be inspected before the framing to allow cover with shingles or roofing. Remember, the electrician isn't supposed to place wire until the building is dried-in, and you certainly wouldn't want to place any insulation where it could get wet. In Chapter 15 we'll take a detailed look at those components.



Who'll Cast the First Stone?

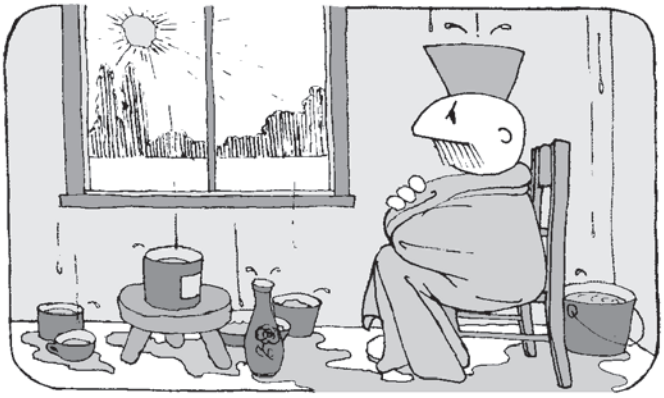
Many years ago, I bought a house using my VA benefits. The house had been built in 1955, and the years hadn't been kind to it. Part of my deal with the VA was that I would "earn" my down payment by painting the house inside and out and installing new roofing. I got a good deal on the paint and my real estate agent supplied the roof shingles. And so, with my wife and kids as "crew," I went to work. My wife and the younger kids did most of the painting, while my oldest boys and I shingled.

Believe it or not, I'd never laid T-lock asphalt shingles before. When one of my boys asked a question I couldn't answer, I went looking for the product information slip in the package of roofing. Boy, was I in for a surprise!

The building codes make it clear: all roofing must come with the name of the manufacturer, the type of roofing, fire-rating, and weight per square, among other things. The slips I found had none of this information. Nothing was printed on the cartons either. So there I was, with a half-finished roof shingled with non-code material. And I was a building inspector! You know what I'd have to do if I caught a roofer doing that!

I traced the roofing supplier through the real estate agent. The supplier said he couldn't remember who his dealer was but insisted the manufacturer was a reputable firm. It's just that he couldn't remember the name. I found more of the material in his yard and advised him to get rid of it — but not in my town! I said if I found any of that nonapproved roofing on any job in town, I'd make *him* tear it off.

I know I shouldn't have, but I finished my roof with the materials we had. As it turned out, the T-locks must have been OK. My son still owns the house and he hasn't had a leak yet. I'll say this, though. The experience makes me feel a little more understanding when I see non-code materials on a job. I still make the crew remove them (having eight kids, I know the "Do as I say, not as I do" line better than most), but I know that getting bogus material can happen to anyone, even a building inspector!



CHAPTER 15

Keeping Your Building Dry and Warm

Every part of a building's construction is important to its whole. But the roof is critical. It's usually the first part of the building damaged in a storm, which can result in exposure of the rest of the building to the elements. If the roof is completely lost, storm damage can destroy a building. Even small leaks can wreak havoc. If you have a wood shingle or shake roof and live in a sunny climate, weathering can be your enemy. Wood roofs can also be a serious fire hazard, which is why they're not used much today. No one wants to pay the high premiums insurance companies demand in wildfire-prone areas. But before we talk about roof coverings, let's see how to support them. As with everything you've read so far, the code is specific when it comes to roof construction.

Wood Roof Framing

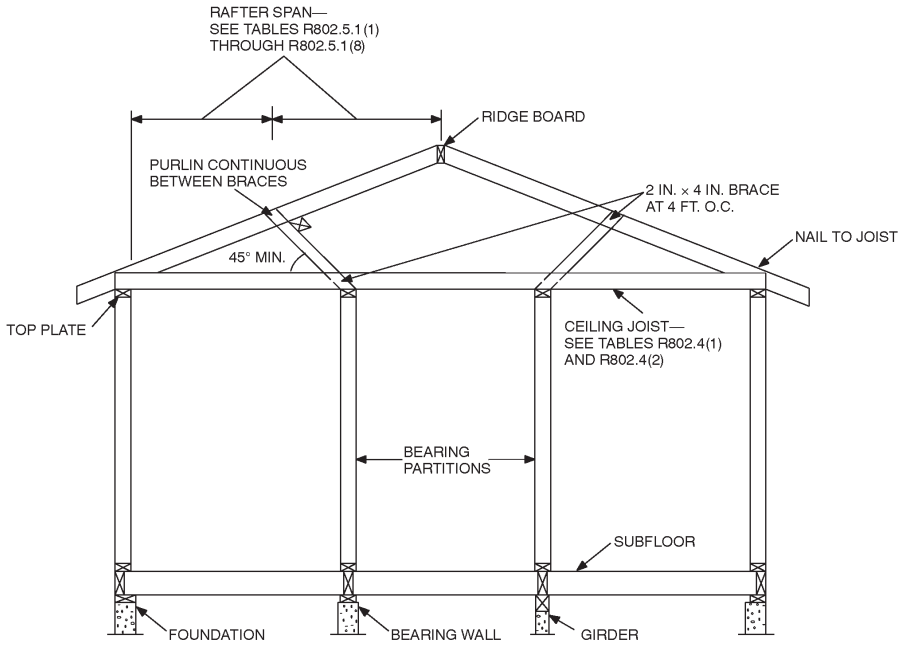
A roof is only as good as its support structure. The basic elements of a typical roof support structure are shown in Figure 15-1. They are:

- Joists: The horizontal, parallel beams supporting the ceiling.
- Rafters: The beams that support the roof, sloping from the ridge to the eaves.
- Ridge Board: A horizontal beam at the ridge of a roof to which the rafters are attached (also called a ridgepole).
- Purlins: Horizontal structural members, running at right angles to the rafters, used for support between rafter end points.
- Braces: The short members that support the purlins and bear on internal walls or partitions.
- Trusses: Preassembled roof structures — made of rafters, joists, braces and connectors.

Wood roof framing is covered in IRC Section R802. The main construction requirements are:

- Rafters must be framed to a ridge board or to each other, with a gusset plate as a tie.

FIGURE R802.5.1
BRACED RAFTER CONSTRUCTION



For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 degree = 0.018 rad.
NOTE: Where ceiling joints run perpendicular to the rafters, rafter ties shall be nailed to the rafter near the plate line and spaced not more than 4 feet on center

Figure 15-1 Braced rafter construction

- Ridge boards must be at least 1 inch thick and at least as deep as the cut end of the rafter.
- At all valleys and hips, install a rafter 2 inches thick or more and at least as deep as the cut end of the rafter.
- Provide support for hip and valley rafters with a brace from the ridge to a bearing partition. If not braced, they must be designed to carry and distribute the specific load at that point.
- Structural members supporting ceiling joists and rafters — such as ridge beams, hips and valleys — must be designed as beams if the roof pitch is less than one in four (25 percent slope).
- Ceiling joists and rafters must be nailed to each other as described in Table R802.5.1(9), shown in Figure 15-2.
- Rafters must be nailed to the top wall plate as described in Table R602.3(1); refer back to Figure 14-22 in Chapter 14.
- Ceiling joists should be continuous. If they aren't, see Section R802.3.
- If ceiling joists aren't connected to the rafters at the top wall plate, install joists connected higher in the attic to act as rafter ties or collar ties, or install rafter ties that provide a continuous tie.
- If ceiling joists aren't parallel to the rafters, rafter ties must be used. See Section R802.3 and Table R802.5.1(9), Figure 15-2, for details.
- Collar ties or ridge straps must be connected in the upper third of the attic space to resist wind uplift. Again, refer back to Table R602.3(1) in Figure 14-22 in the last chapter. Section R802.3 contains details about collar ties.

TABLE R802.5.1(9)
RAFTER/CEILING JOIST HEEL JOINT CONNECTIONS [a.b.c.d.e.f.g]

RAFTER SLOPE	RAFTER SPACING (inches)	GROUND SNOW LOAD (psf) 30				50				70			
		Roof span (feet)											
		12	20	28	36	12	20	28	36	12	20	28	36
		Required number of 16d common nails[a,b] per heel joint splices[c,d,e,f]											
3:12	12	4	6	8	11	5	8	12	15	6	11	15	20
	16	5	8	11	14	6	11	15	20	8	14	20	26
	24	7	11	16	21	9	16	23	30	12	21	30	39
4:12	12	3	5	6	8	4	6	9	11	5	8	12	15
	16	4	6	8	11	5	8	12	15	6	11	15	20
	24	5	9	12	16	7	12	17	22	9	16	23	29
5:12	12	3	4	5	7	3	5	7	9	4	7	9	12
	16	3	5	7	9	4	7	9	12	5	9	12	16
	24	4	7	10	13	6	10	14	18	7	13	18	23
7:12	12	3	3	4	5	3	4	5	7	3	5	7	9
	16	3	4	5	6	3	5	7	9	4	6	9	11
	24	3	5	7	9	4	7	10	13	5	9	13	17
9:12	12	3	3	3	4	3	3	4	5	3	4	5	7
	16	3	3	4	5	3	4	5	7	3	5	7	9
	24	3	4	6	7	3	6	8	10	4	7	10	13
12:12	12	3	3	3	3	3	3	3	4	3	3	4	5
	16	3	3	3	4	3	3	4	5	3	4	5	7
	24	3	3	4	6	3	4	6	8	3	6	8	10

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa.

a. 40d box nails shall be permitted to be substituted for 16d common nails.

b. Nailing requirements shall be permitted to be reduced 25 percent if nails are clinched.

c. Heel joint connections are not required when the ridge is supported by a load-bearing wall, header or ridge beam.

d. When intermediate support of the rafter is provided by vertical struts or purlins to a loadbearing wall, the tabulated heel joint connection requirements shall be permitted to be reduced proportionally to the reduction in span.

e. Equivalent nailing patterns are required for ceiling joist to ceiling joist lap splices.

f. When rafter ties are substituted for ceiling joists, the heel joint connection requirement shall be taken as the tabulated heel joint connection requirement for two-thirds of the actual rafter-slope.

g. Tabulated heel joint connection requirements assume that ceiling joists or rafter ties are located at the bottom of the attic space. When ceiling joists or rafter ties are located higher in the attic, heel joint connection requirements shall be increased by the following factors:

H_C/H_R	Heel Joint Connection Adjustment Factor
1/3	1.5
1/4	1.33
1/5	1.25
1/6	1.2
1/10 or less	1.11

where:

H_C = Height of ceiling joists or rafter ties measured vertically above the top of the rafter support walls.

H_R = Height of roof ridge measured vertically above the top of the rafter support walls.

Figure 15-2 Rafter/ceiling joist heel joint connections

- Ends of ceiling joists must be lapped at least 3 inches, or they can be butted over bearing partitions or beams and toe-nailed to the bearing member. See Section R802.3.2 for details.

Ceiling Joist Spans

IRC Section R802.4 and Tables R802.4(1) and R802.4(2) give the permitted lengths of ceiling joist spans. These two areas of reference cover:

- Wood species and grade
- Joist size (2 x 4 through 2 x 10 inches)
- Joist spacing (12 through 24 inches)

Use Table R802.4(1) if the attic won't be used for storage (live load = 10 psf). Use Table R802.4(2) for limited storage (live load = 20 psf) above the ceiling joists. What if prospective buyers don't adhere to the limitations specified in the code? After they get the keys, they may use it for storage, even though you've built to Table R802.4(1). It's safest to use the criteria required in Table R802.4(2) for limited storage. It then covers either possibility.

If you can't find the wood species or grade you want in Tables R802.4(1) and R802.4(2), you can always use the *Maximum Span Calculator for Joists & Rafters* described in Chapter 14. Just change the fourth box to Ceiling Joist. Then fill in the other boxes. The calculator gives the maximum ceiling joist span. If the span isn't wide enough, pick a stronger wood species or grade, larger joist size or smaller spacing. The calculator will do the work for you.

Rafter Spans

Section R802.5 and Tables R802.5.1(1) through R802.5.1(8) list permitted lengths of rafter spans. They include:

- Wood species and grades
- Rafter sizes (2 x 4 through 2 x 12 inches)
- Rafter spacings (12 through 24 inches)

The last few tables are included to help determine a roof live load of 20 psf, a range of ground snow loads (30 psf through 70 psf), and whether or not the ceiling is attached to the rafters.

Rafter span is measured as the horizontal projection of the rafter, not the actual length of the rafter (see Figure 15-1).

Again, if you don't find the wood species or grade you want in Tables R802.5.1(1) through R802.5.1(8), use the calculator just discussed. This time, change the fourth box to Rafters (Roof Live-Load). Fill in the other boxes and the calculator will figure the maximum rafter span for that set of parameters. If that rafter span isn't wide enough, pick a stronger wood species or grade, larger rafter size, or smaller spacing.

The fourth box on the calculator also gives you the choice of Rafters (Snow Load). But if you select it, you're limited to a snow load of 20 psf. That figure appears in the Live Load (eighth) box. So if you need higher snow loads, choose the Rafter (Roof Live-Load) option in the fourth box. Then put the live load you need in the eighth box. Note: The calculator has been known to overestimate maximum allowable rafter spans, but only at the higher joist sizes — tables with "ceiling not attached to rafters" included in the title. In those situations, use the tables instead of the calculator.

Figure 15-3 Prefabricated truss

Purlins and Braces

Purlins and braces are covered in IRC Section R802.5.1. The main points are:

- You can use purlins and braces to reduce rafter spans, as shown in Figure R802.5.1, Figure 15-1.
- Purlins must be at least the same size as the rafters they support.
- Purlins must be supported by 2 x 4 braces installed to bearing walls, at a slope of at least 45 degrees to the horizontal (Figure 15-1).
- Purlins must be continuous between braces.
- Braces must be spaced 4 feet on center or less, and their unbraced length shouldn't exceed 8 feet.

Trusses

Most residential buildings use prefabricated trusses, like the one shown in Figure 15-3. Using prebuilt trusses is much faster than constructing them on the job site. Wood trusses are covered in IRC Section R802.10. Subsection R802.10.2 says:

> *Wood trusses shall be designed in accordance with accepted engineering practice . . . The truss design drawings shall be prepared by a registered pro-*

fessional where required by the statutes of the jurisdiction in which the project is to be constructed in accordance with Section R106.1.

Section R 802.10.4 stipulates that you can't cut, drill, notch or otherwise change a truss without first getting approval from a registered design professional. You also have to get consent before adding any heavy equipment in an attic space. Talk to your local building officials. They'll let you know the criteria for design drawings and any changes you may want to make to trusses.

Manufactured roof trusses are assembled at the factory with metal connectors or gussets instead of nails. Gussets are made of galvanized metal and are made for specific application with specific loadings. The truss strength depends on:

- Lumber species
- Grade and size of timber
- Size of connectors
- Number of spikes

One problem with prefabricated trusses is that some manufacturers don't follow the exact engineering design. They might use a lower grade of lumber or reduce the size or number of metal connectors. Check the engineering specs and make sure the manufacturer followed them. If he didn't, return the trusses. You don't want to run into problems after the trusses are installed and the roof is on.

Doing this research could delay your job. But if you try to save money by using reduced-quality materials and the inspector finds out, it can cost you a lot more than you'd save. Investigate the different truss types and manufacturers. What if you intend to build a light-frame structure in a seismic zone? If you're building a house on a knoll, would you build to the minimum 20-foot height requirement? For these situations and more, your plans most likely need an engineer's approval. Don't wait to find out — check with a building official for specifics concerning your building location.

Draft Stops

Any enclosed attic with an area of more than 3,000 square feet must be divided by partitions. The partitions should extend from attic floor to roof. They must be made using one of the following:

TABLE R803.1
MINIMUM THICKNESS OF LUMBER ROOF SHEATHING

RAFTER OR BEAM SPACING (inches)	MINIMUM NET THICKNESS (inches)
24	$^5/_8$
48[a]	$1^1/_2$ T & G
60[b]	
72[c]	

For SI: 1 inch = 25.4 mm.
a. Minimum 270 F_b, 340,000 E.
b. Minimum 420 F_b, 660,000 E.
c. Minimum 600 F_b, 1,150,000 E.

Figure 15-4 Minimum thickness of lumber roof sheathing

- At least ½-inch-thick gypsum wallboard
- ⅜-inch-thick wood structural panel (usually plywood or OSB)
- ⅜-inch-thick particleboard

Check with the building inspector before using other materials.

Doors installed to access one section of the attic to another must be self-closing, with automatic latches, and have the same fire resistance as the partition. IBC Section 717.4 gives you details for draft elimination in attics.

An exception is made for attic draft stops if the building is equipped with an automatic sprinkler system, as long as automatic sprinklers are also installed in the combustible concealed spaces. See Section 717.4.2.

So far we've covered foundations, walls and roof framing, giving you a box without a lid. Now you need a roof.

Roof Sheathing

Before you apply the roofing material, you must first sheathe the roof framing with a roof deck. It's usually made from treated APA-rated plywood. IRC Section R803 deals with roof sheathing.

- Table R803.1 (Figure 15-4) gives the minimum thickness of lumber that can be used as roof sheathing for different rafter spacings.

- Sections R905.7 and R905.8 have sheathing specs for wood shingle and shake roofing.
- Spaced lumber sheathing is not allowed in Seismic Design Category D_2.
- Wood structural panel (usually OSB or plywood) roof sheathing must be installed as specified in the Fastener Schedule, Table R602.3(1). Refer back to Figure 14-22 in Chapter 14.

Roof Covering

There are a lot of roof coverings to choose from and many code requirements that a roof covering must conform with. It must:

- Be fire resistant
- Be durable
- Be weather resistant
- Remain attached
- Keep out rain

Fire Classifications

We talked about fire resistance in construction back in Chapter 7. Remember, the whole building will be reduced to a lower fire-resistance grade if any part fails to meet the standards for the higher grade. So if the building type calls for one-hour fire resistance, your roof assembly must also be at least one-hour rated. If you use a combustible roof deck or a nonrated roofing material, your building could be reduced to a lower class — and that could be an expensive mistake.

If you're building to the IBC, fire classification for roof assemblies is covered in Section 1505. The minimum roof covering classification depends on the construction type; see Table 1505.1 (Figure 15-5). Roof coverings must meet the ASTM standards: ASTM E 108, UL 790, or ASTM D 2898 for fire-retardant-treated wood. You don't need to worry about the testing procedure. Just make sure the roof covering you buy is correctly labeled by the testing agency.

TABLE 1505.1[a,b]
MINIMUM ROOF COVERING CLASSIFICATION FOR TYPES OF CONSTRUCTION

IA	IB	IIA	IIB	IIIA	IIIB	IV	VA	VB
B	B	B	C[c]	B	C[c]	B	B	C[c]

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

a. Unless otherwise required in accordance with the *International Wildland-Urban Interface Code* or due to the location of the building within a fire district in accordance with Appendix D.

b. Nonclassified roof coverings shall be permitted on buildings of Group R-3 and Group U occupancies, where there is a minimum fire-separation distance of 6 feet measured from the leading edge of the roof.

c. Buildings that are not more than two stories in height and having not more than 6,000 square feet of projected roof area and where there is a minimum 10-foot fire-separation distance from the leading edge of the roof to a lot line on all sides of the building, except for street fronts or public ways, shall be permitted to have roofs of No. 1 cedar or redwood shakes and No. 1 shingles.

Figure 15-5 Minimum roof covering classification

Table 1505.1 gives the minimum fire-resistance rating allowed for a particular construction type. You can always use a higher-rated material. Read notes "b" and "c." They list exceptions for certain occupancies, building sizes and separation distances.

Roof Assembly Classes

The classes of roof assemblies (A, B, C and nonclassified) are defined in Sections 1505.2 through 1505.5.

> ***1505.2 Class A roof assemblies.*** *Class A roof assemblies are those that are effective against severe fire test exposure. Class A roof assemblies and roof coverings shall be listed and identified as Class A by an approved testing agency. Class A roof assemblies shall be permitted for use in buildings or structures of all types of construction.*

In addition to agency-tested Class A materials, *Class A roof assemblies include those with coverings of brick, masonry, slate, clay or concrete roof tile, exposed concrete roof deck, ferrous or copper shingles or sheets.*

> ***1505.3 Class B roof assemblies.*** *Class B roof assemblies are those that are effective against moderate fire-test exposure.*

In addition to agency-tested Class B materials, *Class B roof assemblies include those with coverings of metal sheets and shingles.*

1505.4 Class C roof assemblies. *Class C roof assemblies are those that are effective against light fire-test exposure.*

1505.5 Nonclassified roofing. *Nonclassified roofing is approved material that is not listed as a Class A, B or C roof covering.*

Class B and C roof coverings are simply defined as any Class B or C roofing assembly. A nonclassified roof covering is usually a built-up roof with a mineral aggregate surface, typically used in nonresidential buildings. The minimum slope design for drainage is ¼ vertical unit in 12 horizontal units (2 percent slope). A coal-tar built-up roof can have a minimum design slope of ⅛ vertical unit in 12 horizontal units (1 percent slope). Modified bitumen, thermoplastic and thermoset membrane assemblies that don't meet Class A, B or C requirements are also nonclassified, as are wood shingles and shakes.

Fire-retardant-treated wood shingles and shakes are covered in Section 1505.6.

Each package of roofing material must have an approved testing agency label and the name and address of the manufacturer. The label must also give the grade. If the roofing was manufactured, the label has to include the weight per roofing square (material that covers 100 square feet of roof when laid). Bulk shipments of roofing material must come with the same information, in the form of a certificate.

Roofing Definitions

Here are definitions of terms you'll come across most often:

Base Ply: *The initial layer, secured to the roof deck, of a multilayer system typically used in built-up roofing.*

Base Sheet: *A product used as the base ply in a built-up roofing membrane.*

Built-up Roofing: *Two or more layers of felt cemented together and surfaced with one of the following: mineral aggregate, smooth coating, or a similar surfacing material.*

Built-up Roofing Ply: *A layer of felt in built-up roofing.*

Cap Sheet: *Roof covering made of organic or inorganic fibers, saturated and coated on both sides with a bituminous compound. It can be surfaced with materials such as mineral granules, mica, talc, ilmenite, or inorganic fibers.*

Wood Shakes and Shingles (fire-retardant treated): *Wood roofing impregnated with fire-retardant chemicals using the full-cell vacuum-pressure process. They're tested for use on Class A, B or C roofs.*

Modified Bitumen Membrane Roof Covering: *One or more layers of polymer-modified asphalt sheet membrane. The sheet materials may be glued on, mechanically attached to the substrate, or held in place with a ballast layer.*

Roofing Square: *A square covers 100 square feet of roof surface when laid to the manufacturer's specs.*

Thermoplastic Membrane Roof Covering: *Sheet membrane made of polymers and other special ingredients. The chemical composition allows individual sheets of the material, by either heat or solvent, to permanently bond together, forming a single sheet covering the whole roof.*

Thermoset Membrane Roof Covering: *A sheet membrane made of polymers and other special ingredients whose chemical composition vulcanizes (cross-links) during manufacturing or during its service life, making it much more durable.*

Vapor Retarder: *A layer of material or a laminate that greatly reduces the flow of water vapor into the roofing system.*

Common Roofing Materials

IRC Section R905 covers 14 approved roofing materials for residential construction. This section includes information on installation, attachment, underlayment requirements, valley linings, etc. Here are the materials and their reference sections in the code.

- Asphalt shingles, Section R905.2

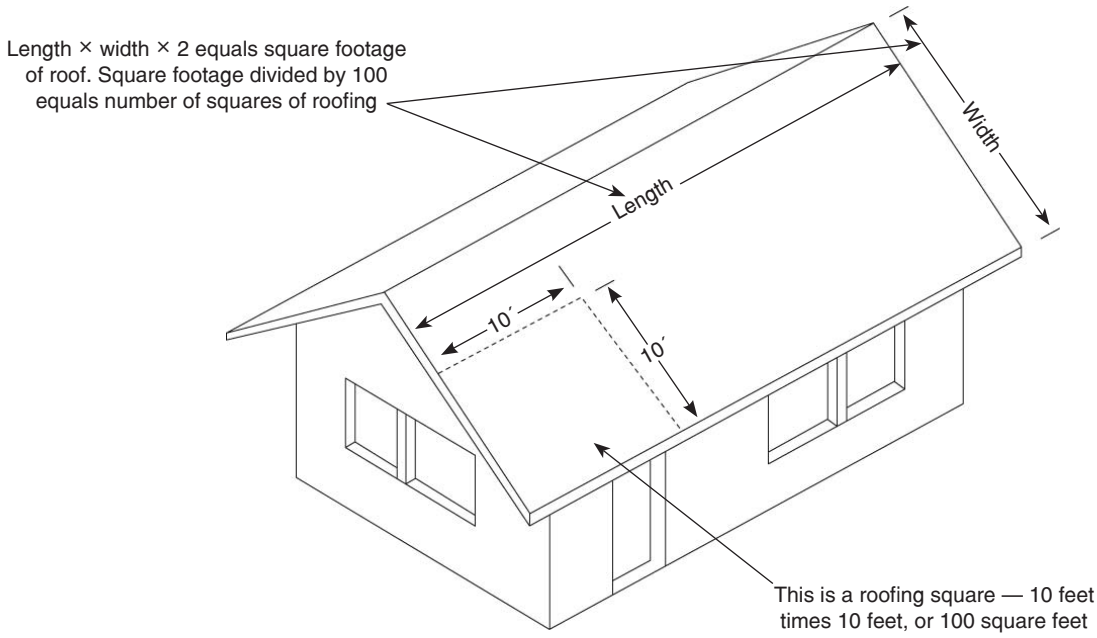


Figure 15-6 Calculating roof coverage

- Clay and concrete tile, Section R905.3
- Metal roof shingles, Section R905.4
- Mineral-surfaced roll roofing, Section R905.5
- Slate and slate-type shingles, Section R905.6
- Wood shingles, Section R905.7
- Wood shakes, Section R905.8
- Built-up roofs, Section R905.9
- Metal roof panels, Section R905.10
- Modified bitumen roofing, Section R905.11
- Thermoset single-ply roofing, Section R905.12
- Thermoplastic single-ply roofing, Section R905.13
- Sprayed polyurethane foam roofing, Section R905.14
- Liquid-applied coatings, Section R905.15

What Is a Roofing Square?

Roofing materials are sold by the *square*. As just defined, a roofing square covers 100 square feet of roof surface, when laid to the manufacturer's specs. It usually takes three bundles of asphalt shingles to cover one square. Remember to measure the roof area, not the floor area. A roof's pitch and overhang add significantly to its area — it can be as much as double the floor area, so be sure and measure the *actual* surface area.

Figure 15-6 shows how to determine roof coverage. To calculate how much material you'll need, find the total roof area in square feet, then divide by 100. This gives you the number of squares you'll need to cover the roof. If there are a lot of ridges and valleys, you could need up to 15 percent more material.

Roof Application Methods

Let's look at the approved methods of applying some of the more common roofing materials.

TABLE R905.3.7 CLAY AND CONCRETE TILE ATTACHMENT		
SHEATHING	ROOF SLOPE	NUMBER OF FASTENERS
Solid without battens	All	One per tile
Spaced or solid with battens and slope < 5:12	Fasteners not required	—
Spaced sheathing without battens	5:12 ≤ slope < 12:12	One per tile/every other row
	12:12 ≤ slope < 24:12	One per tile

Figure 15-7 Clay and concrete tile attachment

Asphalt Shingles

Asphalt shingles are used in temperate climates. They can be applied only on solidly sheathed roofs with a slope of at least 2 inches vertical in 12 inches horizontal. For a roof slope of less than 4 in 12, apply at least two layers of 15-pound felt underlayment. For a steeper roof, you can use just one layer. For details on underlayment application, see IRC Section R905.2.7. Install the asphalt shingles according to the manufacturer's instructions. Use at least two nails for each shingle 9 to 18 inches wide, and four nails for each strip shingle 36 to 40 inches wide.

You can use galvanized steel nails, stainless steel, aluminum or copper roofing nails. The nails must have a minimum 12-gauge shank, with a ⅜-inch-diameter head, and be long enough to go through the roofing material and penetrate the roof deck by at least ¾ inch. If the roof sheathing is less than ¾ inch thick, the nails must extend through the roof sheathing.

Clay and Concrete Tiles

Use clay and concrete tiles on roofs made with solid sheathing or spaced structural sheathing boards. The roofs must have a slope of at least 2½ inches vertical in 12 inches horizontal. As with asphalt shingle installation, apply at least two layers of 15-pound felt underlayment for a roof slope of less than 4 in 12. For a steeper roof, you can use just one layer. For details on applying underlayment with clay or concrete tile, see IRC Section R905.3.3.

Use corrosion-resistant nails with minimum 11-gauge shanks, 5/16-inch-diameter heads, and a length that will allow the nails to go through the roofing material and into the roof deck at least ¾ inch. If the roof deck is less than ¾ inch thick, the nails must extend through it. Tile attaching wire must be at least 0.083 inch in diameter. Perimeter fastening areas include three tile courses, but not less than 36 inches from either side of hips or ridges and edges of eaves and gable rakes; see Section R905.3.6. In snow areas, use at least two nails per tile. In all other cases, use the number of fasteners called out in IRC Table R905.3.7 (Figure 15-7).

Mineral-Surfaced Roll Roofing

Mineral-surfaced roll roofing should only be used on solidly sheathed roofs with a slope of at least 1 in 12. Apply the material according to the manufacturer's specs and IRC Section R905.5.

Slate and Slate-Type Shingles

Use slate and slate-type shingles only on solidly sheathed roofs with a slope of at least 4 in 12. Install slate and slate-type shingles according to the manufacturer's instructions and IRC Section R905.6. The minimum headlap for slate shingles must comply with Table R905.6.5, shown in Figure 15-8.

Built-Up Roofs

Built-up roofing is good only for roofs that are nearly flat. Flat roofs bother me, and I'm not alone. The code requires a slope of at least

TABLE R905.6.5 SLATE SHINGLE HEADLAP	
SLOPE	HEADLAP (inches)
4:12 ≤ slope < 8:12	4
8:12 ≤ slope < 20:12	3
Slope ≤ 20:12	2

For SI: 1 inch = 25.4 mm.

Figure 15-8 Slate shingle headlap

TABLE R905.9.2 BUILT-UP ROOFING MATERIAL STANDARDS	
MATERIAL STANDARD	STANDARD
Acrylic coatings used in roofing	ASTM D 6083
Aggregate surfacing	ASTM D 1863
Asphalt adhesive used in roofing	ASTM D 3747
Asphalt cements used in roofing	ASTM D 3019; D 2822; D 4586
Asphalt-coated glass fiber base sheet	ASTM D 4601
Asphalt coatings used in roofing	ASTM D 1227; D 2823; D 2824; D 4479
Asphalt glass felt	ASTM D 2178
Asphalt primer used in roofing	ASTM D 41
Asphalt-saturated and asphalt-coated organic felt base sheet	ASTM D 2626
Asphalt-saturated organic felt (perforated)	ASTM D 226
Asphalt used in roofing	ASTM D 312
Coal tar cements used in roofing	ASTM D 4022; D 5643
Coal-tar primer used in roofing, dampproofing and waterproofing	ASTM D 43
Coal-tar saturated organic felt	ASTM D 227
Coal-tar used in roofing	ASTM D 450, Types I or II
Glass mat, coal tar	ASTM D 4990
Glass mat, venting type	ASTM D 4897
Mineral-surfaced inorganic cap sheet	ASTM D 3909
Thermoplastic fabrics used in roofing	ASTM D 5665; D 5726

Figure 15-9 Built-up roofing material standards

2 percent, or ¼ inch in 12 inches. Coal-tar roofs can have a minimum design slope of ⅛ inch in 12 inches. But buildings settle over time and materials don't shrink evenly. So the roof will probably develop low spots that trap water, even if the installation is first class. That's a good reason to increase your slope more than the minimum. Then if low spots occur, there's still a good overall slope to the roof.

Built-up roofing materials must meet the ASTM standards shown in IRC Table R905.9.2 (Figure 15-9). Make sure that the label on the material you buy mentions the appropriate standard.

To fasten a roof with adhesive, mop the base sheet with at least 20 pounds of hot asphalt per roofing square. This will give you good, solid attachment. Or use at least 20 pounds of coal-tar pitch for each square.

If you've selected a mineral-aggregate-surfaced roof, apply at least 50 pounds of hot asphalt or other cementing material per roofing square. Then embed at least 400 pounds of gravel or 300 pounds of crushed slag. Attach cap sheets to base sheets with the same amount of cementing material used on other layers.

Hot asphalt should be between 375 and 425 degrees F. Cementing material mustn't be heated to more than 25 degrees F below its *flash point* — the point where it catches fire. Applying heat to asphalt can be like putting a match to the fuse on a stick of dynamite. Heating the material beyond its flash point means big trouble. Hot tar fires have killed people and destroyed property. Don't *ever* heat the tar beyond its flash point temperature, which should be clearly printed on the label.

Always check with the building inspector before you start, in case there are further requirements unique to the jurisdiction where you're working.

Valley Flashing

Roofs with lots of ridges and valleys mean extra work — including valley flashing. Flashing requirements for most roofs are about the same, but there are some differences. The following sections cover flashing requirements for different roofing materials:

- Asphalt shingles, Section R905.2.8.2

- Clay and concrete tiles, Section R905.3.8
- Metal roof shingles, Section R905.4.6
- Slate and slate-type shingles, Section R905.6.6
- Wood shingles, Section 905.7.6
- Wood shakes, Section R905.8.8

Usually, any roof that doesn't end in open space needs to be flashed. Valleys and any edge that abuts another wall, either above or at the side, need to be flashed. Any piece of flashing above another has to overlap that piece, just like asphalt shingles going up a wall. At each course, one piece of L-shaped step flashing is placed on top of the shingle and covered with the next row.

Make sure that all flashing brings water out onto the top of the roofing below. The majority of roof failures are caused by poor flashing jobs, not the primary materials. So make sure your flashing is done right.

Where roofing ends at a wall or an opening, there must be adequate flashing to prevent damming, or else a cricket needs to be installed. Section R905.2.8 describes IRC flashing requirements. Section R905.2.8.3 requires a cricket or saddle where the ridge side of a chimney is more than 30 inches wide. Most IBC flashing requirements are covered in Sections 1503.2 and 1507.2.9.

Attic Ventilation

Attic ventilation and insulation are important parts of roof construction. Make sure any concealed space is ventilated. Enclosed attics and enclosed rafter spacing must have cross ventilation for each separate space. You can provide air through vents in the eaves or cornices. Vents must be protected so that rain or snow can't get in. They could get clogged if insulation is blown into them, so a baffle or blocking strip can be installed between the rafters to prevent clogging and help move the air over the insulation. Make sure there's at least a 1-inch space at each vent hole between the insulation and the roof sheathing. Keep the area clear around the baffles and the vents.

Details of attic ventilation and the formula for the required venting area are in IRC Section R806. The total vent area must be at least $^1/_{150}$ of the horizontal roof area. So if your attic area is 2,000 square feet, you need to provide a total of $13^1/_3$ square feet of attic ventilation openings (2,000 divided by 150). Cover all ventilation holes with corrosion-resistant metal mesh with ⅛-inch minimum to ¼-inch maximum gaps.

There's an exception. If at least 50 percent, but not more than 80 percent, of the ventilators are 3 feet or more above the eaves or cornice area, you can reduce the free ventilating area to $^1/_{300}$ of the roof area. The other 50 percent of the openings must be cornice or eave vents. So the 2,000-square-foot attic would only need $6^2/_3$ square feet of vent area. The same $^1/_{300}$ factor applies if you install a vapor barrier having a specified transmission rate on the warm-in-winter side of a ceiling. See IRC Section R806.2 for specifics.

Attic, Ceiling and Roof Insulation

Every roof structure needs insulation for maximum energy efficiency. It can be installed either under or over the sheathing. We'll talk about over-the-sheathing insulation in a minute. In most houses, insulation is installed between the ceiling joists, so that it doesn't interfere with the roofing. That's fine if the attic area doesn't have to be heated. In winter, in snow areas, it's always easy to see which houses have good ceiling insulation. They're the ones with snow piled on the roof, meaning very little heat is escaping from the house into the attic.

Incidentally, an ice barrier is now required for many roof types in areas where ice damming is a consistent problem. If it's required where you're working, it'll be noted in your local jurisdiction's entry (*Yes* or *No*) in column 8 of IRC Table R301.2(1), Ice Barrier Underlayment Required. (Look back at Figure 1-1 in Chapter 1.)

Attic Access

In most houses you'll need a means of access to the attic area. IRC Section R807.1 says that any house or building with combustible

TABLE N1102.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE AND DEPTH	CRAWL SPACE WALL *R*-VALUE
1	1.2	0.75	0.40	30	13	3	13	0	0	0
2	0.75	0.75	0.40	30	13	4	13	0	0	0
3	0.65	0.65	0.40[e]	30	13	5	19	0	0	5/13
4 except Marine	0.40	0.60	NR	38	13	5	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.35	0.60	NR	38	19 or 13 + 5[g]	13	30[f]	10/13	10, 2 ft	10/13
6	0.35	0.60	NR	49	19 or 13 + 5[g]	15	30[f]	10/13	10, 4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19	30[f]	10/13	10, 4 ft	10/13

a. *R*-values are minimums. *U*-factors and SHGC are maximums. R-19 insulation shall be permitted to be compressed into a 2 × 6 cavity.
b. The fenestration *U*-factor column excludes skylights. The solar heat gain coefficient (SHGC) column applies to all glazed fenestration.
c. The first *R*-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.
d. R-5 shall be added to the required slab edge *R*-values for heated slabs.
e. There are no solar heat gain coefficient (SHGC) requirements in the Marine Zone.
f. Or insulation sufficient to fill the framing cavity, R-19 minimum.
g. "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25% or less of the exterior, R-5 sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25% of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.

Figure 15-10 Insulation and fenestration requirements by component

ceiling or roof construction must have an access opening to any attic area that exceeds 30 square feet and is 30 vertical inches high or more. The framed attic access opening has to be at least 22 inches by 30 inches, and must provide at least 30 inches of clear headroom at some point in the attic space. The opening should be located in an interior hallway or other *readily-accessible* location.

How do you define readily accessible? Some contractors put attic openings in a closet to keep them out of sight. Is this readily accessible? It is, if it's a walk-in closet with hanging rails on three sides — but not if it's a single-row closet. If you're thinking about putting an attic opening in a single-row closet, ask the building inspector and fire marshal before you start building. If they say it isn't accessible, you'll have to locate it somewhere else. And remember, headroom must be at least 30 inches.

Roof-Ceiling Insulation

The IRC spends a lot of time on regulations involving the insulation of roof-ceiling assemblies. Good insulation promotes energy efficiency and fire prevention.

Ceiling Insulation

IRC Section N1102 and Table N1102.1 (Figure 15-10) cover the minimum insulation R-value required for:

- Ceilings
- Wood frame or mass walls
- Floors
- Basement walls
- Slab
- Crawlspace walls

The minimum ceiling R-value depends on the climate zone you're building in (Zones 1 through 8). I've outlined the column named "Ceiling R-Value." Climate zones are found in IRC Figure N1101.2 for the 50 states plus the District of Columbia, Puerto Rico, the U.S. Virgin Islands and the Pacific protectorates. You can also find climate information by county in IRC Table N1101.2.

Insulation has to be fire-resistant and effective. Here's what IRC Section R316.1 says:

> ***R316.1 Insulation.*** *Insulation materials, including facings, such as vapor retarders*

or vapor permeable membranes installed within floor-ceiling assemblies, roof-ceiling assemblies, wall assemblies, crawl spaces and attics shall have a flame-spread index not to exceed 25 with an accompanying smoke-developed index not to exceed 450 when tested in accordance with ASTM E 84 (see ASTM E 84-05 in Chapter 8).

There are a couple of exceptions in the code. One is for insulation installed in a concealed space and the other exception is for cellulose loose-fill insulation (Section R316.1). There's also a specific requirement for exposed attic insulation in Section R316.4:

R316.4 Exposed attic insulation. *All exposed insulation materials installed on attic floors shall have a critical radiant flux not less than 0.12 watt per square centimeter.*

What does this mean? Critical radiant flux is defined in ASTM standard E 970. This fire-test response standard describes how insulation is put in a test chamber, exposed to a flaming ignition source, and then graded on its ability to resist heat in a high-heat-energy environment. Again, you don't have to understand the test procedure — you just need to know there *is* one. Exposed insulation must pass this test. Make sure the material you use has been tested and is labeled as having passed the flame test.

Recessed light fixtures (luminaires) must be sealed to limit air leakage between air-conditioned spaces and those without air conditioning. IRC Section N1102.4.3 explains different ways to do this.

Lighting or heating fixtures in the ceiling can't be close to ceiling insulation because of the heat they produce. This is covered in IRC Section R808.1:

R808.1 Combustible insulation. *Combustible insulation shall be separated a minimum of 3 inches (76 mm) from recessed luminaires, fan motors and other heat-producing devices.*

Back in the old days, I'd see empty metal five-gallon buckets put over recessed lights to keep the insulation clear, but now there's an exception for any heat-producing device that's listed for a clearance of less than 3 inches — or no clearance at all. Fixtures that are listed for use with insulation cover (IC-rated) can be covered by the insulation or have insulation right up to them, as long they're installed according to the manufacturer's instructions.

Roof Insulation

It's a whole new ball game when you use roof insulation over sheathing. Rigid insulation, like polystyrene or urethane, is secured on top of the roof sheathing and then a roofing membrane is secured on top of that. We've touched briefly on two of those — thermoplastic and thermoset membranes. This is also where sprayed polyurethane foam roofing and liquid-applied coatings come into play.

IRC Section R905.14 discusses the application of sprayed polyurethane foam roofing. Use this material only on roofs with a slope of at least a 2 percent, or ¼ inch in 12 inches. Often the foam product is tapered in thickness to get the slope needed. Spray-applied polyurethane foam insulation has to meet ASTM C 1029. Make sure the material you use is labeled as meeting this standard, and install it according to the manufacturer's instructions. After 2 hours, but within 72 hours of applying the foam, protect it with a liquid-applied coating; see Section R905.15. This material has to meet additional ASTM standards, and must be installed according to the manufacturer's instructions.

Roof Drainage

If a roof isn't designed to support built-up water, it has to be sloped for drainage and have a drainage system installed. We talked about this in the section on Rain Loads, in Chapter 10.

Here's a brief reminder of what the IBC requires:

- Install roof drains at the lowest point on the roof.
- Roof drains must be capable of handling the water flowing to them.
- In most areas, a roof drain isn't allowed to drain into the sanitary sewer.

Figure 15-11 Roof drain on built-up roof

- In many areas, roof drainage water isn't allowed to flow over public property or into adjacent property.
- Concealed roof drainage must conform to the plumbing code.

The IRC requires a scupper or overflow drain to direct water to an easily-seen, approved location on the exterior of the building, as described in Section R903.4.1.

Figure 15-11 shows a roof drain on a built-up roof. The grated cover is a leaf strainer. Position the drains so they funnel water from the roof as quickly as possible.

We've discussed how to keep your building from being water-damaged; now let's look at some ways to keep it warm. One way is with a traditional fireplace. Most modern fireplaces are more a decorator statement than a heating element. But some blower-assisted firebox inserts actually heat a room very well.

Fireplaces and Chimneys

Fireplaces and chimneys have to meet strict code requirements. Let's start this section by discussing chimneys.

Chimneys

Chapter 21 of the IBC defines four main types of chimney. Most of their differences are in the flue lining requirements. Included are these descriptions from Section 2102.1:

- ***High-heat appliance type.*** *An approved chimney for removing the products of combustion from fuel-burning, high-heat appliances producing combustion gases in excess of 2,000 degrees F (1093 degrees C) measured at the appliance flue outlet (see Section 2113.11.3).*
- ***Low-heat appliance type.*** *An approved chimney for removing the products of combustion from fuel-burning, low-heat appliances producing combustion gases not in excess of 1,000 degrees F (538 degrees C) under normal operating conditions, but capable of producing combustion gases of 1,400 degrees F (760 degrees C) during intermittent forces firing for periods up to one hour. Temperatures shall be measured at the appliance flue outlet.*
- ***Masonry type.*** *A field-constructed chimney of solid masonry units or stones.*
- ***Medium-heat appliance type.*** *An approved chimney for removing the products of combustion from fuel-burning, medium-heat appliances producing combustion gases not exceeding 2,000 degrees F (1093 degrees C) measured at the appliance flue outlet (see Section 2113.11.2).*

High- and medium-heat appliance types are mostly for industrial uses. Low-heat and masonry units are mainly intended for residential buildings.

Residential chimneys are covered in both IRC Chapters 10, Chimneys and Fireplaces, and Chapter 18, Chimneys and Vents. Refer back to Chapter 8 in this book to find IRC Table R1001.1 (Figure 8-9), Summary of Requirements for Masonry Fireplaces and Chimneys, and IRC Figure R1001.1 (Figure 8-10), Fireplace and Chimney Details.

Chimney Foundations

To cover chimney requirements in more detail, let's start with chimney foundations and work our way up to roof termination. IRC

Sections R1001.2 and R1003.2 describe the requirements for masonry fireplaces, including chimney footings and foundations:

- Footings must be placed on undisturbed earth or engineered fill below frost level, or 12 inches below finished grade in areas not likely to experience frost.
- Footings must be made of concrete at least 12 inches thick or solid masonry units.
- Footings must extend at least 6 inches past the face of the fireplace or foundation wall on all sides.

The code doesn't require an ash dump cleanout, but I strongly recommend one. The client will thank you. An external location is best, but some builders put the access point in the basement. Either way, it must be readily accessible and not be near enough to combustible materials to create a fire hazard. The cleanout must have a ferrous metal or masonry door and frame, and be designed to stay tightly closed when not in use.

Chimney Walls

Masonry residential chimneys must have walls at least 4 inches thick and be fitted with a flue liner. Your choice of liner material depends on the type of appliance connected, as described in IRC Section R1003.11. Residential fireplaces usually have clay flue liners. A clay liner should extend from a point at least 8 inches below the lowest inlet. All liners should go from the top of the smoke chamber to a point above the enclosing walls. The chimney should be as close to vertical as possible — never more than 30 degrees from vertical. Chimneys can't support any load other than their own weight. However, if an engineer designs it with extra reinforcement that will accommodate additional weight, an exception can be made.

During an earthquake, a chimney can become the most vulnerable part of the house. Sometimes the only serious damage to a home is to the chimney. If you're building in Seismic Design Category D_0, D_1 or D_2, masonry or concrete chimneys and fireplaces must be reinforced and anchored, as shown in IRC Sections R1001.3, R1001.4, R1003.3 and R1003.4.

Flue Dimensions

Flue dimensions are critical to an efficient chimney. Smoke doesn't go straight up a chimney; it spirals up. That's why a round chimney is actually the ideal shape. A square flue is also good, since the only dead space is in the corners. A tall, narrow, rectangular flue needs more area to perform adequately. Be sure to review IRC Sections R1003.14 (appliance) or R1003.15 (masonry fireplace) before designing a chimney.

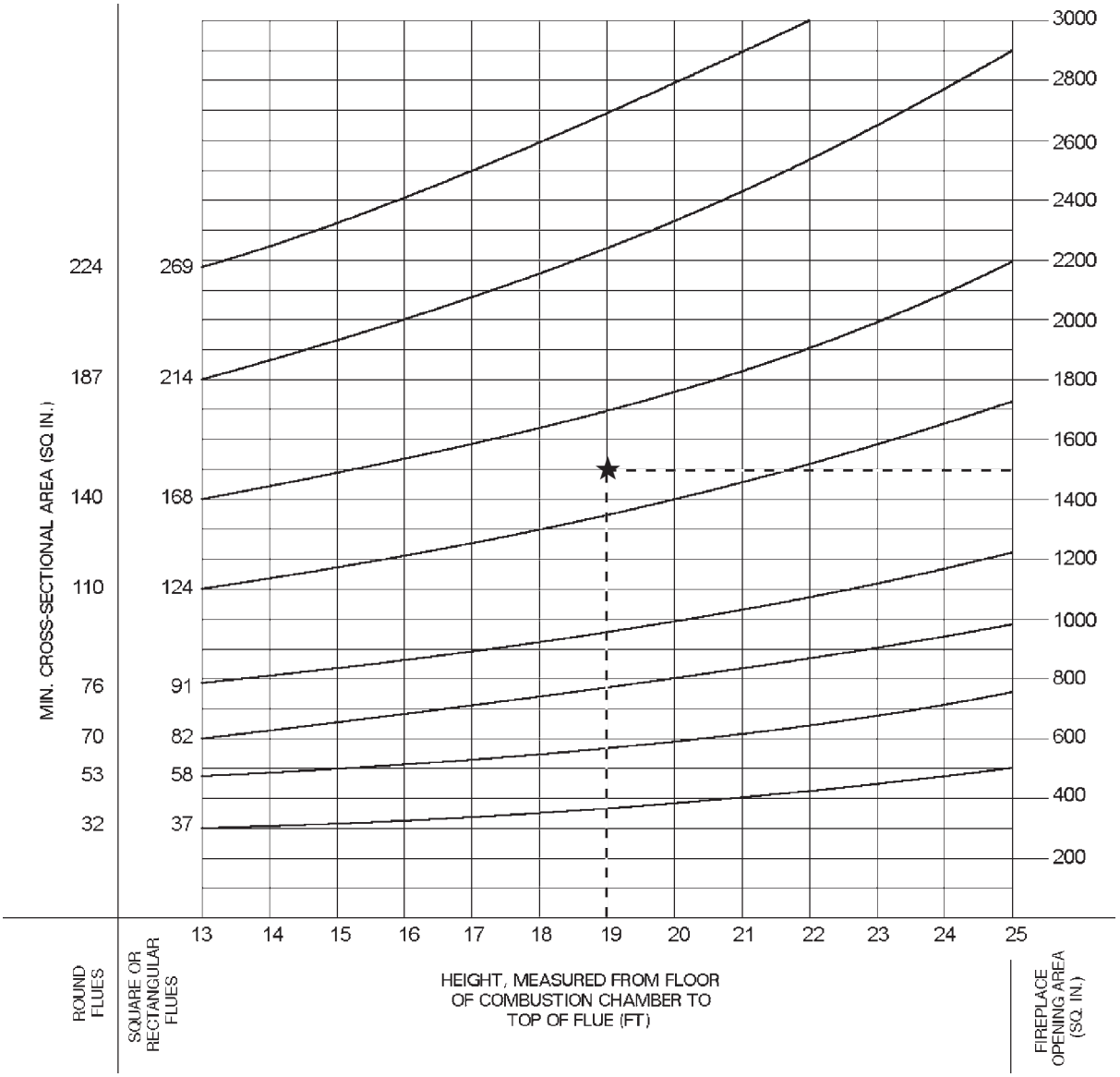
There are two ways to determine flue dimensions of masonry chimneys. You can either do some minor calculations, or read the flue dimensions from a graph. If you choose to calculate the necessary flue dimensions yourself, here are some standards:

- A round chimney flue must have a minimum net cross-sectional area of at least $^1/_{12}$ of the fireplace opening.
- A square chimney flue must have a minimum net cross-sectional area of at least $^1/_{10}$ of the fireplace opening.
- A rectangular chimney flue, with an aspect ratio of 2-to-1 or greater, must have a minimum net cross-sectional area of at least ⅛ of the fireplace opening.

IRC Figure R1003.15.2 (Figure 15-12) shows a graph you can use to determine dimensions. Find the point on the graph where the fireplace opening area (right hand side of the graph) and the chimney height, from the floor of the combustion chamber to the top of the flue, meet. Let's say you have a 1,500-square-inch fireplace opening and a 19-foot-high chimney. I've marked this point on the graph with a star. Now follow the curved lines and find the minimum cross-sectional area of the flue required on the left hand side. The number you need depends on whether you're planning to install a round (far left side) or a square or rectangular flue.

Let's say you're planning a round flue. Your size is about half way between the *curved* 110- and 140-square-inch lines on the graph. So we'll estimate it at 125 square inches. If you're planning a square or rectangular flue, the same two curved lines are marked as 124 and 168 square inches, and we'll estimate the star at 150 square inches.

FIGURE R1003.15.2
FLUE SIZES FOR MASONRY CHIMNEYS



For SI: 1 foot = 304.8 mm, 1 square inch = 645.16 mm^2.

Figure 15-12 Flue sizes for masonry chimneys

TABLE R1003.14(1) NET CROSS-SECTIONAL AREA OF ROUND FLUE SIZES	
FLUE SIZE, INSIDE DIAMETER (inches)	CROSS–SECTIONAL AREA (square inches)
6	28
7	38
8	50
10	78
$10^3/_4$	90
12	113
15	176
18	254

For SI: 1 inch = 25.4 mm, 1 square inch = 645.16 mm^2.
a. Flue sizes are based on ASTM C 315.

Figure 15-13 Net cross-sectional area of round flue sizes

If you did your own calculations, you'd get a round flue size of 125 square inches (1,500 ÷ 12 = 125), and a square or rectangular flue size of 150 square inches (1,500 ÷ 10 = 150). It's no coincidence that we picked a mid-range chimney height. If we'd chosen a shorter chimney, the graph would give you a larger flue size. And if we'd chosen a taller chimney, the graph would have given you a smaller flue size. This is confusing, so let's simplify it: If your chimney is taller than 19 feet, do your own calculations; if it's shorter than 19 feet, use the graph.

If you're using a clay flue lining, you can find the flue dimensions for a round flue in IRC Table R1003.14(1), Figure 15-13, or for a square and rectangular flue in IRC Table R1003.14(2), Figure 15-14.

Chimney Termination

Every chimney must extend at least 2 feet higher than any point of the building within 10 feet horizontally, and must be at least 3 feet above the highest point where the chimney passes through the roof.

When a chimney ends with a spark arrestor, it must meet the requirements of IRC Section R1003.9.1. A spark arrestor may not be a requirement in your area, but you'd sure want one on a wood shingle or shake roof. Spark arrestors are frequently installed when non-combustible roofs are built, too. Check with your local building department or fire marshal to see if one is needed.

When installing a spark arrestor on a masonry chimney, IRC Section R1003.9.1 requires that:

- The open area of the arrestor must be at least four times the open area of the chimney flue.
- The arrestor screen must be 19-gauge galvanized steel or 24-gauge stainless steel and be both heat- and corrosion-resistant.
- The openings in the arrestor screen must allow ⅜-inch-diameter spheres to pass through it, but stop ½-inch-diameter spheres.
- The arrestor must be designed so it can be removed for cleaning the chimney flue. Arrestor screens must also be accessible for cleaning.

TABLE R1003.14(2) NET CROSS-SECTIONAL AREA OF SQUARE AND RECTANGULAR FLUE SIZES	
FLUE SIZE, OUTSIDE NOMINAL DIMENSIONS (inches)	CROSS–SECTIONAL AREA (square inches)
4.5 × 8.5	23
4.5 × 13	34
8 × 8	42
8.5 × 8.5	49
8 × 12	67
8.5 × 13	76
12 × 12	102
8.5 × 18	101
13 × 13	127
12 × 16	131
13 × 18	173
16 × 16	181
16 × 20	222
18 × 18	233
20 × 20	298
20 × 24	335
24 × 24	431

For SI: 1 inch = 25.4 mm, 1 square inch = 645.16 mm^2.

Figure 15-14 Net cross-sectional area of square and rectangular flue sizes

Figure 15-15 Zero-clearance fireplace

Fireplaces

Zero-clearance factory-built metal fireplace inserts are now available, if you don't want to build a masonry fireplace. These prefab fireplaces can be set directly into wood framing, as you can see in Figure 15-15. They must be installed exactly as the manufacturer specifies. It's too early to say if they'll be as durable as masonry fireplaces. But they're much cheaper to install than masonry fireplaces, which have to be built from the ground up.

Masonry Fireplaces

You have a lot to consider if you're installing a masonry fireplace. The firebox must be at least 20 inches deep, except for the Rumford fireplaces described in the following section. The width of the opening isn't too important, but don't make the height more than the size of the fire you intend for it. A small fire in a large, high firebox is usually a smoky fire.

The shape of the back and sides of the firebox determines how well it reflects heat into a room. The shape of the smoke chamber, throat and smoke shelf are also important.

Other things to remember about fireplace design are:

- Masonry fireplaces can be made using solid masonry units, hollow masonry units grouted solid, concrete or stone.
- A 2-inch firebrick lining is usually installed. When installed, the total thickness of the back and side walls, including the firebrick lining, must be at least 8 inches. Joints between firebricks can't be more than ¼ inch.
- If no fireplace lining is installed, the total thickness of the back and side walls must be at least 10 inches.
- The firebox throat can't be less than 8 inches above the top of the fireplace opening.
- The throat opening can't be less than 4 inches deep.
- The passageway above the firebox, including the smoke chamber, the throat and the damper (when fully opened), can't be less than the cross-sectional area of the flue.

IRC Section R1001 covers all the requirements for masonry fireplaces. We've only touched on the main points. Refer to Table R1001.1 and Figure R1001.1 for more information. (See Figures 8-9 and 8-10 in Chapter 8 of this book.)

Rumford Fireplaces

Rumford fireplaces are tall and shallow to reflect more heat than the conventional deep firebox. Named for Count Rumford of Woburn, Massachusetts, they were introduced into use in the 1700s. Thomas Jefferson had Rumford fireplaces installed in Monticello.

The streamlined throat of the Rumford does away with turbulence and carries the smoke off with little loss of heated air. The firebox depth must be at least 12 inches and at least $^{1}/_{3}$ the width of the fireplace opening. The throat must be at least 12 inches above the fireplace lintel and no less than $^{1}/_{20}$ the area of the fireplace opening.

Hearths

The hearth of a masonry fireplace must be at least 4 inches thick and made of brick, concrete, stone or another approved noncombustible slab. It must be supported by noncombustible materials or reinforced to carry its own weight and whatever loads it's meant to take. Make sure the hearth extends at least 16 inches beyond the front of the fireplace opening and at least 8 inches beyond the sides. If your fireplace opening is more than 6 square feet, the hearth has to extend 20 inches in the front and 12 inches on the sides. Hearth extensions must be at least 2 inches thick. An exception to that is if the firebox opening is at least 8 inches above the top of the hearth extensions. Then the hearth extension only has to be ⅜ inch thick. You can find all the details of hearth and hearth extensions in IRC Sections R1001.9 and R1001.10.

Metal Damper Hoods

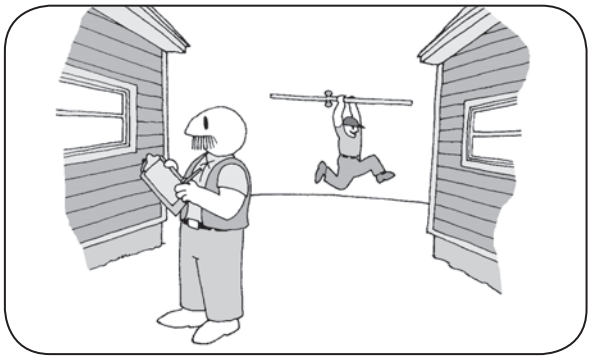
Most masonry fireplaces have metal damper hoods. They usually come complete with smoke shelf, damper, and a properly-sized flue outlet. IRC Section R1001.7.1 says the damper must be made of ferrous metal (iron or steel) and be located at least 8 inches above the top of the fireplace opening. You must be able to operate the damper from the room where the fireplace is installed.

All seams must be smoke-proof and unsoldered, since solder melts at relatively low temperatures. Hoods must be sloped 45 degrees or less, and extend horizontally at least 6 inches past the front of the firebox. Don't install the hood closer than 18 inches to any combustible material, unless its design is approved for that.

Line the top side of the hood with several inches of fiberglass to prevent heat from being lost in the chimney cavity. Always use mortar to secure the hood in place. In the old days, you just stuffed the space with fiberglass. But it was discovered that fiberglass, even though noncombustible, melts and can allow flame to enter the chimney cavity. This could create a fire hazard, so now all hoods must be mortared in.

IRC Section R1001.11 states you can't place combustible materials (like wood beams, joists or studs) within 2 inches of the front face or sides, or within 4 inches of the back of a masonry fireplace. Don't fill these spaces with anything, except to provide fire blocking. See Section R1001.12. We'll talk some more about fireplaces in Chapter 18, when discussing Combustion Air.

There are many exceptions to Section R1001.11 that may be applicable to your situation. So be sure to consult your building code or the building department to get precise details about your job.



The Traveling Solid Core Door

There are probably more ways to fool building inspectors than there are building inspectors to fool. I've learned to never underestimate the ingenuity of an entrepreneur who's determined to save a buck, even if it costs him two dollars to do it. Here's a case in point.

Once I issued permits to a local contractor for three single-family residences on three adjoining lots. His practice was to begin one, get it well along, and then start with the next one. Consequently, for most of the construction, he had three houses at different stages of completion. As he finished each part of the job, he called for the usual inspections.

On the final inspection for the first house, I entered the residence through the door that separated the garage from the entry to the kitchen. The code says any door separating a garage from living space has to be solid core, and for good reason. A solid core door is designed to take heavy use and abuse, and has much greater fire-resistance than a hollow door. Many fires start in the garage, where cars, lawnmowers, cans of gasoline and other flammables are stored. Spending an extra $30 on a solid core door is well worth the money.

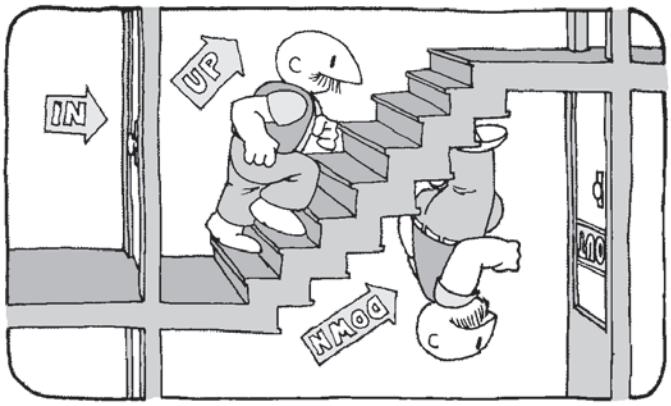
As I came in, I gave the door a couple of raps with my knuckles. The dull thud told me it was solid core, just like the code required. Later I made the same final inspection on each of the other houses. Eventually all three houses passed inspection and were sold.

Several years later the FHA foreclosed on the second of those three houses. They called me in to certify code compliance so the house could be sold under an FHA program. That probably wasn't necessary. After all, I had inspected those houses myself only a few years earlier. Anyhow, I checked the plumbing, made sure kitchen and bath fans exhausted to the outside, counted the foundation vents — all the usual stuff. Everything checkout out.

I started back into the house to write up my report for the FHA. As I went through the opening between the garage and the kitchen, I gave the door a rap with my knuckles. It sounded hollow to me. Funny, why would anyone remove a solid core door and replace it with a hollow core door? While I was pondering this, I had a flash of insight.

I went to the first of the three houses, introduced myself, and asked to check the kitchen door. Sure enough, it was hollow core, too. So I went down to the third house and checked the same door. This time it was a solid core door. Then it dawned on me — I had inspected the same door when I'd made the final inspection on all three houses. The builder had moved that one door from house to house to house, as I moved along in my inspection.

So he'd saved himself $60 — and left two houses non-code-compliant, and at risk for a potentially-lethal fire. What was he thinking?



CHAPTER 16

Means of Egress

This chapter concerns something we rarely think about — exiting a building in an emergency situation. Having the right exit when and where it's needed is vital. If there's a fire, getting out of the structure quickly can mean the difference between life and death. That's why the code is so strict about exits and clearances.

I once plan-checked a building that had a room with no door at all. Nobody could get in, so nobody could get trapped inside. The room was perfectly safe — but totally useless. Can you guess how that happened? The owner didn't like the placement of the original door, so the designer deleted it from the plan. He was interrupted in his work before adding the new door location. When he got back to the drawing, he'd forgotten about it. The person who reviewed the plans didn't catch the mistake, but I did — and fortunately it was easy to fix. Eventually, the builder would have caught the mistake. But the framing and maybe even the drywall could've been done by then. At that stage, putting in the door would have been expensive.

What Are Exits?

We've established that every room in every building needs a way in and out. So let's take a look at exits. The code uses the term Means of Egress to define exits. Section R311 of the IRC and Chapter 10 in the IBC cover Means of Egress, including the definition. IBC Section 1002.1 says:

> ***Means of egress:*** *A continuous and unobstructed path of vertical and horizontal egress travel from any occupied portion of a building or structure to a public way. A means of egress consists of three separate and distinct parts: the exit access, the exit and the exit discharge.*

The following are parts of the exit system:

- Aisles
- Corridors
- Doors

- Exit passageways
- Horizontal exits
- Ramps
- Stairways
- Stair towers
- Exit courts
- Yards
- Gates

Elevators, escalators or moving walkways *cannot* be used as part of a required exit. But there is an exception in the case of access for the physically disabled; see IBC Sections 1003.7 and 1007.4.

> ***1007.4 Elevators.*** *In order to be considered part of an accessible means of egress, an elevator shall comply with the emergency operation and signaling device requirements of Section 2.27 of ASME A17.1.* Standby power must be provided, and the elevator must be able to be . . . *accessed from either an area of refuge . . . or a horizontal exit.*

The code gives you all the rules for using an elevator as part of a required means of egress. But don't forget to check with your building official for his approval.

The IBC addresses many other exit-related terms, some in the form of definitions. The following are a few you should be familiar with:

> ***Accessible means of egress:*** *A continuous and unobstructed way of egress travel from any accessible point in a building or facility to a public way.* (The term *Accessible* specifically applies to wheelchair-accessible and not just accessible in general.)
>
> ***Area of refuge:*** *An area where persons unable to use stairways can remain temporarily to await instructions or assistance during emergency evacuation.*
>
> ***Corridor:*** *An enclosed exit access component that defines and provides a path of egress travel to an exit.*
>
> ***Egress court:*** *A court or yard which provides access to a public way for one or more exits.*
>
> ***Exit:*** *That portion of a means of egress system which is separated from other interior spaces of a building or structure by fire-resistance-rated construction and opening protectives as required to provide a protected path of egress travel between the exit access and the exit discharge. Exits include exterior exit doors at ground level, exit enclosures, exit passageways, exterior exit stairs, exterior exit ramps and horizontal exits.*
>
> ***Exit, horizontal:*** *A path of egress travel from one building to an area in another building on approximately the same level, or a path of egress travel through or around a wall or partition to an area on approximately the same level in the same building, which affords safety from fire and smoke from the area of incidence and areas communicating therewith.*
>
> ***Exit access:*** *That portion of a means of egress system that leads from any occupied portion of a building or structure to an exit.*
>
> ***Exit discharge:*** *That portion of a means of egress system between the termination of an exit and a public way.*
>
> ***Exit enclosure:*** *An exit component that is separated from other interior spaces of a building or structure by fire-resistance-rated construction and opening protectives, and provides for a protected path of egress travel in a vertical or horizontal direction to the exit discharge or the public way.*
>
> ***Exit passageway:*** *An exit component that is separated from all other interior spaces of a building or structure by fire-resistance-rated construction and opening protectives, and provides for a protected path of egress travel in a horizontal direction to the exit discharge or the public way.*
>
> ***Ramp:*** *A walking surface that has a running slope steeper than 1 unit vertical in 20 units horizontal (5-percent slope).*
>
> ***Stairway:*** *One or more flights of stairs, either exterior or interior, with the necessary landings and platforms connecting them, to form a continuous and uninterrupted passage from one level to another.*

Exit passageways are like corridors, but they're built to a higher level of fire resistance. They should not be used for anything other than getting out of the building. That means no permanent or even temporary storage.

A means of egress goes from deep inside the building all the way out of the building. But there's a lot more to it than that. The inspector and the fire marshal expect you to know how many people need to get out quickly from any given point. And there's more to exit access than meets the eye. For example, you could have an aircraft hangar with a 40-foot-wide door. You'd think that would be obviously safe in an emergency. But what if someone in the hangar doesn't have easy access to that exit and can't get out of the building quickly in an emergency? Then you don't have an approved exit.

Exit Standards Promote Safety

The definition of Means of Egress implies that eventually all exits lead outside and to safety. That means when you leave a building through an exit system, you'll eventually reach a public way. What's a public way? The IBC defines it this way:

> ***Public Way.*** *A street, alley or other parcel of land open to the outside air leading to a street, that has been deeded, dedicated or otherwise permanently appropriated to the public for public use and which has a clear width and height of not less than 10 feet (3048 mm).*

To determine the size and number of exits needed for a building, you must know how many people will normally occupy a given space. In Chapter 4, we learned how to find the occupant load using IBC Table 1004.1.1, Maximum Floor Area Allowances per Occupant (Figure 4-1). An occupant load, as described in the building code, is the source of many disagreements. The owner of a store may try to bargain with the inspector. He'll say, "You know, I probably won't have that many customers in my store even on my busiest day. Why can't we figure it on what I think I'll have?"

Here's how the inspector will answer that question: "Because the Code says how you have to figure it, assuming the worst case, and if we don't go with that and something bad happens, we're both going to be answering some very difficult questions."

After all, codes are written to establish safe building standards. But there'll always be people who question these standards. Usually, they'll complain that the standards are too strict. But sometimes the regulations aren't strict enough. Most of them are minimum standards, leaving the inspector very little room for interpretation, except on the upside. That's certainly true of occupant loads.

How do you find the occupant load permitted in any building or part of a building? Divide the floor area by the square feet per occupant required in Table 1004.1.1 (Figure 4-1, back in Chapter 4). What if the table doesn't cover a particular occupancy? Then the building official will make his decision based on which occupancy type most closely matches it. That can lead to legitimate arguments, but the inspector always makes the final decision.

You can increase the allowable floor area by increasing the frontage of the building onto public ways or open spaces. Another method is to install a code-accepted sprinkler system (as detailed in Chapter 4). Or you can provide more exits. But you'll have to have an approved aisle or seating diagram to convince the inspector.

Determining Occupant Load for Exits

The code is based on the assumption that all parts of a building will be fully occupied at the same time. That determines occupant load. If you have a mixed-occupancy building, you've got to design it *also* assuming that each area will always be used to its maximum occupancy. But that doesn't mean that the most restrictive provisions apply to the whole building. Each separate area is rated on its own. The codes assume that all areas will be used to

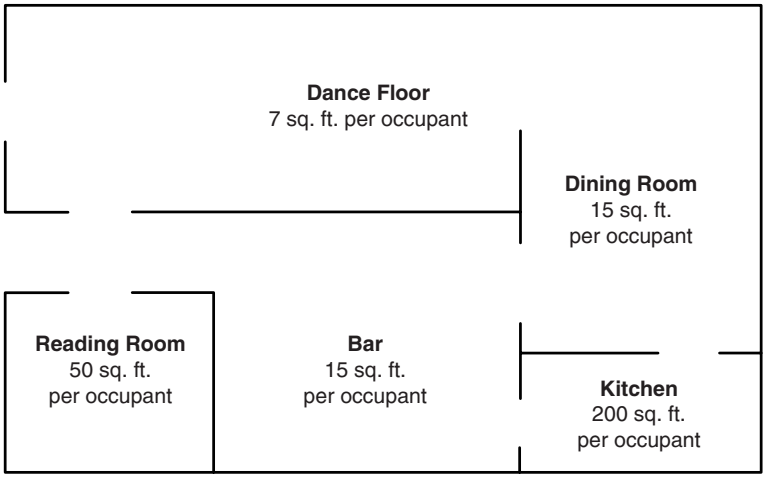


Figure 16-1 Preliminary sketch of lodge building

their maximum capacity simultaneously. Let's look at the lodge example we used earlier in the book. The floor plan is shown in Figure 16-1.

Our lodge has a dance floor, dining room, reading room, bar and kitchen. Back in Chapter 4, you checked IBC Table 1004.1.1 (Figure 4-1), and agreed with the inspector to provide 7 square feet per occupant for the dance floor and 15 square feet per occupant for the dining room and bar. In addition, you'd provide 50 square feet per occupant for the reading room, and 200 square feet per occupant for the kitchen.

Based on these occupant load rates, you decided the lodge building will be 8,100 square feet, and has a design occupant load of 664 people. But the lodge only meets once a week in the large main room, which doubles as the meeting room and dance floor. The dining room is open each day from 3 p.m. to midnight, and the reading room from 10 a.m. until 5 p.m. The bar is open from 11:30 a.m. until midnight on non-dance nights. They hold a dance once a week, and on that day the bar stays open until 1:30 a.m.

Do you need exits that will handle all 664 people? Or can you get by with exits for only the maximum crowd expected to be in the building at any one time? You guessed it. Under the code, exits have to be designed to safely evacuate all 664 people.

Overloading an Occupancy

There's one more thing to consider. You originally designed the bar to hold 100 people. But during an intermission at the dance, there might be *more than* 100 people in there. If the owner hasn't thought of it, the builder should suggest a way to deal with the overflow. Too many people trying to get through exits in an emergency is as bad as not having adequate exits in the first place.

IBC Section 1004.3 says that any room used for assembly purposes that doesn't have fixed seats must have the room's capacity posted where it's easily seen. The sign must indicate how many occupants are allowed in a particular room, and be posted near the main exit or exit-access door. Signs must be readable, permanent, and maintained by the owner. The building owner or manager is required to enforce the maximum capacity. If they don't, the fire marshal has the authority to shut the place down.

If you think overflow crowds could also be a potential problem for your building, talk to the fire marshal. Try to work out a better ratio between the bar area and the dance floor area. This problem won't come up very often, because most dance floors are either in or next to the bar and not in a separate room.

TABLE 1015.1 SPACES WITH ONE MEANS OF EGRESS	
OCCUPANCY	MAXIMUM OCCUPANT LOAD
A, B, E[a], F, M, U	49
H-1, H-2, H-3	3
H-4, H-5, I-1, I-3, I-4, R	10
S	29

a. Day care maximum occupant load is 10.

Figure 16-2 Spaces with one means of egress

Establishing the Number and Size of Exits

Every building or usable portion of a building must have at least one exit. That makes sense. But often you'll need more than one exit.

Number of Exits

The number of exits required is found in IBC Sections 1015 and 1019. Section 1019.2 describes specific building types that only need one exit. Group R-3 buildings are one example. There's a complete list by occupancy type, building height and occupant number in Table 1019.2.

Table 1015.1, Figure 16-2, shows the spaces, by occupancy type and occupant load, that require only a single means of egress. Remember that the code only gives you the minimum requirements. You might want to have two exits even though the code only requires one. Section 1015.1 describes conditions under which two exits *must* be provided:

- When the occupant load is more than what's shown in Table 1015.1 (Figure 16-2).
- When the common path of egress travel is more than what's defined in Section 1014.3 (usually 75 feet or less — see the code for details).
- In boiler, incinerator and furnace rooms (Section 1015.3), refrigeration machinery rooms (Section 1015.4), and refrigerated rooms or spaces (Section 1015.5).

If you're planning to construct an I-2 occupancy building (not listed in Table 1015.1), be sure to check IBC Section 1014.22 regarding exit requirements. Basically, it requires habitable rooms or suites in an I-2 occupancy to have an exit access door leading directly to a corridor. But there are numerous exceptions, so read it carefully.

IBC Section 1019 says that all rooms and spaces on any story must have the minimum number of exits shown in Table 1019.1 (Figure 16-3). The number of exits is based on the occupant load, except as modified in Table 1015.1.

The occupant load refers to any room or space on any story, and the full story itself. So if one story has just two rooms with an occupant load of 400 each, then each room must have two exits. And the full story, with a total occupant load of 800, must have three exits. If your building has a roof that can be accessed by people, it's counted as another story and also must have the required number of exits. The required exits must be maintained from the room or space itself to arrival at grade level or the public way.

So how does all of this affect your lodge building? Remember, its total occupant load is 664. This falls in the range of 501-1,000 in Table 1019.1 (Figure 16-3). That means you have to provide at least three exits to the exterior. Figure 16-1 shows only two exits, so you need to add

TABLE 1019.1 MINIMUM NUMBER OF EXITS FOR OCCUPANT LOAD	
OCCUPANT LOAD (persons per story)	MINIMUM NUMBER OF EXITS (per story)
1-500	2
501-1,000	3
More than 1,000	4

Figure 16-3 Minimum number of exits for occupant load

TABLE 1005.1 EGRESS WIDTH PER OCCUPANT SERVED				
	WITHOUT SPRINKLER SYSTEM		WITH SPRINKLER SYSTEM[a]	
OCCUPANCY	Stairways (inches per occupant)	Other egress components (inches per occupant)	Stairways (inches per occupant)	Other egress components (inches per occupant)
Occupancies other than those listed below	0.3	0.2	0.2	0.15
Hazardous: H-1, H-2, H-3 and H-4	0.7	0.4	0.3	0.2
Institutional: I-2	NA	NA	0.3	0.2

For SI: 1 inch = 25.4 mm. NA = Not applicable.

a. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2.

Figure 16-4 Egress width per occupant served

one more. The exit locations need some work, too. We'll review the code requirements for exit positioning a little later in this chapter.

Exit Size

Now that you know how many exits are needed, you have to figure out their sizes. Exit width is discussed in IBC Section 1005 and Table 1005.1 (Figure 16-4). Section 1005 says that the total exit width (in inches) for any room or space can't be less than the occupant load for that room or space multiplied by the correct factor from Table 1005.1. Here's your formula:

Occupant Load × Factor from Table 1005.1 = Minimum Total Exit Width (in inches)

There's something else you need to know if you have more than one exit. Each exit must be large enough so that if one exit is blocked, the remaining exit capacity will still be at least 50 percent of the required exit capacity. So if you need two exits, one large and one small exit won't necessarily satisfy the required total exit width. If the large exit is blocked, the smaller exit may be less than 50 percent of the required exit width. In that case, the two exits must be the same width.

Let's look at the lodge dance floor again. You decided (back in Chapter 4) that the maximum occupant load for that room was 400 people. The dance floor falls into the category *Occupancies other than those listed below* in Table 1005.1 (Figure 16-4). Remember (from Chapter 5, Group A-3) that sprinklers must be installed in fire areas occupied by more than 300 people. So the factor you must use is 0.15 (outlined in the figure). If there were stairways involved (which there aren't because the lodge is a single story building), the factor would be 0.2.

The minimum total egress width from the dance floor area needs to be the occupant load (400) multiplied by 0.15:

$$400 \times 0.15 = 60 \text{ inches}$$

You'll need a total of at least 5 feet (60 inches) of exit width from the dance floor. And you have to have at least two exits, since 400 is in the first category in Table 1019 (Figure 16-3). That means that each of the two exits must have a clear width of at least 30 inches (60 ÷ 2 = 30). Right? Wrong — read on.

Section 1008.1.1 says that every door opening ... *shall provide a clear width of not less than 32 inches ... measured between the face of the door and the stop, with the door open 90 degrees.* So, each of the two exits from the dance floor must have a clear width of at least 32 inches.

Keep in mind that when you open a 3-foot-wide (36-inch) door to 90 degrees, you'll be lucky to have 34 inches to the stop — usually there's less. Without including the required hardware, a 34-inch door just barely passes the 32-inch clearance required. There are some other limits to remember, too. IBC Section 1008.1.1.1 discusses projections into the clear width of your exit.

> ***1008.1.1.1.*** *There shall not be projections into the required clear width lower than 34 inches (864 mm) above the floor or ground. Projections into the clear opening width between 34 inches (864 mm) and 80 inches (2032 mm) above the floor or ground shall not exceed 4 inches (102 mm).*

So if you have panic hardware and/or an automatic door closer, watch out. Many commercial doors are 7 feet high just so the closer can be above the 80-inch mark. However there's an

exception in IBC Section 1003.3.1, which says door closers and stops may reduce headroom to no less than 78 inches.

Means of egress issues for assembly areas are also covered in IBC Section 1025. Section 1025.1 says:

> ***1025.1 General.*** *Occupancies in Group A, which contain seats, tables, displays, equipment or other material, shall comply with this section.*

If your dance floor will have seats, and obviously your dining room will have chairs and tables, look carefully at this section. Read down to Section 1025.2 which says:

> ***1025.2 Assembly main exit.*** *Group A occupancies that have an occupant load of greater than 300 shall be provided with a main exit. The main exit shall be of sufficient width to accommodate not less than one-half of the occupant load, but such width shall not be less than the total required width of all means of egress leading to the exit.*

The first sentence tells you this section applies to your dance floor (occupant load 400) and the lodge as a whole, since it's designed to accommodate 664 people at once. So you need to make sure that both the dance floor and the lodge building comply with Section 1025.2. The section then goes on to say that the width of the main exit must be able to accommodate no less than half the occupant load.

Let's look at how this affects the dance floor. (We'll look at the impact it has on the complete lodge later, in Requirements for Exterior Exit Doors.) The dance floor has a maximum occupant load of 400, so half that number is 200. The main exit width required for 200 people in a sprinklered building (from Table 1005.1, Figure 16-4) is:

$$200 \times 0.15 = 30 \text{ inches}$$

But remember, Section 1008.1.1 says that the minimum clear exit width allowed is 32 inches. So our minimum main exit width from the dance floor has to be 32 inches. You can always make the exit larger, if you wish.

Since the dance floor occupant load is 400, it must have at least two exits, sized so that if one exit is blocked for any reason, the required total exiting capacity is not reduced by more than 50 percent. That means that the second exit from the dance floor must also be at least 32 inches wide.

Not only is there a minimum size for a door opening, there's a maximum size for a door. Section 1008.1.1 says that the maximum width of a swinging door is 48 inches. If you want to install a main exit door from the dance floor wider than 48 inches, you'll have to install a double door. And, the door height must be at least 80 inches.

There are many exceptions to Section 1008.1.1. Most of them apply to Residential and Institutional occupancies. So if you're building one of those, check this section of the code for details.

Exit Positions

Now let's decide where you'll locate those two 32-inch-wide exits from the dance floor. The code says that if you need two or more doors, they can't be located right next to each other. Here's what the IBC says:

> ***1015.2 Exit or exit access doorway arrangement.*** *Required exits shall be located in a manner that makes their availability obvious. Exits shall be unobstructed at all times. Exit and exit access doorways shall be arranged in accordance with Sections 1015.2.1 and 1015.2.2.*
>
> > ***1015.2.1 Two exits or exit access doorways.*** *Where two exits or exit access doorways are required from any portion of the exit access, the exit doors or exit access doorways shall be placed a distance apart equal to not less than one-half of the length of the maximum overall diagonal dimension of the building or area to be served measured in a straight line between exit doors or exit access doorways. Interlocking or scissor stairs shall be counted as one exit stairway.*

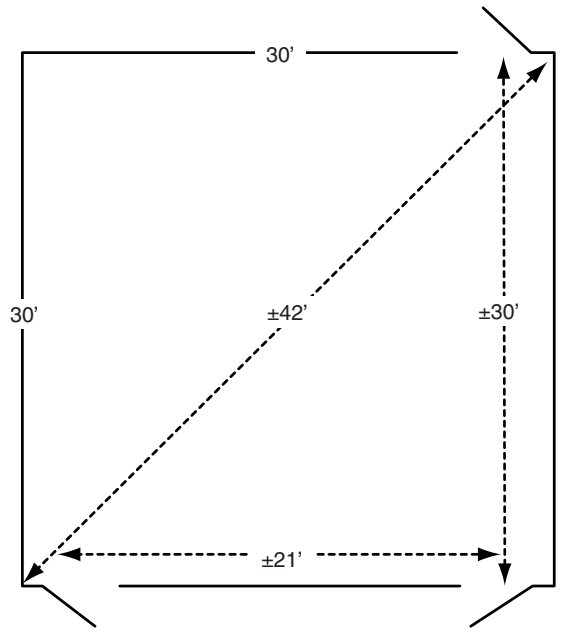


Figure 16-5 Placing exits on a square room

There are two exceptions. Where exit enclosures are provided and where automatic sprinklers are installed, the distance can be shorter. Check the code for the details of each exception.

Let's look at a drawing of another room. The room in Figure 16-5 is 30 feet long by 30 feet wide, or 900 square feet. The maximum overall diagonal dimension of this room is just over 42 feet. To find this, take the square of the length of each of the two sides. Then add them and find the square root of the total — you *do* remember the Pythagorean Theorem, don't you? There may be an easier way, though. If the room is square like this one, multiply the length of one side by 1.414 (30 × 1.414 = 42.4).

Section 1015.2.1 says the doors must be separated by at least half the room's diagonal. That's about 21 feet, in this case. You could put both exits on one wall, as shown in the bottom wall of Figure 16-5. But wouldn't it be better to have one door in the top wall and one in the bottom wall? Yes — if they both would have access to a public way. In fact, I'd highly recommend it.

What If the Area Isn't Square?

Figure 16-6 shows a room 45 feet long by 20 feet wide. It's also 900 square feet. Could you put the two doors directly across from each other in the two long sides of this room? Probably not. Why? Because the room is too narrow. It may have the same square footage, but it has different dimensions, so you have to recalculate the diagonal.

Take the new room length (45 feet) and new width (20 feet) and square them. 45 squared is 2,025, and 20 squared is 400. Together they add up to 2,425 square feet. The square root of 2,425 is almost 50 feet. Remember, you must have at least one-half of that as a minimum distance between the two exits if the room has no sprinklers. That means your two exits have to be at least 25 feet apart. The two doors couldn't be directly opposite each other in the long sides of the room, since there'd be only 20 feet between them. But Figure 16-6 shows how you could arrange the exits. They're still both on the long sides of the room, but offset slightly, with 26 feet between them. That would meet the code. But is it the safest plan possible? I don't think so. Wouldn't it be better to have one exit in each of the long sides, but at opposite ends of the room? And better still to have them in the short sides of the room directly opposite each other? Always remember to plan for the access to a public way as well.

Now let's look at the exit locations in the lodge. The dance floor is about 80 feet long by 30 feet wide, so the diagonal is just over 85 feet.

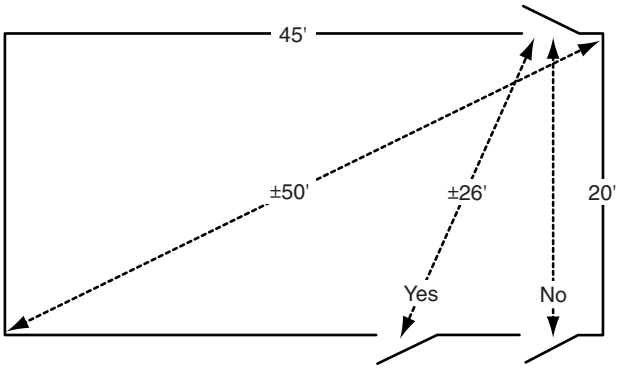


Figure 16-6 Placing exits on a long, narrow room

Two exits would normally need to be at least half this distance apart. But since you need to install sprinklers in the lodge (because the occupant load is greater than 300 and it's an A-3 occupancy), that'll change the required distance. So the two exits from the dance floor need only be one-third of the room's diagonal apart (85 ÷ 3 = 28 1/3 feet). If you look back at Figure 16-1, you'll see that both of the exits on the left side of the room are more than 28 1/3 feet from the exit on the right that goes into the dining room. They're very well placed — on opposite ends of the 80 foot dance floor. That means they meet the code requirement. In a minute, we'll look at whether you need both exits on the left side.

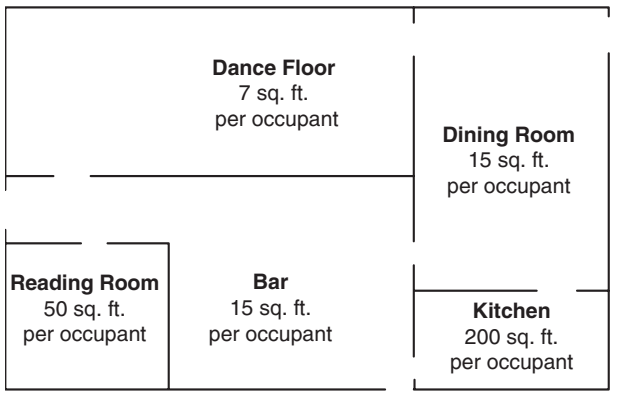


Figure 16-7 Modified lodge building design to meet the code for exits

What About Three or More Exits?

Where can you put the other exits if you need three or more? Go to IBC Table 1019.1 (Figure 16-3) to determine the number of exits you need. We know that at least two of the exits must be spaced apart by at least half (or one-third if sprinklers are installed) of the maximum overall diagonal dimension. The additional exit(s) should be away from the first two, so that if one of them is blocked, the others will be available.

Remember, your lodge building needs three exterior exits because it's an assembly-type occupancy with an occupant load of more than 500. So where should you put the three exits? Look at Figure 16-1 again. This time, think of the building as a whole. Two exits to the public way must be spaced apart more than one-third of the maximum overall diagonal dimension of the fully-sprinklered building. The building is approximately 115 feet long by 70 feet wide, with a diagonal measurement of roughly 135 feet. The two exterior exits must be at least 45 feet apart (135 ÷ 3 = 45).

That's clearly not the case in Figure 16-1. So let's add the second exterior exit at the rear of the building, in the top right-hand corner of the dining room. That's well over 45 feet from the main entrance. Now let's close off the exterior dance floor exit. We now have two exterior exits, but we need one more — placed in a location that will better serve our goal of efficient emergency evacuation, as well as our building use.

Where should you add that third exit? Here's a hint: You can't have a required exterior exit passing through a kitchen. But it would be a very good idea to have an exit on that side of the building. So probably the best location for the third exterior exit is at the back of the bar. Then it can be both a required exterior exit and a way to bring kegs of beer or bar supplies in and out. And, if you plan this exit so that it's close to the kitchen door, you'll have easy access to the kitchen for bringing in food and taking out the garbage.

Aren't you smart? You're serving two purposes with this design. You're meeting the code, and you're making it easier for the owners to carry on their business. Figure 16-7 shows our redesigned lodge with all its new exits in place.

Egress Through Adjoining Areas

When can an exit lead into an adjoining or intervening room or area? First, here are some definitions. *Adjoining rooms* (or areas) are those connected by the same door. *Intervening rooms* (or areas) are rooms (or areas) *between* other rooms (or areas). The answer to the question is that an exit can lead into an adjoining area or intervening area if they're easily accessed and provide a *discernible path of egress travel to an exit*. For example, looking back at the lodge in Figure 16-1, the right-hand exit from the dance floor leads into the dining room. The dining room has access to the outside, through the

bar, back to the main entrance. But this is *not* an obvious path to an exit. However, now that you've added an exterior exit in the top right-hand corner of the dining room (Figure 16-7), you clearly meet the code. The exit door from the dance floor is aligned with the exterior exit door in the dining room. It's a straight path out of the building.

You can get all the details for egress through intervening spaces from IBC Section 1014.2. Exits can't pass through:

- Kitchens
- Storerooms
- Restrooms
- Closets
- Spaces used for similar purposes

And as usual, there are exceptions, so read this section carefully.

Hallways and Corridors

Hallways are considered parts of one- or two-family dwellings and townhouses, so they're covered by the IRC. Corridors are covered by the IBC.

Hallways

The IRC is concerned with two main factors regarding egress: the width and the height of hallways. These are detailed in Sections R311.3 and R305.1.

Residential hallways have to be at least 3 feet wide (that's *net*, and measured after sheetrock is attached) and 7 feet high. The exception is that beams and girders can extend a maximum of 6 inches below the ceiling height.

Corridors

What is a corridor? You'll find the definition in IBC Section 1002.1.

> ***Corridor.*** *An enclosed exit access component that defines and provides a path of egress travel to an exit.*

There's an important restriction applying to corridors and other parts of egress — headroom. The minimum corridor headroom is 7 feet (84 inches). Headroom can't be reduced by objects protruding more than 4 inches, or for more than 50 percent of the ceiling area. See Section 1003.3.1.

Construction requirements for corridors are given in Section 1017. We'll look at the most important: fire resistance (Section 1017.1), corridor widths (Section 1017.2) and dead ends (Section 1017.3).

Fire Resistance

IBC Section 1017.1 says that corridors must meet the fire-resistance rating shown in Table 1017.1 (Figure 16-8). Corridor walls required to be fire-resistance rated must comply with Section 708 for fire partitions. Section 708.3 states that corridors must have a one-hour fire-resistance rating, except as required in Section 1017.1. There are exceptions for Group B and E occupancies and for corridors in open parking garages.

Corridor Widths

In most cases, corridor widths must meet the same requirement as exit widths, that is, they shouldn't be less than 44 inches wide. We discussed exit widths earlier in the chapter. See IBC Section 1005.1 and Table 1005.1 (Figure 16-4) for details.

However, there are exceptions to this width requirement. Corridors can be:

- 24 inches wide for access to electrical, mechanical or plumbing systems
- 36 inches wide for an occupant load of fewer than 50 people
- 36 inches wide inside a dwelling unit

And corridors must be:

- 72 inches wide in Group E with an occupant load of 100 people or more

TABLE 1017.1 CORRIDOR FIRE-RESISTANCE RATING			
		REQUIRED FIRE-RESISTANCE RATING (hours)	
OCCUPANCY	OCCUPANT LOAD SERVED BY CORRIDOR	Without sprinkler system	With sprinkler system[c]
H-1, H-2, H-3	All	Not Permitted	1
H-4, H-5	Greater than 30	Not Permitted	1
A, B, E, F, M, S, U	Greater than 30	1	0
R	Greater than 10	Not Permitted	0.5
I-2[a], I-4	All	Not Permitted	0
I-1, I-3	All	Not Permitted	1[b]

a. For requirements for occupancies in Group I-2, see Section 407.3.
b. For a reduction in the fire-resistance rating for occupancies in Group I-3, see Section 408.7.
c. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2 where allowed.

Figure 16-8 Corridor fire-resistance rating

- 72 inches wide in Group I surgical centers for patients not capable of self-preservation
- 96 inches wide in Group I-2 (hospitals, etc.) where bed movement is required

Dead Ends

If there's more than one exit or exit access doorway required, the exit access must be designed so that there are no dead ends in a corridor that's 20 feet or longer in length. But once again there are exceptions. Dead ends can be:

- 50 feet in certain Group I-3 occupancies (prisons, etc.)
- 50 feet in Groups B and F occupancies, if the building is fully sprinklered
- Unlimited, if the dead-end length is less than 2½ times the dead-end width

Exit Access Travel

A good portion of the travel in exit access areas will be through corridors. Travel distance limitations are covered by IBC Section 1016.1. Exits must be located so that the maximum travel distance from the furthest location to the entrance to an exit complies with Table 1016.1 (Figure 16-9). This is true for each building story.

See notes "a," "b" and "c" at the bottom of IBC Table 1016.1 for changes to these maximum distances in specific circumstances.

Aisles and Aisleways

Aisles and aisleways are the same thing. They're passages for inside traffic within a building (like a theater or other Group A occupancy). Any occupied area of a Group A building containing seats, tables, displays, etc. must have aisles leading to an exit. See IBC Section 1025.9.

Aisle Width

Aisles must be at least 36 inches wide if they have seating on only one side of the aisle, or serve fewer than 50 seats. If they have seating on both sides of the aisle, they must be at least 42 inches wide for level or ramped aisles, and 48 inches wide for aisle stairs. If aisle stairs are bisected by a central handrail, the aisle width must be at least 23 inches on either side. See Section 1025.9.1 for details and some exceptions to the rule.

TABLE 1016.1 EXIT ACCESS TRAVEL DISTANCE[a]		
OCCUPANCY	WITHOUT SPRINKLER SYSTEM (feet)	WITH SPRINKLER SYSTEM (feet)
A, E, F-1, I-1, M, R, S-1	200	250[b]
B	200	300[c]
F-2, S-2, U	300	400[c]
H-1	Not Permitted	75[c]
H-2	Not Permitted	100[c]
H-3	Not Permitted	150[c]
H-4	Not Permitted	175[c]
H-5	Not Permitted	200[c]
I-2, I-3, I-4	150	200[c]

For SI: 1 foot = 304.8 mm.

a. See the following sections for modifications to exit access travel distance requirements:
Section 402: For the distance limitation in malls.
Section 404: For the distance limitation through an atrium space.
Section 1016.2: For increased limitations in Groups F-1 and S-1.
Section 1025.7: For increased limitation in assembly seating.
Section 1025.7: For increased limitation for assembly open-air seating.
Section 1019.2: For buildings with one exit.
Chapter 31: For the limitation in temporary structures.

b. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2. See Section 903 for occupancies where automatic sprinkler systems in accordance with Section 903.3.1.2 are permitted.

c. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1

Figure 16-9 Exit access travel distance

Regardless of the width of the aisle, the distance to the nearest exit can't be more than 200 feet. And, the 200 feet must allow for travel along the aisles without people having to climb over seats. If the building has automatic sprinklers, you can increase the travel distance to 250 feet. See Section 1025.7.

Aisles and aisleways are covered in detail in IBC Sections 1025 and 1014.4. Since this is a specialized subject, check the details of the code for requirements.

Exit Illumination and Signs

Exit illumination and exit signs are covered by IBC Sections 1006 and 1011, respectively.

Exit Illumination

Illumination must be provided for all exits and exit access ways in all occupancies; see Section 1006.1. But there are some exceptions:

- Group U
- Group A (aisle accessways)
- Group R-1
- Group R-2
- Group R-3
- Sleeping units of Group I

The code requires that any time the building is occupied, the exits must be illuminated by at least 1 foot-candle (11 lux) of light at the walking surface level (see Section 1006.2). The light level can be reduced to 20 percent during a performance in theaters, etc., but the full light level must be automatically restored when a fire alarm system is activated.

For some areas of a building, the lights must have an emergency power source so exits will still be lit in the event of a power supply failure. The specific areas that must be covered by an emergency electrical system are shown in Section 1006.3. Details of the actual performance of the emergency lighting facility are given in Section 1006.4.

Exit Signs

Exits signs are required by IBC Section 1011.1, as follows:

- All exit and exit access doors must be marked by an approved exit sign.
- Exit signs must be visible from any direction of egress travel.
- If the exit or path to the exit isn't immediately visible to occupants, access to the exit must be marked by a readily-visible exit sign.
- Exit signs must be placed so that no point in a corridor is more than 100 feet from the sign. Some exit signs may have a smaller listed distance.

There are a number of exceptions. Exit signs aren't required:

- In rooms or areas that require only one exit
- If the main exterior exit door is clearly identifiable as the exit, and not having an exit sign is approved by the building official
- In sleeping areas of Group I-3 occupancies
- In individual sleeping or dwelling units of Group R-1, R-2 or R-3 occupancies
- In Group U occupancies
- In specific areas of Groups A-4 and A-5 occupancies (see Section 1011.1, exception #5, for details)

Exit signs must be illuminated at all times, either by internal or external illumination. This is covered in IBC Sections 1011.2, 1011.4 and 1011.5. Emergency power must be supplied from storage batteries, unit equipment or an on-site generator (Section 1011.5.3). Every exit sign must have plainly legible letters that are at least 6 inches high, with the word EXIT in high contrast with the background (Section 1011.5.1). There are other requirements regarding the width of the letters, spacing, etc. but since you'll probably buy code-approved exit signs, you can leave it to the exit sign manufacturers to read the fine print.

There used to be arguments about whether exit signs should be in red or green. Some said that red would be easier to see. Others pointed out that in a dark, smoke-filled room firefighters could waste time and water on a red glow that turned out to be an exit sign. There must have been a compromise, because now the code doesn't say what color to use. An exit sign can be any color, as long as it's clearly discernible.

All stairways in buildings four or more stories high need stairway identification signs at each floor. They must give the floor number, whether there's roof access for the fire department, and the upper and lower floor numbers the stairway ends on. The sign must also give the story and direction of the exit discharge. It has to be located 5 feet above the landing and be easily seen when the doors are in either the open or closed position (Section 1020.1.6).

Requirements for Exterior Exit Doors

The code has strict rules for exterior exit doors. At least one exterior exit door must meet the requirements of IBC Section 1008.1.1. The main provisions are that the minimum width of each door has to be sufficient for the occupant load and be at least 32 inches in width.

Assembly Occupancies

IBC Section 1025.2 tells you how to plan exterior exits for a Group A building with an occupant load greater than 300. The building must have a main exit that can accommodate at least half the total building occupant load.

Let's look at your lodge building again. How wide does your main exterior exit need to be to handle the occupant load of 664? Be sure to use the correct factor from Table 1005.1 (Figure 16-4). The factor you used before was 0.15. Remember, you have to install sprinklers in the lodge, because it's an A-3 occupancy with an occupant load of more than 300. Half the total building occupant load of 664 would be 332, so:

$$332 \times 0.15 = 49.8 \text{ inches wide}$$

But remember, IBC Section 1008.1.1 says that the maximum width of a swinging door is 48 inches. So you'll have to install double doors. Each leaf of a double-door must have at least 32 inches clear width. So you should install 6-foot-wide double doors as your main exit from the lodge.

And what about the occupants of the dining room, bar and kitchen? The nearest clearly-marked exit for the diners is the one you added in the top right-hand corner in Figure 16-7. It's also the alternative exit for the occupants of the dance floor or the complete lodge in case the primary dance floor exit or the main lodge exit is blocked. In this event, the exit capacity must not be reduced by more than 50 percent. So the new exit in the top right-hand corner of Figure 16-7 should also have 6-foot-wide double doors.

The people in the bar and kitchen will probably head for the clearly-marked exterior exit at the back of the bar. That door needs to be able to handle 100 + 4 people. So it needs to be 104 × 0.15 = 15.6 inches wide. But again, the 32-inch minimum comes into play, so that door must have at least 32 inches of clear width.

There are many exceptions to Section 1008.1.1 covering the size of doors, so always check this section of the code.

The appearance of exit doors must comply with Section 1008.1. They must be readily distinguishable from the adjacent construction — in other words, they must look like doors. You can't disguise them as mirrors or cover them with drapes. And, the fact that they are exit doors must be obvious.

In addition to door size and appearance, there are many subsections to Section 1008.1, Doors. These are:

- Section 1008.1.1.1 Projections into clear width
- Section 1008.1.2 Door swing
- Section 1008.1.3 Special doors
- Section 1008.1.3.1 Revolving doors
- Section 1008.1.3.2 Power-operated doors
- Section 1008.1.3.3 Horizontal sliding doors
- Section 1008.1.3.4 Access-controlled egress doors
- Section 1008.1.3.5 Security grilles
- Section 1008.1.4 Floor elevation
- Section 1008.1.5 Landings at doors
- Section 1008.1.6 Thresholds
- Section 1008.1.7 Door arrangement
- Section 1008.1.8 Door operations
- Section 1008.1.8.1 Hardware
- Section 1008.1.8.2 Hardware height
- Section 1008.1.8.3 Locks and latches
- Section 1008.1.8.4 Bolt locks
- Section 1008.1.8.5 Unlatching
- Section 1008.1.8.6 Delayed egress locks
- Section 1008.1.8.7 Stairway doors
- Section 1008.1.9 Panic and fire exit hardware

We've looked at some of these subjects briefly and we'll be covering more, but we're not going to discuss all of these sections in detail. Read them in the IBC when you're considering the design of exterior doors. They're some of the most critical parts of the code. Exit requirements are often missed, misused, misunderstood and questioned. And they're usually very costly to correct. As I said at the beginning of this section, the code has extensive requirements for exterior exit doors. Serious accidents can occur when occupants can't exit the building quickly and safely.

Distance to Exterior Exits

If the building doesn't have sprinklers, all parts of the building must be 200 feet or less from an exterior exit. You'll see this rule repeatedly in the code.

What about assembly buildings? As we mentioned in the section on aisle widths, IBC Section 1025.7 says that exits must be located so the travel distance to an exit door in a non-sprinklered building is 200 feet or less. It can be 250 feet in a fully-sprinklered building. If there are fixed seats with aisles, the travel distance must include movement along the aisles — *not* over or on the seats. For open-air seating, the travel distance can be up to 400 feet.

In covered mall buildings, IBC Section 402.4.4 says that the maximum distance allowed from any point in the mall to an exit is 200 feet. This applies to every space in the mall. If you're in the back of a store, you still have to be within 200 feet of a mall exit

IRC Exit Door Requirements

What does the IRC require for exit doors? Section R311.4.1 says that no fewer than one exit door in each dwelling unit must comply with code requirements. What are the code requirements?

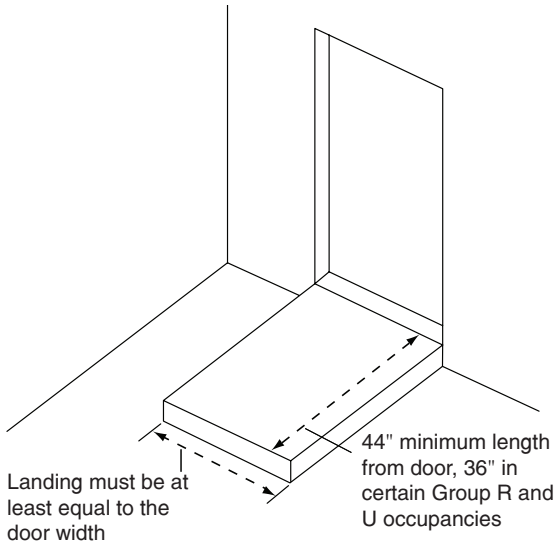


Figure 16-10 Approved landing

If there's only one exit door, it must be located in the habitable portion of the house. The residents can't be required to pass through a garage to exit. The door must be side hinged, and at least 36 inches wide and 80 inches high.

You'd probably put at least two exit doors on a family residence. So, does the second door also have to be side hinged and at least 36 inches wide? The code doesn't say, but most likely, no. It's not unusual to have a 5-foot sliding patio door at the back of a house with a net clear opening of barely 28 inches.

Exit Landings

The code has a lot to say about floor elevation on either side of an exit. You don't want people tripping up or down steps at an exit when they're evacuating the building in an emergency. Tragically, the exit could become blocked by bodies of those trying to escape. It's happened. Consequently, IBC Section 1008.1.4 ensures that exits aren't immediately at the top or bottom of a flight of stairs.

> ***1008.1.4 Floor elevation.*** *There shall be a floor or landing on each side of a door. Such floor or landing shall be at the same elevation on each side of the door. Landings shall be level except for exterior landings, which are permitted to have a slope not to exceed 0.25 unit vertical in 12 units horizontal (2-percent slope).*

So, the landing has to be at the same elevation as the exit. There are some exceptions for certain Group R occupancies. For example, a door can open at the top step of an interior flight of stairs. But the door can't swing *over* the top step. There are some Group R-3 occupancies that don't have to be accessible (Type A or Type B units; see Chapter 23). In those cases, the landing at an exterior doorway can be as much as than 7¾ inches below the top of the threshold. But the door can't swing over the landing. This doesn't apply to an exterior storm or screen door, which *can* swing over stairs or landings.

Landing Dimensions

IBC Section 1008.1.5 requires landings to be at least as wide as the stairway or the door. And the door can't reduce that dimension by more than 7 inches when it's fully opened. If you have an occupant load of 50 or more, doors in any position aren't allowed to reduce the width of the landing by more than 50 percent. The landing length in the direction of travel must be at least 44 inches. But again, there's an exception. In one- or two-family dwellings or townhouses, Group R-3 and Group U occupancies, and within individual units of Group R-2 occupancies, the landing length doesn't have to exceed 36 inches. Figure 16-10 shows an approved landing.

This landing meets the code, but it's clearly the minimum requirement. You'd probably want your landing to exceed the minimum area.

Exit Enclosures

At the beginning of this chapter we defined an exit as:

> ***Exit.*** *That portion of a means of egress system which is separated from other interior spaces of a building or structure*

by fire-resistance-rated construction and opening protectives as required to provide a protected path of egress travel between the exit access and the exit discharge. Exits include exterior exit doors at ground level, exit enclosures, exit passageways, exterior exit stairs, exterior exit ramps and horizontal exits.

In addition to the exterior exit doors at ground level, the exit includes:

- Exit enclosures (usually vertical exit enclosures)
- Exit passageways (usually horizontal continuations of a stairway)
- Horizontal exits
- Exterior exit stairs and exterior exit ramps

Let's look at each of these, starting with exit enclosures. What is an *exit enclosure*? To refresh your memory from the beginning of this chapter:

Exit Enclosure. *An exit component that is separated from other interior spaces of a building or structure by fire-resistance-rated construction and opening protectives, and provides for a protected path of egress travel in a vertical or horizontal direction to the exit discharge or the public way.*

So, when does an exit have to be enclosed? Whenever it's either a vertical exit like a stairway or a ramp, or a horizontal continuation of a stairway — which is called an *exit passageway*.

Vertical Exit Enclosures

Vertical exit enclosures are covered in detail in IBC Section 1020. Section 1020.1 requires interior exit stairways or ramps to be enclosed with fire-resistant barriers. They must have at least a one-hour fire-resistance rating. If they connect four or more stories, the fire-resistant rating must be at least two hours. The number of stories includes any stories below grade, but not mezzanines. Exit enclosures can't be used for anything except egress. Remember what we said about using exit enclosure for storage? *Don't do it!*

Be sure to read the exceptions to Section 1020.1 — there are several. For instance, a two-story stairway, either above or below grade, doesn't have to be enclosed . . . *when the stairway serves an occupant load of fewer than 10* . . . except in Group H and I occupancies.

Also, stairways in Groups R-1, R-2 or R-3 occupancies don't have to be enclosed. But they can only serve and be contained within one residential dwelling unit or sleeping unit.

The required width of an enclosed exit stairway is covered in IBC Section 1007.3. Enclosed exit stairways that are part of an accessible means of egress must have a clear width of at least 48 inches. If handrails are required, a minimum 48-inch width must be maintained between the handrails.

There can't be any openings into the stairway except for the doors themselves and any . . . *equipment and ductwork necessary for independent pressurization, sprinkler piping, standpipes* . . . as detailed in IBC Section 1020.1.2.

In addition, there are requirements for:

- Section 1020.1.3 Ventilation
- Section 1020.1.4 Vertical enclosure exterior walls
- Section 1020.1.5 Discharge identification barrier
- Section 1020.1.6. Stairway floor number signs
- Section 1020.1.7. Smokeproof enclosures

Each of these sections requires full compliance when you're designing vertical exits.

If the stairs in a vertical exit enclosure go down to a basement or any area below grade level, you need an approved barrier at grade level to prevent anyone from accidentally descending into the basement during an emergency; see Section 1020.1.5. And, you must provide directional signs, as discussed in Exit Illumination and Signs.

IBC Section 715.4.4 says that fire doors in vertical exit enclosures and exit passageways must meet a specific fire exposure test. However, this test is not required if the building has approved automatic sprinklers installed throughout.

Horizontal Exit Enclosures

Horizontal exit enclosures are now considered exit passageways. They must meet the requirements of IBC Section 1021.

The width of an exit passageway must comply with Table 1005.1 (Figure 16-4). But it can't be less than 44 inches for an occupant load of 50 people or more. For occupant loads of fewer than 50 people, the width can be 36 inches or more. The required width of the exit passageway can't be obstructed, even by doors opened all the way, or handrails. And doors, in any position, can't reduce the required width by more than 50 percent. Trim and other decorative, nonstructural features can protrude up to 1½ inches into the required width.

The walls, floors and ceilings of exit passageways must be of at least one-hour fire-resistance-rated construction.

An exit passageway that's fire safe usually means it's an emergency exit. Even if it's never needed, it has to be immediately available at all times. That's why you can't have any openings into exit passageways other than the exit doorways, openings at landings or at parts of floors connecting flights.

There must also be a continuation of the passageway on the ground floor leading outside from the stairway. All exit doors must be either one-hour or 90-minute fire-protection assemblies with self-closing or automatic-closing devices.

Exterior Exit Stairs and Ramp Enclosures

Exterior exit stairs and exterior exit ramps don't have to be enclosed. The requirements are covered in IBC Section 1023. You can get all the details from the code. But one section is worth mentioning, Section 1023.2, *Use in a means of egress*.

Exterior exit ramps and stairways can be used as a means of egress, with the following exceptions. They can't be used:

- In Group I-2 (hospitals, nursing homes, etc.);
- In buildings taller than six stories above grade;
- In buildings with occupied floors more than 75 feet above the lowest level of fire department vehicle access.

Stairways

Stairways are dealt with in IBC Section 1009 and IRC R311.5. IBC Section 1009.6 states that stairs, except aisle stairs, can't rise more than 12 feet without a landing at least as wide as the stairs. The run (depth) of the landing can't be less than its width. But it can be a minimum of 48 inches if the stairway is a straight run. See Section 1009.4 for more details.

Spiral stairways are covered by a different set of requirements, which we'll discuss momentarily.

There are specific requirements for stairway width, headroom, stair treads and risers. We'll look at these subjects next.

Stairway Width

Stairway width is determined in the same manner as the vertical exit enclosure width in IBC Section 1005.1 and Table 1005.1 (Figure 16-4). It's based on occupancy type and whether the building is sprinklered. The minimum stairway width is 44 inches, with some exceptions. These are:

- Spiral stairways
- Group A aisle stairs
- Where stairway lifts are installed in Group R-2 or R-3 occupancies
- Stairways serving fewer than 50 people

In the last case, the stairway width can't be less than 36 inches wide.

Stairway Headroom

The minimum headroom clearance for stairways is 80 inches. See Figure 16-11 for more detail. However, for spiral stairways, the minimum headroom is 78 inches.

Stair Treads and Risers

The requirements for stair treads and risers depend on whether your building is a one- or two-family dwelling or townhouse covered by the IRC, or a building covered by the IBC. We'll look at the requirements for each separately.

IRC Requirements

IRC Section R311.5.3 states that the maximum height for a stair riser in a one- or two-family dwelling or townhouse is 7¾ inches. There's no minimum riser height. But whatever the height, the risers can't vary by more than ⅜ inch in any flight of stairs. The minimum tread depth is 10 inches. There's no maximum tread depth, but the tread depth can't vary by more than ⅜ inch in any flight of stairs. These requirements are shown in Figure 16-11.

There are special requirements for winder treads used on curving staircases; see Section R311.5.3.2. Winder treads don't have parallel edges. This kind of stairway can change direction, etc.

There are also requirements for the profile of each tread nose; see IRC R311.5.3.3. They differ between open and solid risers, and cover the projection and beveling of the nose. Again, there are exceptions.

IBC Requirements

The IBC requirements for stairway treads and risers are a little different. Here, riser height is between 4 and 7 inches, and tread depth can't be less than 11 inches. Check Section 1009.3 for all the details and exceptions (especially for Groups R-2, R-3 and U occupancies). The maximum variation in riser height or tread depth is ⅜ inch in any flight of stairs. See Section 1009.3.2. Stairs or ladders used only for equipment placement or repair are exempt.

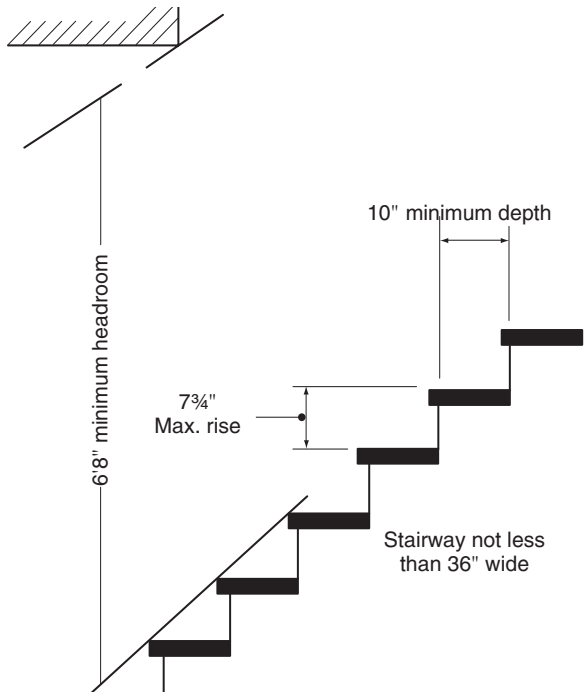


Figure 16-11 Stair details for one- and two-family dwellings and townhouses

Again, there are special requirements for winder treads. Winders aren't permitted in any stairways used as a means of egress, except within a dwelling unit; see Section 1009.3.1.

The basic IBC stairway requirements are summarized in Figure 16-12.

Spiral Stairways

Spiral stairways can be used as part of an exit inside dwelling units. They're also allowed in a space no more than 250 square feet and serving five occupants or fewer. Theater lighting catwalks can have spiral stairways in some cases. See IBC Section 1015.6.

Here are a few requirements for spiral stairways:

- The tread depth must be at least 7½ inches at a point 12 inches from the narrow end
- The riser height must be no more than 9½ inches

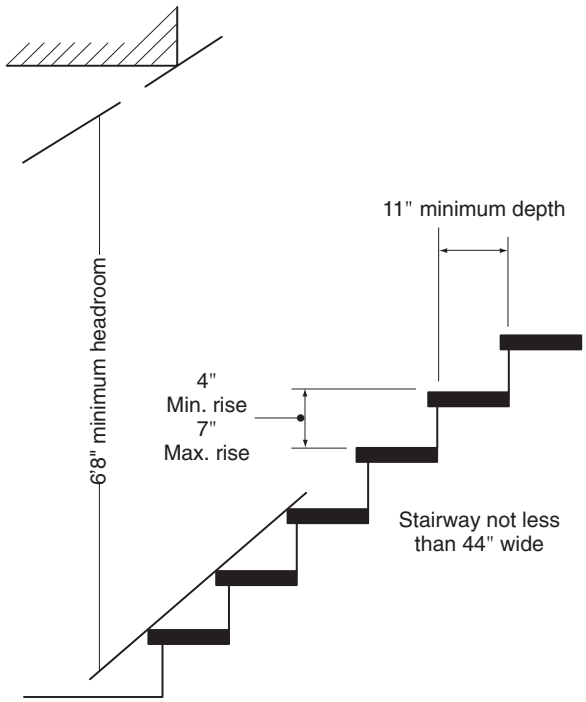


Figure 16-12 Stair details for buildings covered by the IBC

- Stairway headroom must be 6½ feet or more
- Stairway width must be at least 26 inches

You'll find more details in IRC Section R311.5.8.1 and IBC Section 1009.8.

Spiral stairs are used in many homes. And, you'll also see them used for access to mechanical rooms in commercial buildings where heating and air conditioning equipment is located. But they can't be used as public exits.

Under Stairway Space

Any enclosed usable space under stairways in a one- or two-family dwelling or townhouse must be protected on the inside walls, soffits and ceiling with ½-inch gypsum board. See IRC Section R311.2.2.

In non-dwelling buildings, the walls and soffits within enclosed usable spaces under both enclosed and unenclosed stairways must be protected by 1-hour fire-resistant construction or the fire-resistance rating of the stairway enclosure, whichever is the greater; see IBC Section 1009.5.3. Under exterior exit stairways, there can be no enclosed usable space unless it is completely enclosed by 1-hour fire-resistant construction. The open space under exterior stairways can't be used for any purpose.

Handrails

Handrails get a lot of attention in both the IRC and the IBC. They're covered in various subsections of IRC R311 and in IBC Section 1012. The requirements are different for one- or two-family dwellings and townhouses than for other buildings. For instance, in one- or two-family dwellings and townhouses, only one handrail is required on a stairway. Other buildings need handrails on both sides of stairways.

IRC Requirements

Handrails must be provided for a flight of stairs with four or more risers. The handrail height from the sloped plane joining the stair noses must be between 34 and 38 inches, and be continuous for the full length of the flight. See Section R311.5.6. Handrail ends must be returned, or terminated at newel posts or safety terminals. A space of at least 1½ inches is required between the handrail and the wall next to it. The handrail grip size is discussed in detail in Section R311.5.6.3.

Handrails are required on at least one side of all ramps with a slope greater than 1 in 12 ($8^1/_3$ percent). See Section R311.6.3.

IBC Requirements

Section 1009.10 requires that stairways have handrails on each side, and they must comply with Section 1012.

Section 1012 requires a handrail height between 34 and 38 inches above the sloped plane joining the stair nosings. Handrails must

Figure 16-13 Typical exit ramp

have a circular cross-section between 1¼ and 2 inches. If they're not circular, the perimeter dimension has to be between 4 and 6¼ inches with a maximum cross-section of 2½ inches. Clearance between the wall and the handrail must be at least 1½ inches. Sections 1012.4, 1012.5, 1012.7 and 1012.8 go into more detail on handrail continuity, extensions, projections and intermediate sections.

Section 1010.8 says that handrails are required on both sides for ramps with a rise greater than 6 inches, and must comply with Section 1012.

Ramps

Ramps are the subject of IRC R311.6 and IBC Section 1010. Again, requirements are different depending on whether the ramps are for one- or two-family dwellings and townhouses, or for other buildings.

IRC Requirements

For one- or two-family dwellings and townhouses, the requirements are pretty simple. The maximum ramp slope should not be more than 1 in 12, or an $8^1/_3$-percent slope. But if site constraints make this impossible, the ramp slope can be increased to 1 in 8, or a 12½-percent slope.

Shallow ramps don't need a handrail. But if the ramp exceeds a slope of 1 in 12, you'll need a handrail meeting the same requirements for height and size as for stairs. See Sections R311.5.6 and R311.5.6.3.

A minimum 3-foot-square landing must be provided at the bottom of ramps, where they change direction, or where doors open onto ramps.

IBC Requirements

For buildings not covered by the IRC, the requirements are a little more stringent. They're addressed in IBC Section 1010.

Ramps used for exits can't have a slope of more than 1 in 12, or an $8^1/_3$-percent slope. Other ramps can be as steep as 1 in 8, or a 12½-percent slope. The maximum vertical rise of any ramp is limited to 30 inches. The cross slope of any ramp can't be more than 1 in 48.

The width requirements are the same as for corridors (see Section 1017.2), but not less than 36 inches between handrails. And the headroom requirement is the same as for exit doors and stairways — 80 inches. There are requirements for landings, change of direction, doorways, surface finish and handrails, of course, so check out the details in Section 1010.

Figure 16-13 shows a typical exit ramp. Because this ramp's height is less than 30 inches above grade, the handrail need only comply with Section 1012. For ramp heights *more* than 30 inches above grade, Section 1013 says that a guard at least 42 inches high must be provided on each side of the ramp.

Open guards, for ramps of any height above grade, must have baluster spacing or ornamental patterns that will prevent a 4-inch sphere from passing through any opening up to a height of 34 inches above the adjacent walking surface. Between 34 and 42 inches above the adjacent walking surface, an 8-inch sphere must not be able to pass. It appears that the baluster spacing for the ramp in Figure 16-13 may not pass today's code requirements.

We've finished with the chapter on means of egress — and we've just scratched the surface. But at least you now have a basic understanding of the topic, and you know where to find more information when you need it.

Rolling Out the Rock

I don't think any building inspector likes to shut down a job. I know I don't. It's a last resort after everything else has failed. Negotiation is always better than confrontation. And stopping all work causes the worst type of confrontation. But I've had no choice but to order work stoppage a few times. Once I did it as a favor to the contractor, not for a code violation. Here's the story.

A number of years ago, an out-of-town developer applied for a permit on a 22-home tract. I hadn't heard of him before, so I mentioned his name at a regional conference of building inspectors. No one had a good word to say about him. Some predicted trouble right from the start. I decided to keep an eye on him by visiting the tract daily.

Most of the time, I couldn't find anything wrong. When I noticed something that needed attention, I'd note it on a piece of paper and give it to the foreman. The developer would either fix the problem immediately, or explain that the work was scheduled and give me an estimate when it would be finished. I was having no trouble at all with him. He seemed very professional in every way.

Then a funny thing happened. I was making a routine inspection on one of the homes. The sheetrock hangers had been working since morning. As I walked through, I had a feeling that something was wrong. But I couldn't put my finger on it. I went through the place item by item and found nothing unusual. Still, my intuition said to keep looking. I counted the nails in each sheet of drywall, checked the blocking on joints, and everything else I could think of. Still nothing.

I started to leave through the kitchen into an attached garage. As I went through the opening, I ran my hand along the wall where the trim would go. "Here's where the light switch will probably be, "I told myself. But, surprise! There was no opening in the wallboard for the switch. In fact, there were no electrical openings anywhere in the wallboard. I checked rooms that hadn't been rocked yet. There was no electrical wiring anywhere in the walls, and the sheetrock hangers were covering the framing. My intuition hadn't let me down.

How did that happen? Did the foreman make a horrible mistake? Or was the developer hoping to find a buyer who wanted electrical wiring run on the wall surface? But that would be ridiculous. No one wants a home that's wired like a barn. It had to be a mistake.

But what should I do? I had no right to stop work. There was no code violation. Neither the building code nor the electrical code require that wiring be run inside walls, even though that's how everyone does it. But I've never yet seen a new home with exposed wiring, so someone had to stop the work immediately. And that someone had to be me.

I decided to take the heat, and shut down the job. That brought the foreman to me with fire in his eyes. I had no authority to shut down his job, he screamed. And he was right. He'd been told to "rock" that house, and that's what he was going to do.

I suggested to the foreman that we take a break, consider the situation, and make a few calls. He cooled down after a while, and admitted that I was right. The wiring should go in first. It was nice of him to admit that — but it didn't let him off the hook. He still had a house to wire.

Most jurisdictions now require all MEP (Mechanical, Electrical, Plumbing) inspections to be approved for cover before a framing inspection is even allowed.

C H A P T E R 1 7

Finish Materials and Installation Procedures

This chapter gives the information necessary to complete your exterior wall construction. But first, you need to be familiar with the terms and the elements you're expected to know in code compliance.

Here are a few definitions of terms from the IBC that we'll be using:

Cement Plaster: *A mixture of portland or blended cement, portland cement or blended cement and hydrated lime, masonry cement or plastic cement and aggregate and other approved materials as specified in this code.*

Gypsum Board: *Gypsum wallboard, gypsum sheathing, gypsum base for gypsum veneer plaster, exterior gypsum soffit board, predecorated gypsum board or water-resistant gypsum backing board complying with the standards listed in Tables 2506.2* (Figure 17-1), *2507.2* (Figure 17-2) *and Chapter 35 (numerous referenced standards).*

Gypsum Plaster: *A mixture of calcined gypsum or calcined gypsum and lime and aggregate and other approved materials as specified in this code.*

IBC TABLE 2506.2 GYPSUM BOARD MATERIALS AND ACCESSORIES

MATERIAL	STANDARD
Accessories for gypsum board	ASTM C 1047
Adhesives for fastening gypsum wallboard	ASTM C 557
Exterior soffit board	ASTM C 931
Fiber-reinforced gypsum panels	ASTM C 1278
Glass mat gypsum backing panel	ASTM C 1178
Glass mat gypsum substrate	ASTM C 1177
Gypsum backing board and gypsum shaftliner board	ASTM C 442
Gypsum ceiling board	ASTM C 1395
Gypsum sheathing	ASTM C 79
Gypsum wallboard	ASTM C 36
Joint reinforcing tape and compound	ASTM C 474; C 475
Nails for gypsum boards	ASTM C 514, F 547, F 1667
Predecorated gypsum board	ASTM C 960
Steel screws	ASTM C 954; C 1002
Steel studs, load bearing	ASTM C 955
Steel studs, nonload bearing	ASTM C 645
Standard specification for gypsum board	ASTM C 1396
Testing gypsum and gypsum products	ASTM C 22; C 472; C 473
Water-resistant gypsum backing board	ASTM C 630

Figure 17-1 Gypsum board materials and accessories

IBC TABLE 2507.2 LATH, PLASTERING MATERIALS AND ACCESSORIES	
MATERIAL	STANDARD
Accessories for gypsum veneer base	ASTM C 1047
Blended cement	ASTM C 595
Exterior plaster bonding compounds	ASTM C 932
Gypsum base for veneer plasters	ASTM C 588
Gypsum casting and molding plaster	ASTM C 59
Gypsum Keene's cement	ASTM C 61
Gypsum lath	ASTM C 37
Gypsum plaster	ASTM C 28
Gypsum veneer plaster	ASTM C 587
Interior bonding compounds, gypsum	ASTM C 631
Lime plasters	ASTM C 5; C 206
Masonry cement	ASTM C 91
Metal lath	ASTM C 847
Plaster aggregates	
Sand	ASTM C 35; C 897
Perlite	ASTM C 35
Vermiculite	ASTM C 35
Plastic cement	ASTM C 1328
Portland cement	ASTM C 150
Steel screws	ASTM C 1002; C 954
Steel studs and track	ASTM C 645; C 955
Welded wire lath	ASTM C 933
Woven wire plaster base	ASTM C 1032

Figure 17-2 Lath, plastering materials and accessories

Chapter 25 of the IBC is entitled Gypsum Board and Plaster. It covers the following elements of gypsum board, lath, cement plaster (stucco) and gypsum plaster:

- Materials
- Design
- Construction
- Quality

IRC Section R702.2 also deals with gypsum plaster, and Section R702.3 covers gypsum board.

Figures 17-1 and 17-2 list more ASTM standards for these materials than we can cover in this book. Fortunately, it's the manufacturer's responsibility to meet them. Your responsibility is to ensure the materials you use carry the correct labeling for the required standard.

Support Structure Assemblies

A vertical assembly is anything built that rises vertically, better known by a term you'll recognize — a wall. Horizontal assemblies are anything you build that's laid in a horizontal position, commonly known as a floor or a ceiling. We're going to discuss the support structure for gypsum board or lath and plaster installed in vertical and horizontal assemblies — or walls and ceilings.

Wood framing that supports gypsum board or lath and plaster must be at least 2 inches nominal thickness in its narrower dimension (i.e. the 2-inch side of a 2 x 4), as required by IBC Section 2504.1.1. *Nominal* describes the rough dimension of an unplaned member. A planed 2 x 4 is actually somewhere around 1½ inches by 3½ inches. So in this instance, 2-inch nominal means about 1½ inches planed. Studless partitions must be at least 2 inches thick. See Section 2504.1.2. You'll find shear wall construction criteria for both wood and steel framing in IBC Section 2505.

Gypsum Construction

I've seen gypsum wallboard (sheetrock) put up in almost every conceivable way, and even in a few ways I'd have thought were impossible. Unfortunately, most installers are paid by the unit. So they take shortcuts or use fewer nails here and there, so they can put up more material and make money faster.

That's probably why the IBC has strict rules on wallboard installation.

> ***109.3.5 Lath and gypsum board inspection.*** *Lath and gypsum board inspections shall be made after lathing and gypsum board, interior and exterior, is in place, but before any plastering is applied or gypsum board joints and fasteners are taped and finished.*
>
> ***Exception:*** *Gypsum board that is not part of a fire-resistance-rated assembly or a shear assembly.*

IBC TABLE 2508.1 INSTALLATION OF GYPSUM CONSTRUCTION	
MATERIAL	STANDARD
Gypsum board	GA-216; ASTM C 840
Gypsum sheathing	ASTM C 1280
Gypsum veneer base	ASTM C 844
Interior lathing and furring	ASTM C 841
Steel framing for gypsum boards	ASTM C 754; C 1007

Figure 17-3 Installation of gypsum construction

Because of this exception, many jurisdictions now only inspect:

- Nailing on the wall separating the garage from the house
- The garage ceiling (if there's livable space above)
- The area under a stairway

There are restrictions and special handling instructions for gypsum board and lath installation. Gypsum wallboard (or gypsum plaster) can't be used for any exterior surface exposed directly to the weather. See IBC Section 2508.2. This section also requires that weather protection be in place before gypsum wallboard, gypsum lath or gypsum plaster can be installed. Gypsum sheathing can be used on exterior surfaces that will only be exposed to the weather for a short time. We'll discuss Gypsum Sheathing a little later in this chapter. The installation of different kinds of gypsum-based products is covered in the ASTM standards shown in Table 2508.1 (Figure 17-3).

Installing Gypsum Wallboard

The installation of gypsum wallboard is covered by ASTM C 840 and the Gypsum Association publication, GA-216. There are three conventional ways to hang wallboard. The most common method used to be by nailing, but attaching with screws has now replaced nailing as the favored installation. The third commonly used method of attaching wallboard is using an adhesive along with the nails or screws. The only difference between using nails and using screws is that you can space screws 12 inches apart for ceilings or 16 inches apart for walls when installing ⅜-inch wallboard. For other thicknesses, the spacing requirements are a little different. Nails can't exceed 7-inch spacing for ceilings or 8-inch spacing for walls. The gauge, length, head size and diameter of the nails used for different thicknesses of wallboard are shown in IRC Table R702.3.5 (Figure 17-4).

Except as noted in these tables, the details of nailing wallboard aren't specified in the codes. A better guide is the Gypsum Association article, GA-216. The Gypsum Association is an excellent source of information on wallboard application methods. Download GA-216, Application and Finishing of Gypsum Panel Products, free at www.gypsum.org.

Let's look at each of the gypsum wallboard fastening methods.

Single Nailing

GA-216 gives information for nailing wallboard. Here are a few points of interest:

- Gypsum wallboard may be applied parallel or at right angles to the studs.
- Drive nails at least ⅜ inch and not more than 1 inch from the ends and edges of the wallboard.
- Place nails on adjacent ends or edges opposite each other.
- Begin nailing from the center of the wallboard and go toward the edges or outer ends. Nailing sequence is also given in GA-216.
- When nailing, apply pressure on the wallboard next to the nail you're driving. This ensures that the wallboard is secured tightly to the framing member.
- Drive nails with the shank at right angles to the face of the board.
- Use a crown-head hammer.
- With the last blow of the hammer, seat the nail so the head is in a slight uniform dimple formed by the last blow of the hammer.

IRC TABLE R702.3.5
MINIMUM THICKNESS AND APPLICATION OF GYPSUM BOARD

THICKNESS OF GYPSUM BOARD (inches)	APPLICATION	ORIENTATION OF GYPSUM BOARD TO FRAMING	MAXIMUM SPACING OF FRAMING MEMBERS (inches o.c.)	MAXIMUM SPACING OF FASTENERS (inches)		SIZE OF NAILS FOR APPLICATION TO WOOD FRAMING[c]
				Nails[a]	Screws[b]	
Application without adhesive						
$^3/_8$	Ceiling[d]	Perpendicular	16	7	12	13 gage, $1^1/_4''$ long, $^{19}/_{64}''$ head; 0.098″ diameter, $1^1/_4''$ long, annular-ringed; or 4d cooler nail, 0.080″ diameter, $1^3/_8''$ long, $^7/_{32}''$ head.
	Wall	Either direction	16	8	16	
$^1/_2$	Ceiling	Either direction	16	7	12	13 gage, $1^3/_8''$ long, $^{19}/_{64}''$ head; 0.098″ diameter, $1^1/_4''$ long, annular-ringed; 5d cooler nail, 0.086″ diameter, $1^5/_8''$ long, $^{15}/_{64}''$ head; or gypsum board nail, 0.086″ diameter, $1^5/_8''$ long, $^9/_{32}''$ head.
	Ceiling[d]	Perpendicular	24	7	12	
	Wall	Either direction	24	8	12	
	Wall	Either direction	16	8	16	
$^5/_8$	Ceiling	Either direction	16	7	12	13 gage, $1^5/_8''$ long, $^{19}/_{64}''$ head; 0.098″ diameter, $1^3/_8''$ long, annular-ringed; 6d cooler nail, 0.092″ diameter, $1^7/_8''$ long, $^1/_4''$ head; or gypsum board nail, 0.0915″ diameter, $1^7/_8''$ long, $^{19}/_{64}''$ head.
	Ceiling[e]	Perpendicular	24	7	12	
	Wall	Either direction	24	8	12	
	Wall	Either direction	16	8	16	
Application with adhesive						
$^3/_8$	Ceiling[d]	Perpendicular	16	16	16	Same as above for $^3/_8''$ gypsum board
	Wall	Either direction	16	16	24	
$^1/_2$ or $^5/_8$	Ceiling	Either direction	16	16	16	Same as above for $^1/_2''$ and $^5/_8''$ gypsum board, respectively
	Ceiling[d]	Perpendicular	24	12	16	
	Wall	Either direction	24	16	24	
Two $^3/_8$ layers	Ceiling	Perpendicular	16	16	16	Base ply nailed as above for $^1/_2''$ gypsum board; face ply installed with adhesive
	Wall	Either direction	24	24	24	

For SI: 1 inch = 25.4 mm.

a. For application without adhesive, a pair of nails spaced not less than 2 inches apart or more than $2^1/_2$ inches apart may be used with the pair of nails spaced 12 inches on center.

b. Screws shall be Type S or W per ASTM C 1002 and shall be sufficiently long to penetrate wood framing not less than $^5/_8$ inch and metal framing not less than $^3/_8$ inch.

c. Where metal framing is used with a clinching design to receive nails by two edges of metal, the nails shall be not less than $^5/_8$ inch longer than the gypsum board thickness and shall have ringed shanks. Where the metal framing has a nailing groove formed to receive the nails, the nails shall have barbed shanks or be 5d, $13^1/_2$ gage, $1^5/_8$ inches long, $1^5/_{64}$-inch head for $^1/_2$-inch gypsum board; and 6d, 13 gage, $1^7/_8$ inches long, $^{15}/_{64}$-inch head for $^5/_8$-inch gypsum board.

d. Three-eighths-inch-thick single-ply gypsum board shall not be used on a ceiling where a water-based textured finish is to be applied, or where it will be required to support insulation above a ceiling. On ceiling applications to receive a water-based texture material, either hand or spray applied, the gypsum board shall be applied perpendicular to framing. When applying a water-based texture material, the minimum gypsum board thickness shall be increased from $^3/_8$ inch to $^1/_2$ inch for 16-inch on center framing, and from $^1/_2$ inch to $^5/_8$ inch for 24-inch on center framing or $^1/_2$-inch sag-resistant gypsum ceiling board shall be used.

e. Type X gypsum board for garage ceilings beneath habitable rooms shall be installed perpendicular to the ceiling framing and shall be fastened at maximum 6 inches o.c. by minimum $1^7/_8$ inches 6d coated nails or equivalent drywall screws.

Figure 17-4 Minimum thickness and application of gypsum board

- Don't break the paper at the nail head or around the edge of the dimple by over-driving it, and don't use a nail set. The dimple shouldn't be over $^1/_{32}$ inch deep.
- If you tear the face paper, set an additional nail or fastener not more than 2 inches from the tear. Cover the tear with spackle when you spackle the nail-head dimples.
- Follow the nailing schedule, even when you're using adhesives.

Double Nailing

Nail spacing away from the edge of the wallboard can be increased to 12 inches if you use a double-nailing technique in the following manner:

- The second nail in double-nailing must be spaced at least 2 inches from the first nail, but not more than 2½ inches away.
- The nailing sequence for the second set of nails must be the same as for the first set of nails.

Staples

Don't use staples for a single-layer application of gypsum wallboard. Recessing a staple head below the surface of gypsum wallboard can damage the face paper. For more information see GA-216 and ASTM C 840, Standard Specification for Application and Finishing of Gypsum Board.

Screws

There are two advantages to using screws:

1. There's less damage to the board.
2. It eliminates the problem of nails loosening over time.

Fastening wallboard with screws is covered in IRC Section R702.3.6. Screws must be long enough to penetrate wood framing at least ⅝ inch, and through metal framing at least ⅜ inch.

Here are some of the codes' main points for using screws to mount wallboard:

- The head of the screw must be at least 0.315 inch ($^5/_{16}$ inch) in diameter.
- The driving recess must be a No. 2 Phillips design with a minimum depth of 0.105 inch (between $^3/_{32}$ inch and ⅛ inch).
- Screws must be self-drilling and drive into the stud in less than five seconds.
- Screw threads must be able to pull the head of the screw below the surface of the wallboard through four layers of 0.010-inch-thick kraft paper placed over ⅝-inch Type X gypsum wallboard.

For commercial use, wallboard is required to be thicker to get the necessary fire rating. Screws are the common application method for gypsum board over steel studding in commercial construction. See IBC Table 720.1(2), Rated Fire Resistance Periods for Various Walls and Partitions.

Adhesives

In my years as a building inspector, I've made a few people unhappy. Often it was because I wouldn't allow the use of adhesives to attach wallboard — unless a full-time inspector could be present for the installation. Adhesives must be applied according to the manufacturer's specs. The Gypsum Association publication GA-216, Section 7.3, says you must apply an adhesive bead at least ⅜ inch in diameter to the face of all framing members. The only parts exempt from this are the top and bottom (sole) plates. When the wallboard is in place, the bead should spread to an average width of ¾ inch, approximately $^1/_{16}$ inch thick. This is tough to regulate, because you can't see through wallboard to make an inspection. That's why I insist an inspector be present during application.

I've had cases where installers were only putting down spots or thin beads of adhesive. That was usually when the adhesive tube was about to run dry! If there wasn't another tube handy, it'd mean leaving the job to get one — something no one wants to do. They think that once the wallboard's in place, nobody can tell how wide, thick, or continuous the adhesive is. That's why I required constant supervision.

Attaching wallboard by adhesive alone is done just for steel girders or columns. Sometimes adhesive is used in combination with nailing when attaching to framing members. This can reduce nail spacing. See IRC Table R702.3.5 (Figure 17-4). Under the second section of the table, Application with Adhesives, you'll see that the 8-inch nail spacing used in attaching gypsum board to wall framing members can be doubled to 16 inches when combined with adhesive. But it's questionable whether this two-step process justifies using fewer nails.

Study IRC Table R702.3.5 carefully. There are many different applications and combinations — between wall and ceiling, metal or wood studs, nails or screws, with or without adhesive — that you can use to attach gypsum wallboard.

Two-Ply Gypsum Wallboard Installation

There are several situations where a two-ply wallboard installation is preferred. It is sometimes used when extra thickness is required for fire resistance, as shown in IBC Table 720.1(2). You need to apply the second layer at right angles to the base layer in order to achieve the required fire resistance. Also, you'd usually use two layers of ⅜-inch board to cover a curved or round wall.

But here's a big reason for using a two-ply installation: Sheetrock is heavy. If you're working by yourself, it's much easier to install two pieces of ⅜-inch wallboard than one piece that's ¾ inch thick. So, if you need 1 or 1½ inches of wallboard thickness, a two-ply installation may be the best way to go. However, there are manufacturer-produced assemblies that require 1-inch board in a steel framing or shaft wall system. In those cases, you couldn't substitute a 2-ply installation — you'd have to get a helper.

IRC Table R702.3.5 (Figure 17-4) says that you can use different nail spacing if you use two layers of ⅜-inch wallboard to achieve a ¾ inch overall thickness. The nail spacing for the first layer attached to wall framing members can be 16 inches when used with adhesive, or 8 inches without adhesive. The nail spacing for the second layer can be 24 inches when used with adhesive.

Another good thing about two-ply installation is that you get a smoother wall. You attach the first layer just like you would a single layer. Then you put up the second panel with adhesives. You don't need to nail the second layer, except at the top and bottom of the panels. Be sure to hold this layer in place until the adhesive sets up. Usually that doesn't take long. Sections 6.7.3 and 6.7.3.1 of the Gypsum Association article, GA-216 (mentioned above), describe the installation of the second, or face layer, this way:

> ***6.7.3*** *The face layer of gypsum panel products applied to walls shall be placed in position and attached with a sufficient number of nails or screws to hold the gypsum panel products in place until an adhesive bond develops. As an alternate to nails or screws, the second layer of gypsum panel products shall be held in position by temporary fasteners or by shoring with props and headers or other temporary supports until adhesive bond develops.*
>
> > ***6.7.3.1*** *Unless otherwise specified by the gypsum panel product manufacturer, permanent fasteners spaced not more than 16 in. (406 mm) oc shall be used at the top and bottom.*

With a two-ply application, the amount of taping is reduced and the overall finish is neater.

Gypsum Wallboard in Showers and Water Closets

IBC Section 2509.2 regulates gypsum wallboard installation in shower and toilet areas.

- For wall tile in tub and shower areas, and for wall and ceiling panels in shower areas, use cement, fiber cement or glass mat gypsum, meeting ASTM C 1178, C 1288 or C 1325 standards, and installed according to the manufacturer's recommendations.
- For tile on toilet area compartment walls, use water-resistant gypsum backing board. Install it according to GA-216 or ASTM C 840.
- For tile or wall panels in other wall and ceiling areas, you can use regular gypsum wallboard installed according to GA-216 or ASTM C 840.

However, Section 2509.3 says you can't use water-resistant gypsum backing board in the following areas:

- In shower or bathtub compartments over a vapor retarder.
- In areas subject to continuous high humidity or where it will have direct exposure to water.
- On ceilings where the joist spacing is greater than 12 inches for ½-inch-thick board or 16 inches for ⅝-inch-thick board.

Take advantage of the free download of GA-216 (mentioned earlier in Installing Gypsum Wallboard) and study it carefully.

Gypsum Sheathing

Gypsum sheathing is usually chosen for exterior siding on residential properties that will be covered by surface cladding. Gypsum wallboard is used on *interior* walls and ceilings. It's typically painted or covered with a directly-applied finish material.

Gypsum sheathing must conform to ASTM Standard C 79; see IBC Table 2506.2 (Figure 17-1). Its installation must meet the requirements of ASTM Standard C 1280; see Table 2508.1 (Figure 17-3). Gypsum sheathing, unlike gypsum wallboard, can be exposed to the elements for short periods of time until installation of the final cladding material — usually about a month. Unlike gypsum wallboard, gypsum sheathing doesn't have to be carefully finished to fill in joints and cover fasteners. It can be attached using staples.

The fire resistance of gypsum sheathing in different applications can be found in IBC Table 720.1(2), Rated Fire Resistance Periods for Various Walls and Partitions.

Lath

Just like wallboard, lath must be inspected before joints and fasteners are taped and finished, as described in IBC Section 109.3.5.

The IBC and IRC no longer accept wood as a lath material. That can create problems when remodeling older homes, because the new lath may not be the same thickness as the old wood lath. IBC Table 2507.2 (Figure 17-2) shows the only acceptable lath materials.

- Expanded metal lath (covered by ASTM standard C 847)
- Wire lath (covered by ASTM standard C 847)
- Gypsum lath (covered by ASTM standard 37)

Lath and plaster can be used for both interiors and exteriors. These days, it's used more often for exteriors, and wallboard is commonly used for interior walls and ceilings.

Interior Lath

If lath is used for interiors, all three kinds are acceptable: expanded metal lath, wire lath, and gypsum lath.

IRC Section R702.2.1 says the support spacing must not exceed:

- 16 inches, for ⅜-inch-thick gypsum or metal lath
- 24 inches, for ½-inch-thick plain gypsum lath

Gypsum lath must be installed at right angles to the support framing. End joints, in courses next to each other, must be staggered by at least one framing space.

Exterior Use

For exterior use, only corrosion-resistant materials like expanded metal lath or woven wire lath can be used. IRC Section R703.6.1 says the lath must be attached using 1½-inch-long 11-gauge nails with a 7/16-inch head, or 16-gauge staples ⅞ inch long, spaced no more than 6 inches apart.

Metal lath is attached with the long dimension of the sheets at right angles to the supports. You must lap joints by at least one repeat of the mesh pattern at the sides and ends, but not less than 1 inch. You can lap metal rib lath with edge ribs wider than ⅛ inch by nesting the outside ribs (i.e. aligning the indented "diamond" patterns together in the overlapping pieces). If the edge ribs are less than ⅛ inch, lap it ½ inch at the sides, or nest the outside ribs. If the laps don't fall over supports, tie them with 18-gauge wire.

When you're lathing exterior stud walls with metal, you need a weep screed at or below the foundation line. Place the screed at least 4 inches above grade. It allows water to drain to the exterior of the building. See IRC Section R703.6.2.1 for full details.

TABLE R702.1(1)
THICKNESS OF PLASTER

PLASTER BASE	FINISHED THICKNESS OF PLASTER FROM FACE OF LATH, MASONRY, CONCRETE (inches)	
	Gypsum plaster	Portland cement mortar
Expanded metal lath	$^5/_8$, minimum[a]	$^5/_8$, minimum[a]
Wire lath	$^5/_8$, minimum[a]	$^3/_4$, minimum (interior)[b] $^7/_8$, minimum (exterior)[b]
Gypsum lath[g]	$^1/_2$, minimum	$^3/_4$, minimum (interior)[b]
Masonry walls[c]	$^1/_2$, minimum	$^1/_2$, minimum
Monolithic concrete walls[c,d]	$^5/_8$, maximum	$^7/_8$, maximum
Monolithic concrete ceilings[c,d]	$^3/_8$, maximum[e]	$^1/_2$, maximum
Gypsum veneer base[f,g]	$^1/_{16}$, minimum	$^3/_4$, minimum (interior)[b]
Gypsum sheathing[g]	—	$^3/_4$, minimum (interior)[b] $^7/_8$, minimum (exterior)[b]

For SI: 1 inch = 25.4 mm.
a. When measured from back plane of expanded metal lath, exclusive of ribs, or self-furring lath, plaster thickness shall be $^3/_4$ inch minimum.
b. When measured from face of support or backing.
c. Because masonry and concrete surfaces may vary in plane, thickness of plaster need not be uniform.
d. When applied over a liquid bonding agent, finish coat may be applied directly to concrete surface.
e. Approved acoustical plaster may be applied directly to concrete or over base coat plaster, beyond the maximum plaster thickness shown.
f. Attachment shall be in accordance with Table R702.3.5.
g. Where gypsum board is used as a base for portland cement plaster, weather-resistant sheathing paper complying with Section R703.2 shall be provided.

Figure 17-5 Thickness of plaster

Plaster

There are two types of plaster in general use today, portland plaster and gypsum plaster. You can use portland cement plaster for both outdoor and indoor work, but gypsum plaster only for interior work. Both require three coats when applied over metal lath or wire fabric lath. Apply at least two coats over any other material allowed by the code. But remember: Never apply plaster directly to fiber insulation board.

Interior Plaster

Three tables set the standards for plaster. IRC Table R702.1(1) in Figure 17-5 gives the minimum thickness of both kinds of plaster over various plaster bases. Plaster thickness is measured from the face of the base it's applied over. Most of the time, you'll apply two coats of gypsum plaster over gypsum board. But you can apply veneer plaster in one coat, not exceeding $^3/_{16}$ inch, provided the total thickness complies with Table R702.1(1); see Section R702.2.

IRC Table R702.1(2) (Figure 17-6) gives the proportions of aggregate to cementitious materials in gypsum plaster, and Table R702.1(3), shown in Figure 17-7, does the same for portland cement plaster.

Exterior Plaster (Stucco)

You probably know exterior exposed plaster by its more common name, stucco. Before you install an exterior veneer to your building, you must apply a weather-resistant barrier, as described in IRC R703.1 and IBC Section 1404.2.

This is a critical step. If you're planning to install plaster or stucco in a wet or cold location, pay close attention to the weather barrier and the flashing that keeps water outside (or directs it outside). There are many books and special products to help you. Homes in my area of the Northwest are especially vulnerable if flashing is installed improperly. And repair for water damage and rot can be costly. Even in the hotter and drier Southwest, where stucco is the common building material, you must be sure to install proper weather barriers, flashing and insulation to prevent moisture build up. Remember, some moisture will form between the warm side and the cold side of the wall. That's normal. Air is forced in by atmospheric pressure. Then the moisture in the air condenses on the cold surface. If you don't provide a means for it to escape through ventilation or by draining it out to the exterior, you're setting the stage for some serious problems.

TABLE R702.1(2)
GYPSUM PLASTER PROPORTIONS

NUMBER	COAT	PLASTER BASE OR LATH	MAXIMUM VOLUME AGGREGATE PER 100 POUNDS NEAT PLASTER[b] (cubic feet)	
			Damp loose sand[a]	Perlite or vermiculite[c]
Two-coat work	Base coat	Gypsum lath	2.5	2
	Base coat	Masonry	3	3
Three-coat work	First coat	Lath	2[d]	2
	Second coat	Lath	3[d]	2[e]
	First and second coats	Masonry	3	3

For SI: 1 inch = 25.4 mm, 1 cubic foot = 0.0283 m^3, 1 pound = 0.454 kg.
a. Wood-fibered gypsum plaster may be mixed in the proportions of 100 pounds of gypsum to not more than 1 cubic foot of sand where applied on masonry or concrete.
b. When determining the amount of aggregate in set plaster, a tolerance of 10 percent shall be allowed.
c. Combinations of sand and lightweight aggregate may be used, provided the volume and weight relationship of the combined aggregate to gypsum plaster is maintained.
d. If used for both first and second coats, the volume of aggregate may be 2.5 cubic feet.
e. Where plaster is 1 inch or more in total thickness, the proportions for the second coat may be increased to 3 cubic feet.

Figure 17-6 Gypsum plaster proportions

TABLE R702.1(3)
PORTLAND CEMENT PLASTER

Coat	MAXIMUM VOLUME AGGREGATE PER VOLUME CEMENTITIOUS MATERIAL[a]				MINIMUM PERIOD MOIST COATS	MINIMUM INTERVAL BETWEEN
	Portland cement plaster[b] maximum volume aggregate per volume cement	Portland cement-lime plaster[c]				
		Maximum volume lime per volume cement	Maximum volume sand per volume cement and lime	Approximate minimum thickness[d] curing (inches)		
First	4	$^3/_4$	4	$^3/_8$[e]	48 Hours[f]	48 Hours[g]
Second	5	$^3/_4$	5	First and second coats	48 Hours	7 Days[h]
Finish	3[i]	—	3[i]	$^1/_8$	—	Note h

For SI: 1 inch = 25.4 mm, 1 pound = 0.454 kg.
a. When determining the amount of aggregate in set plaster, a tolerance of 10 percent may be allowed.
b. From 10 to 20 pounds of dry hydrated lime (or an equivalent amount of lime putty) may be added as a plasticizing agent to each sack of Type I and Type II standard portland cement in base coat plaster.
c. No plasticizing agents shall be added.
d. See Table R702.1(1).
e. Measured from face of support or backing to crest of scored plaster.
f. Twenty-four-hour minimum period for moist curing of interior portland cement plaster.
g. Twenty-four hour minimum interval between coats of interior portland cement plaster.
h. Finish coat plaster may be applied to interior portland cement base coats after a 48-hour period.
i. For finish coat, plaster up to an equal part of dry hydrated lime by weight (or an equivalent volume of lime putty) may be added to Type I, Type II and Type III standard portland cement.

Figure 17-7 Portland cement plaster

Portland cement plaster, not gypsum plaster, must be used for exterior plastering. It must meet the requirements of IRC Section R703.6.2, as follows:

- At least three coats must be applied over metal lath or wire lath.
- At least two coats must be applied over masonry, concrete, gypsum backing or pressure-treated or naturally decay-resistant wood. Follow the specs for protection against decay in IRC Section R319.1.
- At least two coats must be applied if the plaster surface is completely covered by veneer or other facing material, or is completely concealed. The total thickness has to comply with IRC Table R702.1(1) (Figure 17-5).
- Plaster must cover, but not extend below, lath, paper and screed on wood-frame construction with an on-grade floor slab system.
- Plaster must comply with Table R702.1(3), shown in Figure 17-7.

TABLE 2512.6 CEMENT PLASTERS		
COAT	MINIMUM PERIOD MOIST CURING	MINIMUM INTERVAL BETWEEN COATS
First	48 hours[a]	48 hours[b]
Second	48 hours	7 days[c]
Finish	—	Note c

a. The first two coats shall be as required for the first coats of exterior plaster, except that the moist-curing time period between the first and second coats shall not be less than 24 hours. Moist curing shall not be required where job and weather conditions are favorable to the retention of moisture in the cement plaster for the required time period.

b. Twenty-four-hour minimum interval between coats of interior cement plaster. For alternate method of application, see Section 2512.8.

c. Finish coat plaster is permitted to be applied to interior portland cement base coats after a 48-hour period.

Figure 17-8 Cement plasters

For proper bonding, all surfaces must be clean. Make sure there's no powdery deposit on the surface. It also has to be damp and rough. If the surface isn't rough, apply bonding agents or a portland cement dash bond coat (also called the scratch coat). Mix the dash bond coat in the proportions of 1½ cubic feet of sand to 1 cubic foot of portland cement. Leave the dash bond coat undisturbed and allow it to moist-cure for at least 24 hours. See IBC Section 2510.7.

You can't use any frozen ingredients or apply portland cement plaster to frozen surfaces. Apply plaster only when the outside temperature is above 40 degrees F, unless you can keep the plaster above 40 degrees F both during application and for the following 48 hours. Protect all work from freezing for 24 hours after it sets. See IBC Section 2512.4 for further details.

The second coat, or *brown coat*, and the curing intervals between coats are covered in IBC Sections 2512.5 and 2512.6. The second coat should be applied to give the required thickness. The surface must be rough enough to provide an adequate bond for the finish coat, but smooth enough so there's no variation greater than ¼ inch under a 5-foot straight edge. That's tricky, but achievable for skilled professionals. Both first and second coats must be moist-cured for the times given in Table 2512.6 (Figure 17-8) and according to the ASTM C 926 standard.

The ASTM C 926 standard gives a general description of the time required between coats, taking into consideration that the time will vary with climatic conditions. The primary guideline is that the next coat should be applied as soon as the previous coat is rigid enough to resist:

- Cracking
- The pressure of the new coat application
- The leveling process

IBC Section 2512.9 states that the finish coat must be applied with enough pressure and thickness of material to bond to and conceal the underlying coat.

Exposed Aggregate Plaster

Exposed aggregate plaster is similar to exterior plaster. The difference is that a bedding coat is applied over the first coat of plaster. Then aggregate (like marble chips or pebbles) is embedded. The bedding coat is one part portland cement, one part Type S lime and up to three parts graded white or natural sand, by volume. It must have a minimum compressive strength of 1,000 pounds per square inch. The interior bedding coat is made up of 100 pounds of neat gypsum plaster and up to 200 pounds of graded white sand.

IBC Section 2513 covers all the requirements for exposed aggregate plaster:

> ***2513.1 General.*** *Exposed natural or integrally colored aggregate is permitted to be partially embedded in a natural or colored bedding coat of cement plaster or gypsum plaster, subject to the provisions of this section.*

> ***2513.2 Aggregate.*** *The aggregate shall be applied manually or mechanically and shall consist of marble chips, pebbles or similar durable, moderately hard (three or more on the Mohs hardness scale), nonreactive materials.*

Base coats can be either gypsum plaster or portland cement plaster. Install base coats according to the interior or exterior plaster guidelines we just covered. Cure according to the ASTM C 926 standard.

The bedding coat can be applied directly over the first coat of plaster. The overall thickness, including lath, must be at least ⅞ inch, or ½ inch when applied over concrete or masonry surfaces. Cement plaster bedding coats must retain enough moisture for hydration (hardening) for at least 24 hours. If necessary, you can spray lightly with water.

The surface preparation, application, curing time and method are the same as for exterior concrete. Refer to the section on portland cement plaster, previously discussed, for details.

Pneumatically-Placed Plaster

There are two methods of applying pneumatically-placed plaster or concrete. They're known in the trade as *shotcrete* and *gunite*. Application of the two is very different. In the shotcrete (or wet-gunning) method, the plaster or concrete is premixed. Then it's conveyed down a hose to a nozzle and pneumatically-fired at the surface to be coated. In the gunite (or dry-gunning) technique, only the cement and sand are premixed. Then the mix is conveyed to the nozzle by a high pressure stream of air, where water's added from a separate hose in the correct proportion. Final mixing occurs primarily at the surface being coated.

There's a lot of debate about which of the two techniques is better. Gunite is physically easier to apply, but takes more skill. The hose carrying the cement/sand mix and the water hose are lighter. But, since the mixture is adjusted at the nozzle, controlling the mix application requires skill. The gunite technique also uses higher pressure and more-expensive equipment. The shotcrete hose is heavy because it carries the premixed, wet concrete, but it's ready to go as it arrives at the nozzle.

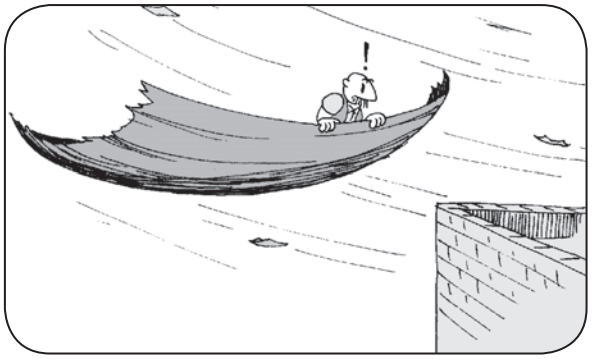
Both methods have particular uses. Gunite is favored for building in-ground swimming pools. Shotcrete is used for the construction of large domes, and for casting structural concrete against earth, such as shoring for an excavation, tunnel, or on an unstable slope. Gunite was the only method covered in the 1997 Uniform Building Code. But now, in the IBC, shotcrete is the only method discussed. This doesn't mean that gunite is no longer acceptable. But if you intend to use it, discuss your plans with a building official first.

The details for applying shotcrete are well-covered in IBC Section 1913, so I won't repeat them here. But the requirement for performing a "test run" in Section 1913.5 is worth mentioning. Basically, the building official can require a test panel to be shot by the nozzleman using the same equipment and conditions he'll use for the actual application. Then the test panel is strength-tested before starting the project. The strength tests must be done by an approved agency. Section 1913.10 gives details of the strength test.

Consequently, there may be a delay between the time the test panel is shot and when the final shotcrete can be placed. Do your homework. Maybe there's an approved testing agency nearby. If so, make prior arrangements for testing to save time. You want to avoid a delay in the final placement of the shotcrete, if possible. Ask your building official if a standard test panel (one already tested) can be used for the strength test. Of course, the same equipment, nozzleman shooting at the same angle, and concrete mix used for the test panel have to be used for the final shotcrete placement. Most jurisdictions require a special inspector to be present for the application, and many require special certifications for both the nozzleman and inspector. Check with your local jurisdiction for exact requirements and instructions.

Each year science and technology bring new materials to the work site, especially in the area of exterior and interior finishes. As new materials and methods appear, the codes that ensure their correct use will become more technical as well. Always consult with your inspector or building department about any new material not covered by the codes.

Now that we have kept out the weather, let's have a look at some of the requirements for conditioning the inside.



A Shot in the Dark

We have high winds in my part of the country, eastern Washington. That's why I'm a stickler on roof installation. But the roofer isn't always to blame when a roof gets blown away. A contractor I know owns an apartment building that had the roof blown off twice before it was a year old. The building has a flat roof with a five-layer mopped-on covering. There's a parapet wall 3 to 4 feet high all the way around the roof perimeter. I know the roofing subcontractor who did the job both times. He's about as professional and conscientious as they come. So why so much damage in one year?

I went out to check the building after the second storm. Roofing material was scattered a hundred yards up and down both sides of the street. Only about a third of the roof was still on top of the building. And there was something funny about what was left. Almost all the remaining roofing was around the roof edges. The center of the roof was almost bare. So I knew the wind hadn't found a weak spot at an edge and worked its way in.

The contractor, the roofer and I walked the entire roof and talked about it. My guess was that wind spilling over the top of the parapet wall caused a vacuum at the roof center. You know how dust swirls in the vacuum behind a big truck going down a dirt road? I guessed the same type of vacuum had sucked up the roof cover. Most parapet walls have penetrations for drains. But this one didn't. The roof drains went down through the exterior wall to ground level. I asked the contractor why.

"I did that to cut down on water stains on exterior walls."

"That's quality construction," I agreed, "but I think it's also turning this roof into an airplane wing in high winds. Why don't you cut a few scupper holes through each parapet wall? That might relieve the vacuum."

We cut three holes along each parapet wall. It was only a shot in the dark, but it must have worked. The roof came through the next winter in perfect shape.

CHAPTER 18

Combustion Air

When I was a building inspector during the "old code" days, I ran into lots of problems concerning combustion air. How much air was enough to supply adequate combustion? That wasn't an easy question to answer back then, and houses are even more tightly constructed today. But now, at least, the code is much clearer.

The "M" section of the IRC, Chapter 17, deals with the provision of combustion air for liquid-fuel-fired (oil) and solid-fuel-fired (coal or wood) appliances.

The "G" section of the IRC, Chapter 24, applies to the use and distribution of fuel gas. Fuel gas refers to natural gas or liquefied petroleum gas (LPG), but not liquefied natural gas (LNG). You'll find the combustion air requirements for fuel-gas-fired appliances in IRC Section G2407.

We'll look at the provisions in these two IRC sections separately, though many of their requirements for combustion air in one- or two-family dwellings and townhouses may be the same. First we'll cover the requirements for combustion air in residences using liquid- and solid-fuel-fired appliances, and then for those residences using fuel-gas-fired appliances. If you're building anything other than a one- or two-family dwelling or a townhouse, you'll need to use the International Mechanical Code (IMC) or the International Fuel Gas Code (IFGC), also published by the ICC.

Towards the end of this chapter, we'll look briefly at the requirements for combustion air for fireplaces and appliances in commercial use.

Liquid- and Solid-Fuel-Fired Appliances

Here's how IRC Chapter 17, Section M1701, begins its discussion on combustion air:

> ***M1701.1 Air supply.*** *Liquid- and solid-fuel-burning appliances shall be provided with a supply of air for fuel combustion, draft hood dilution and ventilation of the*

space in which the appliance is installed, in accordance with Section M1702 or Section M1703. The methods of providing combustion air in this chapter do not apply to fireplaces, fireplace stoves and direct-vent appliances.

> ***M1701.1.1 Buildings of unusually tight construction.*** *In buildings of unusually tight construction, combustion air shall be obtained from outside the sealed thermal envelope. In buildings of ordinary tightness, insofar as infiltration is concerned, all or a portion of the combustion air for fuel-burning appliances may be obtained from infiltration when the room or space has a volume of 50 cubic feet per 1,000 Btu/h (4.83 L/W) input.*

Meeting Combustion Air Requirements

Even though the code has been updated, the requirements for combustion air may still seem a little hazy to some of you. It's complicated because we're dealing with different fuel types in both old and new construction. Most new or recently-remodeled buildings have combustion air inlets for fuel-burning appliances. But older homes may not have combustion inlets, or the inlets may be blocked. For instance, louvered vents that provide air may be blocked by dampers or by items stored in front of them. Or, air inlets can be obstructed as the result of remodeling.

Did you notice the terms *unusually tight construction* and *ordinary tightness* in IRC Section M1701.1.1? What exactly do they mean? Today's code tries to explain. Section M1702 covers *All Air from Inside the Building*, which is when a building has *ordinary tightness*. Section M1703 covers *All Air from Outdoors*, which is when the building has *unusually tight construction*. If a building isn't defined as having unusually tight construction, then it automatically falls into the category of ordinary tightness. Let's look at each of these types of construction.

Unusually Tight Construction

Section M1702.3 says that a building has unusually tight construction when it's sealed so tightly that the air trickling in from outside isn't sufficient for combustion. That's still pretty vague, so here are some guidelines. A building has unusually tight construction if all of the following exist:

- Walls and ceilings exposed to the outside atmosphere have a continuous water vapor retarder with a rating of one perm or less with any openings gasketed or sealed
- Weatherstripping is applied on all windows and doors capable of opening
- Caulking or sealants are applied:
  - to joints around window and door frames
  - between sole plates and floors
  - between wall-ceiling joints
  - between wall panels
  - at openings for plumbing, electrical and gas lines
  - at other openings

New buildings are built to current energy conservation code and would have unusually tight construction. However, if an existing building doesn't fit the definition of unusually tight construction, then it automatically falls into the category of ordinary tightness.

Ordinary Tightness

Buildings with ordinary tightness aren't tightly sealed against air entering from the outside. In these buildings, combustion air is drawn from within the building and replenished by air entering from the outside through unsealed openings. But there has to be enough volume of space from which to draw the required amount of air. You need an *unconfined space* having a volume equal to at least 50 cubic feet per 1,000 Btu/h of the total input rating of all the fuel-burning appliances installed in that space. And, that space must have normal air

infiltration adequate to provide air combustion to the appliances. The space includes all rooms permanently open to the area where the appliance or appliances are installed; see Section M1702.1. We'll look at some examples using this information to calculate combustion air requirements later in the chapter.

What if the available space where the appliance is installed doesn't meet these requirements? Then it's considered a *confined space*, and you'll need two air openings. One opening must be no more than 12 inches from the top, and the other no more than 12 inches from the bottom of the confined space, as shown in IRC Figure M1702.2 (Figure 18-1). Each opening must have a free area of at least 1 square inch per 1,000 Btu/h, and the free area can't be less than 100 square inches. See Sections M1702.2 and M1701.5.

What about fixed louvers covering the openings for combustion air? If they're metal louvers, you can count only 75 percent of the gross opening space as the free air-drawing area. If they're wooden louvers, you can count only 25 percent. For more detail, see Section M1701.5. Section M1701.3 outlaws volume dampers in combustion air openings. That's because they might be closed by mistake, and then there wouldn't be enough combustion air available.

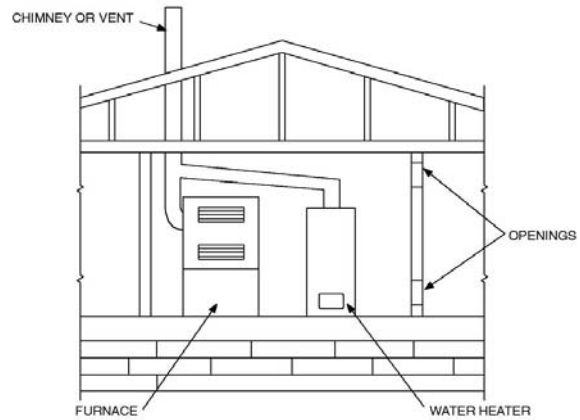
Also, any outside air opening must be above the projected flood elevation (Section M1701.6). Refer back to IRC Table R301.2(1) (Figure 1-1 in Chapter 1).

IRC Section M1701.4 says combustion air can't be drawn from:

- Spaces where the operation of a fan could limit the availability of combustion air
- Spaces where there might be flammable vapors
- Bedrooms, bathrooms or toilet rooms

However, combustion air can be drawn from bedrooms, bathrooms or toilet rooms for solid fuel-fired appliances, but only if the building isn't unusually tight construction, and the room isn't a confined space. This leaves room for interpretation. You probably wouldn't want to put a fireplace in a bathroom or toilet room. But you might want to put a fireplace in a bedroom.

IRC FIGURE M1702.2
APPLIANCES LOCATED IN CONFINED SPACES — ALL AIR TAKEN FROM ADJACENT SPACES WITHIN THE BUILDING



For SI: 1 square inch = 645.16 mm^2, 1 British thermal unit per hour = 0.2931 W.
NOTE: Each opening shall have a free area of not less than 1 square inch per 1,000 Btu/h of the total input rating of all appliances in the enclosure, but not less than 100 square inches.

Figure 18-1 Liquid- and solid-fuel-burning appliances in confined spaces — air from within the building

Btu/h

You'll hear a lot about Btu in this chapter. It stands for British thermal unit. It's the unit of measure for heat-producing appliances such as furnaces, water heaters and ovens.

A Btu is the amount of heat needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit. It's often used to describe the heat value of fuels. The Btu per hour, or Btu/h, measures the heating and cooling power of an appliance. One Watt is approximately 3.4 Btu/h. Btu/h is often abbreviated to just Btu.

Computing Combustion Air Requirements

IRC Section M1702 covers all air from inside the building when the building has only ordinary tightness. Let's see how much combustion air you need for an average small home with ordinary tightness.

Total Size of the Enclosure

First, you need to find the total size of the space that the appliance is drawing its air from. Let's say your single-story home measures 48 feet by 36 feet (1,728 square feet). You have the usual 8-foot ceilings, so that's about 14,000 cubic feet of space. Your furnace is installed in an unfinished basement the same dimensions as the house. So it's also a space of about 14,000 cubic feet. You've estimated your home heating needs are 280,000 Btu/h.

Using the figures from Section M1702.1, you'll see that you need 50 cubic feet for each 1,000 Btu/h. Multiply 280 × 50 and you get 14,000. That's 14,000 cubic feet of combustion air — just what you have available in your basement, but only if there aren't any partitions.

That's where there could be a problem. It's one that you (the builder) can't do much about. An unfinished basement can prove to be more temptation than the future resident handyman can stand. He makes a family room out of the basement. The furnace ends up in a small furnace enclosure or in the corner of the utility room. But the furnace needs an adequate air supply. Just because it's squeezed into a smaller area doesn't change that. So how much is adequate?

Well, it still needs the 14,000 cubic feet of combustion air you calculated. What does this mean for the new owner/weekend handyman? He's got to provide openings in *any* partition he builds. Air must be able to flow freely from all parts of the basement to the furnace.

Air Opening Size

Remember the air opening requirement in Section M1701.5? You need a free area of at least 1 square inch per 1,000 Btu/h, and not less than 100 square inches. So if the combustion air requirement is 280,000 Btu/h, then the free air openings, at *both* the top and bottom of the partition(s), must be 280 square inches. That's 14 inches by 20 inches.

If our owner/handyman *does* put air openings in his partitions, he'll probably cover them with fixed metal louvers. But, as we mentioned earlier, metal louvers reduce the gross air opening(s) by 25 percent. So for each free air opening to be 280 square inches, the gross air opening must be increased by 25 percent. Figure the increase using the following calculation:

$$280 \div (1 - 0.25) = 373 \text{ square inches}$$

That's about 15 inches by 25 inches — some pretty hefty louvers. But if they were wooden louvers, the gross air opening would have to be increased by 75 percent:

$$280 \div (1 - 0.75) = 1{,}120 \text{ square inches}$$

That's 28 inches by 40 inches. Now those are *huge* louvers! But, any combination of openings that equal the required free area, and are within 12 inches of the top *and* within 12 inches of the bottom of the partition(s), will meet this requirement. Just don't forget that the calculated opening area must be at *both* the high and low positions — not divided between the high and low positions. Failing to meet this requirement is the most common mistake made with combustion air venting.

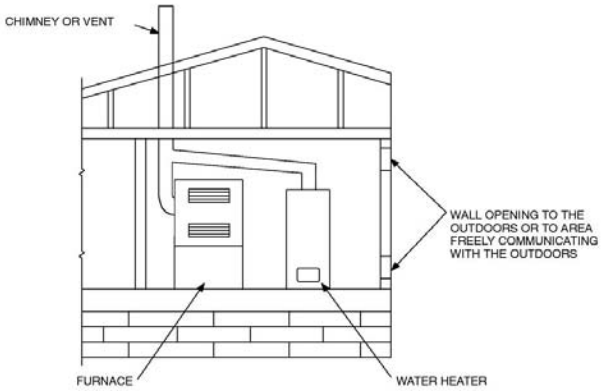
Other Air Users

Here's something else you must consider in your calculations. There are many other air users competing for the air in your house. Kitchen fans, bathroom vents, clothes dryers and fireplaces all remove air from a confined space. Most people aren't even aware of how great this air loss is. Any fan that discharges to the exterior of the building is reducing the amount of available combustible air. So you need to know the air requirements of any exhaust and ventilation systems in the house. These appliances are identified in IRC Section M1701.2.

Supplying Outside Air

If the home or building is built to unusually tight construction, like most structures today, combustion air has to come in from outside. Even if the available space *appears* adequate to supply the calculated amount of combustion air, because there's no air entering through leaks, cracks and drafts, you'll have to provide openings to the outside.

IRC FIGURE M1703.2(1)
APPLIANCES LOCATED IN CONFINED SPACES — ALL AIR TAKEN FROM OUTDOORS THROUGH TWO OPENINGS



For SI: 1 square inch = 645.16 mm^2, 1 British thermal unit per hour = 0.2931 W.
NOTE: Each opening shall have a free area of not less than 1 square inch per 4,000 Btu/h of the total input rating of all appliances in the enclosure.

Figure 18-2 Liquid- and solid-fuel-burning appliances in confined spaces — air from outside wall openings

For unusually tight construction, you need two openings or ducts to bring in combustion air, as described in IRC Section M1703.2. There are four opening options to consider:

1. Openings in outside walls, IRC Figure M1703.2(1) (Figure 18-2)
2. Ducts to outside walls, IRC Figure M1703.2(2) (Figure 18-3)
3. Ducts to outdoor-ventilated attics, IRC Figure M1703.2(3) (Figure 18-4)
4. Ducts to outdoor-ventilated crawl spaces, IRC Figure M1703.2(4) (Figure 18-5)

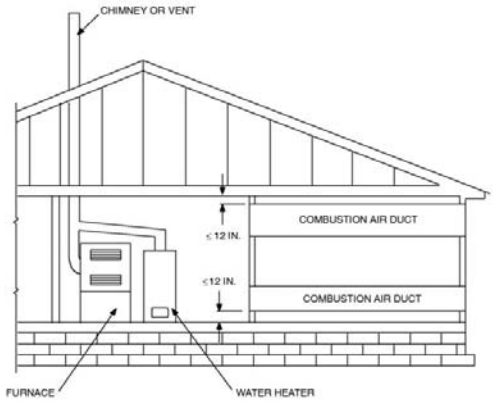
You must locate one opening within 12 inches of the top, and the other within 12 inches of the bottom of the enclosure. The openings can connect to interior spaces so long as they're ventilated directly to the outdoors, such as ventilated attics and ventilated crawl spaces. But the same duct or opening can't serve as both of the two required combustion air openings. When two horizontal ducts to the outside are used (Figure 18-3), the duct for the upper opening must be level or slope upwards from the appliance space — it can't slope downwards, even by a small amount.

Because the air is now being supplied from a never-ending source — the great outdoors — the openings don't have to be as big as they were for a fully-enclosed space; see IRC Section M1703.2.1. Here are the basic requirements for these openings:

- For horizontal openings or ducts (Figures 18-2 and 18-3), each of the two openings must have a free area of at least 1 square inch per 2,000 Btu/h.
- For vertical ducts into a well-ventilated attic (Figure 18-4), the free area openings must be at least 1 square inch per 4,000 Btu/h.
- Ducts must have at least the same cross-sectional area as the gross opening.
- The minimum dimension of ducts must be at least 3 inches.

We'll look at some special requirements for various air supply sources next.

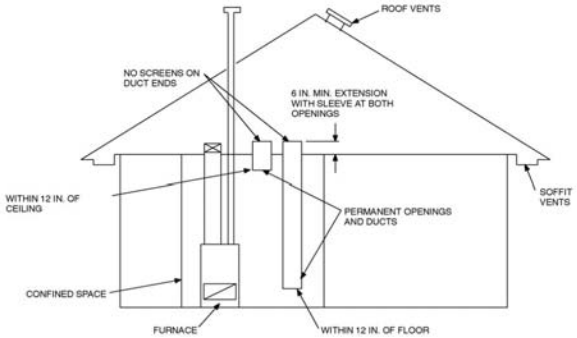
IRC FIGURE M1703.2(2)
APPLIANCES LOCATED IN CONFINED SPACES — ALL AIR TAKEN IN FROM OUTDOORS THROUGH HORIZONTAL DUCTS



For SI: 1 inch = 25.4 mm, 1 square inch = 645.16 mm^2, 1 British thermal unit per hour = 0.2931W.
NOTE: Each opening shall have a free area of at least 1 square inch per 2,000 Btu/h of the total input of all appliances in the space.

Figure 18-3 Liquid- and solid-fuel-burning appliances in confined spaces — air from ducts to the outside

IRC FIGURE M1703.2(3)
APPLIANCES LOCATED IN CONFINED SPACES — ALL AIR TAKEN IN FROM OUTDOORS THROUGH VENTILATED ATTIC



For SI: 1 inch = 25.4 mm, 1 British thermal unit per hour = 0.2931 W, 1 square inch = 645.16 mm^2.
NOTE: Each opening shall have a free area of at least 1 square inch per 4,000 Btu/h of the total input of all appliances in the space. The attic must be sufficiently vented for combustion air to be taken from the attic.

Figure 18-4 Liquid- and solid-fuel-burning appliances in confined spaces — air from a ventilated attic

Crawlspace Combustion Air

If the combustion air is drawn from a ventilated crawlspace and the air is conducted to a well-ventilated attic, the free air opening must be twice what it would be if the air were drawn from the attic. The opening must be at least 1 square inch per 2,000 Btu/h; see IRC Section M1703.4 and Figure 18-5.

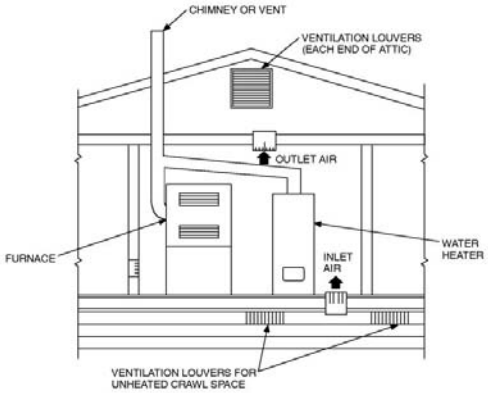
Attic Combustion Air

If air is drawn from and exhausted back into the attic, then the attic must be well-ventilated. Also, the ducts must project with a metal sleeve at least 6 inches above the ceiling joists and the insulation. If the inlet and outlet ducts are concentric, the inlet duct must extend at least 12 inches above the outlet duct; see IRC Figure M1703.3 (Figure 18-6). Finally, the attic ducts must not be screened; see Section M1703.

Outside Opening Covers

Any openings for outside combustion air must be covered with a corrosion-resistant screen. The screen openings must be at least ¼ inch, but less than ½ inch in size. This

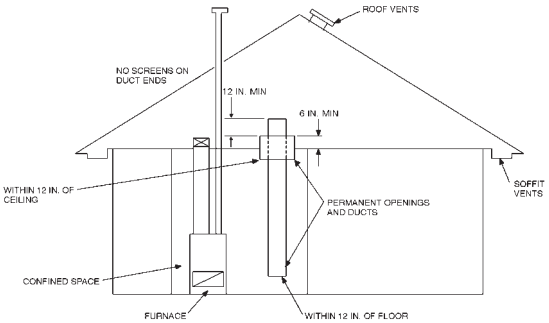
IRC FIGURE M1703.2(4)
APPLIANCES LOCATED IN CONFINED SPACES — INLET AIR TAKEN FROM VENTILATED CRAWL SPACE AND OUTLET AIR TO VENTILATED ATTIC



For SI: 1 square inch = 645.16 mm^2, 1 British thermal unit per hour = 0.2931 W.
NOTE: The inlet and outlet air openings shall have a free area of not less than 1 square inch per 4,000 Btu/h of the total input rating of all appliances in the enclosure.

Figure 18-5 Liquid- and solid-fuel-burning appliances in confined spaces — air from a ventilated crawl space

IRC FIGURE M1703.3
APPLIANCES LOCATED IN CONFINED SPACES — ALL AIR TAKEN FROM OUTDOORS THROUGH VENTILATED ATTIC, INLET DUCT WITHIN OUTLET DUCT



For SI: 1 inch = 25.4 mm, 1 British thermal unit per hour = 0.2931 W, 1 square inch = 645.16 mm^2.
NOTE: Each duct shall have a free area of at least 1 square inch per 4,000 Btu/h of the total input of all appliances in the space. The attic must be sufficiently ventilated to provide the required combustion air.

Figure 18-6 Liquid- and solid-fuel-burning appliances in confined spaces — air from a ventilated attic

prevents mice, squirrels and other critters or wind-blown trash from getting into the ducts; see IRC Section M1703.5. There's an exception: This doesn't apply to attic openings or openings into ventilated crawl spaces if the ventilated crawl space has similar screens at its opening points.

Fuel-Gas-Fired Appliances

All of the information we've covered so far applies to combustion air for liquid- and solid-fuel-fired appliances. If you're planning to use fuel-gas-fired appliances in your construction, you'll need to read IRC Section G2407. Section G2407.1 gives the general requirements for combustion, ventilation and dilution air:

> ***G2407.1 (304.1) General.*** *Air for combustion, ventilation and dilution of flue gases for appliances installed in buildings shall be provided by application of one of the methods prescribed in Sections G2407.5 through G2407.9. Where the requirements of Section G2407.5 are not met, outdoor air shall be introduced in accordance with one of the methods prescribed in Sections G2407.6 through G2407.9. Direct-vent appliances, gas appliances of other than natural draft design and vented gas appliances other than Category I shall be provided with combustion, ventilation and dilution air in accordance with the appliance instructions.*

Section G2407.5 covers the requirements when indoor combustion air alone will be sufficient. If your construction can't meet the requirements for indoor combustion air alone, then you must use one of the following methods to provide combustion air:

- Outdoor combustion air, Section G2407.6
- Combination indoor and outdoor combustion air, Section G2407.7
- Mechanically-supplied combustion air, Section G2407.9
- Engineered solution, Section G2407.8

Indoor Combustion Air Alone

There are two methods for determining the minimum volume of space from which indoor combustion air can be drawn — the *standard method*, and the *known-air-infiltration-rate method*. The standard method states that the volume must be at least 50 cubic feet of area for every 1,000 Btu/h of the total input rating of the appliances in the space; see IRC Section G2407.5.1.

If you know the air-infiltration rate of the building, then you can use the equations shown in Section G2407.5.2 to calculate the minimum space from which air can be drawn, when all the air is drawn from within the building. If the known air-infiltration rate is less than 0.4 air changes per hour (ACH), you *must* use this method. But you can't use rates higher than 0.60 ACH in the equations.

Whichever method you use to determine the required volume of indoor air from which combustion air can be drawn, you'll still need to add up the air volume required for all the appliances located within that space.

Combining Spaces

Rooms connected directly to the space in which the appliance(s) are located can be considered part of the required volume, provided they're connected by openings without doors (that could be accidentally closed) or by combustion air openings (typically louvers). The size and location of these openings are covered in IRC Sections G2407.5.3.1 and G2407.5.3.2. Figure G2407.5.3 (Figure 18-7) shows openings required for appliances that receive combustion air from inside the building.

IRC Section G2407.5.3.1 says that each opening to a connecting area on the same story must have a minimum free area of 1 square inch per 1,000 Btu/h of the total input rating of the appliance(s) in the space, but not less than 100 square inches. One opening must start within 12 inches of the top of the enclosure and one within 12 inches of the bottom, as before. The minimum dimension of any air opening must be at least 3 inches.

IRC FIGURE G2407.5.3
ALL AIR FROM INSIDE THE BUILDING

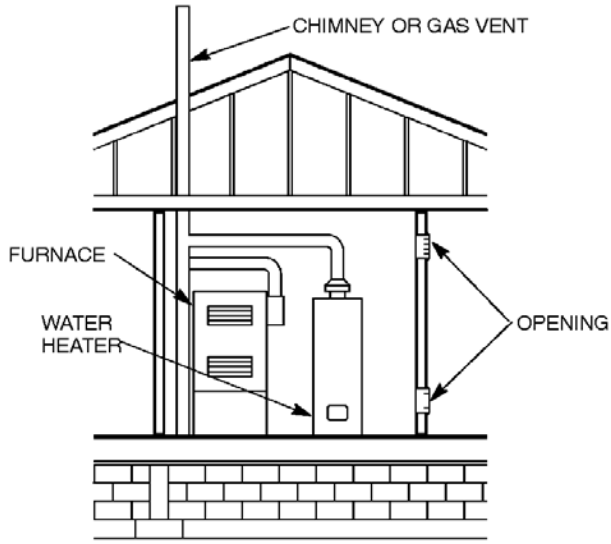


Figure 18-7 Fuel-gas-burning appliance(s) in confined spaces — air only from inside the building

If the connected areas are on different stories, then the openings in doors or floors must have a total minimum free area of 2 square inches per 1,000 Btu/h of the total input rating of the appliance(s) in the space; see Section G2407.5.3.2.

Competition for Make-up Air

Once again, you must consider the other systems in the house that are competing for the same air. These include exhaust fans, kitchen ventilation, clothes dryers and fireplaces; see Section G2407.4. The code doesn't tell you how to do this, just that you must make allowance for them.

Sources for Combustion Air

When the minimum amount of required combustion air can't be supplied from within the building, you must use air openings and ducts to bring an air supply in from the outside. Let's look at the air opening sizes and duct requirements, then consider how best to use them.

Air Opening Size

We discussed gross air opening size and net free area when we covered combustion air openings for liquid- and solid-fuel-fired appliances. Let's review the main points:

- Air opening size requirements are based on the net free area of the opening – if the opening is covered by a louver, grille or screen – not the physical size of the opening.
- If the free area through a design of louver, grille or screen is known, it must be used in calculating the full size opening necessary to provide the free area required.
- If the free area of the louvers isn't known, it must be assumed that metal louvers reduce the physical area by 25 percent and wood louvers reduce the physical area by 75 percent. We provided the calculations for increasing the size of the openings to compensate for the type of louvers in the section on combustion air for liquid- and solid-fuel-fired appliances.
- If screens are used to cover the air openings, the mesh size can't be smaller than ¼ inch.
- Nonmotorized louvers must be fixed in the open position.
- Motorized louvers must be interlocked with the appliances to ensure they're open prior to main burner ignition and during main burner operation. If the louvers close for any reason the main burner must be shut down.

Air Ducts

Air ducts for combustion air (Section 2407.11) must comply with all of the following:

- Ducts must be made of galvanized steel or a material having equivalent rigidity, strength and corrosion resistance (Section M1801).
- No more than one required fire block can be removed if you use stud and joist spaces to carry combustion air ducts within dwellings units.
- Ducts must terminate in an unobstructed space so that combustion air can move freely to the appliances.
- Ducts can serve only a single enclosure and not connect multiple enclosures.
- If two air openings are used, the same ducts (all the way to the source of combustion air) can't serve both upper and lower openings.
- Ducts terminating in an attic space must not be screened.
- Upper horizontal air ducts must be either level or slope upwards towards the source of combustion air. They must never slope downwards.
- Space surrounding a chimney liner, gas vent or plastic piping installed in a manufactured chimney or a chimney constructed of masonry or metal, may not be used to supply combustion air.
- The lowest side of an air intake opening located on the outside of a building must be at least 12 inches above the adjoining grade level.

Outdoor Combustion Air

We listed four methods of supplying outside combustion air for fuel-gas-fired appliances at the beginning of this section. The first method, outdoor combustion air (Section G2407.6), gives you two additional alternatives: a one-permanent-opening method (Section G2407.6.2), and a two-permanent-opening method (Section G2407.6.1). Whichever you use, the minimum dimension of any air opening must be at least 3 inches.

IRC FIGURE G2407.6.2
SINGLE COMBUSTION AIR OPENING, ALL AIR FROM OUTDOORS

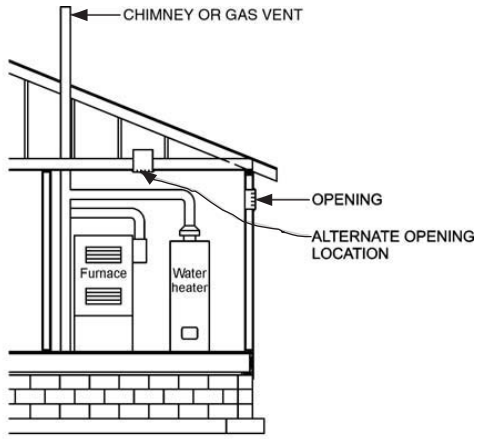


Figure 18-8 Fuel-gas-burning appliance(s) in confined spaces — air from outside the building using one opening

One-Permanent-Opening Method

The requirements for one permanent opening can be summarized as follows:

- The opening must start within 12 inches of the top of the enclosure.
- You must leave at least a 1-inch clearance at the back and sides of the appliance, and a 6-inch clearance at the front.
- The opening must connect directly with the outdoors, or through horizontal or vertical ducts to the outdoors, or to spaces that connect with the outdoors. See IRC Figure G2707.6.2 in Figure 18-8.
- The opening must have a minimum free area of 1 square inch per 3,000 Btu/h of the total input rating for the appliances located in the enclosure.

IRC FIGURE G2407.6.1(1)
ALL AIR FROM OUTDOORS — INLET AIR FROM VENTILATED CRAWL SPACE AND OUTLET AIR TO VENTILATED ATTIC

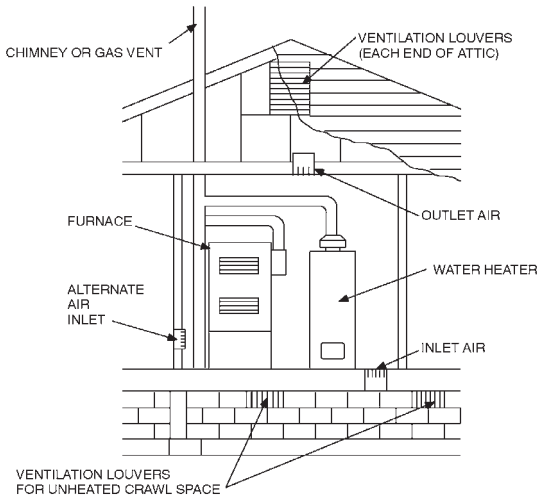


Figure 18-9 Fuel-gas-burning appliance(s) in confined spaces — air from outside the building using two permanent openings

- The opening size mustn't be less than the total area of the vent connectors in the space.

Two-Permanent-Opening Method

The requirements for two permanent openings are:

- One opening must start within 12 inches of the top and the other opening must start within 12 inches of the bottom of the enclosure.
- The openings must connect directly with the outdoors, or through ducts to the outdoors, or to spaces that connect with the outdoors.
- When connecting directly with the outdoors, or via vertical ducts to the outdoors, each of the two openings must have a free area of at least 1 square inch per 4,000 Btu/h of the total input rating for the appliances in the enclosure. See IRC Figure G2407.6.1(1) in Figure 18-9 and IRC Figure G2407.6.1(2) [304.6.1(2)] in Figure 18-10.
- When connecting via horizontal ducts to the outdoors, each of the two openings must have a free area of at least 1 square inch per 2,000 Btu/h of the total input rating for the appliances in the enclosure. See IRC Figure G2407.6.1(3) [304.6.1(3)] in Figure 18-11.

Combination Indoor and Outdoor Combustion Air

The second method of supplying combustion air is a combination of indoor and outdoor air sources; see IRC Section 2407.7. The main requirements for this method to be acceptable can be summarized as follows:

- Where openings connecting interior spaces are used, they must comply with the requirements in IRC Sections G2407.5.3.1 and G2407.5.3.2 and IRC Figure G2407.5.3 (Figure 18-7), which we discussed in Indoor Combustion Air.
- Where outdoor openings are used, their location must comply with IRC Section G2407.6, which we discussed in Outdoor Combustion Air.
- The total available volume of all interior connected spaces divided by the required volume is the *Ratio of Interior Spaces*.
- The minimum size of outdoor openings can be reduced by multiplying the minimum size calculated by the following reduction factor:

  Reduction Factor = (1- Ratio of Interior Spaces)

- The minimum dimension of air openings must be at least 3 inches.

IRC FIGURE G2407.6.1(2) [304.6.1(2)]
ALL AIR FROM OUTDOORS
THROUGH VENTILATED ATTIC

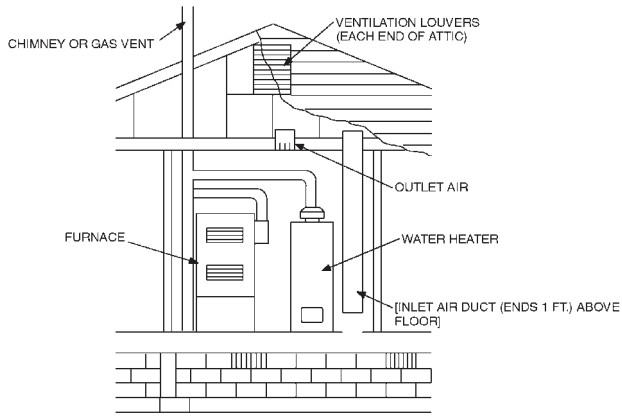


Figure 18-10 Fuel-gas-burning appliance(s) in confined spaces — air from outside the building using two permanent openings

IRC FIGURE G2407.6.1(3) [304.6.1(3)]
ALL AIR FROM OUTDOORS

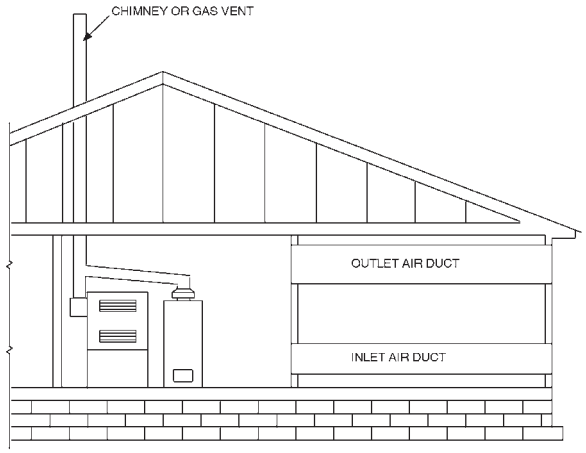


Figure 18-11 Fuel-gas-burning appliance(s) in confined spaces — air from outside the building using two horizontal ducts

Mechanically-Supplied Combustion Air

The third method we'll discuss is mechanically-supplied combustion air; see Section G2407.9. The main requirements are summarized as follows:

- Mechanically-supplied combustion air must be supplied from the outdoors at a rate of at least 0.35 cubic feet per minute per 1,000 Btu/h of the total input rating for all appliances located within the space.
- If exhaust fans are installed, make-up air must be provided to compensate for the air that's exhausted.
- If the building's mechanical ventilation system will provide the combustion air, the system must be capable of supplying the required combustion air *in addition to* the required ventilation air.

An Engineered Solution

The fourth method of supplying combustion air is an engineered solution. IRC Section 2407.8 simply says that you can install an engineered system for supplying combustion air provided it's approved by a building official.

Fireplaces

When I was an inspector, I saw a lot of smoky fireplaces, especially in new homes. Fireplace construction isn't usually the reason for a smoky fireplace. Today's houses are more airtight than ever before. Single-wall construction with plywood sheathing or siding doesn't let in nearly as much outside air as diagonal sheathing or shiplap siding. Storm windows, caulking, weatherstripping and plastic vapor barriers also protect a house against air leakage. In many ways, a "tight ship" is desirable – but not when it comes to fireplaces.

In a tight home, there's competition for any air available inside the house. Furnaces, kitchen and bath fans and fireplaces all need their fair share. During the day, when windows are open and doors are being opened and closed, this isn't a problem. There's plenty of air coming into the house. But it can be a problem at night when all windows and doors are shut tight. When investigating a smoking fire in a fireplace, I usually found that the fire was starved for oxygen. The flames were reaching for any available air.

To prevent this problem, most modern fireplaces are designed with vents and ducts to bring combustion air in from the outside. IRC Section R1006.1 says:

> ***R1006.1 Exterior air.*** *Factory-built or masonry fireplaces covered in this chapter shall be equipped with an exterior air supply to assure proper fuel combustion unless the room is mechanically ventilated and controlled so that the indoor pressure is neutral or positive.*

Commercial Air-Users

Commercial buildings, like restaurants, also have combustion air problems. The vent hoods — and restaurants are required to have many — take a lot of air out of the kitchen. And there are gas-flame grills, water heaters and other appliances eating up the air.

In winter the problem generally gets worse. Windows are kept shut and air conditioning units are turned off. But venting of kitchen vapor and steam continues. The kitchen is an airless box until someone opens a door and momentarily relieves the condition.

The same thing can happen in your house. What happens if you open a door or window to get a breath of fresh air on some windless night? A gust of air blows in and suddenly you're freezing cold. You're living in a vacuum created by your fireplace, furnace and other air-hogging devices. A properly-designed house has a slightly positive pressure, so it doesn't draw in cold air. Proper ventilation is very important. At the end of the next chapter we'll talk about why you have to compensate for all the air being forced outside.

Combustion air is probably the least understood and most overlooked of all a house's potential problems. But with all the devices competing for air, it's something that can't be ignored. Don't forget the tips and code references I've given you here. They'll prove to be very important in this new age of "tight" construction.

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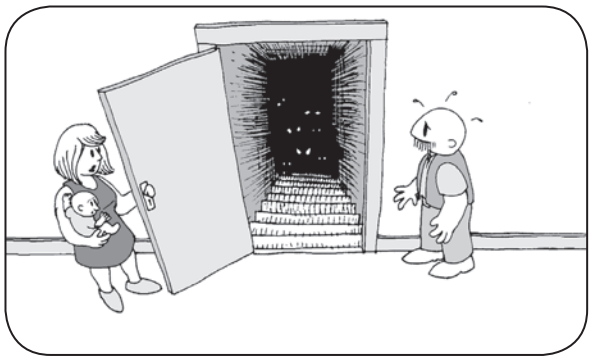


The Day I Got Spooked

In most cities and counties, an inspection is required when gas, water or electric lines are installed or reopened. One day I got a call from a young lady who'd just moved into an older home. A new gas line had been installed and she needed an inspection before the gas company would begin service. Would I please come out and do whatever was required?

After I'd checked the gas line, she asked me to take a look in the basement. She didn't use it, she told me, but she thought there might be something wrong down there. She heard strange noises coming from under the house at night. She was completely serious. My guess was that neighborhood kids were playing down there. "No problem," I told her.

She pointed to a place in the hall where the freezer stood. The basement door was behind it and was both locked and nailed shut. I borrowed a hammer and pried the door open. I tried the light switch just inside the door, but it didn't work.

Dim light coming from the basement showed the outline of furnace duct and an old furnace. The basement must have been a coal bin and furnace room when the home was first built. Judging by the damp, moldy smell, the furnace hadn't been used in many years. Most likely, no one had gone down those stairs into the basement in years, either.

The basement door opened onto a small landing at the top of a flight of stairs. I stood just inside the door for a minute while my eyes became accustomed to the dim light. Squatting down, I could see two windows at the far end of the basement. They must have been obscured by bushes on the outside, as very little light was coming through. From where I stood, I couldn't see any way in or out except the stairway I was standing on, and the two small windows.

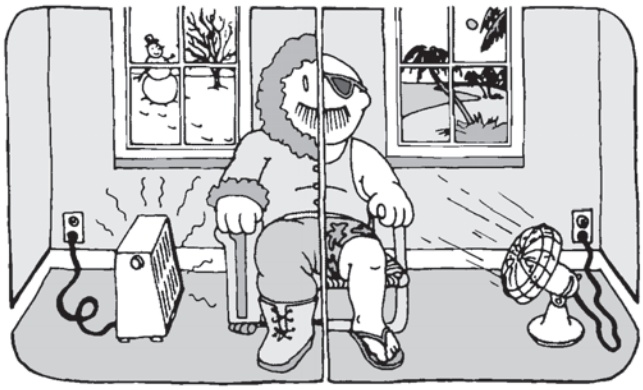
I put my weight on the first step down the flight of stairs. It felt solid. I tested the next. The stairs seemed safe enough. But the further I got from the door at the top of the stairs, the more uncomfortable I felt. The hair on the back of my neck was standing straight up. I remember thinking, "I should get paid extra for exploring haunted houses." No doubt about it, I was scared.

I turned to look back up the stairs. The lady was still there, watching from the basement door. If she hadn't been there, I would have been up the stairs and gone, quick as a wink. Instead, I gave her a weak smile, and then turned to take another cautious step down. A few more steps and I was on the basement floor. I went straight to one window, checked the latch, and then did the same on the second window. Both window latches were stuck in the locked position. The cobwebs around the window frames showed the windows hadn't been opened in years. I turned briskly and went back up the stairs, climbing just slowly enough so it didn't look like I was running.

"Nothing to worry about," I said reassuringly. "Looks fine to me. I'll tell the gas company it's OK to start service."

Then I walked, not ran, to my car and drove away.

Several weeks later I was telling the story to some friends who live just down the street from that house. They both laughed. "Didn't you know?" they asked. "That house is haunted. You should hear some of the ghost stories the tenants used to tell. One couple even moved out. They couldn't sleep at night. But the lady there now says she had someone from the city come out to check the basement. She says it's fine now."



CHAPTER 19

Heating, Ventilating & Air Conditioning (HVAC)

Building codes are complex, but that's understandable. Construction is a complicated subject, and the codes try to cover all the bases. That's why many sections refer to other sections which refer to still more sections. To get one answer, you might have to digest the requirements in all those sections. If you've spent a lifetime working with the code, that's no problem. Building inspectors have spent the time, and are proud to have mastered the code. But builders have other work to do.

I wrote this book for contractors and builders. After you've read it, you should be able to hold your own with the inspector. And you'll know enough about the code to avoid problems before they become expensive mistakes.

Heating, ventilating and air conditioning (HVAC) isn't an easy subject. The 1997 UBC didn't even cover HVAC work. You had to meet two different codes: the Uniform Mechanical Code, published by the International Conference of Building Officials (ICBO) and a code published by the International Association of Plumbing and Mechanical Officials (IAPMO).

Now you can find HVAC requirements for residential property in the IRC. For more complex commercial installations, use the International Mechanical Code® (IMC) and the International Fuel Gas Code® (IFGC), published by the ICC, or your locally-approved code.

For the purposes of this section, though, we'll focus on the IRC.

Most modern buildings have heating, cooling and ventilating equipment. Even if you don't install air conditioning, you'll still put in heating and ventilation. So that's reason enough to read this chapter. It will help you avoid the most common code problems in one- and two-family dwelling and townhouse HVAC work.

Sizing Your System

Getting the right size heating or cooling equipment is a science in itself, so call in the big guns — the HVAC professionals. You probably

don't have the specialized knowledge needed to size this kind of equipment, so let them do the figuring for you. But if you're feeling confident and want to give it a shot, follow the directions in IRC Section M1401.3. You'll be referred to Air Conditioning Contractors of America (ACCA) Manual J, *HVAC Residential Load Calculation*, or other approved heating and cooling calculation methodologies.

The ACCA publishes technical manuals and guides for professionals in HVAC-R and related fields. Manual J is available online at www.acca.org. Just click on the box marked ACCA Online Store.

There are lots of load-calculating software programs. A good one that I recommend can be downloaded at www.energycodes.gov/rescheck/download.stm. This site is hosted by the U.S. Department of Energy. But check with your local building department first. You need to know what HVAC load-calculation format they recognize. Also ask if you need to provide your calculations for their review.

Installing HVAC Equipment

In the previous chapter we discussed how to provide a furnace with enough combustion air. Now we'll find out how to install HVAC equipment so it passes inspection under the IRC.

Chapters 14 and 15 of the IRC cover Heating and Cooling Equipment, and Exhaust Systems, respectively. Let's start with heating and cooling equipment and the basic requirements. Refer to Section M1401. The first items are general installation requirements (Section M1401.1) and access (Section M1401.2).

> ***M1401.1 Installation.*** *Heating and cooling equipment and appliances shall be installed in accordance with the manufacturer's installation instructions and the requirements of this code.*
>
> ***M1401.2 Access.*** *Heating and cooling equipment shall be located with respect to building construction and other equipment to permit maintenance, servicing and replacement. Clearances shall be maintained to permit cleaning of heating and cooling surfaces; replacement of filters, blowers, motors, controls and vent connections; lubrication of moving parts; and adjustments.*

In simple terms — don't ruin good equipment with a bad installation job that makes proper operation and routine maintenance difficult.

Remember, heating equipment gets hot. That's unavoidable. It can also be deadly. A builder who doesn't provide enough combustion air for the system or tries to install the equipment into too small a space may be creating work for the local fire department. Don't do it. There are good reasons for following code recommendations and the manufacturer's design limits.

Every appliance you install has an information plate showing the intended function and capacity. Take the manufacturer's word for it — they know their appliances best. Every appliance is tested in the manner intended for its use. Ignoring the instructions could be dangerous. The data plate on gas, oil and electric heaters and heat pumps has the serial and model numbers with rated capacities. If the tag is missing, return the equipment. Do *not* install it.

If your appliances are installed by an authorized dealer, they'll probably be installed correctly. But just to be sure, inspect the installation. Have the installer leave a copy of the installation and operating instructions attached to the appliance. The inspector will usually ask to see them.

Installing the AC Air Compressor

It's common practice to install an air conditioner's compressor outside. It's the easiest way to get heat out of the building and into the open air. But any equipment installed outside must be approved and labeled for outdoor installation; see Section M1401.4. Always make sure you place it on a level foundation 3 inches above the adjacent ground to prevent excessive vibration, movement, or settling of the unit.

And don't forget about the possibility of local flooding. That's a critical consideration when installing electrical equipment outdoors; see Section M1401.5. If you're installing equipment in a flood-prone area, see in Table R301.2(1) (refer back to Figure 1-1 in Chapter 1), be certain that the installation complies with IRC Section R324.1.5. What does this say? Locate the following equipment at or above the flood elevation:

- HVAC equipment
- Plumbing appliances or fixtures
- Electrical systems
- Service equipment
- Duct work

Related equipment can't be mounted on or be allowed to penetrate through walls designed to break away under flood loads. There is, however, an exception under Section R324.1.5 for certain pieces of equipment, provided that they are . . . *designed and installed to prevent water from entering or accumulating within the components and to resist hydrostatic and hydrodynamic loads and stresses, including the effects of buoyancy, during the occurrence of flooding to the design flood elevation* . . . But that's an expensive option. Most owners don't want to pay the extra cost.

And, always check your local codes to see if there's a sound level (noise) limit or zoning restriction when placing an equipment unit outside.

Equipment Supports and Restraints

When you install HVAC equipment, make sure it's supported by a base or held up by hangers that can sustain the intended load. If you're attaching the appliance permanently, fix it in position so there's no chance of accidental movement. It has to maintain its position under both vertical and lateral loads — including wind, snow and seismic activity.

Appliances must be accessible for inspection, service, repair and replacement. If it's an underfloor or attic installation, you need an access hole big enough to remove the largest piece of the appliance, but not less than 20 by 30 inches. You also need a 30- by 30-inch work area or platform in front of the service side of the unit, and a 24-inch-wide stable path to get to it. Make sure there's a light and a service receptacle (electric outlet) near the unit. If the appliance is installed in a closet or alcove, you still need 30 inches of clear working area in front of the control side of the equipment, and you need to keep 3 inches clear at the sides, back and top. There's more detail about appliance access and clearance in IRC Section M1305.

Automatic Control Devices

All heating appliances must be equipped with safety controls to cut the fuel supply to the main burner in case of unsafe conditions. These conditions could include out-of-limit operation or failure of the pilot or ignition system, among others. Almost all heaters meet the appropriate standard, but it's always best to make sure that the one you choose has been approved.

Heating appliances connected to ducts must have two separate temperature-limiting controls:

- An automatic resetting control that prevents the discharge air temperature from exceeding 200 degrees F (93 degrees C);
- A manual resetting control that prevents the discharge air temperature from exceeding 250 degrees F (121 degrees C).

Gas Shutoff Valves

A word of caution: If natural gas is supplied to the property, don't attempt to hook up a butane or propane appliance to it. If by some chance you get it to light at all, it'll just sputter along. You probably won't burn the house down, but you won't heat it either. On the other hand, if you attempt to use butane or propane gas in an appliance made for natural gas, it can be deadly. The gas opening is too big — a natural gas appliance running on butane becomes a huge blowtorch. Don't try it.

Install two approved shutoff valves: one within 3 feet of the appliance and the other at the service meter. For each valve, provide a union connection, an approved appliance connector, or an approved (and listed) quick-disconnect device between the appliance and the valve. Many of the manufactured flex connectors also qualify as an approved union. A union connection makes it easier to change out appliances. Connectors for residential ranges and clothes dryers can't be over 6 feet long. Other appliances, such as water heaters, can't have a connector more than 3 feet long.

The shutoff valve closest to the appliance must be in the same room or space, and within sight of the appliance. It can't interfere with the maintenance or removal of the appliance. The shutoff valve can be inside or under the appliance, but it has to be accessible. Accessible, in this case, means that a service technician can remove the appliance without removing the shutoff valve.

Don't conceal or extend appliance connectors through a wall, partition, floor or ceiling, or the equipment housing or casing. The connectors must be big enough to handle the total demand of the connected appliance. Only use appliance connectors listed in IRC Section G2422.1.

Here's another important safety note. In earthquake-prone locations, such as California, authorities recommend keeping a tool near the service entrance for closing the gas shutoff valve. If there's any sign of a leak after an earthquake, the owner can easily shut off the gas until the system has been checked.

Heating Systems

The IRC covers a wide range of heating systems, including:

- Central furnaces; see Section M1402 (Oil), ANSI/UL 727 (Oil) and UL 1995 (Electric)
- Heat pump equipment; see IRC Section M1403 and UL 1995
- Baseboard convectors; see IRC Section M1405 and IRC Part VIII — Electrical
- Radiant heating systems; see IRC Section M1406 and IRC Part VIII — Electrical
- Duct heaters; see IRC Section M1407 and IRC Part VIII — Electrical
- Vented floor furnaces; see IRC Section M1408 and UL 729
- Vented wall furnaces; see IRC Section M1409 and UL 730
- Vented room heaters; see IRC Section M1410, ASTM E 1509, and UL 896 or UL 1482
- Fireplace stoves; see IRC Section 1414 and UL 737
- Masonry heaters; see IRC Section M1415 and IRC Section R1006

The IRC doesn't provide details on installing a particular heating system type. There are just too many. Most installation instructions are specific to a manufacturer, and even a specific model, based on intensive testing by a listing agency. The code refers you to the relevant listing agency or ASTM standard, as shown above. Every listed appliance or piece of equipment comes with the manufacturer's installation instructions. These should specify all the critical information needed by the installer and the inspector, including the *Testing/Listing Agency* and the *listing number*. If the inspector has any questions about your installation, you'll most likely need to provide this information in order to pass inspection.

If you're considering HVAC installation as a specialty, you can buy any of the UL standards by going to www.comm-2000.com.

One- or two-family dwellings or townhouses are usually heated by oil-fired, gas-fired or electric heating systems. Many use forced- or gravity-air systems. The IRC now includes a whole section taken from the International Fuel Gas Code. If you intend to use a gas-fired system in your building, read IRC Part VI — Chapter 24, Fuel Gas.

Let's see how the IRC deals with the different heating system types.

Central Furnaces

Central furnaces have to meet the requirements of ANSI/UL 727 for oil-fired furnaces and UL 1995 for electric furnaces. For gas-fired systems, see IRC Chapter 24.

Clearances must meet manufacturer's requirements. Combustion air specs must meet the conditions described in Chapter 18 of this book. Also, the space in front of combustion air openings must be unobstructed for at least 6 inches; see IRC Section M1402.3. This isn't always under your control, since you have no way of knowing where the owner is going to put furniture. But if you put the air openings in a hallway, it's less likely the owner will block them.

Heat Pump Equipment

Heat pumps are basically air conditioners that work in both directions. And like air conditioners, their compressors are installed outside the building. They extract heat from the outside air and bring it into the building, or vice versa. Even when it's cold outside, some heat can still be extracted and carried in to the heating coil using a piped fluid. The circulated air extracts heat from the heating coil and sends it to rooms via a duct system.

The total free opening area of the outside and return air ducts must be at least 6 square inches per 1,000 Btu/h; see IRC Section M1403.1. This doesn't apply to a heat pump installed outdoors because there's no shortage of outside air. However, always check the manufacturer's instructions for required clearances, whether installing inside or out.

Just as for air conditioners, the foundations for outside heat pump units must be at least 3 inches above the ground, as you'll see in Section M1403.2. This allows for free flow and drainage of defrost water.

Baseboard Convectors

Baseboard convectors can be either hot water heated from a central furnace or electrically heated. If electrically heated, they must conform to the manufacturer's instructions and the requirements of IRC Part VIII, Electrical, Section M1405.

Radiant Heating Systems

Radiant heating systems are usually installed in the building's floor. They're designed to work either by:

- Conducting hot water through pipe work (hydronic heating), or
- Using electrically-heated coils installed in the floor.

This type of space heating has been used for nearly two thousand years. The Romans were using hydronic heating as early as 67 A.D. The emperor Caligula even had it installed in his imperial barge. At that time, a wood fire and terra cotta pipes were used. The principle was simple: hot water circulating through pipes placed in the floor. This same method of radiant heating is used today, only with different fuel and pipe types.

Under-floor radiant heat is an excellent choice for heating. Temperatures are higher at floor level and decrease toward the ceiling. Because radiant heat is installed under the entire floor surface, heat is distributed evenly throughout the room. There aren't any hot spots. Radiant heat puts the heat where the people are, not up by the ceiling.

The IRC covers both types of systems, hydronic heating (Section M2103) and electrical radiant heating (Section M1406).

Hydronic Heating

Hydronic heating coils are usually embedded in a concrete floor. They can be sandwiched between the subfloor and the finished floor, or attached to the subfloor from below. Get details from the Hydronic Heating Association at www.comfortableheat.net. There are many approved piping materials for embedding in concrete or gypsum materials, as you'll see in IRC Section M2103.1. PEX (cross-linked polyethylene) tubing, with a minimum rating of

100 psi at 180 degrees F, is one of the most common. Many companies make PEX products, but there's a big difference among the products, as well as their applications. Make sure you get the right one for your job.

Embedded tubing joints won't be accessible after installation. The joints must comply with Section M2103.2. Before embedding, the pipe work must be tested to at least 100 psi for 30 minutes. This is to make sure there are no visible leaks at the joints. See Section M2103.3 for more information.

Electrical Radiant Heating

Electrical radiant heating systems are discussed in IRC Section M1406. The electrical installation requirements are described in Chapters 33 through 42 of the IRC and the mechanical (panel) installation requirements are covered in IRC Chapter 14, Sections M1406.3 through M1406.6.

If you're installing heating panels on wood framing, they must be:

- Installed parallel to framing members;
- Mounted between the members or secured to their surface;
- Nailed or stapled through the unheated parts of the panel no closer than ½ inch from the heating element;
- Installed as complete units — unless listed for field cutting.

If you're installing heating panels in concrete or masonry, they must be:

- Identified as being suitable for this type of installation;
- Installed according to the manufacturer's instructions;
- Installed where they don't bridge expansion joints, unless protected for this installation location.

If you're installing heating panels on gypsum assemblies, the operating temperature can't exceed 125 degrees F.

You must install finish surfaces over heating panels according to the manufacturer's instructions. If you use nails or other fasteners, make sure they don't pierce the radiant heating elements.

Duct Heaters

Electric duct heaters are self-contained heating units. They're designed to be installed in standard air handling systems. Some duct heaters are stand-alone units. Others are designed to be integral parts of other equipment. And still others are designed for direct attachment to equipment like air conditioners, heat pumps or blowers.

Most duct heaters are designed with electrical resistance elements. They're arranged to efficiently transfer heat to the air stream. The electrical installation requirements for electrical duct heating systems are covered in Chapters 33 through 42 of the IRC. All other installation requirements are covered in IRC Sections M1407.2 through M1407.5.

The heating elements of electric duct heaters work at very high temperatures, which can create a fire hazard. That's why proper installation is so critical. The heater must be equipped with an interlock system that prevents heater operation if the fan isn't working. Insulation close to the heater must be classified for the maximum temperature produced at the duct surface.

Duct heaters shouldn't be attached to ducts within 4 feet of an air conditioner or heat pump. An exception can be made if approved by the manufacturers of both the duct heater and the air conditioner or heat pump. Duct heaters will eventually need to be serviced or repaired, so install them where they're easily accessible.

Vented Floor Furnaces

Vented floor furnaces are installed under the floor of a room or hallway and covered with a vent. They're an economical way to heat individual rooms or small houses. I once lived in a 1,200-square-foot house in Southern California

where the only heat came from a single-vented floor heater in the hallway between the living room and bedrooms. It worked fine for that small living area. The only bad thing was that the vent grill got very hot. Vented floor furnaces are usually gas-fired and lit by a piezo ignition system. No matches or gas pilots are needed, and they usually have low-voltage control systems. That means they can continue operating even if there's a power failure.

Vented floor furnaces must conform to UL 729 and be installed according to the manufacturer's instructions. The location of vented floor furnaces is very important and is covered in IRC Section M1408.3.

Vented floor furnaces must be located:

- With both floor and wall registers at least 6 inches from the wall;
- With furnace registers at least 12 inches from doors in any position, draperies, or anything combustible, and at least 5 feet below combustible material.

Vented floor furnaces must *not* be located:

- So the burner assembly sticks out into any occupied under-floor space;
- In concrete floor construction built on grade;
- Where a door can swing open within 12 inches of the grill opening.

These restrictions for location of floor furnaces are mostly to prevent a fire. But service access is also important. Provide at least an 18- by 24-inch service access opening in the foundation, or a trap door at least 22 by 30 inches; see Section M1408.4.

The installation requirements for a vented floor furnace are given in Section M1408.5. A floor furnace thermostat must be in the same room as the floor furnace register. Floor furnaces must be:

- Supported separately from the floor furnace register;
- Installed at least 6 inches above the ground, or 2 inches if the lower 6 inches of the furnace is sealed to prevent water entry;
- Installed so they're not supported from the ground.

If excavation is needed for floor furnace installation, excavate at least 30 inches from the control side of the furnace and 12 inches from the other sides. The floor of the excavated hole must slope away from the furnace at a shallow angle of less than 45 degrees. This will keep water flowing away from the unit.

Vented Wall Furnaces

Vented wall furnaces are similar to vented floor furnaces, but they're mounted in the wall between studs. These furnaces are usually 5 feet to 6 feet tall. The air can be circulated by convection or with an installed blower. They usually heat only one room. But some models are designed to heat two adjoining rooms.

Most vented wall furnaces are gas fired and lit by a piezo ignition system. Some have a continuously burning pilot. Vented wall furnaces must conform to UL 730 and be installed according to the manufacturer's instructions. Again, location, installation and access are the main concerns of the code. See IRC Sections M1409.2, M1409.3 and M1409.4.

Vented wall furnaces must *not* be located:

- Where they would cause a fire hazard to adjacent walls, floors, doors or furnishing;
- Where they will circulate air from bathrooms to adjoining rooms;
- Where a door can swing open to within 12 inches of the furnace air inlet or outlet. (Doorstops must not be used to prevent doors from swinging, since they can always be removed, causing a fire hazard.)

If you're planning to install a vented wall furnace, make sure the wall is thick enough to meet the manufacturer's installation requirements. You can't attach ducts to a wall furnace. You *can* install casing extensions or boots if they're listed as part of the appliance. Install a manual emergency shut-off valve ahead of all the appliance controls.

Provide access for cleaning heated surfaces, removing burners and replacing broken parts. The manufacturer usually makes the front panel removable so these repairs can be made easily by a service technician.

Vented Room Heaters

Vented room heaters are free-standing units that are fixed in place. They're gas fired and have a vent pipe for exhaust. The vent pipe is either visible or installed inside the wall behind the unit. Some units have a flame feature to create a natural, log-fire look. Others come with blowers to increase hot air circulation. They're most often used as single-room heaters.

Vented room heaters must conform to UL 1482 or UL 896, and be installed according to the manufacturer's specifications. Floor mounting requirements are the main focus of the code, details of which are found in IRC Section M1410.2. Vented floor heaters must be mounted on a noncombustible floor material extending out at least 18 inches from all sides of the unit. As an alternative, you can use an approved floor protector. Some heaters are listed for installation without needing an approved floor protector.

Fireplace Stoves

Fireplace stoves (also called *fireplace inserts*) fit into the existing fireplace and use the chimney for the venting pipe. They're generally gas fired, with the usual ignition and control features, and are used as single-room heaters. They can also have a natural log-fire feature. Fireplace stoves must conform to UL 737 and be installed according to the manufacturer's instructions. Hearth extension requirements are the primary topics of the code; see IRC Section M1414.2. The supporting structures for the fireplace stove and the hearth extension must be at the same level. But the point where the hearth extension ends and the floor area around it begins must be visible.

You can get fireplace inserts that burn hardwood pellets. There are also high-efficiency wood-burning appliances, but they're not approved in all jurisdictions. Check with your local authorities before you choose your unit.

Masonry Heaters

Masonry heaters have many names, including:

- Masonry stoves
- Russian stoves
- Russian heaters
- Russian fireplaces
- German tiled stoves
- Finnish masonry stoves
- Finnish contra-flow fireplaces

They all have one thing in common — they're large masonry structures that provide a focal point for a great room or open-style residence. Masonry heaters are covered in IRC Chapter 10, Chimneys and Fireplaces. Masonry heaters must comply with ASTM E 1602 or UL 1482 and be installed according to the manufacturer's instructions.

There are requirements for footings and clearances, but the bulk of the code information concerns seismic reinforcement; see IRC Section R1002.4. A masonry heater must be anchored to the masonry foundations in Seismic Design Categories D_0, D_1, and D_2. You must also provide seismic reinforcing if the height of the heater is more than 3½ times its width, and if the masonry chimney that serves the heater is supported by the heater.

If the masonry chimney and the heater facing share a common wall, the chimney must be reinforced according to Section R1003.

The firebox floor of a masonry heater must be made of noncombustible material, at least 4 inches thick, and be supported on a noncombustible footing. There shouldn't be any combustible material within 36 inches of the outside surface of the heater. The space around a masonry heater must be fully vented to allow the free flow of air around all heater surfaces.

Venting Appliances

Appliance venting is covered in IRC Chapter 24, Fuel Gas, Sections G2426 through G2452. In these sections you find information on:

- Gas-fired room heating appliances
- Clothes dryers
- Cooking appliances
- Water heaters

IRC Chapter 15, Exhaust Systems, covers exhaust vents for:

- Clothes dryers
- Range hoods
- Open-top broiler units
- Toilet rooms and bathrooms

First, let's look at venting gas-fired heating equipment. Venting is extremely important for all gas-fired appliances. Even though natural gas isn't toxic in itself, it can replace all the oxygen in a room, which can rapidly lead to suffocation and death. Did you know that incomplete burning of any fuel gas can produce carbon monoxide? When you breathe in carbon monoxide, it replaces the oxygen in your blood and can result in carbon monoxide poisoning. Carbon monoxide is invisible and has no smell. Without warning, you quietly go to sleep and never wake up. Correct installation and maintenance of gas-burning equipment is critical to ensure complete burning of the fuel gas. That's why approved venting is essential. It's also a good idea to install CO detectors anywhere they might be needed, especially near sleeping rooms.

If you follow the manufacturer's installation instructions for gas-burning equipment, you'll eliminate most risks. Two excerpts from IRC Chapter 24 are useful. They're in Section G2404, under General Definitions:

> ***Vent.*** *A pipe or other conduit composed of factory-made components, containing a passageway for conveying combustion products and air to the atmosphere, listed and labeled for use with a specific type or class of appliance.*
>
> > ***Special gas vent.*** *A vent listed and labeled for use with listed Category II, III and IV gas appliances.*
> >
> > ***Type B vent.*** *A vent listed and labeled for use with appliances with draft hoods and other Category I appliances that are listed for use with Type B vents.*
> >
> > ***Type BW vent.*** *A vent listed and labeled for use with wall furnaces.*
> >
> > ***Type L vent.*** *A vent listed and labeled for use with appliances that are listed for use with Type L or Type B vents.*
>
> ***Vented Gas Appliance Categories.*** *Appliances that are categorized for the purpose of vent selection are classified into the following four categories:*
>
> > ***Category I.*** *An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.*
> >
> > ***Category II.*** *An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that is capable of causing excessive condensate production in the vent.*
> >
> > ***Category III.*** *An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.*
> >
> > ***Category IV.*** *An appliance that operates with a positive vent static pressure and with a vent gas temperature that is capable of causing excessive condensate production in the vent.*

Notice the UL requirements for the different types of vents and appliances in IRC Section G2426.1. All vents, except for single-wall metal pipe vents, which are covered in Sections G2427.7.1 through G2427.7.12, must be UL-listed as follows:

- Type B and BW vents must be tested to UL 441
- Type L vents must be tested to UL 641
- Vents for Category II and III appliances must be tested to UL 1738

Plastic vents for Category IV appliances don't have to be UL-listed if they're installed as specified by the appliance manufacturer.

There's extensive detail in the code on insulating, sizing, type and installation of vents.

IRC TABLE G2427.4 TYPE OF VENTING SYSTEM TO BE USED	
APPLIANCES	TYPE OF VENTING SYSTEM
Listed Category I appliances Listed appliances equipped with draft hood Appliances listed for use with Type B gas vent	Type B gas vent (Section G2427.6) Chimney (Section G2427.5) Single-wall metal pipe (Section G2427.7) Listed chimney lining system for gas venting (Section G2427.5.2) Special gas vent listed for these appliances (Section G2427.4.2)
Listed vented wall furnaces	Type B-W gas vent (Sections G2427.6, G2436)
Category II appliances	As specified or furnished by manufacturers of listed appliances (Sections G2427.4.1, G2427.4.2)
Category III appliances	As specified or furnished by manufacturers of listed appliances (Sections G2427.4.1, G2427.4.2)
Category IV appliances	As specified or furnished by manufacturers of listed appliances (Sections G2427.4.1, G2427.4.2)
Unlisted appliances	Chimney (Section G2427.5)
Decorative appliances in vented fireplaces	Chimney
Direct-vent appliances	See Section G2427.2.1
Appliances with integral vent	See Section G2427.2.2

Figure 19-1 Type of venting system to be used

I'll emphasize just a few points. To understand all the requirements, make sure you read IRC Sections G2426 through G2452 carefully.

Vent Insulation

Vents from heating equipment get very hot, so it's important to insulate the vents from combustible materials; see Section G2426.4.

Where vents pass through insulated assemblies you must:

- Install an insulation shield made from at least 26-gauge sheet metal;
- Provide clearance to any combustible material to meet the manufacturer's installation instructions.

Where vents pass through attic space you must:

- Terminate the insulation shield at least 2 inches above any insulation material;
- Secure the insulation shield to prevent any accidental movement.

Vent Type Selection

The type of venting system to be used with an appliance is specified in IRC Section G2427.4 and Table G2327.4 (Figure 19-1).

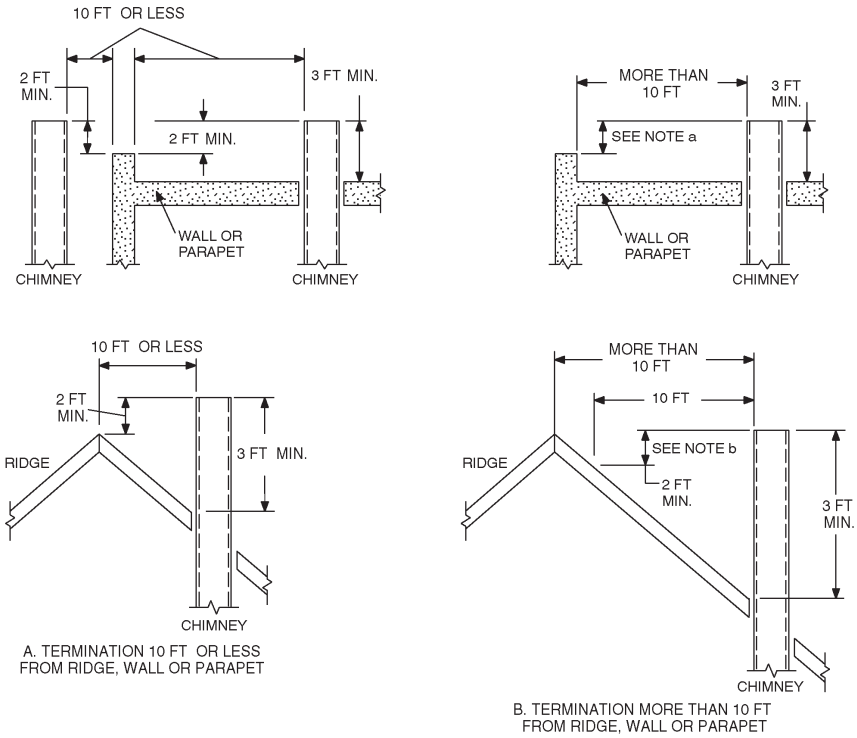
Vent Termination

The termination of chimneys, single-wall metal vent pipes and gas vents is covered in IRC Section G2427.5.3 and Figure G2427.5.3 (Figure 19-2), and Section 2427.6.4 and Figure G2427.6.4 (Figure 19-3).

The code requires that chimneys and single-wall metal vent pipes extend:

- At least 3 feet above the highest point where a chimney passes through the roof;
- At least 2 feet higher than any part of the building within 10 feet horizontally;
- At least 5 feet above the highest connected draft hood outlet or flue collar.

IRC FIGURE G2427.5.3
TYPICAL TERMINATION LOCATIONS FOR CHIMNEYS AND SINGLE-WALL METAL PIPES



For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.
NOTES:
a. No height above parapet required when distance from walls or parapet is more than 10 feet.
b. Height above any roof surface within 10 feet horizontally.

Figure 19-2 Termination points for chimneys and metal pipes

The type of termination for gas vents depends on their size and location.

- Gas vents 12 inches or less in diameter and located at least 8 feet from a vertical wall must terminate above the roof, as shown in IRC Figure G2427.6.4 (Figure 19-3).
- Gas vents more than 12 inches in diameter or located within 8 feet of a vertical wall must terminate at least 2 feet above the highest point where they pass through the roof. And they must terminate at least 2 feet higher than any part of the building within 10 feet horizontally.

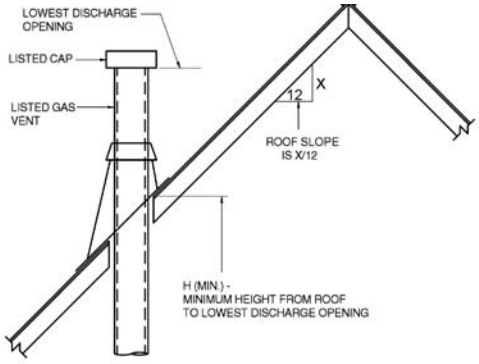
Factory-built chimneys or gas vents can't be terminated with decorative shrouds. There's an exception if the shroud is listed for use with the chimney or gas venting system being put in, and it's installed according to the manufacturer's instructions.

There's also a minimum height requirement for Type B, L or B-W gas vents; see Section G2427.6.5.

- Type B or L gas vents must terminate at least 5 feet above the highest connected draft hood or flue collar.
- Type B-W gas vents must terminate at least 12 feet above the bottom of the wall furnace.

All Type B and L vents should be installed near vertical. You're allowed to have one offset up to 60 degrees, but any additional offsets must be less than 45 degrees. Support all

IRC FIGURE G2427.6.4
GAS VENT TERMINATION LOCATIONS FOR LISTED CAPS 12 INCHES OR LESS IN SIZE AT LEAST 8 FEET FROM A VERTICAL WALL



ROOF SLOPE	H (minimum) ft
Flat to $^{6}/_{12}$	1.0
Over $^{6}/_{12}$ to $^{7}/_{12}$	1.25
Over $^{7}/_{12}$ to $^{8}/_{12}$	1.5
Over $^{8}/_{12}$ to $^{9}/_{12}$	2.0
Over $^{9}/_{12}$ to $^{10}/_{12}$	2.5
Over $^{10}/_{12}$ to $^{11}/_{12}$	3.25
Over $^{11}/_{12}$ to $^{12}/_{12}$	4.0
Over $^{12}/_{12}$ to $^{14}/_{12}$	5.0
Over $^{14}/_{12}$ to $^{16}/_{12}$	6.0
Over $^{16}/_{12}$ to $^{18}/_{12}$	7.0
Over $^{18}/_{12}$ to $^{20}/_{12}$	7.5
Over $^{20}/_{12}$ to $^{21}/_{12}$	8.0

For SI: 1 foot = 304.8 mm.

Figure 19-3 Gas vent termination locations

offset vents. An angle that exceeds 45 degrees is considered a horizontal run. The total length of horizontal run, including the vent connector, can't exceed 75 percent of the vertical height of the vent. Never put manually-operated dampers in the vent connector for any equipment; see Section G2427.13. However, listed automatically-operated dampers are acceptable; see Section G2427.14. Make sure all unused openings in vents are sealed.

Individual venting systems are covered in specific sections:

- Direct-vent systems; see Section G2427.2.1
- Appliances with integral vents; see Section G2427.2.2
- Mechanical draft systems; see Section G2427.3.3

The sizing of vents is a science that can take years to master. But there are tables in IRC Section G2428 to help you.

Wall Furnace Venting

Vented wall furnaces are covered by IRC Section G2436. They must:

- Be vented as required in Section G2427.
- Be installed so that they don't cause a fire hazard to walls, floors, combustible furnishings or doors.
- Not circulate air from bathrooms to other parts of the building when installed between bathrooms and adjoining rooms.

- Be located so that a door can't swing within 12 inches of the furnace air inlet or outlet. A door stop can't be used to ensure this, because a door stop can be removed.
- Not have ducts attached. Casing extension boots mustn't be used unless listed as part of the appliance.
- Be accessible for the cleaning of heating surfaces, the removal and replacements of burners and other components, and other maintenance as required.
- Be installed so that panels, grilles and access doors that need to be removed for servicing aren't attached to the building construction.

Vents for wall furnaces are usually placed inside the wall cavity. Here are some general guidelines for installing wall furnace venting.

- Attach Type BW gas vents to a solid header plate designed for the furnace you're installing. Use the base plate furnished with the equipment.
- The stud space where you're installing the Type BW vent should be free of obstructions, except required fire-stop spacers in multistory buildings. All ceiling and floor plates should be cut flush.
- The vent clearance provided by the base plate, ceiling spacer straps and fire-stop spacers should be maintained after all wall coverings are in place. If the wall covering is perforated lath, metal lath or building paper, install a sheet metal barrier between the vent and the wall covering.
- If the vent is listed only for single-story use, don't use it in a multistory building except on the top floor. A multistory vent can go in either single or multistory structures.
- The stud space in a single-story building or the top floor of a multistory building should be open to an attic space or a ventilated roof flashing equipped with a storm collar. Instead of a ventilated roof flashing, you can vent the stud space with an opening into the room heated by the wall heater. The opening should be within 12 inches of the top of the space.
- If you're installing a vented recessed wall furnace in a stud space, ventilate it at the first ceiling plate above the furnace with the ceiling plate spacer furnished with the vent. Use the fire-stop space at each floor or ceiling.
- Install a suitable metal guard at the floor line of each floor to assure required clearance from combustible material.
- When a Type BW gas vent is installed in an existing building, remove the wall covering on one side of the vent so it's open for installation and inspection.
- Type BW gas vents should extend from the header plate of the vented wall furnace to the highest ceiling plate through which the vent passes, including any offsets or crossovers. From that point, you can complete the vent with a Type B gas vent.

Venting Other Gas Appliances

You can find detailed IRC requirements for venting other appliances in the following sections:

- Vented Gas Fireplaces, Section G2434
- Vented Gas Fireplace Heaters, Section G2435
- Floor Furnaces, Section G2437
- Clothes Dryers, Sections G2438 and G2439
- Sauna Heaters, Section G2440
- Pool and Spa Heaters, Section G2441
- Forced-Air Warm-Air Furnaces, Section G2442
- Conversion Burners, Section G2443

- Unit Heaters, Section G2444
- Unvented Room Heaters, Section G2445
- Vented Room Heaters, Section G2446
- Cooking Appliances, Section G2447
- Water Heaters, Section G2448
- Air Conditioners, Section G2449
- Illuminating Appliances, Section G2450
- Infrared Radiant Heaters, Section G2451
- Boilers, Section G2452

Follow the manufacturer's instructions for all appliances, controls, vents and accessories. As a builder, I know that there are times when the job will go a whole lot easier if you cut a corner or two. And it's tempting, especially when you're under the gun and when there's a cost-saving for you. But as a building inspector, I also know that inspectors look long and hard at appliance installations. A nonapproved cut-rate job can end up costing you a bundle.

Other Exhaust Systems

Before we leave this topic, here are the other exhaust systems that are covered in the IRC. You'll find them in Chapter 15, in the following sections:

- Clothes Dryer Exhausts, Section M1502
- Range Hoods Section, M1503
- Microwave Ovens, Section M1504
- Overhead Exhaust Hoods, Section M1505
- Exhaust Ducts, Section M1506
- Mechanical Ventilation, Section M1507

There are a few items worthy of special notice in those sections which we'll look at more closely now.

Clothes Dryer Exhausts

The length of a clothes dryer exhaust can't exceed 25 feet, excluding the transition duct. Reduce the maximum exhaust length by 2½ feet for every 45-degree bend and 5 feet for every 90-degree bend, unless you use large radius bends. Then you can calculate the correct length using the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Fundamentals Handbook. There's an exception to the 25-foot limitation if the manufacturer's spec on the dryer allows a longer exhaust; see Section M1502.6.

IRC TABLE M1507.3 MINIMUM REQUIRED EXHAUST RATES FOR ONE- AND TWO-FAMILY DWELLINGS	
AREA TO BE VENTILATED	VENTILATION RATES
Kitchens	100 cfm intermittent or 25 cfm continuous
Bathrooms—Toilet Rooms	Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous

For SI: 1 cubic foot per minute = 0.0004719 m^3/s.

Figure 19-4 Minimum exhaust rates for one- and two-family dwellings

Range Hood Exhausts

Range hood exhaust rates are covered by Section M1503.3, and Table M1507.3 (Figure 19-4).

Bathroom Exhausts

Exhaust air from bathrooms and toilet rooms must go directly outdoors. These exhaust systems may not be recirculated inside the residence or be vented:

- to an attic or crawlspace
- to anywhere else inside the residence
- to another dwelling unit

See Section M1506.2 for details.

Cooling Systems

Today, most new homes in the U.S. are constructed with built-in cooling (air conditioning) systems. Although some coastal communi-

ties in the West don't need air conditioning, most new homes have the systems anyway.

There are two conventional cooling methods. If you live in the dry Southwest, you might be comfortable with an evaporative cooler — sometimes called a *swamp cooler*. In more humid climates, evaporative coolers are useless, and you need a refrigeration cooler.

There's also a third, less-common type of cooling system — absorption cooling. It's based on 150-year-old technology that uses heat as the driving force for the cooling cycle instead of an electric motor-driven compressor. This isn't as efficient as electric-powered systems, but it may have a cost-saving advantage. It uses natural gas, which can be relatively inexpensive in the summer months. Because of the high cost of electricity, this method is gaining in popularity. It's widely-used in the Japanese commercial air-conditioning market. In the U.S., it's more commonly used in large commercial installations than in home cooling systems. For information, go to the U.S. Department of Energy website, www.eere.energy.gov. Enter *absorption cooling* in the search box.

The IRC discusses all three types of cooling systems.

Refrigeration Cooling Equipment

Refrigeration cooling is usually done with cooling coils on the downstream side of the forced-air home heating system. These coils may contain the refrigerant itself, but that's uncommon. Normally, the cooling agent is cooled by the compressor unit on the outside of the residence, and piped into the cooling coils above the furnace. Air is then blown over the coils, cooled, and transported to the rooms where it's needed. This is done through a system of insulated ducts. In humid climates, there can be a serious moisture problem. When warm, humid air passes over the cooling coils, moisture condenses on the coils. This moisture must be collected and automatically piped out of the system to a drain, or to the outside of the property.

The code requirements for refrigeration cooling are in IRC Section M1411. Residential systems, where the refrigeration coils are installed in the ventilation supply for a warm-air furnace, are covered in Section M1411.2. Here are a few of the code requirements:

- The cooling coils must be located downstream from the heat exchanger, unless the manufacturer specifies otherwise.
- The furnace blower must be rated for not less than ½-inch water column static pressure.
- If you're adding cooling coils to an existing furnace, the cooling coils must operate within the temperature rise specified for the furnace.

The installation of an air conditioning system isn't covered by the code. An HVAC engineer simply follows the manufacturer's installation instructions.

Condensate

A main concern of the code is cooling coil condensate. Condensate can get you into a lot of trouble. In humid climates, or any climate, you've got to get rid of it — quickly, effectively and legally. Moisture buildup can cause major structural damage. You also want to prevent mold from getting a foothold. It not only destroys property, but it can be toxic to people and pets. And finally, moisture does serious damage to electronics. Water and electronics don't mix, as you may have found out for yourself at one time or another.

If your heat exchanger is above lot grade, condensate disposal is much easier than if it's in a basement. To handle condensate in a basement without a floor drain, you may be able to locate the underfloor sewer and connect with that, or you can install a condensate sump and pump the condensate to an approved location.

Many cities require a floor drain or floor sink whenever plumbing fixtures are installed below grade. Some plumbers resisted this requirement at first — but it didn't take them long to see the benefit. Think about it. Every clothes washer, water heater, and toilet is going to fail someday. And when that happens, the first thing you have to do is get rid of the water. It's no picnic to replace an appliance if you have to start by bailing water out through the basement window.

Let's look at what the code requires. First, IRC Section M1411.3 says you must install a condensate disposal system. The code is very specific about where you dispose of the condensate — it has to be conveyed *to an approved place of disposal*. It can't be conveyed *into a street, alley or other areas where it would cause a nuisance.*

Where is *an approved place of disposal*? The code doesn't tell you specifically, but a drain is an obvious place. Wherever you decide to convey it, just be sure your disposal location is approved. Check with your local building official if you're unsure.

The code also requires that a secondary drain system be installed if damage could occur in the event the primary disposal system fails. All equipment will eventually fail, even if it's serviced regularly, so this is a practical requirement. Backup condensate disposal systems are covered in Section M1411.3.1. They suggest several approved secondary drain options that you can install, including:

1. An auxiliary drain pan under the cooling coils with a separate drain. The drain pan must be at least 3 inches deep, 3 inches wider and longer than the coils, and made of a noncorrosive material. The pipe work from the pan must be an approved material, with at least a ¾-inch internal diameter (see Section M1411.3.2) and maintain at least a 1-percent slope away from the pan. It has to discharge to a conspicuous place where the occupants will immediately recognize that there's been a stoppage in the primary condensate disposal.
2. An auxiliary drain line to the primary drain pan, connected at a higher point than the primary drain line, and discharging to a conspicuous place as in number 1 above.
3. A water-level detector in the primary drain pan, the primary drain line or the overflow drain line. This detector will shut the unit down if the primary drain is blocked.
4. An auxiliary drain pan, as in number 1 above, under the cooling coils with a water-level detector that will shut the unit off prior to overflow.

The problem with the last two options is that, because you can't see that the condensate pan isn't draining, the air conditioning unit stops working for no apparent reason. This can result in an expensive and maybe unnecessary service call. An easily-seen indicator light that signals when the water-level detector has activated can solve this problem.

Refrigerant Line Insulation

Refrigerant lines must be covered with insulation having a specified thermal resistance and external surface permeance tested to the ASTM E 96 standard; see IRC Section M1411.5. You don't have to worry about the actual figures if the insulation installed meets the listed standard.

Access

Make sure there's plenty of access space for servicing and inspecting the heat exchanger; usually a space of about 36 inches wide by 80 inches high is acceptable. If the unit is in an attic, you can reduce the servicing and inspecting space to 20 inches by 30 inches minimum clear space, but no smaller than is needed to remove the largest piece of equipment.

If the heat exchanger is under the floor or in an attic, you need a light source and an electrical outlet close to the equipment. If the building lighting is adequate, you don't have to install a separate light.

All filters, fuel valves and air handlers must have clear access space. If the access is right next to the equipment, the space must measure at least 22 inches by 30 inches.

A word of warning: Take extra care if your furnace/heat exchanger is located in a garage at floor level. Be sure that any source of combustion is at least 18 inches above the floor and protect the unit from being bumped by cars pulling in to park. If there's no alternative than to place the unit in front of a parking space, put a steel post or a bollard in front of the unit. It's no longer acceptable to use only a curb to block the car's front wheels. If it's possible to drive a car over a curb and into a furnace, eventually someone will do it.

Evaporative Cooling Equipment

Evaporative cooling equipment is covered in IRC Section M1413. Evaporative coolers are most effective in low humidity climates, so their use is limited to specific areas of the country. These systems are commonly used in the dry Southwestern states. Evaporative coolers cool and filter the air. Hot outside air is drawn through a water-moistened filter and then blown through the house. To work effectively, windows and/or doors must be left open to force the moist air from the house.

The code doesn't give much advice on this type of cooler. They must be installed according to the manufacturer's instructions, and be at least 3 inches above the surrounding grade. The most important requirement is that you protect residential drinking water from backflow; see Section M1413.2.

Absorption Cooling Equipment

Finally, absorption cooling equipment is addressed in IRC Section M1412. Absorption cooling equipment produces chilling through the input of heat energy instead of mechanical energy. Because of this, absorption coolers were once quite common in commercial facilities having large boiler plants with excess capacity during the cooling season. Unfortunately, since absorption cooling isn't as efficient as refrigerant cooling, for a while it looked like it was headed for extinction. But new developments in this technology — such as using geothermal and solar water heating systems — are giving absorption coolers a new lease on life.

The code doesn't provide many guidelines for these systems except that installation must be according to the manufacturer's instructions. Like the compressor of a refrigerant cooling system, the absorption cooling unit is usually installed outside. Insulated cooling lines carry liquid to coils installed above the home's furnace. This system also produces condensation, so the same condensate requirements that apply to refrigerant cooling systems also apply here; see Section M1411.3.

IRC TABLE M1601.1.1(1)
CLASSIFICATION OF FACTORY-MADE AIR DUCTS

DUCT CLASS	MAXIMUM FLAME-SPREAD RATING
0	0
1	25

Figure 19-5 Factory-made air ducts

Ducting

Last but not least, you need to know the code requirements for ducting, allowable sources of return air, and the use of outside air. They're covered in IRC Chapter 16. First let's look at ducting.

The code requires that duct system designs comply with Air Conditioning Contractors of America (ACCA) Manual D (or other approved method). To get a copy of this manual, go to www.acca.org. Just click on the box in the upper left-hand corner marked ACCA Online Store.

IRC Sections M1601.1.1 and M1601.1.2 cover aboveground and underground duct systems. Most installations are aboveground, so we'll spend our time on them. Underground systems don't differ significantly from aboveground systems except that metal ducts placed underground or under a concrete slab must be fully encased in 2 inches of concrete, or be of an approved material, and they must be located outside the structural load zone. If you need to know about underground duct systems, check the code for details.

It's important to keep in mind that heating equipment connected to ducts isn't allowed to supply air at a temperature higher than 250 degrees F. This avoids any fire hazard. Here are some other important points:

- Factory-made ducts must be constructed of Class 0 or Class 1 materials. See Table M1601.1.1(1) in Figure 19-5.

IRC TABLE M1601.1.1(2) GAGES OF METAL DUCTS AND PLENUMS USED FOR HEATING OR COOLING				
TYPE OF DUCT	SIZE (inches)	MINIMUM THICKNESS (inch)	EQUIVALENT GALVANIZED SHEET GAGE	APPROXIMATE ALUMINUM B & S GAGE
Round ducts and enclosed rectangular ducts	14 or less over 14	0.013 0.016	30 28	26 24
Exposed rectangular ducts	14 or less over 14	0.016 0.019	28 26	24 22

For SI: 1 inch = 25.4 mm.

Figure 19-6 Gauges of metal ducts and plenums

- Ducts made of fibrous material must conform to either the SMACNA or the NAIMA *Fibrous Glass Duct Construction Standards*. Check the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) website at www.smacna.org or the North American Insulation Manufacturers Association (NAIMA) website at www.naima.org for these articles.
- Metal ducts must meet the minimum thickness requirements of Table M1601.1.1(2), Figure 19-6.
- Duct systems must be constructed of materials with a flame spread index of 200 or less.
- Return air ducts or plenums can be made of gypsum products. But surfaces can't be exposed to condensation, and the input air temperature must not exceed 125 degrees F.
- If cavities between stud walls, or spaces between floor joists are used as air plenums, they must meet specific requirements. Check the code for details.

Ducts must have adequate insulation. That's a vital factor. The materials used for duct insulation must meet the following specific requirements (see Section M1601.2.1 for more details):

- Materials used to cover or line ducts, including any adhesives, must have a flame spread index of 25 or less and a smoke-developed index of 50 or less, when tested to ASTM standards E84 and E2231. They must also meet ASTM standard C411 for flame, glow, smolder or smoke.
- External duct insulation must be legibly marked, at no more than 36-inch intervals, with the manufacturer's name, flame spread and smoke-developed indexes, and the R-value at the installed thickness specified.

In addition, IRC Section M1601.3.4 requires that duct insulation meet the following:

- A vapor retarder must be installed on the outside of cooling duct insulation passing through non-conditioned spaces. This can be 2-mil-thick aluminum foil or other approved material.
- Duct coverings can't pass through a fire-blocked wall, ceiling or floor.
- If ducts are on the outside of the building, they must be protected from the elements.

Other requirements cover:

- Vibration isolators
- Joints and seams
- Support
- Fire blocking
- Duct separation
- Ducts located in garages

- Flood hazard areas
- Under-floor plenums

You'll find the details in Sections M1601.2.2 through M1601.4.

Return Air and Outside Air

Return air must be taken from inside the building; see Section M1602**.** The code allows some dilution with outside air, but it doesn't define how much.

The IRC states, in part, that it's more important for you to know where you *can't* get the return air than where you can; see Section M1602.2. Return air can't be taken from the following areas:

- Where it will pick up bad odors, fumes or flammable vapors;
- Any hazardous or unsanitary location or a refrigeration machinery room;
- A closet, bathroom, toilet room, kitchen, garage, mechanical room, furnace room or other dwelling unit;
- Any dwelling unit, guest room or patient room other than the room where the air originates;
- Any area with a volume less than 25 percent of the entire volume served by the supply air system, unless there are permanent openings to areas that have the required 25 percent volume;
- A room or space that contains fuel-burning equipment, where the room or space is the only source of return air, except for the following situations:
    1. The volume of the room or space is greater than 1 cubic foot per 10 Btu/h of the fuel-burning equipment;
    2. The volume of return air taken from the room or space is about equal to the volume of air discharged back to the room or space;
    3. The return-air inlets aren't within 10 feet of any fuel-burning appliance firebox or draft hood in the same room or space.

If an outside return-air source is used, inlet openings must be protected with screens. The mesh size must be between ¼ inch and ½ inch; see Section M1602.3.

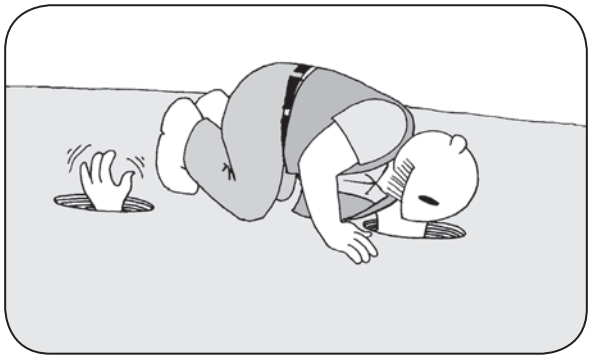
Make-Up Air

We talked about make-up air at the end of the last chapter. Think about all the things that create negative pressure in a house:

- Kitchen exhaust hoods (some are quite powerful)
- Kitchen downdraft ranges (even more powerful)
- Bathroom exhaust fans (often 100 cfm or more)
- Clothes dryers
- Vented gas appliances

That's a lot of air leaving the building. So where does air come into the building? There are several means of venting air into the building. Sometimes a make-up air vent with an atmospheric damper is used. Often a Swedish wall vent is put in each room. If you don't install some kind of a system, you can count on air coming in that you'd like to avoid: like a cold draft from around windows or doors.

Many jurisdictions require fresh air circulation from the outside, and regulate indoor air quality. Even if it's not required, it's an excellent idea. One method uses a duct to the outside, a motorized damper, and a controller that runs one of the fans and opens the damper, on a timer. It brings the outside air into the duct system, directing it through the filter and disperses it to all the rooms in the house. You can also connect the controller to your kitchen exhaust fan for make-up air. I recommend this if your kitchen exhaust fan exceeds 300 cfm. Your HVAC contractor can easily handle this job for you.



The Plugged Sewer

Once in a while something happens on a construction site that you think can't be happening. You've probably got a favorite story of your own. Here's mine.

A developer was building an enclosed shopping mall in Kennewick — one of the first in eastern Washington. As usual, the city ran the utilities to the property line. From there, piping to each unit was the developer's responsibility. The shopping center required hundreds of feet of mainline sewer, feeder lines, and lines to individual shops.

Sewer lines, manholes and cleanouts have to be inspected before they're covered with backfill and compacted. The best way to inspect a sewer is to shine a flashlight straight down the line. If the inspector at one end can see the beam at the other end, the line must be straight, on grade and clear of obstructions.

The work on the lines continued for several months. As each section of line was completed, I checked it carefully. This was a major project and I wanted it to be as good and trouble-free as we could make it. Finally I was able to certify that the line was constructed properly and would flow in the right direction.

Eighteen months later, with the mall nearly ready to open, the main sewer line stopped flowing, not just once, but regularly. Running a Roto-Rooter through the line would get it flowing again — but only temporarily. That shouldn't happen. In fact, it couldn't be happening. The line was perfect. I'd checked every foot of it myself.

After about a month of removing blockages, the superintendent asked me to help him recheck the grade at each manhole. We checked carefully and couldn't find anything wrong with the line pitch. It should have worked perfectly. Still, sewage would not flow through that line.

Completely by accident, a workman noticed a length of 2 x 4 floating in a manhole one afternoon. It was too long to pull out, so he called the foreman, who notified the superintendent, who called me to the job. We cut the 2 x 4 into short lengths to get it out of the line. When the pieces were placed end to end on the sidewalk, we had assembled a 2 x 4, 18 feet long. Solids would gather on the end of the timber and gradually build a dam. Removing the timber solved the blockage problem, but how did that 2 x 4 get into the line?

I'd certified the line as clear. There was no way the timber could have been placed in the line after my inspections. I'm afraid we'll never know the answer to that mystery. But I always double-checked for stray lumber when I inspected sewer lines after that!

When the mall was completed, the developer held an opening ceremony for everyone involved in the construction. To commemorate the city's participation, the superintendent presented me with a piece of the offending 2 x 4. I thanked him and his crew, but had to decline the souvenir. Our office has a strict policy on accepting gifts from contractors — We don't!

CHAPTER 20

Plumbing for Residences

Plumbing is a big topic. We've been discussing plumbing systems as they're incorporated into building plans, but now we're going to discuss the code in reference to general residential requirements.

Several jurisdictions use the IRC and the IBC for building codes only, and have adopted the Uniform Plumbing Code (IAPMO) for plumbing. Make sure you know which code applies on your job. We'll be discussing the IRC in this chapter.

Although the subject of plumbing comes up in several previous chapters, the IRC begins the topic of plumbing with Part VII, Chapter 25, Plumbing Administration. This is where you'll find the minimum code requirements for any plumbing job. The rest of the code information on plumbing installations is spread out over eight chapters — which makes it hard to use the code as a guide for planning your plumbing jobs. I've tried to organize the material here, from job start to job finish, so that it'll be more useful for you. We'll begin with underground utilities and end with fixture installation, covering each task in the order you'd probably follow when installing a plumbing system in a residence. So, without further introduction — let's start with sewers.

Building Sewers

The building drainage system is what's inside the building. It extends 2 feet past the building and hooks to the building sewer. The building sewer runs from that point to either a public or private sewage disposal system.

Any building with plumbing fixtures installed must have a public or private water supply and a public or private sewer, as described in IRC Section P2602.1. And there are more conditions if there's a potential for flooding. Check IRC Table R301.2(1) (refer back to Chapter 1, Figure 1-1) to see if this applies in your area.

IRC TABLE P3002.2 BUILDING SEWER PIPE	
MATERIAL	STANDARD
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 2661; ASTM D 2751; ASTM F 628
Asbestos-cement pipe	ASTM C 428
Cast-iron pipe	ASTM A 74; ASTM A 888; CISPI 301
Coextruded composite ABS DWV schedule 40 IPS pipe (solid)	ASTM F 1488
Coextruded composite ABS DWV schedule 40 IPS pipe (cellular core)	ASTM F 1488
Coextruded composite PVC DWV schedule 40 IPS pipe (solid)	ASTM F 1488
Coextruded composite PVC DWV schedule 40 IPS pipe (cellular core)	ASTM F 1488; ASTM F 891
Coextruded composite PVC IPS-DR-PS DWV, PS140, PS200	ASTM F 1488
Coextruded composite ABS sewer and drain DR-PS in PS35, PS50, PS100, PS140, PS200	ASTM F 1488
Coextruded composite PVC sewer and drain DR-PS in PS35, PS50, PS100, PS140, PS200	ASTM F 1488
Coextruded composite PVC sewer and drain PS 25, PS 50, PS 100 (cellular core)	ASTM F 891
Concrete pipe	ASTM C 14; ASTM C 76; CSA A257.1M; CSA A257.2M
Copper or copper-alloy tubing (Type K or L)	ASTM B 75; ASTM B 88; ASTM B 251
Polyethylene (PE) plastic pipe (SDR-PR)	ASTM F 714
Polyolefin pipe	ASTM F 1412; CSA B181.3
Polyvinyl chloride (PVC) plastic pipe (Type DWV, SDR 26, SRD35, SDR41, PS50 or PS100)	ASTM D 2665; ASTM D 2949; ASTM D 3034; ASTM F 1412; CSA B182.2; CSA B182.4
Stainless steel drainage systems, Types 304 and 316L	ASME A112.3.1
Vitrified clay pipe	ASTM C 425; ASTM C 700

Figure 20-1 Building sewer pipe

Table R301.2(1) is the table of environmental conditions completed by the jurisdiction adopting the code. Section P2602.2 says this about flood-resistant installations:

- The water supply must be designed and built to keep floodwater out.
- The sewage system must be designed and built to keep floodwater out and prevent sewage from getting into the floodwater.

Building Sewer Materials

IRC Table P3002.2 (Figure 20-1) has a list of approved sewer pipe materials.

All plumbing materials must comply with the appropriate standard. And they must be tested or certified by a third-party agency, as required by IRC Section P2608.4 and Table P2608.4 (Figure 20-2). *Third-party certified* is the same as *listed* in previous codes: The manufactured product meets minimum quality standards. *Third-party tested* means that each part has been tested and has passed the test before it gets the tag.

In the past, common drain pipe materials were:

- Cast iron
- Galvanized steel
- Galvanized wrought iron
- Lead
- Copper
- Brass
- ABS-DWV
- PVC-DWV
- Extra-strength vitrified clay pipe
- Other approved materials with a smooth and uniform bore

But things are different now. Galvanized steel can only be used at least 6 inches above ground. Vitrified clay pipe can only be used in

IRC TABLE P2608.4 PRODUCTS AND MATERIALS REQUIRING THIRD-PARTY TESTING AND THIRD-PARTY CERTIFICATION		
PRODUCT OR MATERIAL	THIRD-PARTY CERTIFIED	THIRD-PARTY TESTED
Backflow prevention devices	Required	—
Plumbing appliance	Required	—
Plumbing fixtures	—	Required
Potable water supply system components and potable water fixture fittings	Required	—
Sanitary drainage and vent system components	Plastic pipe, fittings, and pipe related components	All others
Special waste system components	—	Required
Storm drainage system components	Plastic pipe, fittings, and pipe related components	All others
Subsoil drainage system components	—	Required
Waste fixture fittings	Plastic pipe, fittings, and pipe related components	All others
Water distribution system safety devices	Required	—

Figure 20-2 Third-party testing and certification

underground installations. Galvanized wrought iron and lead are no longer on the approved list for building sewer systems. And, copper and brass are typically too expensive to use as sewer pipe material.

Today, ABS or PVC pipes are favored for sewer use. They're lighter, easier, and cheaper to install than vitrified clay pipe, and they can be used in both aboveground and underground installations. ABS or PVC pipes provide good flow because of their smooth finish inside. They don't rot, rust, corrode or collect waste. And, they're strong enough to hold up under earth loads and mechanical damage, even in cold weather. They *will* break if they're torn out of the ground by a backhoe. I know this from experience. But for the money, they're the best you can get.

Estimating Sewer Size

The size of a sewer is based on the number of fixture units in your plumbing system. Notice I said fixture *units*, not just fixtures. Fixture units are based on an estimated amount of water each fixture will use. This is called a *drainage fixture unit* (or d.f.u.). Total the number of drainage fixture units for the fixtures you're planning to install. IRC Table P3004.1 in Figure 20-3 lists common fixtures and the number of units for each one. Fixture groups are at the bottom of the table. If you have a fixture that isn't listed, ask your building official for a d.f.u. value.

The plans examiner may count the drainage fixture units and check your sewer size. The examiner will use IRC Table P3005.4.2 (Figure 20-4) to establish whether or not your building sewer line is big enough to carry the load. For a typical installation, your building sewer line will most likely be well above the threshold required. Of course, you (or the designer) should have already determined this before the examiner sees the plans. The plans examiner's job is to simply confirm your numbers — not figure them out for you.

Let's find the correct sewer size for a typical 2,000-square-foot, 2½-bath house.

Fixture	d.f.u.
Kitchen group (dishwasher and sink with or without garbage disposer):	2
Laundry group:	3
Multiple-bath groups — 2.5 baths:	9
Total:	14

If you can, use the groups in the bottom section of Table P3004.1 (Figure 20-3) to get your d.f.u. values. It's easier than having to list each fixture and its d.f.u. separately. The total d.f.u value for your 2,000-square-foot, 2½-bath house is 14.

Now let's look at Table P3005.4.2 to see what size sewer your house needs. All the numbers in the table are larger than 14. So you say, "I can use the smallest diameter sewer pipe listed

IRC TABLE P3004.11 DRAINAGE FIXTURE UNIT (D.F.U.) VALUES FOR VARIOUS PLUMBING FIXTURES	
TYPE OF FIXTURE OR GROUP OF FIXTURES	DRAINAGE FIXTURE UNIT VALUE (d.f.u.)[a]
Bar sink	1
Bathtub (with or without shower head and/or whirlpool attachments)	2
Bidet	1
Clothes washer standpipe	2
Dishwasher	2
Floor drain[b]	0
Kitchen sink	2
Lavatory	1
Laundry tub	2
Shower stall	2
Water closet (1.6 gallons per flush)	3
Water closet (greater than 1.6 gallons per flush)	4
Full-bath group with bathtub (with 1.6 gallon per flush water closet, and with or without shower head and/or whirlpool attachment on the bathtub or shower stall)	5
Full-bath group with bathtub (water closet greater than 1.6 gallon per flush, and with or without shower head and/or whirlpool attachment on the bathtub or shower stall)	6
Half-bath group (1.6 gallon per flush water closet plus lavatory)	4
Half-bath group (water closet greater than 1.6 gallon per flush plus lavatory)	5
Kitchen group (dishwasher and sink with or without garbage grinder)	2
Laundry group (clothes washer standpipe and laundry tub)	3
Multiple-bath groups[c]:	
1.5 baths	7
2 baths	8
2.5 baths	9
3 baths	10
3.5 baths	11

For SI: 1 gallon = 3.785 L.

a. For a continuous or semicontinuous flow into a drainage system, such as from a pump or similar device, 1.5 fixture units shall be allowed per gpm of flow. For a fixture not listed, use the highest d.f.u. value for a similar listed fixture.

b. A floor drain itself adds no hydraulic load. However, where used as a receptor, the fixture unit value of the fixture discharging into the receptor shall be applicable.

c. Add 2 d.f.u. for each additional full bath.

Figure 20-3 Drainage fixture unit (d.f.u.) values

— 1½ inches." But don't you think that's pretty narrow for a sewer pipe? You're right. Note "b" says *No water closets*. And we know there are multiple toilets in this house. Look at the pipe diameters in the first column that have "b" after them. This tells you that you can't use 1½-, 2- or 2½-inch-diameter pipes. So the smallest pipe you can use for your sewer is 3 inches.

Building Sewer Grade

IRC Section P3005.3 requires that horizontal building sewers run in uniform alignment at a uniform slope to the disposal point. Sewer pipes 3 inches or more in diameter must have at least a 1-percent uniform slope (⅛ inch per foot). Drain pipes less than 3 inches in diameter must have a slope of at least 2 percent (¼ inch per foot).

Why doesn't the code give you a maximum slope? What if the building sewer drops straight down? Is that a problem? Yes, it could be. There are slopes that are too steep, causing liquid to run away from the solids. The solids left behind can build up dams and cause blockages. I recommend using a ¼-inch-per-foot slope across the property to the property line. If the street sewer is lower, drop the line at about a 45-degree angle to the sewer connection. That saves money, since you don't have to dig a deep trench across the property.

IRC TABLE P3005.4.2 MAXIMUM NUMBER OF FIXTURE UNITS ALLOWED TO BE CONNECTED TO THE BUILDING DRAIN, BUILDING DRAIN BRANCHES OR THE BUILDING SEWER			
DIAMETER OF PIPE (inches)	SLOPE PER FOOT		
	$^1/_8$ inch	$^1/_4$ inch	$^1/_2$ inch
$1^1/_2$ [a,b]	—	Note a	Note a
2[b]	—	21	27
$2^1/_2$[b]	—	24	31
3	36	42	50
4	180	216	250

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. $1^1/_2$-inch pipe size limited to a building drain branch serving not more than two waste fixtures, or not more than one waste fixture if serving a pumped discharge fixture or garbage grinder discharge.

b. No water closets.

Figure 20-4 Maximum number of fixture units allowed

What if your street sewer is too shallow for a slope of ¼ inch per foot? The code allows a minimum slope of ⅛ inch per foot. If the street sewer is still too shallow, you'll need to install a sewage pump; see IRC Section P3007.1.

Your sewer line must run at least 2 feet below any building or structure, and 1 foot below the ground surface.

Trenching, Support and Backfilling

The specs for trenching, support and backfilling are given in IRC Sections P2604. If you excavate just enough to form a bed for pipe in the bottom of a trench, you must provide solid and continuous load-bearing support for the pipe joints. If you overexcavate the trench, you need to backfill with compacted earth, sand, fine gravel or another granular material. Never allow pipes to be supported by rocks or blocks at any point. When trenching in rocky or unstable soil, you need to overexcavate, then backfill at least two pipe diameters with material that's suitable to provide good support for the pipe.

After you lay the pipe, backfill the trench with earth. This must be *clean* dirt — not discarded construction material, debris, rocks, broken concrete or frozen chunks. Cover the pipe with at least 12 inches of tamped earth. Place the backfill carefully and evenly, in 6-inch layers, on each side of the pipe, tamping it to keep the correct pipe alignment.

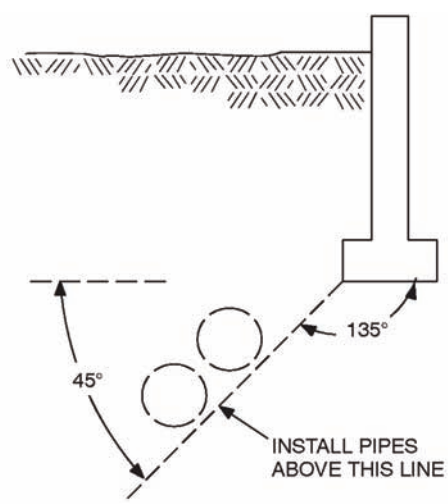
If you plan to install trenching parallel to the footings, there's a special requirement included to protect the building footings. It says that the earth under footings shall not be disturbed below a line drawn at 45 degrees from their bottom edge. See IRC Figure P2604.4 (Figure 20-5).

Dual-Use Trenches

One of the most commons questions I was asked while serving as a building inspector was, "Can I use the same trench for both the water service and the sewer?" The simple answer is yes. The detailed answer is in IRC Section P2904.4.2. If you're going to have a dual-use trench, the sewer pipe must be made of a material approved for underground use inside a building. Section P3002.1 and Table P3002.1(2) (Figure 20-6) list these approved materials.

If the sewer pipe isn't made of one of these listed materials, the water-service pipe and the sewer pipe must be separated by at least 5 feet.

IRC FIGURE P2604.4
PIPE LOCATION WITH RESPECT TO FOOTINGS



For SI: 1 degree = 0.018 rad.

Figure 20-5 Pipe location with respect to footings

IRC TABLE P3002.1(2) UNDERGROUND BUILDING DRAINAGE AND VENT PIPE	
MATERIAL	STANDARD
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 2661; ASTM F 628; CSA B181.1
Asbestos-cement pipe	ASTM C 428
Cast-iron pipe	ASTM A 74; CISPI 301; ASTM A 888
Coextruded composite ABS DWV schedule 40 IPS pipe (solid)	ASTM F 1488
Coextruded composite ABS DWV schedule 40 IPS pipe (cellular core)	ASTM F 1488
Coextruded composite PVC DWV schedule 40 IPS pipe (solid)	ASTM F 1488
Coextruded composite PVC DWV schedule 40 IPS pipe (cellular core)	ASTM F 891; ASTM F 1488
Coextruded composite PVC IPS-DR, PS140, PS200 DWV	ASTM F 1488
Copper or copper alloy tubing (Type K, L, M or DWV)	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 306
Polyolefin pipe	ASTM F 1412; CSA B181.3
Polyvinyl chloride (PVC) plastic pipe (Type DWV)	ASTM D 2665; ASTM D 2949; CSA B181.2
Stainless steel drainage systems, Type 316L	ASME A112.3.1

Figure 20-6 Underground drainage and vent pipe

Or, the water-service pipe can be put on a solid ledge at least 12 inches above and to one side of the sewer pipe. The water-service pipe can cross the sewer pipe at minimal separation if it's sleeved with an approved material for at least 5 feet on either side of the sewer pipe.

Cleanouts

Cleanouts are an integral part of any drainage system. If there's one other thing you can count on besides death and taxes, it's this: drains will get blocked. The code assists you in making it easy to unblock drains by requiring cleanouts at specific points in the line. There are 11 subsections on the subject of cleanouts; see Section P3005.2. We're just going to look at the ones I've found are the most useful.

There should be a cleanout close to the junction of the building drain and the building sewer, but it's not essential if there's a cleanout on a soil stack, 3 inches or larger, within 10 feet of that junction. The cleanout can either be inside or outside the building wall. Bring it up to the finish grade or to the lowest floor level. You can use an approved 2-way cleanout for both the building drain and the building sewer (Section P3005.2.7).

What if your building is a long way from the public sewer? You might have to install several cleanouts, or even a manhole. The code requires a cleanout every 100 feet. The maximum distance between manholes is 300 feet (Section P3005.2.2).

Try to run the sewer in a straight line. If that isn't possible, install a cleanout whenever there's more than a 45-degree change of direction. What if you have more than one change of direction? Install a cleanout every 40 feet, regardless of the number of direction changes (Section P3005.2.4).

Install each cleanout so that it opens in the direction of flow to allow for cleaning (Section P3005.2.8). The size of the cleanouts should be the same size as the pipe they serve, up to 4 inches. For larger pipes, you can still use 4-inch cleanouts (Section P3005.2.9). Check the code for exceptions to these requirements.

Each cleanout must extend vertically to grade level (Section P3005.2.3). Cleanouts must be accessible. The minimum clearance in front of a cleanout is 18 inches on 3-inch and larger pipes, and 12 inches on smaller pipes. Don't cover cleanouts with finish material (Section P3005.2.5).

I don't recommend that cleanouts be installed in a basement unless they're at the base of a vertical stack. Cleanouts in a basement floor can be a serious problem. When they're initially installed, the basement floor hasn't yet been poured. The inspector notes that a

cleanout is installed. Weeks, or months, later, the basement floor is put in. When the house is finally completed, the cleanout can end up under a stairway, covered with carpet, or even covered with concrete.

Backwater Valves

Read this next section carefully, so you're sure you understand it. The code requires a backflow preventer to keep pollutants from being sucked back into the water system if there's a water-pressure failure. You need to know the difference between a backflow preventer and a backwater valve. They aren't the same. Here's the code definition of each.

> ***Backflow preventer:*** *A device or means to prevent backflow.*
>
> ***Backwater valve:*** *A device installed in a drain or pipe to prevent backflow of sewage.*

I strongly suggest a backwater valve for any house with plumbing in the basement. It keeps the basement from filling with sewage if the sewer line gets stopped up. If that isn't enough to convince you to install one, check with your building official. Many areas require them when the job includes a basement.

Here's what IRC Section P3008 says about backwater valves. Install a backwater valve if the plumbing has fixtures with flood level rims below the next upstream manhole cover of the public sewer system. Backwater valves should:

- Be installed close to where the drain leaves the building
- Be accessible
- Have watertight access covers

Backwater valves need noncorrosive bearings, etc. and a positive mechanical seal. They work by allowing sewage to flow downstream past a flapper valve — as long as the main sewer is flowing normally. If there's a stoppage downstream, the flapper valve swings shut. That keeps sewage out of the basement. At least, that's the theory. It usually works pretty well. A backwater valve doesn't cost much. How much? A lot less than the cost of cleaning up sewage backups in the basement!

But what happens to the backwater valve when the pipe clogs and the homeowner calls Roto-Rooter? A powerful drain snake usually rips the valve to shreds. The homeowner won't even know he has a problem until the city sewer stops up and his basement fills with sewage. And his insurance might not cover the loss. Make sure the homeowner knows he needs to have the valve checked immediately after the drains have been cleaned out. There are some newly-designed backwater valves out there. The manufacturers brag that they've solved the problem of valve damage during "snaking." But I'd check the valve anyway, once the drain's been cleaned.

Inspections

Each section of your plumbing must be inspected before being concealed. Sewers are normally tested with water under pressure to be sure the joints don't leak. Here's how to perform the test:

- Plug the building outlet where it connects with the public sewer. You can get special plugs at a plumbing supply store.
- Add a section of vent stack at least 10 feet higher than any part of the system you're testing.
- Fill the vent stack with water and watch for leaks.

The inspector will be satisfied if there's no sign of a leak after 15 minutes (Section P2503.4).

Drain, Waste and Vent (DWV) Systems

The next part of the plumbing installation consists of the drain, waste and vent (DWV) system. Drain and waste systems are covered in IRC Chapter 30, and vents in Chapter 31. We'll just look at the highlights.

IRC TABLE P3002.1(1) ABOVE-GROUND DRAINAGE AND VENT PIPE	
MATERIAL	STANDARD
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D 2661; ASTM F 628; CSA B181.1
Brass pipe	ASTM B 43
Cast-iron pipe	ASTM A 74; CISPI 301; ASTM A 888
Coextruded composite ABS DWV schedule 40 IPS pipe (solid)	ASTM F 1488
Coextruded composite ABS DWV schedule 40 IPS pipe (cellular core)	ASTM F 1488
Coextruded composite PVC DWV schedule 40 IPS pipe (solid)	ASTM F 1488
Coextruded composite PVC DWV schedule 40 IPS pipe (cellular core)	ASTM F 1488; ASTM F 891
Coextruded composite PVC IPS-DR, PS140, PS200 DWV	ASTM F 1488
Copper or copper-alloy pipe	ASTM B 42; ASTM B 302
Copper or copper-alloy tubing (Type K, L, M or DWV)	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 306
Galvanized steel pipe	ASTM A 53
Polyolefin pipe	CSA B181.3
Polyvinyl chloride (PVC) plastic pipe (Type DWV)	ASTM D 2665; ASTM D 2949; CSA B181.2; ASTM F 1488
Stainless steel drainage systems, Types 304 and 316L	ASME A112.3.1

Figure 20-7 Above-ground drainage and vent pipe

IRC Section P3002, Table 3002.1(1) (Figure 20-7), and Table 3002.1(2) (look back to Figure 20-6) cover the materials you can use in the DWV system.

Joints and Connections

It's virtually impossible to build a drainage system without joints — and joints are where you get leaks. So the code spends a lot of time on joints and connections, as you'll see in IRC Section P3003. When you're dealing with pipe joints, it's important to know what types of joints are *not* allowed. You can't use any of the following joints in the drainage system:

- Running threads and bands
- Cement or concrete joints
- Mastic or hot-pour bituminous joints
- Solvent-cement joints between different types of plastic pipe
- Joints between different diameter pipes made with elastomeric rolling O-rings
- Joints made with fittings not approved for the specific application
- Saddle-type fittings

Drainage and vent piping can't be drilled, tapped, burned or welded. Check IRC Sections P3003.3 through P3003.19 for approved joints and their details.

Tightness and testing of DWV joints are covered in Section P3003.1 and P2503.5. Joints must be tight enough to pass water or gas tests, described in Section P2503.5 for rough and for finished plumbing.

The water test is performed in the same manner as the sewer test — 10 feet of water must be held for 15 minutes without any leaks. The gas test is done by pressurizing the rough plumbing with air to 5 psi, and maintaining that pressure for 15 minutes without having to add more air. If the test is successful, the plumbing meets code.

The details on DWV fittings for direction changes are in IRC Section P3005.1 and Table P3005.1, in Figure 20-8. If you use a combination of fittings, heel or side inlets or increasers, read the provisions in Sections P3005.1.1 through 4.

Like sewer systems, DWV systems need cleanouts (Section P3005.2). The requirements are just about the same.

IRC TABLE P3005.1 FITTINGS FOR CHANGE IN DIRECTION			
TYPE OF FITTING PATTERN	CHANGE IN DIRECTION		
	Horizontal to vertical[c]	Vertical to horizontal	Horizontal to horizontal
Sixteenth bend	X	X	X
Eighth bend	X	X	X
Sixth bend	X	X	X
Quarter bend	X	X[a]	X[a]
Short sweep	X	X[a,b]	X[a]
Long sweep	X	X	X
Sanitary tee	X[c]	—	—
Wye	X	X	X
Combination wye and eighth bend	X	X	X

For SI: 1 inch = 25.4 mm.
a. The fittings shall only be permitted for a 2-inch or smaller fixture drain.
b. Three inches and larger.
c. For a limitation on multiple connection fittings, see Section P3005.1.1.

Figure 20-8 Fittings for change in direction

To size your drain and waste system correctly, use Table P3004.1 (Figure 20-3). That's the same table you used to calculate the drainage fixture unit (d.f.u.) values for your sewer system. Except this time, you need to use the individual d.f.u. values from the top of the table.

Count the number of drainage fixture units connecting to each section of the drain and waste system. Then check Section P3005.4.1 and Table P3005.4.1 (Figure 20-9). The total of the d.f.u. values on each section of the drain and waste system determines the size of piping you need to install. So, if you have six or fewer units on a horizontal fixture branch (outlined in Figure 20-9), use a minimum of 2-inch piping. The smallest drain piping you can use is 1½ inches. There is an exception — you can use 1¼-inch piping to drain a single fixture. But remember, just as in sizing sewer systems, note "b" says that the smallest drain for a water closet (toilet) is 3 inches.

The drain stack size must be at least the same as the largest horizontal branch connected to it. The plans examiner may count the number of fixture units and check your proposed branch and stack sizes against Table P3005.4.1 to make sure they're big enough to carry the load.

You'll find the slope for drain branches in the same table you used for the sewer system, IRC Table P3005.4.2 (Figure 20-4).

Vents and Venting

As we said earlier, vents are the subject of IRC Chapter 31. Venting allows your drainage system to breathe so waste can flow freely. Your system will probably drain even if it's not vented — eventually. But the whole system works much better when it's vented. Also, venting prevents the water from siphoning out of the traps and potentially exposing the occupants to sewer gases (methane). You can use vent piping and fittings made of any material approved for the rest of the system. See Table P3002.1(1) in Figure 20-7.

The basic specs are in IRC Sections P3101 and P3102. Every trap or trapped fixture must be vented by an approved method — with no exceptions. The venting system can't be used for any other purpose. And the vent system for each building drain needs at least one vent pipe going directly outdoors, usually through the roof.

What about vent sizing? A vent must be at least half the diameter of the drain it serves, but never less than 1¼ inch (Section P3113). If the *developed length* of a vent is more than 40 feet, increase the vent pipe size by one nominal pipe size; see Section P3113.2 for the definition of developed length. This requirement applies to the entire length of the vent.

IRC TABLE P3005.4.1 MAXIMUM FIXTURE UNITS ALLOWED TO BE CONNECTED TO BRANCHES AND STACKS		
NOMINAL PIPE SIZE (inches)	ANY HORIZONTAL FIXTURE BRANCH	ANY ONE VERTICAL STACK OR DRAIN
$1^1/_4$[a]	—	—
$1^1/_2$[b]	3	4
2[b]	6	10
$2^1/_2$[b]	12	20
3	20	48
4	160	240

For SI: 1 inch = 25.4 mm.
a. $1^1/_4$-inch pipe size limited to a single–fixture drain or trap arm. See Table P3201.7.
b. No water closets.

Figure 20-9 Maximum fixture units allowed

Vent Pipe Grades, Connections and Terminations

Vents keep the waste system at normal air pressure so liquids can drain smoothly. There are many do's and don'ts when it comes to vent construction. You can get all the vent requirement details from IRC Sections P3103 through P3114. Here are just a few of them:

- All vents and branch vent pipes must be graded and supported. If installed correctly, moisture and condensate will drain back into the drainage pipe by gravity. Drops and sags aren't allowed.
- Every vent joining a horizontal drain must connect above the centerline of the horizontal drain pipe.
- Vent connection to a fixture drain, except for toilets and similar fixtures, can't be below the weir of the trap.
- The vent must rise vertically to a point at least 6 inches above the flood level of the highest trap or trapped fixture being served.
- Vents must extend at their full size above the roof or outside of the building.
- Vents have to extend through approved roof flashing. Vents can't be used as flag poles or support for flag poles, TV aerials, etc., unless anchored appropriately.
- Vents can't be located less than 4 feet directly under any openable window, door, air intake, vent shaft or other opening. They can't terminate within 10 feet horizontally of any opening unless they're at least 2 feet above the top of the opening. And they can't end under the overhang of a structure with soffit vents.
- On outdoor installations, vent pipes must end at least 10 feet from the lot line and extend 10 feet above the surrounding ground.
- In high snow-load areas, you'll need to check with the local jurisdiction adopting the code to find out the minimum number of inches above the anticipated snow accumulation that the vents must extend. The number of inches, like the expected snow level, varies among jurisdictions. However, if a roof is used for something other than weather protection, the extension must be at least 7 feet.
- In high-frost areas (where the 97½ percent outside design temperature is 0 degrees F), the above-roof vent size must be at least 3 inches. Any increase in pipe diameter to get this size must be at least 12 inches below the roof, inside the building.

Indirect Waste Pipes

An indirect waste pipe doesn't connect directly to the drainage system. It discharges liquid waste indirectly. First, it passes through the air, then into a plumbing fixture, waste receptor or drain that *is* connected directly to the drainage system.

The condensate drain from an air conditioning system is an example of an indirect waste. The water from the air conditioner may go into an open floor drain in a basement. The advantage of an indirect waste connection is that you don't have to install a vent line. But you do need an air break (gap) between the drain and the flood line of the receptor. This air break keeps drain water out of the plumbing fixture.

IRC Section R202 defines indirect waste pipes, air breaks and air gaps:

> ***Indirect waste pipe:*** *A waste pipe that discharges into the drainage system through an air gap into a trap, fixture or receptor.*
>
> ***Air break, drainage system:*** *An arrangement in which a discharge pipe from a fixture, appliance or device drains indirectly into a receptor below the flood-level rim of the receptor, and above the trap seal.*
>
> ***Air gap, drainage system:*** *The unobstructed vertical distance through free atmosphere between the outlet of a waste pipe and the flood-level rim of the fixture or receptor into which it is discharging.*

Many appliances have an air break device or anti-siphon system. Air breaks and anti-siphon systems prevent used water from being drawn back into the water supply. An anti-siphon device is required on all hose bib connections. Dishwashers have an air break — the small dome-shaped device usually next to the kitchen faucet. Why are the faucets in kitchen sinks, tubs and bathroom sinks installed so high? Because even if the sink or tub is filled to overflowing, there's still space between the top of the water and the faucet opening so water can't siphon back into the faucet. That's an air break.

Receptors

Receptors are covered in IRC Section P2706. Section R202 defines them as follows:

> ***Receptor:*** *A fixture or device that receives the discharge from indirect waste pipes.*

Waste receptors must be:

- Shaped, and have enough capacity, to prevent splashing or flooding
- Readily accessible for inspection and cleaning
- Trapped and vented
- Fitted with a removable strainer or basket
- Installed in ventilated spaces

Do *not* install a waste receptor in a bathroom or a closet.

You can install a standpipe above a waste receptor. You've probably seen this in your laundry room at home. The standpipe provides the receptor outlet for the washing machine water. It has to extend at least 18 inches, but not more than 42 inches, above the trap weir. Remember to leave enough access so you can use a drain snake when needed.

Can you connect a line from the laundry tray to the standpipe? Yes, as long as the standpipe extends at least 30 inches above the crown weir, and the outlet from the tray is 30 inches or less from the standpipe trap.

The output of an indirect waste pipe can't discharge into sinks used for household or cooking purposes. But the code does allow discharge of the output from a dishwasher into the kitchen sink. The kitchen sink trap acts as the waste receptor.

Traps and Interceptors

Traps are covered in IRC Section P3201. Every plumbing fixture, except those with built-in traps, must be separately trapped. Section R202 defines a trap as:

> ***Trap:*** *A fitting, either separate or built into a fixture, that provides a liquid seal to prevent the emission of sewer gases without materially affecting the flow of sewage or waste water through it.*

Traps are usually made of an approved plastic. But the code also allows lead, cast iron and cast or drawn brass. Traps must have a liquid seal of at least 2 inches but not more than 4 inches. Traps for floor drains must be of a deep seal design or be fitted with a trap primer.

The vertical distance from the fixture outlet to the trap weir must not exceed 24 inches. The horizontal distance from the centerline of the fixture outlet to the centerline of the inlet of the trap must not exceed 30 inches. Can you use one trap to serve more than one fixture? Yes. A single trap can serve two or three similar fixtures. But these fixtures must be kitchen sinks, laundry tubs or lavatories next to each other with a continuous waste system. And the fixture outlets can't be more than 30 inches apart. If the trap is serving three fixture outlets, it must be installed on the central fixture outlet.

Every trap must have a vent pipe to prevent siphonage, aspiration and back pressure. The vent assures free air circulation throughout the system. Set trap seals level and protect them from freezing.

What size trap do you need for a particular fixture? The trap size must be at least as large as indicated for each type of plumbing fixture in Table P3201.7 (Figure 20-10). But it can't be larger than the drainage pipe for the fixture.

Water Supply and Distribution

Now let's look at the water supply and distribution system. You wouldn't build a residential property without a supply of drinking water. But are you actually required to by code? Yes, you are. You'll find that requirement in IRC Section P2901. Each dwelling unit must have a

IRC TABLE P3201.7 SIZE OF TRAPS AND TRAP ARMS FOR PLUMBING FIXTURES	
PLUMBING FIXTURE	TRAP SIZE MINIMUM (inches)
Bathtub (with or without shower head and/or whirlpool attachments)	$1^1/_2$
Bidet	$1^1/_4$
Clothes washer standpipe	2
Dishwasher (on separate trap)	$1^1/_2$
Floor drain	2
Kitchen sink (one or two traps, with or without dishwasher and garbage grinder)	$1^1/_2$
Laundry tub (one or more compartments)	$1^1/_2$
Lavatory	$1^1/_4$
Shower (based on the total flow rate through showerheads and bodysprays)	
Flow rate:	
5.7 gpm and less	$1^1/_2$
More than 5.7 gpm up to 12.3 gpm	2
More than 12.3 gpm up to 25.8 gpm	3
More than 25.8 gpm up to 55.6 gpm	4
Water closet	Note a

For SI: 1 inch = 25.4 mm.
a. Consult fixture standards for trap dimensions of specific bowls.

Figure 20-10 Size of traps and trap arms for plumbing fixtures

supply of *potable* water. Potable water is water that's good for drinking, cooking or washing. It must be supplied in the amounts, and at the pressure, set out in IRC Chapter 29.

Water is considered potable if it meets the requirements of the local health authority. IRC Section R202 defines it this way:

> ***Potable water:*** *Water free from impurities present in amounts sufficient to cause disease or harmful physiological effects and conforming in bacteriological and chemical quality to the requirements of the public health authority having jurisdiction.*

You can also install a supply of nonpotable water. But if you do, you must clearly mark each system in the approved manner. If there's any chance that the homeowner might drink from a nonpotable supply — or use it for cooking or cleaning — be sure it's marked. For example, write in black letters against a yellow background: "Nonpotable water. DO NOT DRINK."

Protecting the potable water in the water supply system from contamination is a major concern of the code. Some areas, as just mentioned, have both drinking water (potable) systems, and irrigation water (nonpotable) systems. It's quite common to recycle water for irrigation in Southern California and in desert areas where water is scarce. Irrigation water might be provided only during the growing season. But what if the homeowner needs to irrigate earlier or later than the normal growing season? Can he connect the domestic water supply to his yard sprinklers? In most cases, the answer is a definite *No*.

The code says you can't install or connect potable water supply piping, or any plumbing fixture, if it's possible for any of the following to enter any part of the potable water system:

- Used water
- Unclean water
- Polluted or contaminated water

This is how the IRC puts it:

> ***P2902.1 General.*** *A potable water supply system shall be designed and installed as to prevent contamination from nonpotable liquids, solids or gases being introduced into the potable water supply. Connections shall not be made to a potable water supply in a manner that could contaminate the water supply or provide a cross-connection between the supply and a source of contamination unless an approved backflow-prevention device is provided. Cross-connections between an individual water supply and a potable public water supply shall be prohibited.*

That's pretty clear. However, there are ways that the water supply system can become contaminated. For instance, suppose you did use your potable water system to water the lawn. How could that contaminate the drinking water system? Your hose doesn't carry germs, does it? After all, who hasn't taken a drink from a garden hose? Unfortunately, a garden hose

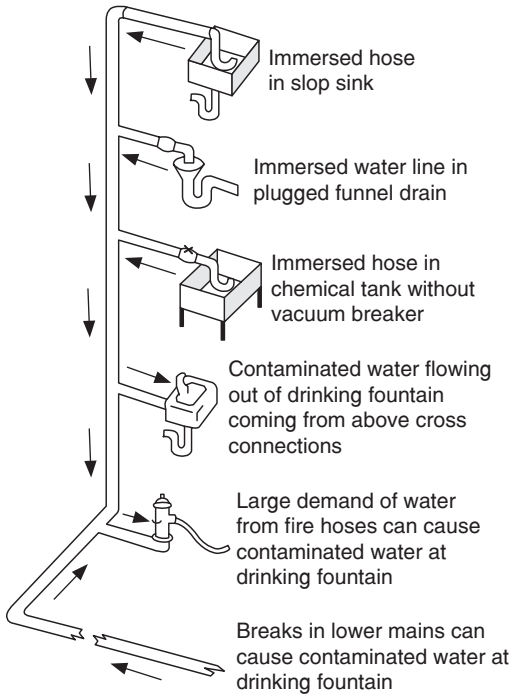


Figure 20-11 How cross-contamination can cause health hazards

sitting in the hot sun can be a veritable breeding ground for biological activity. And, watering isn't the only use for a hose. Sometimes homeowners connect plant food or insecticide sprayers to their hoses.

What if someone crashes his car into a fire hydrant? It happens every day. The main water valve must be closed until repairs are made. There's no pressure anywhere. In fact there may be negative pressure. Open a fixture anywhere and air is sucked back into the pipe. The hose that was just being used to spray a water/insecticide mix on the garden is now sucking insecticide back into itself. And, it could also go all the way back to the water main. Then, when the fire hydrant is fixed, insecticide is going to be delivered to homes all over the neighborhood. Murphy's Law says that anything that *can* happen, will happen — and this has actually happened!

Contamination is a serious issue. The only sure way to avoid this type of contamination is by eliminating cross connections. Figure 20-11 shows several ways that cross connections can create health hazards. In situations where the code *does* allow a cross connection, it also requires an *approved backflow-prevention device*. We'll look at those next.

Backflow Protection

There's now a requirement that all plumbing fixture fittings provide backflow protection meeting ASME standard A112.18.1. Supply lines and fittings for all plumbing fixtures must be installed to prevent backflow. Make sure the plumbing fixture fittings you use meet this standard. Backflow protection of the potable water supply is covered in IRC Section P2902.3 and Table P2902.3, shown in Figure 20-12.

Six different backflow prevention systems are discussed in the IRC:

1. Air gaps, P2902.3.1
2. Atmospheric-type vacuum breakers, P2902.3.2
3. Backflow preventers with intermediate atmospheric vents, P2902.3.3
4. Pressure-type vacuum breakers, P2902.3.4
5. Reduced pressure principle backflow preventers, P2902.3.5
6. Double check valve assemblies, P2902.3.6

We're only going to discuss air gaps. You can get details on other types of backflow prevention from the code if you need them.

An air gap must be at least twice the diameter of the outlet opening, but never less than the sizes specified in Table P2902.3.1 (Figure 20-13). The air gap length is measured vertically from the lowest end of a water supply outlet to the flood level rim of the fixture or receptor that the potable water outlet discharges into. Install an air gap at the discharge point of a relief valve or piping. Manufacturers must design air gaps into their dishwashing and clothes washing appliances.

The protection of potable water outlets and potable water connections are also covered in Section 2902. These include connections to:

- Boilers, Section P2902.5.1
- Heat exchangers, Section P2902.5.2

IRC TABLE P2902.3
APPLICATION FOR BACKFLOW PREVENTERS

DEVICE	DEGREE OF HAZARD[a]	APPLICATION[b]	APPLICABLE STANDARDS
Air gap	High or low hazard	Backsiphonage or backpressure	ASME A112.1.2
Air gap fittings for use with plumbing fixtures, appliances and appurtenances	High or low hazard	Backsiphonage or backpressure	ASME A112.1.3
Antisiphon-type fill valves for gravity water closet flush tanks	High hazard	Backsiphonage only	ASSE 1002 CSA CAN/CSA B125
Backflow preventer with intermediate atmospheric vents	Low hazard	Backpressure or backsiphonage Sizes $^1/_4$″ – $^3/_4$″	ASSE 1012 CSA B64.3
Double check backflow prevention assembly and double check fire protection backflow prevention assembly	Low hazard	Backpressure or backsiphonage Sizes $^3/_8$″ – 16″	ASSE 1015, AWWA C510 CSA B64.5, CSA B64.5.1
Double check detector fire protection backflow prevention assemblies	Low hazard	Backpressure or backsiphonage (Fire sprinkler systems) Sizes 2″ – 16″	ASSE 1048
Dual-check-valve-type backflow preventer	Low hazard	Backpressure or backsiphonage Sizes $^1/_4$″ – 1″	ASSE 1024, CSA B64.6
Hose connection backflow preventer	High or low hazard	Low head backpressure, rated working pressure backpressure or backsiphonage, Sizes $^1/_2$″ – 1″	ASSE 1052, CSA B64.2.1.1
Hose-connection vacuum breaker	High or low hazard	Low head backpressure or backsiphonage Sizes $^1/_2$″, $^3/_4$″, 1″	ASSE 1011, CSA B64.2, CSA B64.2.1
Laboratory faucet backflow preventer	High or low hazard	Low head backpressure and backsiphonage	ASSE 1035, CSA B64.7
Pipe-applied atmospheric-type vacuum breaker	High or low hazard	Backsiphonage only Sizes $^1/_4$″ – 4″	ASSE 1001 CSA B64.1.1
Pressure vacuum breaker assembly	High or low hazard	Backsiphonage only Sizes $^1/_2$″ – 2″	ASSE 1020, CSA B64.1.2
Reduced pressure detector fire protection backflow prevention assemblies	High or low hazard	Backsiphonage or backpressure (Fire sprinkler systems)	ASSE 1047
Reduced pressure principle backflow preventer and reduced pressure principle fire protection backflow preventer	High or low hazard	Backpressure or backsiphonage Sizes $^3/_8$″ – 16″	ASSE` 1013, AWWA C511 CSA B64.4, CSA B64.4.1
Spillproof vacuum breaker	High or low hazard	Backsiphonage only Sizes $^1/_4$″ – 2″	ASSE 1056
Vacuum breaker wall hydrants, frost-resistant, automatic draining type	High or low hazard	Low head backpressure or backsiphonage Sizes $^3/_4$″ – 1″	ASSE 1019, CSA B64.2.2

For SI: 1 inch = 25.4 mm.
a. Low hazard—See Pollution (Section 202). High hazard—See Contamination (Section 202).
b. See Backpressure (Section 202). See Backpressure, Low Head (Section 202). See Backsiphonage (Section 202).

Figure 20-12 Application for backflow preventers

- Lawn irrigation systems, Section P2902.5.3
- Automatic fire sprinklers, Section P2902.4.4
- Solar systems, Section P2902.5.5

The inspector examines and tests the backflow prevention systems after they're installed to make sure they work; see Section P2503.7. Certain types of backflow preventers — like double check valve assemblies, double-detector check valve assemblies, reduced pressure backflow preventers and pressure vacuum breaker assemblies — must be tested *at the time of installation*, *immediately after repair* and *at least annually.*

It's reasonable to assume a backflow preventer will be tested at the time of installation and immediately after repair. After all, it'll probably be installed and repaired by a professional plumber. But *at least annually* is a difficult requirement to enforce. It's a good idea, but how do you enforce a requirement when most homeowners won't even know about it? After the work is done and the inspector has signed off, should the plumber leave a notice about the annual inspection, posting it close to the backflow preventer? Maybe he should. Some jurisdictions mandate this, but there's no requirement for it in the IRC. Check with your local water authority.

IRC TABLE P2902.3.1 MINIMUM AIR GAPS		
FIXTURE	MINIMUM AIR GAP	
	Away from a wall[a] (inches)	Close to a wall (inches)
Effective openings greater than 1 inch	Two times the diameter of the effective opening	Three times the diameter of the effective opening
Lavatories and other fixtures with effective opening not greater than $^1/_2$ inch in diameter	1	1.5
Over-rim bath fillers and other fixtures with effective openings not greater than 1 inch in diameter	2	3
Sink, laundry trays, gooseneck back faucets and other fixtures with effective openings not greater than $^3/_4$ inch in diameter	1.5	2.5

For SI: 1 inch = 25.4 mm.

a. Applicable where walls or obstructions are spaced from the nearest inside edge of the spout opening a distance greater than three times the diameter of the effective opening for a single wall, or a distance greater than four times the diameter of the effective opening for two intersecting walls.

Figure 20-13 Minimum air gaps

Piping Protection

We now know how to protect the potable water supply in the residence. What about protecting the water supply coming from the public water supply to the residence? We discussed dual-use trenching earlier in the chapter. But there are many other problems you need to avoid when it comes to water supply piping: physical damage, breakage and corrosion, and freezing, These are covered in Section P2603.

Piping installed through holes or notches in studs, joists, etc., and less than 1½ inches from the nearest edge of the framing, must be protected by a steel plate (IRC Section P2603.2.1). There's an exception for cast iron or galvanized steel pipe. Plates must be at least $^1/_{16}$-inch thick, cover the area of the pipe where the framing is notched or bored, and extend at least 2 inches below top plates and above bottom plates.

If pipes pass through or under walls, they must be protected from breakage (Section P2603.3). Pipes must also be protected from external corrosion if they pass through concrete or cinder walls and floors, cold-formed steel framing or other corrosive material. Use a protective sheathing or wrapping, at least $^1/_{40}$-inch thick. The code doesn't prescribe what material to use, only that it must withstand any reaction from lime and acid of concrete, cinder or other corrosive material. The wrapping must allow for expansion and contraction to prevent any rubbing action. It's typical to install a pipe sleeve, a square hole blocked out, or a cored hole (if the pipe is in concrete) 1 inch larger than the pipe. The pipe is then caulked in the center using polyethylene foam or protected by placing multiple wraps of tape or polyethylene film around the pipe.

Water service pipe must be buried at least 12 inches deep or at least 6 inches below the frost line, whichever is greater. If Table R301.2(1) (refer back to Figure 1-1 in Chapter 1) shows a winter design temperature of 32 degrees F or lower for your building area, water, soil, or waste pipes must *not* be installed in the following locations:

- Exterior walls
- Attics or crawl spaces
- Outside the building
- Any other place subjected to freezing temperature

The code does allow you to install piping in these locations if you provide good protection against freezing. You can do this by heat, insulation, or both. But heating sources can lose power and insulation can be damaged. So neither method is completely reliable. It's best to avoid installing pipes in these areas if at all possible.

IRC TABLE P2903.6 WATER-SUPPLY FIXTURE-UNIT VALUES FOR VARIOUS PLUMBING FIXTURES AND FIXTURE GROUPS			
TYPE OF FIXTURES OR GROUP OF FIXTURES	WATER-SUPPLY FIXTURE-UNIT VALUE (w.s.f.u.)		
	Hot	Cold	Combined
Bathtub (with/without overhead shower head)	1.0	1.0	1.4
Clothes washer	1.0	1.0	1.4
Dishwasher	1.4	—	1.4
Full-bath group with bathtub (with/without shower head) or shower stall	1.5	2.7	3.6
Half-bath group (water closet and lavatory)	0.5	2.5	2.6
Hose bibb (sillcock)[a]	—	2.5	2.5
Kitchen group (dishwasher and sink with/without garbage grinder)	1.9	1.0	2.5
Kitchen sink	1.0	1.0	1.4
Laundry group (clothes washer standpipe and laundry tub)	1.8	1.8	2.5
Laundry tub	1.0	1.0	1.4
Lavatory	0.5	0.5	0.7
Shower stall	1.0	1.0	1.4
Water closet (tank type)	—	2.2	2.2

For SI: 1 gallon per minute = 3.785 L/m.

a. The fixture unit value 2.5 assumes a flow demand of 2.5 gpm, such as for an individual lawn sprinkler device. If a hose bibb/sill cock will be required to furnish a greater flow, the equivalent fixture-unit value may be obtained from this table or Table P2903.6(1).

Figure 20-14 Water-supply fixture-unit values

Water Pressure Requirements

The minimum water pressure from the local water authority should be 40 psi. The maximum water pressure supplied to the building should be 80 psi. If the pressure in the main supply exceeds 80 psi, install a pressure-reducing valve; see IRC Section P2903.3. This is different from a pressure-relief valve, noted in IRC Section M2002.4.

Section P2903.4 says you must install a device to control increased pressure due to thermal expansion where:

- The pressure on the downstream side of a pressure-reducing valve is more than the pressure-reducing valve setting (for water service system sizes 2 inches or less).
- A backflow prevention device, check-valve or other device is installed on a water supply system with a storage water heater.

Water Supply System Design

The rest of IRC Chapter 29 covers the design of the water supply system, including:

- Sizing of pipes and meters
- Materials to use
- Joints and connections

We'll just cover some of the basics on piping sizes and fixtures.

Sizing the Water Meter and Distribution Piping

Sizing the water meter and the pipe work for the water service mains, branch units and risers is more complicated than it used to be. It was a lot easier using the pre-2000 versions of the code. Be sure to read Sections P2903.6, *Determining water-supply fixture units*, and P2903.7, *Size of water-service mains, branch mains and risers*, and carefully look over Tables P2903.6 (Figure 20-14) and P2903.7 (Figure 20-15).

IRC TABLE P2903.7
MINIMUM SIZE OF WATER METERS, MAINS AND DISTRIBUTION PIPING BASED ON WATER SUPPLY FIXTURE UNIT VALUES

Pressure Range—50 to 60 psi

METER AND SERVICE PIPE (inches)	DISTRIBUTION PIPE (inches)	MAXIMUM DEVELOPMENT LENGTH (feet)									
		40	60	80	100	150	200	250	300	400	500
3/4	1/2[a]	3	3	2.5	2	1.5	1	1	1	.5	.5
3/4	3/4	9.5	9.5	9.5	8.5	6.5	5	4.5	4	3	2.5
3/4	1	32	32	32	32	25	18.5	14.5	12	9.5	8
1	1	32	32	32	32	30	22	16.5	13	10	8
3/4	1 1/4	32	32	32	32	32	32	32	32	29	24
1	1 1/4	80	80	80	80	80	68	57	48	35	28
1 1/2	1 1/4	80	80	80	80	80	75	63	53	39	29
1	1 1/2	87	87	87	87	87	87	87	87	82	70
1 1/2	1 1/2	151	151	151	151	151	151	139	120	94	79

Figure 20-15 Minimum size of water meters, mains and distribution piping

Determining the required meter and pipe work sizes is a four-step process. We'll use an example to explain the code, which should make it a little clearer.

Step 1: Calculate the Total W.S.F.U. Value — First, let's figure out how many water supply fixture units (w.s.f.u.) you need for the building's water system and its various branches. Do this the same way as you did for the drainage fixture units (d.f.u.) on the sewer system, using IRC Table P2903.6 in Figure 20-14. We'll use the example we used earlier — a 2,000-square-foot, 2½-bath home.

List the fixtures you plan to install with their w.s.f.u. values from the *Combined* column.

Fixture Group	Qty.	Combined w.s.f.u. value	Total
Full-bath group with bathtub	2	3.6	7.2
Half-bath group	1	2.6	2.6
Hose bibb	2	2.5	5.0
Kitchen group	1	2.5	2.5
Laundry group	1	2.5	2.5
Total			19.8

We'll round up to the next whole number, and use a total w.s.f.u. value of 20.

Step 2: Calculate the Available Water Pressure — Next, calculate the available water pressure at the highest water outlet in the building. Get the minimum daily static service pressure from the local water authority. You may then need to make three possible modifications to that number. Let's assume a minimum daily static service pressure available (MDSSPA) of 80 psi.

- Modification 1. Reduce the MDSSPA by 0.5 psi for each foot that the height differs between the elevation of the source of supply and the highest water outlet in the building. Let's say that your building has two stories and the highest water outlet in the building is 15 feet above the source of supply. Reduce the MDSSPA by 15 × 0.5 = 7.5. That gives you a figure of: 80 – 7.5 = 72.5 psi.
- Modification 2. Deduct any pressure losses due to special equipment installed. These include backflow preventers, water filters or water softeners. Use the manufacturer's specs for the pressure losses. If you install a water softener, it will usually reduce the pressure by 15 psi. We now have: 72.5 – 15 = 57.5 psi.

- Modification 3. Deduct any pressure drop of more than 8 psi for the installation of special plumbing fixtures. Some of these are temperature-controlled showers or flushometer tank toilets. For our example, let's assume that you're not planning to install any of these, so there won't be any additional pressure drop to deduct. So, the total available pressure you'll use in your next calculation will be 57.5 psi.

Step 3: Find the Effective Maximum Developed Piping Length — Calculate the maximum developed length of piping between the source of supply and the fixture in the building that's the farthest away. Multiply that number by 1.2 (to compensate for pressure loss through fittings). Let's say the maximum length of any pipe work in your two-story, 2,000-square-foot building is 80 feet. Multiply that number by 1.2 (80 × 1.2 = 96 feet). That gives an effective maximum developed piping length of 96 feet.

Now you have the numbers you need. Use them to calculate the meter size and the distribution pipe work size from the meter to the various branches you plan to install in the water system.

2-story, 2,000-sq.-foot, 2½-bath home

Water-supply fixture-unit (w.s.f.u) value: 20

Available water pressure: 57.5 psi

Effective maximum developed piping length: 96 feet

Step 4: Meter and Service Pipe Size and Distribution Pipe Size — Now look at the tables in IRC Table P2903.7. The tables give you a choice of four pressure ranges: 30 to 39 psi, 40 to 49 psi, 50 to 60 psi, or more than 60 psi. Find the one that matches the available water pressure you calculated above. In our example, it's 57.5 psi, so the third of the four tables is the one you want, *Pressure Range — 50 to 60 psi*. That table is shown in Figure 20-15.

Select the correct column for *Maximum Developed Length* (feet). There are 10 choices, 40 feet up to 500 feet. Always use the column higher than the number calculated. In our example this number was 96 feet, so use the 100 feet column (outlined).

Find the number in that column that is the same as or the next higher number than the one we calculated for the w.f.s.u. value in our example. Our w.f.s.u. value was 20. The next higher number in the 100 column is 32 (outlined).

Finally, look at the far left-hand column, *Meter and Service Pipe (inches)* and the *Distribution Pipe* (*inches*) column directly to its right. Moving left from our outlined number 32 in the example, these numbers are ¾ inch for the *Meter and Service Pipe* size, and 1 inch for the *Distribution Pipe* size (outlined).

That's all there is to it. Now you know how to find the meter size to install, as well as the size of the distribution pipe work from the meter to the various branches.

Sizing Branch Piping

How do you determine the size of pipe work you need for each branch? Easy. Just calculate the total w.f.s.u. value for all of the fixtures you plan to install on each branch. Use Table P2903.6 (Figure 20-14), just like you did in Step 1 of our example. If the water on a branch will be:

- Only hot, use the *Hot* column
- Only cold, use the *Cold* column
- Both hot and cold, use the *Combined* column

So, for a cold water branch going directly from the distribution pipe to one of the full bath groups, the w.s.f.u. value you need is 2.7 (from the *Cold* column). Now calculate the length of pipe you need. Let's assume that you'll need 30 feet of pipe. Multiply that number by 1.2 to allow for pressure loss through the fittings. This gives you an effective maximum developed length for that branch of 36 feet (30 × 1.2 = 36 feet).

Now go back to IRC Table P2903.7, Pressure Range — 50 to 60 psi (Figure 20-15), and select the column that's the same as or next greater than 36 feet, which is the 40 feet column. Find the w.f.s.u. value larger than 2.7, which is 3. Look to the left to the second column and locate the pipe size you need for that branch line. In this case, it's ½-inch pipe.

Repeat these calculations for each branch line from the distribution pipe to each one of the water branches you plan to install in the residence.

If you plan to use manifolds as part of the water distribution system, you'll need to study IRC Section P2903.8.

The pipe materials for the water service pipe work, water distribution pipe work and pipe fittings are given in IRC Section P2904, and Tables P2904.4, P2904.5 and P2904.6. Detailed requirements for fittings and joints are given in Sections P2904.6 through P2904.18.

Finally you'll need valves. You'll find information on them in IRC Section P2903.9. Each dwelling must have its own shutoff valve near the entrance of the water service. Use a full-open valve with minimal flow restriction and a bleed orifice to provide for drainage. Or install a separate bleed valve. You'll also need a shutoff valve at the curb or property line, as required by the local authority.

A water heater must have its own easily-accessible, full-open shutoff valve in the cold water supply, close to the water heater. Each plumbing fixture except bathtubs and showers must have an individual, easily-accessible shutoff valve in the fixture supply pipe.

Fixtures

There's not much to say about fixtures, except that they must be installed properly, which means according to the manufacturers' instructions. Even if the sewer rough-in is done the right way, installing fixtures incorrectly can make a mess of the job.

Remember this: Every fixture will have to be repaired some day. Repair and replacement can be easier if the original installation is done correctly. Fixture shutoff valves need to be readily-accessible. Retaining rings and brackets should be mounted square and snug. Supply and waste lines should connect smoothly without straining either side of the joint. Threaded couplings should be turned snug without over-tightening or cross-threading.

The IRC discusses many different fixtures in Chapter 27, Plumbing Fixtures, including:

- Fixtures, Faucets and Fixture Fittings, Section P2701
- Waste Receptors, Section P2706
- Showers, Section P2708
- Shower Receptors, Section P2709
- Lavatories, Section P2711
- Water Closets, Section P2712
- Bathtubs, Section P2713
- Sinks, Section P2714
- Laundry Tubs, Section P2715
- Food Waste Grinder, Section P2716
- Dishwashing Machines, Section P2717
- Clothes Washing Machines, Section P2718
- Floor Drains, Section P2719
- Whirlpool Bathtubs, Section P2720
- Bidet Installations, Section P2721
- Macerating Toilet Systems, Section P2723
- Specialty Temperature Control Devices and Valves, Section P2724

IRC Chapter 28 covers water heaters.

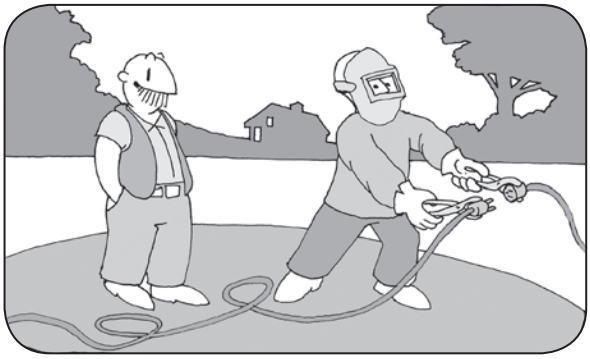
Always read the sections that apply to your installation in case there's something you need to be aware of. For instance, a boiler must be equipped with a pressure-relief valve set at the maximum rating of the boiler. Discharge from the valve should be piped by gravity to a drain within 18 inches of the floor or an open receptor.

The IRC covers the space required for toilet, bath and shower fixtures; see Section R307 and Figure R307.1 (look back at Figure 5-5 in Chapter 5 of this book). Always use nonabsorbent materials (usually tile) to finish the following:

- Floors for bathtubs and showers
- Walls above bathtubs with showers
- Stand-alone shower compartments

These wall surfaces must go at least 6 feet above the floor. Caulk or seal around the base of showers, tubs, and toilets, to complete the job.

This concludes our coverage on the code's plumbing requirements. Next we'll look at Electrical.



Trade Secrets I Can Share

My preference as a building inspector has always been to stay on good terms with the contractors and superintendents I meet. That's not always easy. I'm the bad-news guy, about as popular as the tax collector, at least in the eyes of some. But I try to keep things in perspective. Someone has to do my job. It might as well be me. And, I still get a sense of satisfaction when issuing a Certificate of Occupancy. That's my finish line. When I reach that point, I've done the best I can and I pass responsibility onto someone else.

I get no pleasure writing correction notices. In reality, taking the time to write them slows me down. Every time I walk on a job, I hope not to find violations, and sometimes I'm lucky. I only have about 20 minutes to complete most inspections. Rough-ins and final inspections take about twice that long, sometimes an hour or more. The more writing required, the longer I'll be stuck on that job site.

Violations must be described clearly, and the code section involved must be cited. If the location of the problem isn't clear on paper, I'll mark the framing or concrete with a grease pencil. I'm always willing to discuss any item on the correction notice. It's my job. I don't take it personally when a contractor questions my judgment or knowledge. I've been wrong before; contractors love when I admit it. And when I'm right, I take the time to explain what the code requires and why. Contractors like that, too.

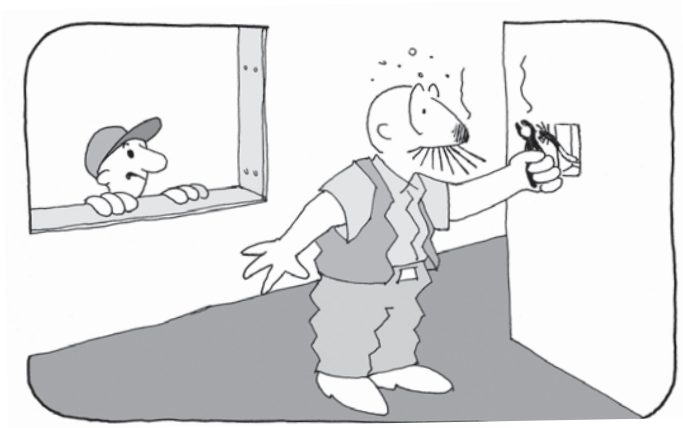
A few years ago, I started a list of the most common violations and their code references. I used that list to refresh my memory when writing correction notices. It saved time and prevented embarrassing mistakes. My list got longer and longer. When it was about eight pages, a contractor saw me using the list and asked for a copy. I wish I'd thought of that! I started passing out my list to any contractor who asked for it. Many did, and put the list to good use — saving countless reinspections. Now, there are lists better than mine offered by commercial publishers.

When writing correction notices, I try to avoid offending anyone. Few contractors violate the code deliberately. Most violations are caused either by a simple mistake or poor supervision. Somebody just didn't understand the code. I remember what it was like when I was new in the business. I made mistakes because I didn't know any better. I appreciated anyone with patience and understanding who could show me a better way. Now it's payback time. I try to show the same patience and consideration others extended to me years ago.

If I have to go back for more than two or three reinspections, I'll make an appointment on the job site with the superintendent. We'll walk the job together, checking the work. I want the super to see the job from my perspective. Understanding that we're both on the same team nearly always solves the problem. Then, usually, the next reinspection is the last.

If violations are minor on the final inspection and if the contractor has a good reputation in my office, I'll sign a Certificate of Occupancy on the spot. It isn't my job to delay progress. Let the contractor wrap up the last few items after occupancy.

There's no magic in any of this. You won't find it in any code book or manual for code inspectors. And it might not work in a large metropolitan office. But it's worked for me on hundreds of jobs over 20 plus years.



"That reminds me, Boss, I turned the power back on."

C H A P T E R 2 1

Electrical Systems for Residences

Electrical systems for one- or two-family dwellings and townhouses are covered in IRC Part VIII, Electrical, Chapters 33 through 42. These chapters are based on the National Electrical Code, NEC® (NFPA 70-2005), published by the National Fire Protection Association (NFPA), headquartered in Quincy, Massachusetts. The National Electrical Code covers every phase of safe electrical installation, and is the official electrical code of most cities, counties and states in the U.S., and the most widely-recognized and adopted electrical code in the world. It's updated and republished every three years.

In this chapter, we'll cover one- and two-family dwellings and townhouses. They fall under the NFPA 70A code, National Electrical Code Requirements for One- and Two-Family Dwellings. In addition, the IRC allows other wiring methods permitted by the general NFPA 70 (without an A) code.

This chapter will be limited to 120/240-volt, 0- to 400-amp, single-phase systems; see Section E3301.2. We'll cover the installation of electrical systems, equipment and components, both indoor and outdoor. These include services, branch circuits, wiring methods, power and lighting distribution, and devices and lighting fixtures.

General Requirements

The general layout of the electrical system for a one-family dwelling includes the service entrance, meter, panelboard (or loadcenter), branch circuits and remote disconnects. Before we look at these installations, let's check some of the general code requirements.

Inspection and Labeling

All new electrical work must be inspected by a building official; see IRC Section E3303.2. Parts of existing systems affected by new electrical work must also be inspected. The code doesn't

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say how much alteration is allowed before you need an inspection. If the building official is at your project inspecting something else, discuss your rewiring plans with him. Or just call the inspector at his office and ask.

All electrical equipment and materials must be listed for their application. They also require the label of an approved agency. If the manufacturer of the equipment has provided instructions for installation, always follow them.

Interruption Ratings

Equipment designed to interrupt at fault levels must have an interrupt rating of at least 10,000 amps. Equipment designed to interrupt at other levels must have an interrupt rating at the nominal circuit voltage that's enough for the current to be interrupted; see Section E3304.2.

Equipment Protection

If the equipment you install is rated only for *dry locations*, *Type I*, or *indoor use only*, protect it from the elements during construction. See IRC Section E3304.4. Close any unused openings in boxes. Provide protection that's equal to the box itself. Recess metallic plugs or plates in nonmetallic boxes at least ¼ inch from the outer surface of the box; see Section E3304.5.

Install boxes or enclosures to protect against accidental contact with energized parts operating at 50 volts or more (Section E3304.8). Don't locate panelboards and overcurrent protection devices in bathrooms or clothes closets (Section E3305.4).

Working Spaces

Leave working space in front of panelboards and other live parts that are likely to need maintenance while they're energized. This space must:

- Be at least 36 inches deep,
- Be at least 30 inches wide (or the width of the equipment, whichever is greater),
- Extend at least 6½ feet from the ground,
- Allow equipment door(s) to open at least 90 degrees.

In existing dwelling units, exception 110.26(E) of the NEC allows service equipment or panelboards that don't exceed 200 amperes to be located in spaces where the headroom is less than 6½ feet.

Electrical installation equipment can't extend more than 6 inches beyond the front of the electrical equipment; see Section E3305.2.

Leave a clear space above the panelboard. The space must extend to the ceiling or at least 6 feet, whichever is less. It has to be at least the width and depth of the panelboard. No unrelated equipment, piping, ducts, etc. can be in this space, except for suspended ceilings with removable panels; see Section E3305.3. Provide artificial lighting for all indoor working spaces that house panelboards and other service equipment; Section E3305.6.

Conductor and Connector Types

Copper conductors are most commonly used in one- or two-family dwellings. But because of copper's high price, some contractors use aluminum for the service supply. That's especially true for the larger sizes (6 gauge and up). The code allows both materials for many uses. But if the code doesn't specify the material, you must use copper. Aluminum's conductivity is only about 65 percent of copper's. So if you're using aluminum wiring, use a larger gauge size. (The larger the wire diameter, the smaller the gauge number.)

Aluminum has more thermal expansion than copper. When aluminum wires heat up, the connections can loosen, causing arcing, and a resulting fire hazard. Be careful when using aluminum conductors. Make sure the devices and connectors are rated for use with aluminum. Devices and connectors approved for use with aluminum wiring are marked CO/ALR (Copper/Aluminum Revised).

The minimum conductor size you can use for feeders and branch circuits is No. 14 (copper) and No. 12 (aluminum); see Section E3306.3. The minimum size for service-entrance conductors is given in IRC Chapter 35, Services.

Leave at least 6 inches of conductor free when splicing or terminating conductors or when connecting to fixtures (Section E3306.10.3). Don't mix different metal conductors. If there's to be physical contact between a copper and an aluminum conductor, do *not* join, splice or terminate them together unless the splice is listed for that purpose; see Section E3306.8.

Individual current-carrying conductors must be insulated, with the insulation identified as one of the following types (Section E3306.5):

- RH – Rubber-coated heat-resistant cable for dry locations.
- RHW, RHW-2 – Rubber-coated, heat- and moisture (water)-resistant cable for wet or dry locations.
- THHN – Thermoplastic high heat-resistant nylon-coated cable for dry locations.
- THHW – Thermoplastic high heat- and moisture (water)-resistant cable for wet or dry locations.
- THW, THW-2 – Thermoplastic heat- and moisture (water)-resistant cable for wet or dry locations.
- THWN, THWN-2 – Thermoplastic heat- and moisture (water)-resistant nylon-coated cable for wet or dry locations.
- TW – Thermoplastic-coated moisture (water)-resistant cable for wet or dry locations.
- UF – Underground feeder cable.
- USF – Underground service feeder cable.
- USE-2 – Underground service entrance cable.
- XHHW, XHHW-2 – Cross-linked high heat- and water-resistant cable for wet or dry locations.

These are the individual insulated wiring types that you can install in a one- or two-family dwelling. Each cable type is rated for 600-volt operation. Heat-resistant cables are rated for 167 degrees F in dry, and 140 degrees F in wet conditions. High heat-resistant cables are rated at 194 degrees F (dry) and 167 degrees F (wet). Use the correct conductor for each application. But remember, if you use individual conductors, they generally must be installed in a raceway or conduit. Check Section R3804 to find the appropriate requirements for installing conductors in conduits and raceways.

Today, most houses are wired using NM (nonmetallic sheath) cable assemblies, commonly known as Romex, rather than individual conductors in conduits or raceways. Individual conductor wiring is typically reserved for large-scale installations. Romex consists of insulated conductors and a grounding conductor assembled together and wrapped in a thin plastic sheath. Romex is light and the smooth plastic sheath makes it very easy to pull through holes drilled in wall studs. It's easy to strip the sheathing and easy to cut. These labor-saving qualities, and the fact that it's relatively inexpensive to manufacture, make it extremely popular for use in wood-frame residential construction.

Keep in mind that internal conductors in NM cable (Romex) aren't usually identified by the type of insulation surrounding the individual conductors. Also, Romex isn't approved for use in wet or damp locations. The conductor requirements for NM type cable are covered in Section E3605.4.4. Note that there's a special provision if two NM cables, containing two or more current-carrying conductors, are bundled together and pass through wood framing that'll be fire- or draft-stopped using thermal insulation or sealing foam. The allowable ampacity of the conductors must be adjusted according to Table E3605.3, as discussed in the section on Conductor Sizing to follow.

Electrical Service Supply

The electrical service from the public utility transformer to a one- or two-family dwelling or townhouse can either be overhead or underground (lateral service). Underground service does away with those unsightly poles, but it costs more. We'll discuss the two types of service entrances separately.

First, here are a few general requirements that deal directly with the service supply. IRC Section E3501.2 says that a one- or two-family

dwelling can be supplied by only one service. Service conductors supplying one building must *not* pass through the interior of any other building; see Section E3501.3. Don't install service conductors in the same raceway as feeder and branch-circuit conductors; see Section E3501.4.

Overhead Service-Drop Supply

Clearance is one of the main concerns with overhead drop and service lines. You don't want someone to be able to reach out or up and touch the cables. Provide at least 3 feet between open conductors, or multiconductor cables without an overall outer jacket, and:

- The sides and bottoms of windows that open
- The sides of doors, porches decks, stairs, ladders, fire escapes, balconies

There's no clearance requirement for non-openable windows or above openable windows, in IRC Section E3504.1. But you still don't want cables too close to the window tops. There's also no clearance requirement between windows and service entrance cables or cables in a raceway. The raceway provides full protection from accidental shock; see IBC Figure E3504.1.

Provide at least 8 feet of vertical clearance above a flat roof. Maintain that height for at least 3 feet in all directions, as in Section E3504.2.1. If the roof carries any foot traffic, increase the height to 10 feet. But if the roof has a 1 in 3 slope (about 18 degrees) or more, roof clearance only has to be 3 feet. The clearance from the overhang of a roof must be at least 18 inches.

Provide at least 10 feet of clearance above grade, 12 feet above residential property, and 18 feet above public streets or parking areas; see Section E3504.2.2.

Above Ground Service-Entrance Conductor Protection

Overhead service-drop cables must be insulated; see IRC Section E3306.5. There's an exception for a grounded copper conductor, but it must be in a raceway, as per Section E3505.1.

Figure 21-1 Public utility transformer

Protect above ground service-entrance cables against physical damage in areas near sidewalks, driveways or close to awnings, shutters, etc. Protect the cables with:

- Rigid metal conduit
- Intermediate metal conduit
- Schedule 80 rigid nonmetallic conduit
- Electrical metallic tubing
- Other approved means; see Section E3505.5

If cables will be exposed to direct sunlight, install insulated cable listed for sunlight resistance. This avoids UV breakdown of the insulation over time (Section E3505.6).

If you install raceways for protection against physical damage, make sure they're approved for wet conditions and they're raintight where the service connection is made; see Section E3505.9.1. Provide drain points to allow any water entering the raceway to drain away; see Section E3505.8.

Underground (Lateral) Service

IRC Section E3703 covers underground service entrance requirements. Sections E3703.1 through E3703.9 discuss the installation of underground service lateral conductors from the utility-supplied transformer (Figure 21-1) to the dwelling.

IRC TABLE E3703.1 MINIMUM COVER REQUIREMENTS, BURIAL IN INCHES					
	TYPE OF WIRING METHOD OR CIRCUIT				
LOCATION OF WIRING METHOD OR CIRCUIT	1 Direct burial cables or conductors	2 Rigid metal conduit or intermediate metal conduit	3 Nonmetallic raceways listed for direct burial without concrete encasement or other approved raceways	4 Residential branch circuits rated 120 volts or less with GFCI protection and maximum overcurrent protection of 20 amperes	5 Circuits for control of irrigation and landscape lighting limited to not more than 30 volts and installed with type UF or in other identified cable or raceway
All locations not specified below	24	6	18	12	6
In trench below 2-inch-thick concrete or equivalent	18	6	12	6	6
Under a building	0 (In raceway only)	0	0	0 (In raceway only)	0 (In raceway only)
Under minimum of 4-inch-thick concrete exterior slab with no vehicular traffic and the slab extending not less than 6 inches beyond the underground installation	18	4	4	6 (Direct burial) 4 (In raceway)	6 (Direct burial) 4 (In raceway)
Under streets, highways, roads, alleys, driveways and parking lots	24	24	24	24	24
One- and two-family dwelling driveways and outdoor parking areas, and used only for dwelling-related purposes	18	18	18	12	18
In solid rock where covered by minimum of 2 inches concrete extending down to rock	2 (In raceway only)	2	2	2 (In raceway only)	2 (In raceway only)

For SI: 1 inch = 25.4 mm.

a. Raceways approved for burial only where encased concrete shall require concrete envelope not less than 2 inches thick.

b. Lesser depths shall be permitted where cables and conductors rise for terminations or splices or where access is otherwise required.

c. Where one of the wiring method types listed in columns 1 to 3 is combined with one of the circuit types in columns 4 and 5, the shallower depth of burial shall be permitted.

d. Where solid rock prevents compliance with the cover depths specified in this table, the wiring shall be installed in metal or nonmetallic raceway permitted for direct burial. The raceways shall be covered by a minimum of 2 inches of concrete extending down to the rock.

e. Cover is defined as the shortest distance in inches (millimeters) measured between a point on the top surface of any direct-buried conductor, cable, conduit or other raceway and the top surface of finished grade, concrete, or similar cover.

Figure 21-2 Minimum wiring burial requirements

Underground cabling is much more apt to be damaged than overhead wiring. Since it can't be seen, it can be accidentally dug up. I've seen this happen more than once. Take the time to protect underground wiring properly. Section E3703.3 covers this in detail. Specific cables are listed for underground use. It's common to use a cable that's rated for direct burial, such as USE-2. You can also use other service entry cabling, as long as it's listed for wet locations and it's protected. This protection can be:

- Rigid metal conduit (RMC)
- Intermediate metal conduit (IMC)
- Nonmetallic raceways (NMR), including rigid nonmetallic conduit (RNC)
- Other approved raceway

The conduit or raceway must be listed for direct burial without concrete encasement.

By using a more protective covering, you can reduce the burial depth, as shown in IRC Table E3703.1 (Figure 21-2). The details for underground service entry cables are in the four outlined boxes. Acceptable burial depth can be

as little as 4 inches if you protect the cables with RMC, IMC or NMR under at least 4 inches of concrete. But be aware that this method is approved only if there's no vehicular traffic. You'll need as much as 24 inches of coverage if you install direct burial USE-2 cable with no additional protection.

What's required when you install direct burial cable without encasing it in concrete? You must identify its location. Put a warning ribbon in the trench at least 12 inches above the cable (see Section E3703.2). Where direct burial cabling emerges from grade, protect it with conduit or raceway. Extend the protection from a point at least 18 inches below grade to a least 8 feet above grade. If there's any chance the cable might be damaged, discuss your decision whether or not to bury the cable unprotected (or even protected) with a building official. It's his call.

Backfill the service entrance trench carefully (Section E3703.5). Don't let the cabling or raceway be damaged by large rocks, paving materials, sharp objects or corrosive materials. Loose soil that can be well-compacted makes an excellent backfill material. If the compaction could cause damage to the cabling, protect it with boards, sleeves or granular material.

Service Size and Rating (Ampacity)

The service size is based on the projected need of the residence, and is measured in amperes. The code says that the ampacity of ungrounded (hot) conductors for one-family dwellings must be at least 100 amps, 3-wire, and be able to carry at least the load served. For other installations, like townhouses, the ampacity must be at least 60 amps; see Section E3502.1. The minimum of 60 or 100 amps is the base from which you start in determining the service size you need. The actual size is determined by calculating the general lighting and receptacle outlet requirements based on the square footage of the residence, plus the electrical load of the appliances that will be installed. The larger the residence and the more high-demand electrical appliances required, the larger the service you'll need.

IRC TABLE E3502.2 MINIMUM SERVICE LOAD CALCULATION
LOADS AND PROCEDURE
3 volt-amperes per square foot of floor area for general lighting and general use receptacle outlets.
Plus
1,500 volt-amperes total number of 20-ampere-rated small appliance and laundry circuits.
Plus
The nameplate volt-ampere rating of all fastened-in-place, permanently connected or dedicated circuit-supplied appliances such as ranges, ovens, cooking units, clothes dryers and water heaters.
Apply the following demand factors to the above subtotal:
The minimum subtotal for the loads above shall be 100 percent of the first 10,000 volt-amperes of the sum of the above loads plus 40 percent of any portion of the sum that is in excess of 10,000 volt-amperes.
Plus the largest of the following:
Nameplate rating(s) of the air-conditioning and cooling equipment.
Nameplate rating(s) of the heating where a heat pump is used without any supplemental electric heating.
Nameplate rating of the electric thermal storage and other heating systems where the usual load is expected to be continuous at the full nameplate value. Systems qualifying under this selection shall not be figured under any other category in this table.
One-hundred percent of nameplate rating of the heat pump compressor and sixty-five percent of the supplemental electric heating load for central electric space-heating systems. If the heat pump compressor is prevented from operating at the same time as the supplementary heat, the compressor load does not need to be added to the supplementary heat load for the total central electric space-heating load.
Sixty-five percent of nameplate rating(s) of electric space-heating units if less than four separately controlled units.
Forty percent of nameplate rating(s) of electric space-heating units of four or more separately controlled units.
The minimum total load in amperes shall be the volt-ampere sum calculated above divided by 240 volts.

Figure 21-3 Minimum service load

Calculating the Service Load

IRC Section E3502.2 and Table E3502.2 (Figure 21-3) provide you with a guide for calculating the minimum service load for ungrounded service conductors and devices.

Let's look at an example based on a 2,000-square-foot, 2½-bath house. We'll assume you plan to install:

4 – 20-amp rated small appliance circuits

1 – Cooktop with 9,600 volt-amp (VA) rating

1 – Double oven with 9,600 volt-amp (VA) rating
1 – Dishwasher with 1,500 volt-amp (VA) rating
1 – Clothes dryer with 6,850 volt-amp (VA) rating
1 – Air conditioning unit with 9,600 volt-amp (VA) rating
1 – Gas-fired water heater (no electric water heater)
1 – Gas-fired space heating (no electrical space-heating equipment)

First we'll calculate the minimum total volt-amperes we need to supply, using Table E3502.2:

3 volt-amps per square foot of floor area
3 VA × 2,000 = 6,000 VA
4 20-amp rated small appliance circuits
4 × 1,500 VA = 6,000 VA
1 Cooktop 9,600 VA
1 × 9,600 VA = 9,600 VA
1 Double oven 9,600 VA
1 × 9,600 VA = 9,600 VA
1 Dishwasher 1,500 VA
1 × 1,500 VA = 1,500 VA
1 Clothes dryer 6,850 VA
1 × 6,850 VA = 6,850 VA

Subtotal volt-amps rating 39,550 VA

Now take 100 percent of the first 10,000 VA plus 40 percent of anything above 10,000 VA. This gives you:

10,000 × 1 (100%)	10,000 VA
39,550 – 10,000 = 29,550 × 0.40 (40%)	+11,820 VA
Minimum subtotal load	21,820 VA
Add in the air conditioner	+ 9,600 VA
Minimum total load	31,420 VA

Then, divide the minimum total VA load by 240 volts to get the minimum total load in amps:

31,420 VA ÷ 240 V = 131 amps

So, the *minimum* service you must provide to your 2,000-square-foot house is 131 amps. The next higher service rating is 150-amp, but 200-amp service equipment is an industry standard. Since it's usually less expensive and readily available, your best choice is the industry standard, which in this case is the 200-amp service. This will also give the homeowner the flexibility to add on other facilities at a later date.

The voltage rating of the supply to the home must be 3-wire, 120/240-volt, single-phase service with a grounded neutral; see Section E3502.4. In this system, there are 120 volts between either of the two ungrounded (hot) conductors and the neutral. There are 240 volts between the two ungrounded conductors. The 120-volt supply is used for general-purpose receptacles and lighting. The 240-volt supply is used for cooking, air conditioning, heating, clothes drying and other high-demand loads.

Service Conductor Size

What size service-entrance conductor should you install if you go with the industry-standard 200-amp service for your 2,000-square-foot house? You'll find that information in IRC Section E3503. Table E3503.1, Figure 21-4, lists sizes for the following conductor types:

- Ungrounded service-entrance conductors (above ground)
- Ungrounded service lateral conductors (below ground)
- Ungrounded service conductors (between the service point and the service disconnect)
- Ungrounded feeder conductors (between the service equipment and any branch-circuit overcurrent devices)
- Grounded conductor size (neutral)

Look at the Table in Figure 21-4. Under *Allowable Ampacity*, find 200 amp service load, then look across to the left to see the conductor sizes you can use for that load (outlined). You can use No. 2/0 copper or No. 4/0 aluminum or copper-coated aluminum conductors for ungrounded and grounded service conductors. And you can use a No. 4 copper or No. 2 aluminum or copper-coated aluminum conductor for the grounding electrode conductor.

Now look at Note "c" in Table E3503.1. In addition to the requirement that an unprotected 6 AWG grounding electrode closely follow a structural surface for physical protection, the NEC requires that it be securely fastened to the construction.

TABLE E3503.1
SERVICE CONDUCTOR AND GROUNDING ELECTRODE CONDUCTOR SIZING

CONDUCTOR TYPES AND SIZES—THHN, THHW, THW, THWN, USE, XHHW, THW-2, THWN-2, XHHW-2, SE, USE-2 (Parallel sets of 1/0 and larger conductors are permitted in either a single raceway or in separate raceways)		ALLOWABLE AMPACITY	MINIMUM GROUNDING ELECTRODE CONDUCTOR SIZE[a]	
Copper (AWG)	Aluminum and copper–clad aluminum (AWG)	Maximum load (amps)	Copper (AWG)	Aluminum (AWG)
4	2	100	8[b]	6[c]
3	1	110	8[b]	6[c]
2	1/0	125	8[b]	6[c]
1	2/0	150	6[c]	4
1/0	3/0	175	6[c]	4
2/0	4/0 or two sets of 1/0	200	4[d]	2[d]
3/0	250 kcmil or two sets of 2/0	225	4[d]	2[d]
4/0 or two sets of 1/0	300 kcmil or two sets of 3/0	250	2[d]	1/0[d]
250 kcmil or two sets of 2/0	350 kcmil or two sets of 4/0	300	2[d]	1/0[d]
350 kcmil or two sets of 3/0	500 kcmil or two sets of 250 kcmil	350	2[d]	1/0[d]
400 kcmil or two sets of 4/0	600 kcmil or two sets of 300 kcmil	400	1/0[d]	3/0[d]

For SI: 1 inch = 25.4 mm.

a. Where protected by a ferrous metal raceway, grounding electrode conductors shall be electrically bonded to the ferrous metal raceway at both ends.

b. Eight AWG grounding electrode conductors shall be protected with metal conduit or nonmetallic conduit.

c. Where not protected, 6 AWG grounding electrode conductors shall closely follow a structural surface for physical protection. The supports shall be spaced not more than 24 inches on center and shall be within 12 inches of any enclosure or termination.

d. Where the sole grounding electrode system is a ground rod or pipe as covered in Section E3508.2, the grounding electrode conductor shall not be required to be larger than 6 AWG copper or 4 AWG aluminum. Where the sole grounding electrode system is the footing steel as covered in Section E3508.1.2, the grounding electrode conductor shall not be required to be larger than 4 AWG copper conductor.

Figure 21-4 Conductor sizing

Service Disconnect

You need to install a service disconnect to disconnect the service-entrance conductors from the dwelling's conductors; see IRC Section E3501.6. The service disconnect must be in an easily accessible location. It can be either outside or inside of the building, nearest to the location of the service entrance. The main service disconnect is usually the main breaker in the panelboard, down line from the service meter. Each ungrounded service conductor must have overload protection; see Section E3503.3.

System Grounding

System grounding is a major concern of the code, which is why there are so many main sections devoted to getting it right. Make a careful study of IRC Sections E3507 through E3511.

Use a grounding electrode conductor to connect the equipment grounding conductors, the service equipment enclosures, and the grounded service conductor to the grounding electrode(s); see Section E3507.4.

Size the grounding electrode conductor using Table E3503.1 (Figure 21-4). You can connect the grounding electrode conductor anywhere from the service point to the service disconnect, but *not* on the load side of any service disconnect; see Section E3507.2.

Protect the grounding electrode conductor from physical damage with conduit or cable armor, or place it where it can't be damaged. Some conditions apply, as you'll see in Section E3510.2. Actively protect a No. 4 or larger grounding electrode conductor if there's potential for major damage. You can use RMC, IMC, EMT, rigid nonmetallic conduit, or cable armor. You're allowed to fasten a No. 6 grounding

electrode conductor to the outside of the building without using protection if the conductor isn't exposed to physical harm. Otherwise, protect it using one of the materials just listed. Grounding electrode conductors smaller than No. 6 must always be actively protected.

Metallic grounding electrode conductor protection must be electrically continuous from the point where it's attached to cabinets or equipment all the way to the grounding electrode. Connect any breaks in the continuity of protection by bonding each end of the protection to the grounding conductor. (We'll discuss bonding shortly.)

The Grounding Electrode

There are many different grounding electrodes described in the IRC. Among them are:

Metal underground water pipe, Section E3508.1.1 (this must be used if one is present)

Concrete-encased electrode, Section E3508.1.2 (this must be used if reinforced concrete, within and near the bottom of a concrete foundation or footing in direct contact with the earth, is present)

Ground rings, Section E3508.1.3

Rod and pipe electrodes, Section E3508.1.4

Plate electrodes, Section E3508.1.5

Let's look more closely at using a metal underground water pipe as a grounding electrode. Details of the other types of grounding electrodes are in the code, if you need them.

A typical grounding electrode is a continuous metal underground water pipe that's in contact with the earth for at least 10 feet (Section E3508.1.1). But there's important additional information in the following subsection. A metal underground water pipe grounding electrode, alone, isn't enough. You must add one of the other four types of grounding electrodes, as stated in E3508.1.1.1:

. . . A metal underground water pipe shall be supplemented by an additional electrode of a type specified in Sections E3508.1.2 through E3508.1.5. The supplemental electrode shall be bonded to the grounding electrode conductor, the grounded service entrance conductor, a nonflexible grounded service raceway or any grounded service enclosure.

So, a metal underground pipe, 10 feet long, does *not* make an adequate grounding electrode by itself. You must use it if it's present, but you must also add a secondary grounding electrode.

A concrete-encased grounding electrode (Section E3508.1.2) should be used as one of the grounding electrodes, if one is present. Look for a rebar stub left exposed above the foundation. You need at least ½-inch diameter rebar, 20 feet long, covered by at least 2 inches of concrete, in direct contact with the earth. Bond the exposed rebar to the grounding electrode conductor using a listed connector.

If there's no exposed rebar, use a ground ring for the secondary grounding electrode, as described in Section E3508.1.3. You can use 20 feet of bare copper conductor, at least No. 2, partially encircling the building, in direct contact with the earth. Bond the secondary grounding electrode to the primary grounding electrode, the grounding electrode conductor, and any protective raceway being used.

Some objects that *can't* be used as grounding electrodes:

- An interior metal water pipe that's more than 5 feet from the point of entrance to the building. It also can't be used as a conductor to interconnect electrodes that are part of a grounding electrode system; see Section E3508.1.1.
- An aluminum pipe or rod; see Section E3508.5. Aluminum rapidly develops an oxide coating when in contact with air, so it won't provide adequate contact to ground.
- A metal underground gas pipe; see Section E3508.6.

Bonding

Good bonding ensures electrical continuity and an unobstructed path for any fault current. The IRC stresses the importance of bonding in Section E3509. Bond together the noncurrent-carrying metal parts of the service raceways

or service cable armor, all service enclosures containing service conductors, and any metallic raceways or armor enclosing a grounding electrode (Section E3509.2).

Provide an accessible means, outside of enclosures, of connecting intersystem bonding and grounding electrode conductors; see Section E3509.3. Acceptable methods of bonding are given in Section E3509.4. A bonding jumper (a connector that *jumps* across a gap) must be at least the full size shown in Table E3503.1 (Figure 21-4) for grounding electrode conductors.

Sections E3509.6 and E3509.7 require that metal water piping or other metal piping, either inside or attached to the outside of a building, that could become energized, including gas piping, must be bonded to one of the following:

- The service equipment enclosure
- The grounded conductor at the service
- The grounding electrode conductor

Use a bonding jumper sized as mentioned above.

Finally, the grounding electrode conductor must be securely connected mechanically and electrically to the grounding electrode. You can use listed lugs, pressure connectors, clamps, etc. But *don't* use a soldered connection. Full details can be found in Section E3511.

Branch Circuits and Feeders

A typical one-family dwelling will have a single panelboard connected to the incoming service. Branch circuits come out from the panelboard. In this case, there aren't any feeder circuits.

But if the incoming service is split to more than one panelboard, each panelboard will be supplied by a feeder circuit. If your electrical system involves feeder circuits, you'll need to study IRC Section E3604. We're only going to discuss branch circuits here.

The following definitions, from IRC Section E3401, are helpful to know:

Arc-Fault Circuit Interrupter: *A device intended to provide protection from the effects of arc-faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc-fault is detected.*

Branch Circuit: *The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).*

Branch Circuit, Appliance: *A branch circuit that supplies energy to one or more outlets to which appliances are to be connected, and that has no permanently connected luminaires that are not a part of an appliance.*

Branch Circuit, General Purpose: *A branch circuit that supplies two or more receptacle outlets or outlets for lighting and appliances.*

Branch Circuit, Individual: *A branch circuit that supplies only one utilization equipment.*

Branch Circuit, Multiwire: *A branch circuit consisting of two or more ungrounded conductors having voltage difference between them, and a grounded conductor having equal voltage difference between it and each ungrounded conductor of the circuit, and that is connected to the neutral or grounded conductor of the system.*

Circuit Breaker: *A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.*

Continuous Load: *A load where the maximum current is expected to continue for 3 hours or more.*

Ground-Fault Circuit-Interrupter: *A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds the value for a Class A device.*

Panelboard: *A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and*

equipped with or without switches for the control of light, heat or power circuits, designed to be placed in a cabinet or cutout box placed in or against a wall, partition or other support, and accessible only from the front.

Residential panelboards rated for 225 amps or less, and for 240 volts, are often called load centers. The two terms mean the same thing, and NEC rules and definitions apply to both.

Branch Circuits Required

You can install as many branch circuits as you want. You're only limited by the number of circuit breakers in the panelboard. But there is a minimum. IRC Section E3603.5 says that the number of branch circuits must be enough to supply the load served. Determine how many branch circuits you'll need by calculating the total load required and the maximum ampacity per branch circuit. We'll cover this in the next section.

Provide enough 15-amp branch circuits for general lighting and receptacle outlets. You also have to supply at least the following:

- One separate, individual branch circuit for central heating equipment; see Section E3603.1. Equipment like humidifiers and air cleaners can be connected to the same branch circuit.
- Two 20-amp branch circuits to serve all wall and floor receptacle outlets in the kitchen, pantry, breakfast and dining area; see Section E3603.2. Both of these branch circuits must serve the kitchen countertop. They can also be used to supply other outlets in the kitchen area — including the refrigerator.
- One 20-amp branch circuit for laundry area receptacles; see Section E3603.3. Don't use this circuit to supply outlets in any other area.
- One 20-amp circuit for bathroom area receptacles; see Section E3603.4. Again, don't use this circuit to supply other loads in the bathroom, such as lights, heaters and fans, or outlets in any other area.

IRC TABLE E3602.13
BRANCH-CIRCUIT REQUIREMENT — SUMMARY

	CIRCUIT RATING		
	15 amp	20 amp	30 amp
Conductors: Minimum size (AWG) circuit conductors	14	12	10
Maximum overcurrent-protection device rating Ampere rating	15	20	30
Outlet devices: Lampholders permitted	Any type	Any type	N/A
Receptacle rating (amperes)	15 maximum	15 or 20	30
Maximum load (amperes)	15	20	30

a. These gages are for copper conductors.
b. N/A means not allowed.

Figure 21-5 Branch-circuit requirement

Branch Circuit Rating

The rating requirements for branch circuits are covered in detail in Section E3602. The basics are found in Section E3602.13 and Table E3602.13 (Figure 21-5).

Here are some important points. Kitchen cooking ranges rated 8.75 kVA or more are common in today's households. They must be supplied by a 40-amp-rated circuit; see Section E3602.9.1. Electric space-heating and water-heating appliances must be considered continuous loads (Section E3602.10). The significance of this is found in Section E3601.2. What if a branch circuit supplies a continuous load or a combination of continuous and noncontinuous loads? Then the ampacity of the branch circuit must serve 125 percent of the continuous load plus any noncontinuous load. However, you can base the branch circuit rating for permanently installed air conditioners and heat pumps on the minimum circuit ampacity marked on the equipment; see Section E3602.11. In general, a branch circuit may carry a maximum load of only 80 percent of its nominal capacity if 50 percent or more of its load is continuous.

Conductor Sizing

Sizing conductors can be a little complicated. If you plan to use individual conductors in a raceway or conduit, you have to take a couple of factors into consideration. IRC Table E3605.1

IRC TABLE E3605.1 ALLOWABLE AMPACITIES							
CONDUCTOR SIZE	CONDUCTOR TEMPERATURE RATING						CONDUCTOR SIZE
	60°C	75°C	90°C	60°C	75°C	90°C	
AWG kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, USE, XHHW	Types RHW-2, THHN, THHW, THW-2, THWN-2, XHHW, XHHW-2, USE-2	Types TW, UF	Types RHW, THHW, THW, THWN, USE, XHHW	Types RHW-2, THHN, THHW, THW-2, THWN-2, XHHW, XHHW-2, USE-2	AWG kcmil
	Copper			Aluminum or copper-clad aluminum			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14	20	20	25	—	—	—	—
12	25	25	30	20	20	25	12
10	30	35	40	25	30	35	10
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0

For SI: °C = [(°F)-32]/1.8.

Figure 21-6 Allowable ampacities

(Figure 21-6) gives the allowable ampacities for copper and aluminum or copper-clad aluminum conductor sizes for specific cable insulation types and temperature ratings. Let's look at how you'd use the table to select your cable type.

If you're installing a 30-amp branch circuit, it would appear that you can use any one of the four cable types outlined in Table E3605.1 and summarized in Figure 21-7. But make sure you allow for the ambient temperature and conductor proximity corrections, as well as the breaker limitations, all of which we'll discuss in the sections to follow.

Ambient Temperature Correction

You'll need to adjust the cable type and conductor size using a correction factor if the ambient temperature in your area is ever above 86 degrees F. What's meant by ambient temperature? It's not defined in the code. And local jurisdictions aren't required to quote a maximum figure in Table R301.2(1) (Chapter 1, Figure 1-1). Winter Design Temperature and Mean Annual Temperature are given, but not a maximum ambient temperature. So use the maximum temperature recorded locally in recent years, or ask your local building official for guidance.

Temperatures above 86 degrees F are a common occurrence in most areas of the U.S. during the summer months. For instance, every state except Alaska reached 90 degrees on at least one day in July, 2006. Many parts of the U.S. reach 96-104 degrees F for short periods of time in the summer. And some areas of the

Cable Type	Conductor Size	Conductor Metal
TW or UF	No. 10	Copper
RHW-2, THHN, THHW, THW-2, THWN-2, XHHW or XHHW-2	No. 12	Copper
TW or UF	No. 8	Aluminum or Copper-Clad Aluminum
RHW-2, THHN, THHW, THW-2, THWN-2, XHHW, or XHHW-2	No. 10	Aluminum or Copper-Clad Aluminum

Figure 21-7 Cable type, conductor size and conductor metal options for a 30-ampere load

TABLE E3605.2
AMBIENT TEMPERATURE CORRECTION FACTORS

AMBIENT TEMP. °C	FOR AMBIENT TEMPERATURES OTHER THAN 30°C (86°F), MULTIPLY THE ALLOWABLE AMPACITIES SPECIFIED IN TABLE E3605.1 BY THE APPROPRIATE FACTOR SHOWN BELOW						AMBIENT TEMP. °F
	CONDUCTOR TEMPERATURE RATING						
	60°C	75°C	90°C	60°C	75°C	90°C	
	Types TW, UF	Types RHW, THHW, THW, THWN, USE, XHHW	Types RHW-2, THHN, THHW, THW-2, THWN-2, XHHW, XHHW-2, USE-2	Types TW, UF	Types RHW, THHW, THW, THWN, USE, XHHW	Types RHW-2, THHN, THHW, THW-2, THWN-2, XHHW, XHHW-2, USE-2	
	Copper			Aluminum or copper-clad aluminum			
21-25	1.08	1.05	1.04	1.08	1.05	1.04	70-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	78-86
31-35	0.91	0.94	0.96	0.91	0.94	0.96	87-95
36-40	0.82	0.88	0.91	0.82	0.88	0.91	96-104
41-45	0.71	0.82	0.87	0.71	0.82	0.87	105-113
46-50	0.58	0.75	0.82	0.58	0.75	0.82	114-122
51-55	0.41	0.67	0.76	0.41	0.67	0.76	123-131
56-60	—	0.58	0.71	—	0.58	0.71	132-140
61-70	—	0.33	0.58	—	0.33	0.58	141-158
71-80	—	—	0.41	—	—	0.41	159-176

For SI: °C = [(°F)-32]/1.8.

Figure 21-8 Temperature correction factors

Southwest get into the 105-113 degrees F temperature range. Temperature correction factors are given in IRC Section E3605.2 and Table E3605.2 (Figure 21-8). The Fahrenheit temperature ranges are shown in the far right-hand column.

Let's look at an example. Earlier, we saw that there were four different cable types that we could use for a 30-amp branch circuit. One of those was a No. 12 THHN copper cable. Can we use that cable if the maximum ambient temperature is in the 96-104 degrees F range? Check the table. Find 96-104 in the ambient temperature in degrees F column on the far right-hand side of Figure 21-8. Now look across that row to the left and find the correction factor for type THHN copper cable. The correction factor is 0.91 (double outlined in the figure). Multiply the rated ampacity of the cable (30 amps) by the correction factor (0.91) to determine its Allowable Ampacity in the 96-104 degree F range:

30 amps × 0.91 = 27.3 amps

So this won't work for a 30-amp branch circuit. You need the next higher-rated cable, which is No. 10 type THHN copper. It's rated at 40 amps at 86 degrees F ambient temperature, so it meets a 30-amp rating requirement at ambient temperatures as high as 104 degrees F:

40 amps × 0.91 = 36.4 amps.

Conductor Proximity Correction

In addition to the ambient temperature correction, you may need to apply a conductor proximity correction. Conductors give off heat. Multiple bundled conductors can't rid themselves of heat as easily as a single or just a few bundled conductors. If you have four or more conductors in a raceway, or they're bundled for 24 inches or more, apply the conductor proximity correction factor provided in Section E3605.3 and Table E3605.3, Figure 21-9.

TABLE E3605.3
CONDUCTOR PROXIMITY ADJUSTMENT FACTORS

NUMBER OF CURRENT-CARRYING CONDUCTORS IN CABLE OR RACEWAY	PERCENT OF VALUES IN TABLE E3605.1
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 and above	35

Figure 21-9 Conductor adjustment factors

Looking at the table in Figure 21-9, you see that if you have 4 to 6 conductors in a raceway, or bundled for more than 24 inches, the allowable ampacity of the cabling is now only 80 percent of its single conductor rating (outlined in the figure). Let's go back to our earlier example. The 40-amp-rated cable that was reduced to 36.4 amp allowable ampacity, in the ambient temperature range 96–104 degrees F, is now reduced even more:

36.4 × 80 percent = 29.1 amps

That's if four to six of these cables are close to each other. So again, the cable no longer meets a 30-amp rating requirement. You'll have to use the next higher-rated cable, which is No. 8 for type THHN copper. This cable is rated at 55 amps at 86 degrees F ambient temperature, and in the 96-104 degrees F ambient temperature range, it's rated at:

55 amps × 0.91 = 50.1 amps

So if you bundle four to six of these cables, their allowable ampacity rating will be:

50.1 × 80 percent = 40.1 amps

This now meets your 30-amp rating requirement. Use this example to help do the math for any other combinations of ambient temperature and bundled cables.

Other Temperature Limitations

What if the termination provision for the equipment you're installing (let's say a panelboard) is rated for 100 amps or less? You can use conductors, such as type TW, that are rated for 60 degrees C (140 degrees F). But if it's over 100 amps, you must use conductors rated for at least 75 degrees C (167 degrees F). That includes RHW, THHW, THW, THWN, USE, or XHHW; see Section E3605.4.

Overcurrent Protection

All ungrounded (hot) circuits must be protected against overcurrent by an overcurrent device, typically a circuit breaker, at the point where the conductors get their supply; see Section E3605.5. The overcurrent protection rating of circuit breakers for small conductors can't exceed the figures shown in IRC Table E3605.5.3 (Figure 21-10).

IRC TABLE E3605.5.3 OVERCURRENT-PROTECTION RATING			
COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM		
Size (AWG)	Maximum overcurrent-protection-device rating[a] (amps)	Size (AWG)	Maximum overcurrent-protection-device rating[a] (amps)
14	15	12	15
12	20	10	25
10	30	8	30

a. The maximum overcurrent-protection-device rating shall not exceed the conductor allowable ampacity determined by the application of the correction and adjustment factors in accordance with Sections E3605.2 and E3605.3.

Figure 21-10 Overcurrent-protection rating

So, for our 30-amp branch circuit, with a 30-amp breaker, the minimum size conductor we can use is 10 AWG (No. 10) for copper conductors or 8 AWG (No. 8) for aluminum or copper-clad aluminum conductors (outlined in Figure 21-10) regardless of any ambient temperature or conductor proximity corrections we need to make.

Install circuit breakers where they're easily accessible and where they won't be exposed to physical damage. The most common place is in the main panelboard. Keep the circuit breakers away from anything that could catch fire, like clothes in a closet. Finally, in case the thought crossed your mind, don't locate circuit breakers in a bathroom (Section E3605.7).

Circuit Identification

Identify the purpose of each circuit on the panelboard. Mark each one on the face of, or inside, the door. In older dwellings, identifying circuit breakers can often be a problem for new owners. If the circuit breakers aren't clearly identified, they'll have to figure out which breaker disconnects which branch circuit. Make your identifications clear, detailed and legible, as now required by code; see Section E3606.2.

IRC TABLE E3701.2 ALLOWABLE WIRING METHODS	
ALLOWABLE WIRING METHOD	**DESIGNATED ABBREVIATION**
Armored cable	AC
Electrical metallic tubing	EMT
Electrical nonmetallic tubing	ENT
Flexible metal conduit	FMC
Intermediate metal conduit	IMC
Liquidtight flexible conduit	LFC
Metal-clad cable	MC
Nonmetallic sheathed cable	NM
Rigid nonmetallic conduit	RNC
Rigid metallic conduit	RMC
Service entrance cable	SE
Surface raceways	SR
Underground feeder cable	UF
Underground service cable	USE

Figure 21-11 Allowable wiring methods

Wiring Methods

Not all wiring methods are permitted in all applications. The fourteen wiring methods allowed by the code — and their abbreviations — are shown in IRC Table E3701.2 (Figure 21-11). You can only use single conductors if they're part of one of these recognized wiring methods.

All the conductors of a circuit, including the equipment grounding conductors and bonding conductors, must be contained in the same cable, cord, raceway or trench; see Section E3701.3.

The wiring methods you can use for various applications are shown in Table E3701.4 (Figure 21-12).

Most wood framed residential wiring applications fall under the NM column. For other nonstandard allowable applications, select one

TABLE E3701.4
ALLOWABLE APPLICATIONS FOR WIRING METHOD

ALLOWABLE APPLICATIONS (application allowed where marked with an "A")	AC	EMT	ENT	FMC	IMC RMC RNC	LFC[a]	MC	NM	SR	SE	UF	USE
Services	—	A	A[h]	A[i]	A	A[i]	A	—	—	A	—	A
Feeders	A	A	A	A	A	A	A	A	—	A[b]	A	A[b]
Branch circuits	A	A	A	A	A	A	A	A	A	A[c]	A	—
Inside a building	A	A	A	A	A	A	A	A	A	A	A	—
Wet locations exposed to sunlight	—	A	A[h]	A[d]	A	A	A	—	—	A	A[e]	A[e]
Damp locations	—	A	A	A[d]	A	A	A	—	—	A	A	A
Embedded in noncinder concrete in dry location	—	A	A	—	A	—	—	—	—	—	—	—
In noncinder concrete in contact with grade	—	A[f]	A	—	A[f]	—	—	—	—	—	—	—
Embedded in plaster not exposed to dampness	A	A	A	A	A	A	A	—	—	A	A	—
Embedded in masonry	—	A	A	—	A[f]	A	A	—	—	—	—	—
In masonry voids and cells exposed to dampness or below grade line	—	A[f]	A	A[d]	A[f]	A	A	—	—	A	A	—
Fished in masonry voids	A	—	—	A	—	A	A	A	—	A	A	—
In masonry voids and cells not exposed to dampness	A	A	A	A	A	A	A	A	—	A	A	—
Run exposed	A	A	A	A	A	A	A	A	A	A	A	A
Run exposed and subject to physical damage	—	—	—	—	A[g]	—	—	—	—	—	—	—
For direct burial	—	A[f]	—	—	A[f]	A	A[f]	—	—	—	A	A

For SI: 1 foot = 304.8 mm.
a. Liquid-tight flexible nonmetallic conduit without integral reinforcement within the conduit wall shall not exceed 6 feet in length.
b. The grounded conductor shall be insulated except where used to supply other buildings on the same premises. Type USE cable shall not be used inside buildings.
c. The grounded conductor shall be insulated.
d. Conductors shall be a type approved for wet locations and the installation shall prevent water from entering other raceways.
e. Shall be listed as "Sunlight Resistant."
f. Metal raceways shall be protected from corrosion and approved for the application.
g. RNC shall be Schedule 80.
h. Shall be listed as "Sunlight Resistant" where exposed to the direct rays of the sun.
i. Conduit shall not exceed 6 feet in length.

Figure 21-12 Allowable applications for each wiring method

TABLE E3702.1
GENERAL INSTALLATION AND SUPPORT REQUIREMENTS FOR WIRING METHODS

INSTALLATION REQUIREMENTS (Requirement applicable only to wiring methods marked "A")	AC MC	EMT IMC RMC	ENT	FMC LFC	NM UF	RNC	SE	SR[a]	USE
Where run parallel with the framing member or furring strip, the wiring shall be not less than $1^1/_4$ inches from the edge of a furring strip or a framing member such as a joist, rafter or stud or shall be physically protected.	A	—	A	A	A	—	A	—	—
Bored holes in framing members for wiring shall be located not less than $1^1/_4$ inches from the edge of the framing member or shall be protected with a minimum 0.0625-inch steel plate or sleeve, a listed steel plate or other physical protection.	A[k]	—	A[k]	A[k]	A[k]	—	A[k]	—	—
Where installed in grooves, to be covered by wallboard, siding, paneling, carpeting, or similar finish, wiring methods shall be protected by 0.0625-inch-thick steel plate, sleeve, or equivalent, a listed steel plate or by not less than $1^1/_4$-inch free space for the full length of the groove in which the cable or raceway is installed.	A	—	A	A	A	—	A	A	A
Securely fastened bushings or grommets shall be provided to protect wiring run through openings in metal framing members.	—	—	A[j]	—	A[j]	—	A[j]	—	—
The maximum number of 90-degree bends shall not exceed four between junction boxes.	—	A	A	A	—	A	—	—	—
Bushings shall be provided where entering a box, fitting or enclosure unless the box or fitting is designed to afford equivalent protection.	A	A	A	A	—	A	—	A	—
Ends of raceways shall be reamed to remove rough edges.	—	A	A	A	—	A	—	A	—
Maximum allowable on center support spacing for the wiring method in feet.	4.5[b, c]	10	3[b]	4.5b	4.5[i]	3[d]	2.5[e]	—	2.5[e]
Maximum support distance in inches from box or other terminations.	12[b, f]	36	36	12[b,g]	12[h,i]	36	12	—	12

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 degree = 0.009 rad.
a. Installed in accordance with listing requirements.
b. Supports not required in accessible ceiling spaces between light fixtures where lengths do not exceed 6 feet.
c. Six feet for MC cable.
d. Five feet for trade sizes greater than 1 inch.
e. Two and one-half feet where used for service or outdoor feeder and 4.5 feet where used for branch circuit or indoor feeder.
f. Twenty-four inches where flexibility is necessary.
g. Thirty-six inches where flexibility is necessary.
h. Within 8 inches of boxes without cable clamps.
i. Flat cables shall not be stapled on edge.
j. Bushings and grommets shall remain in place and shall be listed for the purpose of cable protection.
k. See Sections R502.8 and R802.7 for additional limitations on the location of bored holes in horizontal framing members.

Figure 21-13 Wiring method requirements

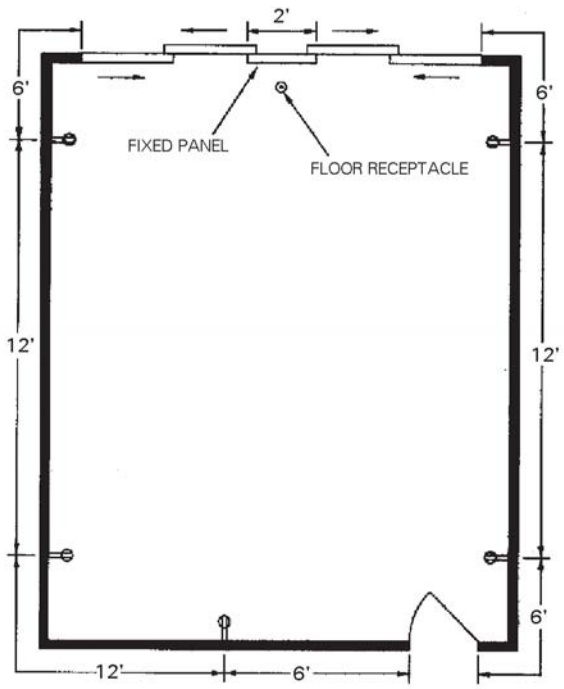
of the wiring methods with an A in its column. An A means you can use the wiring method in that application; a dash (—) means you can't. For example, you can use any one of the 14 wiring methods, except USE, for branch circuits (outlined) or inside a building (outlined). But if you're going to embed the wiring in noncinder concrete in a dry location (dashed outlined) or in contact with grade (dashed outlined), you must use one of these following five wiring methods: EMT, ENT, IMC, RMC or RNC. Make sure you comply with the notes at the bottom of the table. Note "c" (outlined) tells you that if you want to use service entrance cable (SE) for branch circuits (double outlined), the grounded conductor must be insulated.

We discussed underground applications earlier in the section on Underground (Lateral) Service.

Wiring Installation Requirements

The general installation and support requirements for each wiring method are shown in Table E3702.1 (Figure 21-13).

FIGURE E3801.2
GENERAL USE RECEPTACLE DISTRIBUTION



For SI: 1 foot = 304.8 mm.

Figure 21-14 Receptacle distribution

In this table, once again, an A means the installation requirement applies to that wiring method; a dash (—) means it doesn't. Let's look at an example. If you're using any one of the following four wiring methods, ENT, NM, UF or SE, you must provide securely fastened bushings or grommets to protect the wiring where it runs through openings in metal framing members (outlined). This requirement doesn't apply to the other 10 wiring methods. Again, make sure you comply with the notes at the bottom of the table. In our example, Note "j" (outlined) says you must ensure the bushings and grommets remain in place and are listed for cable protection.

In this section we'll discuss the location of:

- Receptacle outlets
- Ground-fault circuit interruption (GFCI)
- Arc-fault circuit interruption (AFCI)
- Lighting outlets

Receptacle Outlets

Receptacle outlets are installed in many different locations, both inside and outside a dwelling. Each area has its own requirements. Make sure you check — and follow — the code requirements for each particular location.

Habitable Rooms

Install receptacle wall outlets in all living rooms, bedrooms, or similar areas of a dwelling so that no place along the wall line is more than 6 feet from a receptacle. On any wall space wider than 2 feet, the maximum distance between receptacles is 12 feet. This includes fixed panels between sliding doors on exterior walls, as shown in IRC Section E3801.2, Figure 21-14.

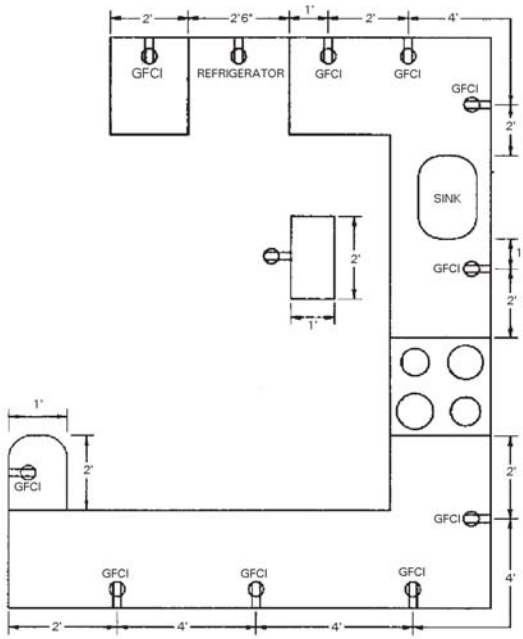
Don't count floor receptacles unless they're located within 18 inches of the wall. Space receptacles an equal distance apart, as best you can. Install at least one receptacle in any hallway longer than 10 feet (Section E3801.10).

Countertops

Install a wall receptacle wherever a kitchen or dining room countertop is 12 inches wide or wider. No point along the wall line may be more than 24 inches from a receptacle. See IRC Section E3801.4 and Figure E3801.4 (Figure 21-15). Don't install countertop receptacles on the walls directly behind a stove or sink. Not only are those impractical locations, they could also create a shock or burn hazard for the homeowner. Say the homeowner has been using a hand mixer to make a cake. She reaches for the spatula and instead knocks it into the sink, where dishes are soaking. As she puts her hand in to get it, her sleeve catches the cord on the mixer and it too slips into the sink. What happens? Well, at best, the mixer will short out. The ground-fault circuit interruption (GFCI) should prevent electrocution — but maybe not a nasty shock. Better that there's no outlet close enough for that event to occur.

Countertop wall outlets must be installed no more than 20 inches above the countertop. Outlets in the countertop surface must *not* be installed in a face-up position because of

FIGURE E3801.4
COUNTERTOP RECEPTACLES



For SI: 1 foot = 304.8 mm.

Figure 21-15 Countertop receptacles

potential spills. Install at least one receptacle for any island countertop or peninsula countertop larger than 24 inches by 12 inches.

Countertop spaces separated by range tops or refrigerators are considered individual spaces. Supply them with receptacles as required.

Appliances

Install receptacles for appliances, like refrigerators, within 6 feet of the intended location for the appliance; see IRC Section E3801.5.

Bathroom

Install at least one wall receptacle within 36 inches of the outside edge of each sink if you're planning dual sinks in the countertop (IRC Section E3801.6). You can either install one wall receptacle between the two sinks, or two receptacles — one on each side. Again, don't install outlets in a face-up position on any countertop surface.

Laundry

Install at least one receptacle in a laundry area to serve the appliances (IRC Section E3801.8). It's typical to install a 240-volt outlet for a clothes dryer, though it's not required by the code. Even if the initial homeowner plans to use a gas-fired clothes dryer, a subsequent owner may prefer an electric dryer. It's much easier and less expensive to install a 240-volt outlet during construction than to do a retrofit later.

Garages and Basements

Install at least one outlet in an attached garage or a detached garage supplied with electrical power, in addition to any outlets required for a garage laundry area; see IRC Section E3801.9.

Install at least one receptacle in an unfinished basement. What if part or all of it has been finished to a habitable state? Install receptacle outlets in the habitable space as you would on any habitable room wall. Install at least one receptacle in any unfinished space.

Next to HVAC Equipment

In a crawlspace or attic containing HVAC equipment, install a separate standard outlet on the same level and within 25 feet of the equipment; see IRC Section E3801.11.

Outdoors

Install at least one receptacle at both the front and back of each dwelling where the egress is to grade level. These outlets can't be more than 6½ feet above grade. See IRC Section E3801.7 for details.

Ground-Fault Circuit-Interruption Protection (GFCI)

A *ground-fault* is an accidental electrical path between the power at an outlet and a grounded surface. It's caused when current leaks and electricity escapes to the ground. The path it

follows to the ground is critical. If someone's body happens to be in the path, they could be injured, burned, shocked, or even killed.

A good example of the need for ground-fault protection in a bathroom is dropping a plugged-in hair dryer into a sink or bathtub full of water. That's not an uncommon occurrence. If the only thing that touches the water is the dryer, it causes a ground-fault but no serious injury. But if the person is touching the water too, it's a very different matter. They become part of the path to ground, and that could be fatal. GFCI protection is a lifesaver, literally. And that's why it's required in most areas of the home where you might be using appliances or tools.

A GFCI receptacle constantly monitors the flow of electricity to and from the receptacle. It detects any loss of current to ground. If the current flowing from the receptacle differs, even by a very small amount, from that returning to it, the GFCI immediately switches off the power to the receptacle. The GFCI interrupts the power so quickly that it can prevent a lethal dose of electricity. The person may still get a painful shock, but it probably won't cause a serious injury or electrocution.

You can provide ground-fault circuit-interruption protection in one of two ways. Either replace the standard branch circuit breaker in the panelboard with a GFCI breaker, or install a GFCI receptacle outlet.

GFCI protection must be provided for all 120-volt, 15- and 20-amp outlet receptacles in the following locations:

- Kitchens; see IRC Section E3802.6
- Bathrooms; see Sections E3802.1, and E3802.10 for electrically heated floors in bathrooms
- Laundry, utility and bar sinks, where the outlet is within 6 feet of the outside edge of the sink; see Section E3802.7
- Garages or similar storage or work areas, including boat houses; see Sections E3802.2 and E3802.8
- Crawlspaces; see Section E3802.4
- Unfinished basements; see Section E3802.5
- Outdoors; see Section E3802.3
- A pool area, where the outlet is within 20 feet of the inside walls of the pool, spa or hot tub; see Section E4103.1.4. Receptacles for pool pump motors must also have GFCI protection

Arc-Fault Circuit-Interruption Protection (AFCI)

Arc-fault circuit interrupters, AFCIs, are fairly new electrical devices. They're covered in IRC Section E3802. AFCIs are designed to protect against fire caused by an arcing fault in home electrical wiring. This is a critical situation: over 40,000 fires each year are caused by faulty home wiring. Arcing is the major problem, since it creates so much heat. It can ignite any combustible materials close by, like bedding, drapes, carpets, paper or even wood. Arcing faults are common in damaged or worn-out wires and cords. Damage can be caused by puncturing wire insulation during careless installation of cable staples or by homeowners when driving a nail to hang a picture. Other causes are:

- Incorrect installation of outlets or switches
- Cords caught in doors or under furniture
- Furniture pushed up against plugs in an outlet
- Natural aging
- Cord exposure to heat vents and sunlight

AFCI protection is usually built into special circuit breakers that replace standard circuit breakers in the panelboard. Standard circuit breakers only respond to current overloads and short circuits. They don't protect against arcing conditions that produce erratic current flow. An AFCI breaker is designed so that normal arcs don't cause the AFCI to trip. An example of a normal arc is when light switches are turned on or off.

Most AFCIs are designed into standard circuit breakers. They combine traditional overload and short-circuit protection with arc-fault protection. You can also use a stand-alone AFCI device. AFCI circuit breakers have a test button and look similar to ground-fault circuit-interrupter (GFCI) circuit breakers. Some designs combine both GFCI and AFCI protection.

Until the end of 2007, branch circuits supplying all outlets in bedrooms must have one form of arc-fault circuit interruption, either stand-alone or the combination type; see Section E3802.12. But starting January 1, 2008, all AFCI protection must be provided by combination-type AFCI circuit breakers. You'll no longer be allowed to install stand-alone types.

Lighting Outlets

You must install at least one lighting outlet controlled by a wall switch in each habitable room, as described in IRC Section E3803.2. In any room other than a kitchen or bathroom, this outlet can be a wall receptacle controlled by a wall switch. This is the minimum requirement; you'll probably want to install more outlets and switches. Take into consideration the size of the rooms and whether or not they have multiple entrances and exits.

In hallways, stairways, attached garages and detached garages provided with power, install at least one lighting outlet controlled by a wall switch (Section E3803.3). Also, at each entrance/exit point at grade level, install at least one lighting outlet on the outside wall that's controlled by an inside wall switch. Stairways with six or more risers must have a wall switch at the top and bottom of each floor level. You can use remote, central or automatic lighting controls for hallways, stairways and outdoor exit points in place of manual wall switches.

Finally, provide at least one lighting outlet controlled by a wall switch in attics, crawlspaces, utility rooms and basements used for storage or for equipment requiring maintenance; see Section E3803.4. The switch can be located in the lighting outlet if appropriate. Install a switch at the entrance/exit point and a lighting outlet close to any equipment requiring maintenance.

Conduit and Wiring Installation

In this section we'll cover the installation of raceways, conduit, fittings and junction boxes, and the wiring they contain.

All metallic conduit, raceways, cable armor, fittings, junction boxes and enclosures must be mechanically joined to ensure continuous electrical conductivity because they may be used to maintain an effective ground to all receptacle boxes and other enclosures; see IRC Section E3804.1. However, short sections of raceways, used only for cable support or protection, don't have to be mechanically or electrically connected. Nonmetallic conduit sections, raceways, etc. must be mechanically continuous even though they won't provide electrical continuity; see Section E3804.2.

Nonmetallic conduit, going through stud cavities or joist spaces used for air handling, must pass through the space perpendicular to the long dimension of the stud or joist; see Section E3804.7.

The maximum number of conductors that conduit or tubing can carry is shown in a set of ten tables: IRC Tables E3804.6(1) through E3804.6(10). They cover all conduit types and sizes, both metallic and nonmetallic, and the allowable types of insulation and conductor sizes; see Section E3804.6. Let's look at one example. Electrical metallic tubing (EMT) is covered in Table E3804.6(1), Figure 21-16. This table shows the maximum number of conductors allowed in EMT, for trade sizes ⅛ (0.71-inch outside diameter) through 2 (2.2-inch outside diameter)), the full range of allowable insulation types (RHW through XHHW), and conductor sizes (No. 14 through No. 4/0).

The other tables cover:

- Electrical Nonmetallic Tubing (ENT), Table E3804.6(2)
- Flexible Metallic Conduit (FMC), Table E3804.6(3)
- Intermediate Metallic Conduit (IMC), Table E3804.6(4)
- Liquid-Tight Flexible Nonmetallic Conduit (FNMC-B), Table E3804.6(5)

TABLE E3804.6(1)
MAXIMUM NUMBER OF CONDUCTORS IN ELECTRICAL METALLIC TUBING (EMT)

TYPE LETTERS	CONDUCTOR SIZE AWG/kcmil	TRADE SIZES (inches)					
		$^1/_2$	$^3/_4$	1	$1^1/_4$	$1^1/_2$	2
RHW, RHW-2	14	4	7	11	20	27	46
	12	3	6	9	17	23	38
	10	2	5	8	13	18	30
	8	1	2	4	7	9	16
	6	1	1	3	5	8	13
	4	1	1	2	4	6	10
	3	1	1	1	4	5	9
	2	1	1	1	3	4	7
	1	0	1	1	1	3	5
	1/0	0	1	1	1	2	4
	2/0	0	1	1	1	2	4
	3/0	0	0	1	1	1	3
	4/0	0	0	1	1	1	3
TW	14	8	15	25	43	58	96
	12	6	11	19	33	45	74
	10	5	8	14	24	33	55
	8	2	5	8	13	18	30
RHW[a], RHW-2[a], THHW, THW, THW-2	14	6	10	16	28	39	64
	12	4	8	13	23	31	51
	10	3	6	10	18	24	40
	8	1	4	6	10	14	24
RHW[a], RHW-2[a], TW, THW, THHW, THW-2	6	1	3	4	8	11	18
	4	1	1	3	6	8	13
	3	1	1	3	5	7	12
	2	1	1	2	4	6	10
	1	1	1	1	3	4	7
	1/0	0	1	1	2	3	6
	2/0	0	1	1	1	3	5
	3/0	0	1	1	1	2	4
	4/0	0	0	1	1	1	3
THHN, THWN, THWN-2	14	12	22	35	61	84	138
	12	9	16	26	45	61	101
	10	5	10	16	28	38	63
	8	3	6	9	16	22	36
	6	2	4	7	12	16	26
	4	1	2	4	7	10	16
	3	1	1	3	6	8	13
	2	1	1	3	5	7	11
	1	1	1	1	4	5	8
	1/0	1	1	1	3	4	7
	2/0	0	1	1	2	3	6
	3/0	0	1	1	1	3	5
	4/0	0	1	1	1	2	4
XHHW, XHHW-2	14	8	15	25	43	58	96
	12	6	11	19	33	45	74
	10	5	8	14	24	33	55
	8	2	5	8	13	18	30
	6	1	3	6	10	14	22
	4	1	2	4	7	10	16
	3	1	1	3	6	8	14
	2	1	1	3	5	7	11
	1	1	1	1	4	5	8
	1/0	1	1	1	3	4	7
	2/0	0	1	1	2	3	6
	3/0	0	1	1	1	3	5
	4/0	0	1	1	1	2	4

For SI: 1 inch = 25.4 mm.
a. Types RHW, and RHW-2 without outer covering.

Figure 21-16 Conductors in electrical metallic tubing

- Liquid-Tight Flexible Nonmetallic Conduit (FNMC-A), Table E3804.6(6)
- Liquid-Tight Flexible Metal Conduit (LFMC), Table E3804.6(7)
- Rigid Metal Conduit (RMC), Table E3804.6(8)
- Rigid PVC Conduit, Schedule 80 (PVC-80), Table E3804.6(9)
- Rigid PVC Conduit Schedule 40 (PVC-40), Table E3804.6(10)

Boxes, Conduit Bodies and Fittings

IRC Section E3805.1 instructs you to install a box (wiring enclosure) or a conduit body (separate portion of conduit with a removable access cover) at each:

- Conductor splice
- Receptacle outlet
- Wall switch point
- Pull switch point
- Junction point

There are exceptions when a junction box is integrated into the equipment being installed, or at splices or taps in underground cables. There are more exceptions as well. Read the full list in Sections E3805.1.1 through E3805.1.7.

All metal boxes must be grounded, as stated in Section E3805.2. Nonmetallic boxes can only be used with nonmetallic sheathed cable, and nonmetallic cable wiring methods, raceways and flexible cords; see Section E3805.3.

Surface-mounted outlet boxes must be at least ½ inch deep measured internally (Section E3805.4). Flush-mount outlet boxes must be at least $^{15}/_{16}$ inch deep.

Flush-mount boxes must be fully enclosed at the back and sides and provide support for the electrical device. The screws attaching the box to the structure must not be used to support the device in the box; see Section E3805.5.

You may need to install a special box to mount a luminaire (light fixture). This is mandatory if it weighs more than 6 pounds, as you can see in Section E3805.6. Luminaires, like chandeliers, weighing over 50 pounds must be supported separately from the outlet box (Section E3805.7). Ceiling fans or combined ceiling fan/light fixtures can't be installed with a standard outlet box providing their only support. Outlet boxes specifically designed and marked for this purpose must be used to support fixtures up to 70 pounds; see Section E3805.9.

In damp or wet locations, use boxes listed for those conditions. Install them so that moisture can't enter the box (Section E3805.11).

Sizing Boxes

How do you know what size box to install? That depends on the size and number of conductors; see IRC Section E3805.12 and Table E3805.12.1 (Figure 21-17). Count the number of conductors originating outside the box that will be terminated or spliced inside the box. A conductor that passes straight through the box without termination or splicing should only be counted once (Section E3805.12.2.1).

Now select a box from Table E3805.12.1 that's the correct size to hold that number conductors of the appropriate conductor size. For example, if you're using No. 6 conductors, and you have 3 conductors entering the box, 4 conductors leaving the box and 1 conductor passing straight through, you have a total of 8 conductors. Now find a box in Table E3805.12.1 that will accept that many conductors. There's only one, $4\,^{11}/_{16}$ x 2⅛ square (outlined). You can obviously use a larger box, but not a smaller one. Remember to leave room for clamps, support fittings, devices, and equipment grounding conductors. Check Sections E3805.12.2.2 through E3805.12.2.5.

A conduit body that encloses No. 6 or smaller conductors must have at least twice the cross-sectional area of the conduit to which it's connected. (Twice the cross-sectional area is about 1½ times the diameter.) An exception is made if it's a short-radius conduit body; see Section E3805.12.3.

TABLE E3805.12.1 MAXIMUM NUMBER OF CONDUCTORS IN METAL BOXES								
BOX DIMENSIONS (inches trade size and type)	MAXIMUM CAPACITY (cubic inches)	MAXIMUM NUMBER OF CONDUCTORS[a]						
		No. 18	No. 16	No. 14	No. 12	No. 10	No. 8	No. 6
$4 \times 1^1/_4$ round or octagonal	12.5	8	7	6	5	5	4	2
$4 \times 1^1/_2$ round or octagonal	15.5	10	8	7	6	6	5	3
$4 \times 2^1/_8$ round or octagonal	21.5	14	12	10	9	8	7	4
$4 \times 1^1/_4$ square	18.0	12	10	9	8	7	6	3
$4 \times 1^1/_2$ square	21.0	14	12	10	9	8	7	4
$4 \times 2^1/_8$ square	30.3	20	17	15	13	12	10	6
$4^{11}/_{16} \times {}^{11}/_4$ square	25.5	17	14	12	11	10	8	5
$4^{11}/_{16} \times {}^{11}/_2$ square	29.5	19	16	14	13	11	9	5
$4^{11}/_{16} \times 2^1/_8$ square	42.0	28	24	21	18	16	14	8
$3 \times 2 \times 1^1/_2$ device	7.5	5	4	3	3	3	2	1
$3 \times 2 \times 2$ device	10.0	6	5	5	4	4	3	2
$3 \times 2 \times 2^1/_4$ device	10.5	7	6	5	4	4	3	2
$3 \times 2 \times 2^1/_2$ device	12.5	8	7	6	5	5	4	2
$3 \times 2 \times 2^3/_4$ device	14.0	9	8	7	6	5	4	2
$3 \times 2 \times 3^1/_2$ device	18.0	12	10	9	8	7	6	3
$4 \times 2^1/_8 \times 1^1/_2$ device	10.3	6	5	5	4	4	3	2
$4 \times 2^1/_8 \times 1^7/_8$ device	13.0	8	7	6	5	5	4	2
$4 \times 2^1/_8 \times 2^1/_8$ device	14.5	9	8	7	6	5	4	2
$3^3/_4 \times 2 \times 2^1/_2$ masonry box/gang	14.0	9	8	7	6	5	4	2
$3^3/_4 \times 2 \times 3^1/_2$ masonry box/gang	21.0	14	12	10	9	8	7	4

For SI: 1 inch = 25.4 mm, 1 cubic inch = 16.4 cm^3.
a. Where no volume allowances are required by Sections E3805.12.2.2 through E3805.12.2.5.

Figure 21-17 Maximum number of conductors in metal boxes

Installation of Boxes, Conduit Bodies and Fittings

The installation of boxes, conduit bodies and fittings is covered in IRC Section E3806. Protect conductors from rubbing inside boxes or conduit bodies. Use a substantial fitting that can provide a smoothly-rounded insulating surface. Also, close all openings securely in boxes or conduit bodies where conductors enter. They must be adequately sealed, typically with a rubber or fiber gasket supplied as part of the conduit body, to prevent moisture from getting in.

Close any unused openings in boxes or conduit bodies. They need to provide the same protection as the wall of the box. Metal plugs used in nonmetallic boxes must be recessed at least ¼ inch from the outer surface of the box.

When installing a box with a flush-type cover or faceplate in a wall or concrete ceiling, tile or other noncombustible material, you must set the front edge of the box, the plaster ring, the extension ring and the extender back behind the finished surface by ¼ inch or less.

When a box is installed in walls or ceilings made of wood or any other combustible material, the front edge must then be flush with, or stick out from, the finished surface.

You mustn't leave any gaps larger than ⅛ inch around a box with a flush-type cover or faceplate when installing it in plaster or plaster-

board surfaces. Have your drywall installer cut tight neat holes, or tape tight to the box. If this isn't done, even though the cover plate conceals the gap, it doesn't protect the box. You must seal the gap with caulk or use a cover plate with a sealing gasket. Pay special attention to mounting and supporting boxes, enclosures and raceways. Details are in Section E3806.8.

All outlet boxes must be permanently covered by a faceplate or some other type of cover. Metallic covers must be grounded. Normally, you ground by ensuring the metallic faceplate fixing screws are in good contact with the grounded device. If the faceplate is painted or coated with wall covering, make sure the mounting screws holes are clear to the metal surface.

Panelboards and Cabinets

Panelboards and cabinets are covered in Section IRC E3807. Don't use enclosures holding main breakers and circuit breakers as junction boxes, gutters or raceways for conductors passing through or tapping off to other switches or breakers unless enough space is provided for this purpose. Conductors can't fill more than 40 percent of the cross-sectional area of the wiring space at any point. Conductors, splices and taps can't fill more than 75 percent of the cross-sectional area of the wiring space.

Install waterproof panelboards or cabinets in wet or damp locations. If you're surface-mounting a cabinet in a damp location, install it so that moisture can't enter the cabinet. When it's mounted, there must be at least ¼ inch of air space between the cabinet and the wall or other support structure. If raceways or cables enter a panelboard above the level of uninsulated live parts in a wet location, the fittings must be listed for wet locations.

When mounting panelboards or cabinets in walls made of concrete, tile or other noncombustible material, set the front surface back from the finished surface by ¼ inch or less. For walls made of wood or other combustible material, mount the cabinet flush with the finished surface or allow it to stick out from the surface. In plaster, drywall or plasterboard, only gaps ⅛ inch or less are permitted around the edge of the cabinet.

Close any unused openings in panelboards and cabinets. Provide the same effective protection as for the wall of the cabinet itself. Metal plugs used in nonmetallic cabinets must be recessed at least ¼ inch from the outer surface of the box. Close any unused openings in the panelboard with approved fittings. Again, provide the same protection here as for the wall of the cabinet itself.

Protect conductors from rubbing where they enter panelboards and cabinets. IRC Section E3807.6 says: *Conductors entering cabinets and panelboards shall be protected from abrasion and shall comply with Section E3806.1.1.* You must also adequately close all openings in panelboards and cabinets where conductors enter.

Securely fasten cables entering an enclosure to the enclosure. Cables with nonmetallic sheaths can enter the top of a surface-mounted enclosure if the entrance is through a raceway no less than 18 inches and no more than 10 feet long. This is allowed only under a specific set of conditions set forth in Section E3807.8. Check there for details.

Grounding

Grounding is covered in IRC Section E3808. All metallic conductor enclosures must be grounded, unless they're short sections of raceways used only for support or protection. Metallic fittings joining underground rigid nonmetallic conduit are also exempt if they're covered by at least 18 inches of earth or they're encased in concrete.

Ground any exposed noncurrent-carrying metal part of fixed equipment that could accidentally become hot, if it is:

- Within 8 feet vertically or 5 feet horizontally of earth or grounded metal objects and likely to come into human contact
- Located in a wet or damp situation, and not isolated
- In electrical contact with metal

The exposed noncurrent-carrying parts of luminaires (lights) and motor-operated water pumps also must be grounded.

TABLE E3808.12 EQUIPMENT GROUNDING CONDUCTOR SIZING		
RATING OR SETTING OF AUTOMATIC OVERCURRENT DEVICE IN CIRCUIT AHEAD OF EQUIPMENT, CONDUIT, ETC., NOT EXCEEDING THE FOLLOWING RATINGS (amperes)	MINIMUM SIZE	
	Copper wire No. (AWG)	Aluminum or copper-clad aluminum wire No. (AWG)
15	14	12
20	12	10
30	10	8
40	10	8
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1

Figure 21-18 Grounding conductor sizing

Don't make a grounding connection to a grounded connector (neutral) on the load side of the main breaker.

Section E3808.8 lists the acceptable equipment grounding conductors that you can run with or use to enclose circuit conductors. Their installation is covered in Section E3808.11. Many types of metallic conduit or raceway are considered acceptable grounding conductors. Copper conductors, solid or stranded, insulated or bare, wire or busbar, make acceptable grounding materials as well. A copper, aluminum or copper-clad aluminum wire used as a grounding conductor must be sized according to Section E3808.12 and Table E3808.12 (Figure 21-18). For example, a 20-amp breaker (outlined in the table) protecting a branch circuit needs at least a No. 12 copper wire or a No. 10 aluminum or copper-clad aluminum wire as the grounding conductor.

IRC Section E3808.4 says the grounding conductor must have sufficiently low impedance (resistance to AC current) to allow the circuit breaker to operate effectively under fault conditions.

You can't use the earth itself as the only effective ground-fault current path, nor can you use flexible metal conduit or liquid-tight flexible metal conduit as an equipment-grounding conductor unless specific conditions are met (Sections E3808.8.1 and E3808.8.2).

The continuity of your grounding conductors is critical if they're going to provide effective fault protection. They get a lot of attention in the code, as you can see in Sections E3808.13 through E3808.18. If you use jumpers to ensure continuity, size them according to Table E3808.12 (Figure 21-18). You can install jumpers either inside or outside a raceway. If they're installed outside, they can't be longer than 6 feet and must be routed with the raceway. Jumper installation is covered in Section E3808.20.

Flexible Cords

You can connect an appliance using a flexible cord only if the connection (plug and receptacle) is designed for easy removal of the appliance for maintenance, repair or simply to move it. The appliance must also be listed for flexible cord connection. You can't use flexible cords as an easy alternative to fixed wiring. Flexible cords can't pass through or be concealed by walls, ceiling or floors; see Section E3809.

Devices and Luminaires

In this section we'll cover light fixtures and other devices at the end of the electrical wiring line, which include switches and receptacles.

Switches

Switches are some of the easiest electrical items to install, but there's a lot to know about them. They must disconnect the ungrounded (hot) conductor and not the grounded conductor (neutral) of a circuit. There's an exception when the switch disconnects all the conductors at the same time; see Section E3901.8. Wire three-way and four-way switches so that all switching is only on the ungrounded (hot) conductors (Section E3901.9). Switches connected directly to aluminum connectors must be marked CO/ALR (copper/aluminum revised); see Section E3901.2.

IRC TABLE E3902.1.2 RECEPTACLE RATINGS FOR VARIOUS SIZE MULTIOUTLET CIRCUITS	
CIRCUIT RATING (amperes)	RECEPTACLE RATING (amperes)
15	15
20	15 or 20
30	30
40	40 or 50
50	50

Figure 21-19 Receptacle ratings for multioutlet circuits

Always install a vertically-operated, single-throw switch so the up position is the ON position; see Section E3901.3. It may be different in other countries, but in the U.S. up is ON. Don't install wall switches with the center point of the lever in the up position any higher than 6 feet 7 inches above the floor (Section E3901.6). And don't install switches in wet locations such as tubs or showers, unless they're integral to the tub or shower assembly (Section E3901.7).

IRC Section E3806.5 covers how to mount flush-type switches in boxes recessed in the wall. Install the switch so the extending plaster ears are seated against the surface of the wall. If the box is flush with the wall, or sticks out from the wall, install the switch so the mounting yoke (frame) or strap of the switch is seated against the box; see Section E3901.10.

Receptacles

Receptacles and cord connectors must be pin, not lampholder, type. They must be rated for at least 15 amps, and either 125 volts or 250 volts (IRC Section E3902.1). Single receptacles must be rated at least equal to the branch circuit supplying them. Two or more receptacles connected to a branch circuit supplying two or more receptacles must be rated according to the circuit rating shown in IRC Table E3902.1.2 (Figure 21-19).

Receptacles rated at 20 amps or less, connected directly to aluminum connectors, must be marked CO/ALR (copper/aluminum revised). See Section E3902.3.

A faceplate must completely cover the opening of the box containing the receptacle, and seat against the finished surface. The receptacle face must be flush with or project from faceplates made of insulating material. For metal faceplates, the receptacle face must project at least $^{1}/_{64}$ inch; see Section E3902.5. That's not easy to measure. As long as the receptacle sticks out from a metal faceplate just a tiny bit, it should meet code. But there are some exceptions you need to know about.

Always install receptacles in boxes. The mounting requirements for boxes and receptacles are similar to those for switches. See IRC Sections E3901.10 and E3902.6. Don't install receptacles in, or directly above, a tub or shower stall, and pay special attention to receptacles installed outdoors or in damp or wet locations. See Sections E3902.8 through E3902.12.

Fixtures

Light fixtures produce heat. Incandescent lamps are a lot hotter than fluorescent lamps. Any combustible material next to a light fixture mustn't be exposed to temperatures higher than 194 degrees F (Section E3903.2). I highly recommend installing compact fluorescent lamps (CFLs) instead of incandescent lamps. They're a little more expensive, but give off much less heat, use about one-quarter of the energy, and last a lot longer. Not only will CFLs make a difference in the homeowner's year-round lighting expense, they'll also help reduce the air conditioning bill in the summer. Keep in mind, however, that most CFLs can't be controlled on a dimmer.

Recessed fixtures that are installed in walls or ceilings must be listed as thermally protected; see IRC Sections E3903.5, E3903.6 and E3903.7. Be sure that any exposed conductive parts of lighting fixtures are grounded (Section E3903.3).

In a bathroom, you can't have any part of a cord-connected fixture, hanging fixture, pendant, light track, or ceiling fan within a space 3 feet horizontally and 8 feet vertically from the top of the bathtub rim. In a shower area, it's measured from the shower stall threshold (Section E3903.10). Any fixtures in this zone

must be listed for damp locations. If they might get hit with shower spray, they must be listed for wet conditions. Fixtures located in other damp or wet locations are covered in Sections E3903.8 and E3903.9.

Finally, pay special attention to the installation of lighting fixtures in clothes closets, as this can be hazardous due to the heat; see Section E3903.11. This section of the code is full of instructions; be sure to read it carefully so you get it right.

Fixture Installation

Install fixtures so that there's easy access to the fixture-to-circuit conductor connections without having to disconnect any of the wiring; see IRC Section E3904.3.

If a fixture weighs more than 6 pounds, or is more than 16 inches long, Section E3904.4 says you can't support it by the screw lamp fixture alone. It will require a specially-designed box for mounting; see also Section E3805.6.

If you surface-mount a fixture with a ballast on combustible low-density cellulose fiberboard, the material must be listed for that purpose. Space the fixture at least 1½ inches from the fiberboard's surface (Section E3904.7).

Don't install insulation within 3 inches of a ceiling can enclosure or above recessed ceiling cans. There's an exception for cans specifically identified for contact with insulation (i.e. Type IC); see Section E3904.9. Space the recessed parts of any can at least ½ inch from combustible material, unless listed for contact with insulation; see Section E3904.8.

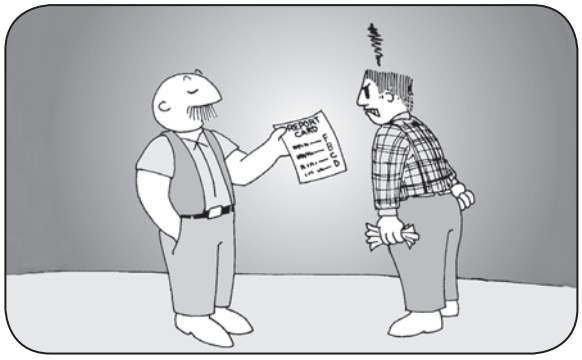
Track Lighting

Track lighting must be permanently installed and connected to its own branch circuit; see IRC Section E3905.1. The track must be grounded and its sections securely connected to maintain ground continuity (Section E3905.6). Don't install track lighting using a flexible cord connected to an outlet receptacle.

IRC Section E3905.4 says you must not install track lighting where:

- Physical damage is possible
- Wet or damp conditions may occur
- Corrosive vapors are possible
- The location is classified as hazardous
- The location is concealed
- The track would extend through a wall or partition
- The track would be within 5 feet of the floor, unless protected from damage
- The track would be within a space 3 feet horizontally and 8 feet vertically from the top of a bathtub rim

This completes our review of the Electrical section of the IRC. For complete information on electrical installations, get a copy of NEC 2005, Pocket Guide to Residential Electrical Installations by Charles Miller. It's published by the National Fire Protection Association and is available at their online bookshop, www.nfpa.org/catalog.



What's Your Category?

I've been inspecting buildings for a long time. I try not to, but I can't avoid putting the contractors I deal with into one of five categories. Normally, I don't talk about this, but I want to share it with you. There's a reason. You should know enough to stay out of the wrong categories!

Category A contractors could get a permit from me on their say-so alone. I've even looked the other way when one of these guys had to start a job in a hurry, before the plans were drawn or a permit issued. You get to be a Category A contractor by knowing as much or more about building and the code as anyone in the community. You do nothing but quality work that meets the highest professional standards, no matter what the situation and no matter who's watching. Category A contractors usually get the best jobs from owners with the deepest pockets. They're nearly always busy. Though this is a small group, they set a good example for everyone in the industry.

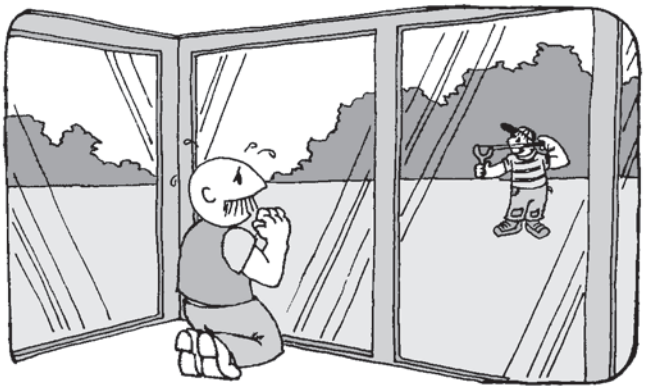
Category B contractors know as much about construction as Category A contractors. But they have to buy most jobs with low bids or by hustling a little harder. This is a large group. If nothing bad happens, Category B contractors turn out good work at bargain prices. But when the fat hits the fire, Category B guys will cut corners. They'll compromise on quality to save their margin. They'll let a few things slide by if no one is going to notice. That's why I have to notice.

Category C contractors don't know as much about construction as either Category A or Category B contractors. Most would like to be as skilled as their more experienced brethren. But they don't know how. Few knowingly try to cheat the owner or confuse the inspector. But inexperience and carelessness show in their work. Not all Category C contractors are new at building. They just don't learn as fast as others. That's why I'm patient with them. I'll explain anything as often as necessary. But I keep my eyes open. Again, this is a large group.

Category D contractors just don't seem to care. They usually know what they should be doing, but they aren't going to do it until someone makes them. That someone is usually me. I won't use the word lazy for these guys. Maybe the word sluggish is better.

Category F contractors stand alone. I sometimes wonder what makes these guys tick. You could camp out in the middle of the project and Category F contractors would still try to cheat and get around you any way they can. It's almost a game with them.

A couple of years ago, I gave a talk to our local home builders' association. I explained my five construction categories. That was a mistake. My little talk hurt the pride of some good builders and friends who don't happen to be at the top of my list. So I don't say much about my categories anymore. In fact, I wish I'd never said anything. But you should know that everyone in the construction industry is earning a reputation every day — either for craftsmanship and professionalism, or for the lack of it. My advice is simple. Guard your professional reputation like you protect your favorite saw. Nothing you're likely to own is more valuable. And once it's lost, it's hard to recover.



CHAPTER 22

Glass, Glazing, Skylights and Patio Covers

Glazing is an important part of building construction. Who wants to live in a house without windows? And skylights, which are great sources of additional lighting, are becoming more popular every day.

Glass and Glazing

You and I might call it glass and glazing, but architects and engineers call it *fenestration*. The word comes from the Latin, *fenestra*, which means window. So, if you fenestrate, you install windows. When I was a builder, I can't ever remember fenestrating, but I sure installed a lot of windows!

Let's start with a definition from IRC Section R202 and some of the basics from Section R303.

> ***Glazing area:*** *The interior surface area of all glazed fenestration, including the area of sash, curbing or other framing elements, that enclose conditioned space. Includes the area of glazed fenestration assemblies in walls bounding conditioned basements.*

The glazing area (windows) of all rooms where people live must be at least 8 percent of the floor areas, unless adequate mechanical ventilation and artificial lighting is provided. For example, a living room that's 15 feet by 20 feet (300 square feet) must have at least 24 square feet (0.08 × 300 = 24) of window area. (See Section R303.1 and its exceptions.) This is the *minimum* requirement. Most people would like more than that. If you plan to install much larger windows, make sure you comply with your local energy conservation code.

Each state has adopted its own energy code. Some states, such as Washington and Alaska, have adopted specific energy codes, and some use the International Energy Conservation Code (IECC) (available at www.iccsafe.org) or a slightly modified version. Typically, these codes regulate the amount of glazing allowed — sometimes as a percentage of floor area and sometimes as a

function of wall area. To understand the difference between energy codes, energy standards, and the model energy code, check the U.S. Department of Energy's site at www.energycodes.gov/implement/pdfs/codes101.pdf.

The *openable* window area has to be at least 4 percent of the floor area. So, staying with the same example — for the 300-square-foot living room, there must be 12 square feet of openable window area. And these window(s) must be easily accessible or readily controlled by the building occupants.

An adjoining room can also be a source of light and ventilation — if at least half of the common wall is open. The opening must be at least 10 percent of the floor area of the interior room, and not less than 25 square feet; see IRC Section R303.2. The minimum opening area is 20 square feet if the exterior room is a sunroom addition.

Bathrooms and toilet areas usually need at least 3 square feet of window area, and half of this must be openable; see Section R303.3. Do you need windows in bathrooms and toilet areas? Not necessarily. But you must provide artificial light, and at least 20 cfm of continuous (always running) or 50 cfm of intermittent (turned on and off by a switch) ventilation to the outside.

Glass Thickness Required

Before the year 2000, codes included graphs and guidance on glass thickness and type for areas of glass in different wind load conditions. Chapter 24 of the IBC now gives you formulas, graphs and modification factor tables to make these calculations. Most contractors don't have time to work through them, so I won't make you do it, either. Just contact your local glass supplier and give them a list with the locations and dimensions of your glazing areas. Let them do the calculations for you.

However, if you want to do your own calculations, you can buy a software package from Standards Design Group, Inc. of Lubbock, Texas, for window glass design, which includes finding the wind load on structures. Their website is www.standardsdesign.com.

The IRC assumes you'll buy the windows you need from your supplier, so that code focuses on approved anchoring methods rather than calculations for window thickness and type; see Section R613.8.

Window Anchorage Methods

Anchor windows and glass doors according to the manufacturer's instructions in order to achieve the design pressure specified by the plans. They should be firmly anchored to the building's main force-resisting system (walls) as illustrated in IRC Figures R613.8(1) through R613.8(8).

Anchoring to Masonry, Concrete or Other Structural Substrate

A window opening should always be a bit larger than the window being installed. This allows for an easy fit, as well as room to adjust the window so that it's plumb and square. If it isn't plumb and square, it may not open properly or close tightly. Where there's adequate clearance, you can anchor a treated wood frame to a brick or concrete opening and secure the window to the frame. Sometimes, however, the opening is just slightly larger than the window being installed. In that case, you'll need to use other methods to secure the window. Follow the manufacturer's installation instructions carefully. There are always minimum clearances to allow for expansion, and often there's a clearance required for special mounting brackets or jamb clips.

It's difficult to anchor directly to brick or concrete, so you must take extra care when jamb mounting. The installation instructions may call for wood shims (thin tapered strips) or bucks (continuous strips of wood). Unlike shims, bucks may not be tapered or thinner on one end or side. The IRC gives the following directions on their use. Where the wood shim or buck thickness is less than 1½ inches, anchor the window or glass door assemblies through the jamb, as shown in IRC Figure R613.8(1) (Figure 22-1). It's important to shim correctly and to not stress the window jamb when securing through the frame.

IRC FIGURE R613.8(1)

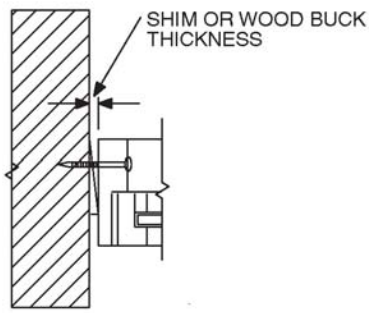
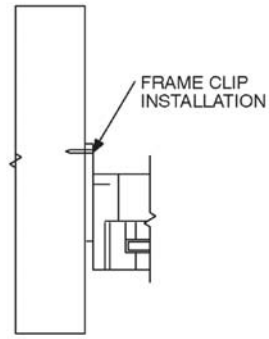


Figure 22-1 Secure through the frame

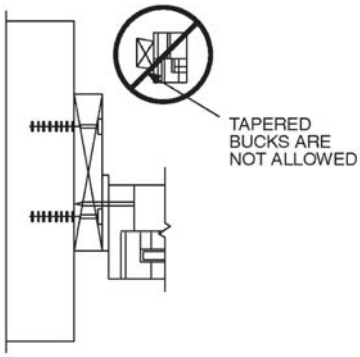
IRC FIGURE R613.8(2)



APPLY FRAME CLIP TO WINDOW OR DOOR IN ACCORDANCE WITH PUBLISHED MANUFACTURER'S RECOMMENDATIONS.

Figure 22-2 Anchor using frame clip

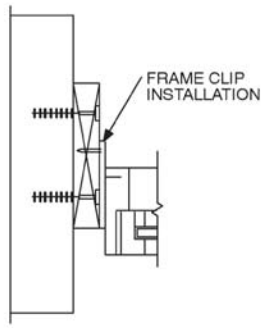
IRC FIGURE R613.8(3)



THROUGH THE FRAME ANCHORING METHOD. ANCHORS SHALL BE PROVIDED TO TRANSFER LOAD FROM THE WINDOW OR DOOR FRAME INTO THE ROUGH OPENING SUBSTRATE.

Figure 22-3 Anchor through the frame

IRC FIGURE R613.8(4)



APPLY FRAME CLIP TO WINDOW OR DOOR FRAME IN ACCORDANCE WITH PUBLISHED MANUFACTURER'S RECOMMENDATIONS. ANCHORS SHALL BE PROVIDED TO TRANSFER LOAD FROM THE FRAME CLIP INTO THE ROUGH OPENING SUBSTRATE.

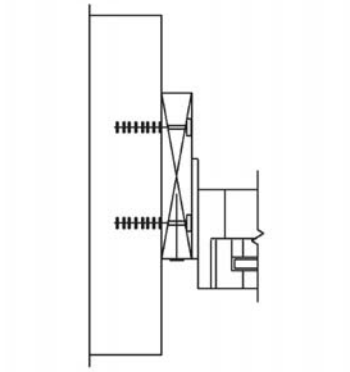
Figure 22-4 Anchor using frame clip

If you're using jamb clips and anchors, embed them directly into the masonry or concrete; IRC Figure R613.8(2) (Figure 22-2). The anchors must be capable of transferring the load from the window or door frame into the rough opening substrate; see Section R613.8.2.1.

Where the wood shim or buck thickness is 1½ inches or more, fasten the buck to the masonry or concrete frame. Don't use tapered bucks. If the buck extends past the interior face of the window, anchor the window using one of the methods illustrated in the following figures:

- Through the frame, IRC Figure R613.8(3) (Figure 22-3)
- By jamb clip, IRC Figure R613.8(4) (Figure 22-4)
- Through the flange to the secured wood buck, IRC Figure R613.8(5) (Figure 22-5)

IRC FIGURE R613.8(5)



APPLY ANCHORS THROUGH FLANGE IN ACCORDANCE WITH PUBLISHED MANUFACTURER'S RECOMMENDATIONS.

Figure 22-5 Anchor through the flange

IRC FIGURE R613.8(6)

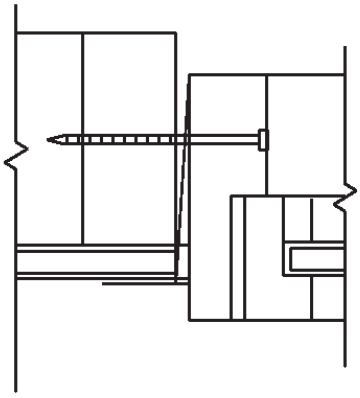


Figure 22-6 Anchor through the frame

Anchoring to Wood or Other Approved Framing Material

The same cautions and notes for masonry anchoring also apply to installing windows in a wood frame wall. But there are some additional considerations to watch for. When you look at the installations illustrated in Figures 22-6 through 22-8, note that the flange is outside the wall sheathing. This is very important. The flange on the bottom of the window should be outside, or on top of the building paper or flashing. If "moisture stop" is used to wrap the window frame, then the flange should be on top of it on all sides, but the flange should be inside the building paper or membrane on the sides and top of the window.

Use one of the following methods to anchor windows to wood or other approved framing materials:

- Through the frame, IRC Figure R613.8(6) (Figure 22-6)
- By frame clip, IRC Figure R613.8(7), (Figure 22-7)
- Through the flange, IRC Figure R613.8(8), (Figure 22-8)

Check the clearances for sides, top, and sill specified by the manufacturer, and the required anchoring. Often, the instructions will tell you not to nail the flange on the head (and sometimes the sill) even though these flanges may have nail holes provided.

I can't stress enough the need to follow the manufacturer's instructions for every product you use. There are many high-tech products that appear similar, but each has specific individual characteristics. Moisture damage claims are probably the biggest single issue keeping home insurance costs high and construction lawyers in business. Many of these are the result of poorly fitted or installed doors and windows.

IRC FIGURE R613.8(7)

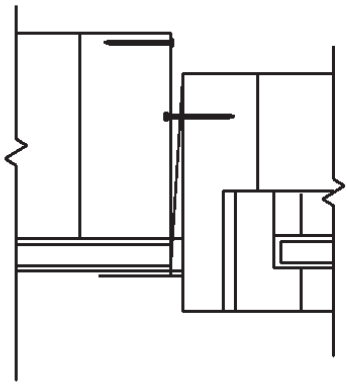


Figure 22-7 Anchor using frame clip

IRC FIGURE R613.8(8)

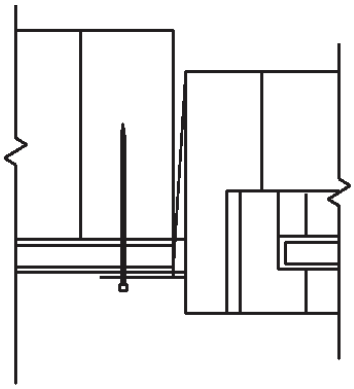


Figure 22-8 Anchor through the flange

Glazing Subject to Human Impact Loads

IRC Section R308.3 deals with a subject important to all builders. It covers the types of glazing you can use in windows and doors in hazardous locations; in other words, where they can be accidentally hit or broken by people. We'll look at hazardous locations in more detail shortly. Here are a few examples of locations where you'll need to install code-approved glazing materials:

- Glass doors
- Glazing next to doors
- Sliding glass doors
- Storm doors
- Shower doors
- Bathtub enclosures
- Glazing close to any walking surface

There are five types of glazing materials that are acceptable for use in hazardous locations. They are:

1. Laminated glass
2. Fully-tempered glass
3. Heat-strengthened glass
4. Wired glass
5. Approved rigid plastics

Section R308.3 says that these products must meet the Consumer Products Safety Commission standard, CPSC 16 CFR Part 1201, Safety Standard for Architectural Glazing Materials (1977). You can find it on the CPSC website at www.access.gpo.gov/nara/cfr/waisidx_04/16cfr1201_04.html.

There's a list of hazardous location glazing types in Table 308.3 (Figure 22-9). It refers to two different classes: Category I and Category II. What's the difference between these two categories? Check the CPSC standard. There are two tests to classify glazing materials; an impact test and an accelerated environmental durability test.

The impact test determines how much force a glazing material can withstand. You won't have to perform it, but it's helpful to understand how materials are classified.

The impact test uses a leather punching bag filled with 100 pounds of lead shot. The material test sample is the largest size manufactured — up to 34 inches by 76 inches. The sample

TABLE R308.3
MINIMUM CATEGORY CLASSIFICATION OF GLAZING

EXPOSED SURFACE AREA OF ONE SIDE OF ONE LITE	GLAZING IN STORM OR COMBINATION DOORS (Category Class)	GLAZING IN DOORS (Category Class)	GLAZED PANELS REGULATED BY ITEM 7 OF SECTION R308.4 (Category Class)	GLAZED PANELS REGULATED BY ITEM 6 OF SECTION R308.4 (Category Class)	GLAZING IN DOORS AND ENCLOSURES REGULATED BY ITEM 5 OF SECTION R308.4 (Category Class)	SLIDING GLASS DOORS PATIO TYPE (Category Class)
9 sq ft or less	I	I	NR	I	II	II
More than 9 sq ft	II	II	II	II	II	II

For SI: 1 square foot = 0.0929 m^2.

Figure 22-9 Glazing classification

is held horizontally, fully supported on all four sides, and the punching bag is dropped on the center of the sample (plus or minus 2 inches). The height of the drop is 18 to 18½ inches for Category I, and 48 to 48½ inches for Category II. The higher drop creates a much greater impact force on the test sample. So, Category II glass must be considerably stronger than Category I to withstand the more demanding test.

The sample passes the test if any of the following occurs:

- The sample doesn't break.
- The sample breaks, but the 10 largest pieces don't weigh more than the weight of 10 square inches of the glazing material.
- The sample breaks, but there's no opening big enough for a 3-inch-diameter solid steel ball weighing 4 pounds, 13 ounces to fall through. The ball is placed gently on the opening and left there for one second.

There's a lot more detail on the standard and the tests that you can read when you have time. But this gives you a good idea of the strength of safety glass. It has to be pretty strong to withstand a 100-pound weight dropped from a height of 4 feet. And it needs to be. How many times have you heard of people running into their sliding glass (Category II) patio doors?

Identification of Safety Glazing

Both you and the inspector want to be sure that the glazing material you're installing meets safety standards. Safety glass has to carry . . . *a manufacturer's designation specifying who applied the designation, designating the type of glass and the safety glazing standard with which it complies, which is visible in the final installation* (Section R308.1). The marking must be non-removable. If a sticker is used, it must not be possible to remove it without destroying the sticker.

Hazardous Locations

Now let's look at the list of hazardous glazing material locations in IRC Section R308.4. This is the condensed version — if you need more detail, read this section of the IRC.

1. Swinging doors, except for louvers and jalousies.
2. Unframed swinging doors.
3. Fixed and sliding panels of sliding doors or bi-fold closet doors.
4. Storm doors.
5. Doors and enclosures for bathtubs and showers, hot tubs, whirlpools, saunas and steam rooms or glazing in any part of a building wall enclosing these compartments if the bottom edge of the glass is less than 60 inches above the floor.
6. Fixed or operable panels next to a door where the glazing is within 24 inches of the door and the bottom edge of the glazing is less than 60 inches above the floor.

   There's an exception if a wall or permanent barrier is between the door and the panel. Panels at right angles to the door frame are not hazardous locations unless they're in the wall against which the door opens, or the door gives access to a closet or storage area 3 feet deep or less.
7. Fixed or operable panels, except for the locations mentioned in items 5 and 6 above, that meet all four of the following conditions (there's an exception if a protective bar is installed; see Section R308.4, Exception 5):
   i. An exposed area of an individual panel is greater than 9 square feet
   ii. The bottom edge is less than 18 inches above the floor
   iii. The top edge more than 36 inches above the floor
   iv. There's a walking surface within 36 inches horizontally of the panel
8. Glazing in railings, including structural baluster panels and nonstructural infill panels, regardless of area or height above a walking surface.
9. Walls and fences enclosing indoor and outdoor swimming pools, hot tubs and spas, where the glazing is

within 60 inches of the water's edge and the bottom edge is less than 60 inches above a walking surface.

10. Walls adjacent to stairways, landings and ramps within 36 inches of a walking surface, where the exposed surface of the glass is less than 60 inches above the walking surface. (There's an exception if a protective bar, handrail, guardrail or guard wall is installed; see Section R308.4, Exceptions 5 and 9.)
11. Walls adjacent to stairways within 60 inches of the bottom tread, when the exposed surface of the glass is less than 60 inches above the nose of the tread. Again, there's an exception if a protective bar, handrail, guardrail or guard wall is installed; see Exception 9.

If you look back at Table 308.3 (Figure 22-9), you'll see that for most of these locations you'll need to install a Category II glazing material. Category II materials are required when the exposed surface area of one side of one lite is greater than 9 square feet. Don't get caught installing regular glass where safety glass is required. You won't want to have to change it out after the final inspection, and you won't get your Certificate of Occupancy until you make it right.

The following locations are *not* considered hazardous and don't require special materials:

- Glazed openings in doors too small for a 3-inch sphere to pass through.
- Decorative glass in swinging doors and fixed or operable panels that a 3-inch sphere can't pass through.
- Outboard panes in insulating glass panels within 36 inches of a walking surface, but where the bottom edge of the glass is at least 25 feet above the walking surface, grade or a roof.
- Louvered windows or jalousies at least nominal $^{3}/_{16}$-inch thick and no longer than 48 inches; see Section R308.2. The exposed glass edges must be smooth. Wired glass with exposed wire on the long edges can't be used.
- Mirrors and glass panels mounted or hung on surfaces that provide continuous backing support.
- Glass block panels used as masonry units; see Section R610.

Skylights

Skylights are covered in Section R308.6 of the IRC, and in two chapters of the IBC: Chapter 24, which covers glass skylights; and Chapter 26, which discusses plastic skylights.

Here's how the IRC defines skylights:

> ***Skylights and sloped glazing:*** *Glass or other transparent or translucent glazing material installed at a slope of 15 degrees (0.26 rad) or more from vertical. Glazing materials in skylights, including unit skylights, solariums, sunrooms, roofs and sloped walls are included in this definition.*
>
> ***Unit skylight:*** *A factory assembled, glazed fenestration unit, containing one panel of glazing material, that allows for natural daylighting through an opening in the roof assembly while preserving the weather-resistant barrier of the roof.*

Skylight Materials

The same types of glazing materials used for safety glazing can be used in skylights:

- Laminated glass
- Fully tempered glass
- Heat-strengthened glass
- Wired glass
- Approved rigid plastic

Approved rigid plastic panes are the most common material used for unit skylights.

For laminated glass used in skylight panels, the required thickness of the polyvinyl butyral (PVB) interlayer depends on the surface area of the skylight and its height above the walking surface; see IRC Section R308.6.2, Item 1. If the surface area is 16 square feet or less and the

highest point of the glass above a walking surface is not more than 12 feet, the minimum thickness of the interlayer can be 0.015 inch. For larger surface areas and greater heights, the interlayer thickness must be at least 0.030 inch.

If you want to use fully tempered or heat-strengthened glass, you may have to install a wire safety screen below the skylight. That depends on the skylight area, slope and height above the walking surface (IRC Sections R308.6.3 through R308.6.5). Screen features are given in IRC Section R308.6.7.

Glass Skylights

IBC Section 2405.2 states that all monolithic (single-pane) or multi-layer glazing systems used as skylights must be made of laminated glass (with a minimum 30-mil PVB or equal interlayer), wired glass, or heat-strengthened or fully tempered glass.

Standard annealed glass can only be used in a skylight if:

- The walking surface below is permanently protected from falling glass or the area below the skylight isn't a walking surface, or
- The skylight is part of a commercial or detached noncombustible greenhouse, and the height of the greenhouse at the ridge doesn't exceed 30 feet above grade. The greenhouse can only be used for growing plants, and it can't be open to the public.

If you install heat-strengthened or fully tempered glass in a single-layer skylight, include a protective screen below, but within 4 inches, of the glazing. The screen must:

- Support twice the weight of the glass;
- Be firmly fastened to the supports;
- Be made of a noncombustible material, at least 0.08 inch thick, with 1-inch by 1-inch mesh or smaller.

There are more details and several exceptions. Be sure to check IBC Section 2405.3 if you're thinking about installing glass skylights without screens.

Mounting

Skylight frames must be built of noncombustible materials in all buildings except Types III, IV and V. A curb may be required for the skylight frame. Even if it isn't required, curbing is a good idea. It's neater and provides a more leak-resistant skylight. The skylight must be able to carry any roof load (rain, snow, wind) routed to it. If the roof slope is 45 degrees or more, you can install the skylight in the plane of the roof; see IBC Section 2405.4. If the slope is at an angle less than 45 degrees, mount the skylight at least 4 inches above the plane of the roof.

Pre-formed skylights have to comply with the American Architectural Manufacturers Association standard, AAMA/WDMA/CSA 101/I.S.2/A440. And that approval must be stated on the label; see IBC Section 2405.5. A short version of the standard is on the AAMA website at www.aamanet.org/upload/CMB-5-05.pdf.

Plastic Skylights

Pre-formed skylights are almost always made from a light-transmitting plastic, such as Plexiglas or a similar plastic. The mounting specs are nearly the same as for glass skylights. Mount the skylight on a curb at least 4 inches above the plane of the roof; see IBC Section 2610.2. Protect the edges of the skylight with metal or other noncombustible material.

Flat or corrugated plastic skylights must have a 1 in 3 (33 percent) slope, or about 18½ degrees. Dome-shaped skylights must rise above the mounting flange by at least 10 percent of the maximum span of the dome, but not less than 3 inches; see Section 2610.3. So, for a 24-inch by 36-inch domed skylight, with a maximum span of 36 inches, the dome must rise at least 3.6 inches above the mounting flange (10 percent of 36 inches is 3.6 inches).

The maximum area of plastic skylight allowed within a single curb is 100 square feet. There's an exception if the building has smoke and heat vents or an automatic sprinkler system; see IBC Section 2610.4. The total skylight area in a roof can't be more than:

- One-third of the floor area sheltered by the roof for Class CC1 materials
- One-fourth of the floor area sheltered by the roof for Class CC2 materials

These areas can be doubled to two-thirds and one-half, respectively, if the building has smoke and heat vents or an automatic sprinkler system.

What are CC1 and CC2 materials? IBC Section 2606.4 defines them as:

> ***Class CC1:*** *Plastic materials that have a burning extent of 1 inch (25mm) or less where tested at a nominal thickness of 0.06 inch (1.5 mm), or in the thickness intended for use, in accordance with ASTM D 635.*
>
> ***Class CC2:*** *Plastic materials that have a burning rate of 2.5 inches per minute (1.06mm/s) or less where tested at a nominal thickness of 0.06 inch (1.5 mm), or in the thickness intended for use, in accordance with ASTM D 635.*

Finally, plastic skylights must be separated from each other by at least 4 feet. There's an exception if the building is fully sprinklered, or in some Group R-3 occupancies (IBC Section 2610.6). Also, you can't install a plastic skylight within 6 feet of an exterior wall if that wall has an opening that needs protection; see IBC Section 704.8 and Table 704.8 (IBC Section 2610.7).

Other Plastic Applications

The word plastic is a broad term covering many different materials. Chapter 26 of the IBC discusses these plastic applications:

- Foam plastic insulation, Section 2603
- Interior finish and trim, Section 2604
- Plastic veneer, Section 2605
- Light-transmitting plastics, Section 2606
- Light-transmitting plastic wall panels, Section 2607
- Light-transmitting plastic glazing, Section 2608
- Light-transmitting plastic roof panels, Section 2609
- Light-transmitting plastic skylight glazing, Section 2610
- Light-transmitting plastic interior signs, Section 2611

The code uses the term light-transmitting plastic. It's so called to indicate a difference from the general term plastic — which just means that the material's capable of being molded (even concrete, in its liquid form, is plastic).

There have been countless technological advances and changes in plastics over the years, keeping the engineers and code-writers on their toes. Now, plastics are used in many building applications. These include:

- Foam insulation
- Light-transmitting exterior wall and roof panels
- Skylights
- Light-diffusing systems for electrical fixtures
- Partitions
- Awnings
- Patio covers
- Canopies
- Solar collectors

The main requirement of plastic is that it has enough strength and durability to withstand design loads. Methods of installing plastics aren't clearly defined in the code. And it isn't too specific about fastenings, either. Fasteners must also be able to withstand the design load and include space for the expansion and contraction of the material. Your job is to satisfy the inspector with the quality of your material. If you're using a well-known brand, this shouldn't be a problem. The inspector will most likely be familiar with it.

Light-Transmitting Plastic Glazing Material

In a Type VB building (the least fire-resistant construction type), doors, sashes and framed openings that don't have to be fire protected can be glazed with any approved plastic material; see Section 2608.1.

But the use of plastics is more regulated in other building types. For instance, light-transmitting plastic glazing can't cover more than 25 percent of any wall surface on any story. No single pane of plastic glazing material above the first story can be higher than 4 feet

or have an area of more than 16 square feet, per IBC Section 2608.2. You can increase this area by 50 percent for fully-sprinklered buildings.

You can't install light-transmitting plastic glazing more than 75 feet above grade. And here's an unusual requirement. You must install an approved flame barrier between plastic glazed units in adjacent stories. This can be either a horizontal barrier or vertical panels. Extend the barrier at least 30 inches beyond the exterior wall in the plane of the floor. If you install vertical panels, they must be at least 4 feet high. This is to deflect heat from any fire below so the plastic won't melt, which would be extremely hazardous to people and property. But, remember, you don't have to meet this requirement if your building is fully sprinklered.

Light-Transmitting Plastic Roof Panels

Light-transmitting plastic materials are commonly used for roof panels. But plastic roof panels can't be used in Groups H (high-hazard), I-2 (hospitals, etc.), and I-3 (prisons, etc.). Light-transmitting roof panels can be used in all other occupancy types if all three of the following situations exist:

1. The building is fully sprinklered.
2. The roof construction doesn't need a fire-resistance rating according to IBC Table 601 (refer back to Figure 4-4 in Chapter 4 of this book). That means that light-transmitting roof panels can only be used for Types IIB, IIIB or VB construction.
3. The roof panels meet the requirements of IBC Chapter 15. But Chapter 15 doesn't address light-transmitting roof panels specifically, so it's easier to just ask the inspector if your application meets the code. And that's a lot faster than skimming through Chapter 15 looking for reasons why it doesn't!

If light-transmitting roof panels are acceptable for your application, there are still restrictions similar to those for plastic skylights. Individual plastic roof panels must be separated from each other by at least 4 feet. There are exceptions for fully-sprinklered and low-hazard buildings (like pool shelters and commercial greenhouses); see Section 2609.2.

IBC TABLE 2609.4 AREA LIMITATIONS FOR LIGHT-TRANSMITTING PLASTIC ROOF PANELS		
CLASS OF PLASTIC	MAXIMUM AREA OF INDIVIDUAL ROOF PANELS (square feet)	MAXIMUM AGGREGATE AREA OF ROOF PANELS (percent of floor area)
CC1	300	30
CC2	100	25

For SI: 1 square foot = 0.0929 m^2.

Figure 22-10 Area limitations for light-transmitting plastic roof panels

Don't install plastic roof panels within 6 feet of an exterior wall with an opening that requires protection; see IBC Section 704.8 and Table 704.8 (refer to Figure 7-1 back in Chapter 7). The maximum area of plastic roof panel is limited to the square footage or a percentage of the floor area sheltered, depending on the class of plastic; see IBC Table 2609.4 (Figure 22-10).

This area limitation can be doubled in a fully-sprinklered building. Usually there's no area limitation for low-hazard buildings, commercial greenhouses or terrace and patio roof coverings in Group R-3.

Patio Covers

Appendix H of the IRC talks about patio covers. They're defined in Section AH102:

> ***Patio covers.*** *One-story structures not exceeding 12 feet (3657 mm) in height. Enclosure walls shall be permitted to be of any configuration, provided the open or glazed area of the longer wall and one additional wall is equal to at least 65 percent of the area below a minimum of 6 feet 8 inches (2032 mm) of each wall, measured from the floor. Openings shall be permitted to be enclosed with (1) insect screening, (2) approved translucent or transparent plastic not more than 0.125 inch (3.2 mm) in thickness, (3) glass conforming to the provisions of Section R308, or (4) any combination of the foregoing.*

Let's make this simple. You can enclose the patio with partial walls if the longer wall and one other wall are open or glazed for at least the top 65 percent of the wall height. If the patio sides are a minimum 6 feet 8 inches, you can only enclose the bottom 35 percent of these two sides. That would make your wall height, on average, 2 feet 4 inches (35 percent of 6 feet 8 inches). You can make the wall height less than the code maximum, but not more. If the patio sides are 10 feet high, then the enclosing wall height on these two sides can't be higher, on average, than 3 feet 6 inches (35 percent of 10 feet). The top 65 percent of the wall can be screened or glazed with an approved glass or light-transmitting plastic, or left open.

Patio Cover Uses

IRC Section AH103 covers the allowed uses of patio covers:

> ***AH103.1 General.*** *Patio covers shall be permitted to be detached from or attached to dwelling units. Patio covers shall be used only for recreational, outdoor living purposes and not as carports, garages, storage rooms or habitable rooms.*

That last phrase, "*and not as carports, garages, storage rooms or habitable rooms*," is very important. Some manufacturers claim you can use their patio covers for carports. But the code says you can't. Find out if the unit is a patio cover or a carport. And don't take that fast-talking salesman's word for it! Get the manufacturer's name, make, model number, and product specs. Then call the inspector. He'll check his Evaluation Reports and find out if the patio cover is approved for your application. If it's a common national brand, he'll have the information for you quickly. You'll need his approval when you apply for a permit, anyway, so you might as well start off on the right foot.

Where the frost line depth is zero, as shown in IRC Table R301.2(1) (look back to Figure 1-1, in Chapter 1), you can install a patio cover on a slab on grade without footings; see IRC Section AH106. But the concrete slab must be at least 3½ inches thick. You can form the slab with 2 x 4s to give it this thickness. Of course, this assumes that the patio cover won't be supporting live or dead loads of more than 750 pounds per column.

Patio covers and carports are subject to stresses and strains not found in other structures. They have to withstand the stress limits of the code, all dead loads, and a minimum vertical live load of 10 pounds per square inch. And one other very critical load: the uplift load. Because of their construction, patio covers and carports are vulnerable to uplift. They have to resist a minimum wind uplift load equal to the horizontal wind load pushing upward against the roof surface. But if your patio cover is less than 10 feet above grade, the uplift load you must use is only 75 percent of the horizontal wind load.

That concludes our review of glass, glazing, skylights and patio covers. Next we'll look at accessibility. That's accessibility for the disabled, not just general access to specific areas as we've encountered before.

Speak Softly and Carry a Big Stick

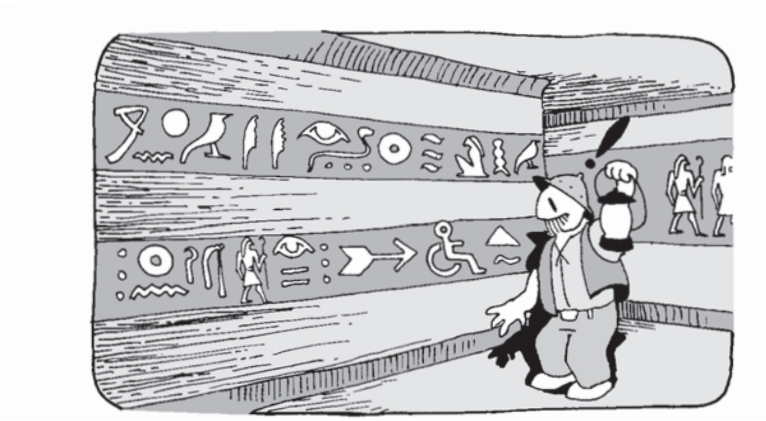
Every building inspector's big stick is his or her code-authorized authority to issue a stop work order. If I stopped work every time I saw a code violation in progress, some jobs would come to a screeching halt several times a month. But that doesn't happen. Our job is to work with contractors. You give them notice of the violation and an opportunity to fix it. They're not the enemy — and neither should you be.

Many building departments go years without halting a job. In fact, I've known inspectors who've served an entire career without using that big stick. And that's really best for everyone. If you shut down a job, you'd better be sure about what you're doing and be ready to take the heat. The contractor in question is likely to go over your head and call the mayor or someone on the city council, claiming that some ignorant fool in the building department is doing permanent damage to the city.

Most stop work orders happen after a bond of trust has been broken. I remember a situation where a utility contractor was getting ready to install a building sewer on private property. The inspector suspected the contractor might not be licensed, and he needed a day or so to confirm with the state license board. On Friday afternoon, the inspector got a pledge from the job superintendent that he would hold off on the sewer work until the license issue was resolved. The following Tuesday, the inspector drove out to the job and found 500 feet of 8-inch sewer pipe had been installed and backfilled. The inspector invoked IBC Section 114.1 and issued a stop work order. He had no choice.

By nightfall, the city manager, city attorney and city council were all involved. They had a well-known licensed plumber do the top-off test. The pressure test was fine. Then they rolled a golf ball down the 500 feet of pipe to check the pipe grade. But it never rolled out the other end. The golf ball must have found a low spot and settled there. I guess if the ball had rolled out at the public sewer end, the inspector would have signed off on the job, and that would have been the end of it — though I've never found anything in the code about doing an inspection with a golf ball. However, it turned out that the contractor was licensed, but he still ended up having to dig up 500 feet of sewer pipe to correct the grade. He was in such a hurry to get the sewer work done, he didn't take the time to do it right.

The code gives building inspectors an even bigger sword to wield, if necessary. That's the right to issue a citation for unlawful continuance (IBC 114.3 and IRC R114.2). Most building inspectors don't need to issue citations. The threat of withholding a Certificate of Occupancy gives us plenty of leverage. But inspectors who check existing buildings for life safety issues sometimes need that extra muscle. A citation carries the threat of legal penalties for continuing work after being served with a stop work order, or failure to perform work to remove an unsafe condition. That usually gets a contractor's attention!



CHAPTER 23

Accessibility for the Disabled

If you're in commercial construction or construct residential buildings that include four or more dwelling units, this chapter is one you should read carefully. The Americans with Disabilities Act of 1990 ushered in a new era of awareness regarding the rights of the disabled — and the regulations required to convert awareness into action for the millions of disabled people whose access to public buildings and facilities had been limited or denied.

If you build only one- and two-family dwellings, you probably already know that they're exempt from disabled access requirements. The IRC only mentions this briefly in Sections R322.1 and R323.3:

> ***R322.1 Scope.*** *Where there are four or more dwelling units or sleeping units in a single structure, the provisions of Chapter 11 of the International Building Code for Group R-3 shall apply.*

> ***R323.3 Accessibility.*** *Elevators or platform lifts that are part of an accessible route required by Chapter 11 of the International Building Code, shall comply with ICC A117.1.*

ICC A117.1 is the *Accessible and Usable Buildings and Facilities* standard adopted by the International Code Council (ICC) from the American National Standards Institute (ANSI) standard. It's available at the ICC website at www.iccsafe.org. If you purchase the 2006 I-Codes on the CD Designer Collection, it's included on the CD-ROM along with the IBC and the IRC.

What do these two sections mean? Simply stated, disabled access requirements don't apply to Type R occupancy buildings with fewer than four dwelling units. This is confirmed in Section 1103.2.4 of the IBC:

> ***1103.2.4 Detached dwellings.*** *Detached one- and two-family dwellings*

and accessory structures, and their associated sites and facilities, are not required to be accessible.

So, you can skip the rest of this chapter if you build only one- and two-family homes or townhouses with no more than three dwelling units.

Or, you can read on and perhaps learn something valuable that you might need for future jobs.

Effects of Accessibility Requirements on Construction

The Americans with Disabilities Act of 1990 changed everything in the construction industry. All buildings except those containing one to three dwelling units were affected. Contractors could no longer build a set of steps and say they were an entrance or exit. Chapter 11 on Accessibility in the Uniform Building Code was completely rewritten for the 1994 edition. And the accessibility requirements of the code have been changing ever since. Accessibility is still covered in Chapter 11 of the IBC, but that's about the only thing that's remained the same. Take accessibility requirements seriously or you'll have big problems.

The code only gives minimums. You might want to do more, or your local building department may insist on more. Ask your inspector if local regulations are stricter than the IBC.

Definitions and Requirements

The terms *accessible* and *accessibility* refer to the physically disabled. See IBC Section 1101.1:

> ***1101.1 Scope.*** *The provisions of this chapter shall control the design and construction of facilities for accessibility to physically disabled persons.*

The code also uses these terms when it discusses access to equipment for maintenance, etc. But it's usually quite obvious when the code is addressing access for people who aren't disabled. If you have any questions, ask your building official.

We'll start with some definitions from IBC Section 1102. Once you understand the definitions, you'll know what to look for.

> ***Accessible:*** *A site, building, facility or portion thereof that complies with this chapter.*
>
> ***Accessible route:*** *A continuous, unobstructed path that complies with this chapter.*
>
> ***Accessible unit:*** *A dwelling unit or sleeping unit that complies with this code and the provisions for Accessible units in ICC A117.1.*
>
> ***Circulation path:*** *An exterior or interior way of passage from one place to another for pedestrians.*
>
> ***Common use:*** *Interior or exterior circulation paths, rooms, spaces or elements that are not for public use and are made available for the shared use of two or more people.*
>
> ***Detectable warning:*** *A standardized surface feature built in or applied to walking surfaces or other elements to warn visually impaired persons of hazards on a circulation path.*
>
> ***Dwelling unit or sleeping unit, multistory:*** *A dwelling unit or sleeping unit with habitable space located on more than one story.*
>
> ***Dwelling unit or sleeping unit, Type A:*** *A dwelling unit or sleeping unit designed and constructed for accessibility in accordance with this code and the provisions for Type A units in ICC A117.1.*
>
> ***Dwelling unit or sleeping unit, Type B:*** *A dwelling unit or sleeping unit designed and constructed for accessibility in accordance with this code and the provisions for Type B units in ICC A117.1, consistent with the design and construction requirements of the federal Fair Housing Act.* (See www.usdoj.gov/crt/housing/title8.htm for more details.)

Employee work area: *All or any portion of a space used only by employees and only for work. Corridors, toilet rooms, kitchenettes and break rooms are not employee work areas.*

Intended to be occupied as a residence: *This refers to a dwelling unit or sleeping unit that can or will be used all or part of the time as the occupant's place of abode.*

Multilevel assembly seating: *Seating that is arranged in distinct levels where each level is comprised of either multiple rows, or a single row of box seats accessed from a separate level.*

Public entrance: *An entrance that is not a service entrance or a restricted entrance.*

Public-use areas: *Interior or exterior rooms or spaces that are made available to the general public.*

Restricted entrance: *An entrance that is made available for common use on a controlled basis, but not public use, and that is not a service entrance.*

Service entrance: *An entrance intended primarily for delivery of goods or services.*

Wheelchair space: *A space for a single wheelchair and its occupant.*

After reading these definitions, you might wonder, "What's the difference between Accessible units and Type A and Type B dwelling or sleeping units?" You'll find the answer in Section 1107 of the IBC, which we'll look at shortly, and Chapter 10 of the ICC A117.1. But first let's review what types of disabilities the code is concerned with.

All Disabilities?

The IBC doesn't tell you the particular disabilities to allow for when you design and construct buildings. In Section 1101.2, it just refers you to the ICC A117.1 standard.

Section 101 of the ICC A117.1 standard says:

The specifications in Chapters 3 through 9, and Sections 1002 (Type A Dwelling units) *and 1004* (Dwelling units with accessible communication features — this omits Section 1003, Type B Dwelling units) *of this standard make sites, facilities, buildings and elements accessible to and usable by people with such physical disabilities as the inability to walk, difficulty walking, reliance on walking aids, blindness and visual impairment, deafness and hearing impairment, incoordination, reaching and manipulation disabilities, lack of stamina, difficulty interpreting and reacting to sensory information, and extremes of physical size. The intent of these sections of the standard is to allow a person with a physical disability to independently get to, enter, and use a site, facility, building, or element.*

That's a pretty complete list. The government has enacted laws to benefit these disabilities, but like many regulations, the effort is evolving. Not all circumstances or situations may be covered. Expect requirements on access for the disabled to increase as their needs become better understood. Eventually, the safe access, use, and enjoyment of all facilities by the disabled should be on a par with people who have no disabilities.

Where is Accessibility Required?

IBC Section 1103.1 clearly sets out where accessibility is required:

1103.1 Where required. *Sites, buildings, structures, facilities, elements and spaces, temporary or permanent, shall be accessible to persons with physical disabilities.*

However, there are many exceptions:

- One- and two-family dwellings and townhouses three stories or less are exempt; see Section 1103.2.4.
- Existing and historic buildings may or may not be exempt. If you're planning to modify an existing building, carefully study Section 3409. An existing building that's intended for a use other than originally approved (group or occupancy) must have, among other requirements, these three things:

1. At least one accessible building entrance
2. Proper signage
3. At least one accessible parking spot, with an accessible route to the accessible entrance

See Section 3409.4 for details. If these standards aren't possible to attain, you must come as close to these requirements as you can. But the code doesn't say how to make that decision. It's probably going to be up to the building official, and he may require an engineer's certification. In a case like this, it's always a good idea to check with your building official in advance of construction.

IBC Section 1103.2 exempts the following structures from accessibility requirements:

- Employee work areas. But they must be built to allow a disabled person to approach, enter and exit. A work area less than 150 square feet and at least 7 inches above the finished area is fully exempt. If the area is covered by an audible alarm system, the wiring system must have capacity for the future addition of a visual alarm appliance; see Section 907.9.1.2. Employee work areas must meet the requirements of Sections 1007, which covers accessible means of egress, and 1104.3.1, Employee work areas.
- Group U utility buildings are mostly exempt, except for agricultural buildings where you must provide access to paved work areas and areas open to the general public, and any private garages that are required to have accessible parking.
- Construction sites.
- Raised platforms, like observation galleries and prison guard towers, and the routes to them.
- Unoccupied areas accessible only by ladders, catwalks, etc.
- Spaces accessed only by maintenance, repair or monitoring personnel, like elevator pits and mechanical equipment rooms.
- Single-occupant structures accessed only by above- or below-ground passageways, like toll booths that are accessed only by underground tunnels.
- Residential Group R-1 buildings with five or fewer sleeping units that are also occupied by the proprietor, like Bed & Breakfasts.
- The areas of a building having a day care facility (Groups A-3, E, I-4 and R-3), except the facility itself.
- Common-use areas of prisons that only serve inmates and security personnel.
- Fuel-dispensing systems. The systems must still comply with ICC A117.1, Section 308.2.1 or 308.3.1. The unobstructed forward and side reach heights at a fuel-dispensing system must be between 15 and 48 inches above the ground.
- Walk-in coolers and freezers used only by employees.

If you encounter any of these situations, study the details in the noted sections of the code. Just make sure that your building design allows for disabled access, if it's required.

The IBC discusses, in depth:

- Accessible routes, Section 1104
- Accessible entrances, Section 1105
- Parking and passenger loading facilities, Section 1106
- Dwelling units and sleeping units, Section 1107
- Special occupancies, Section 1108
- Other features and facilities, Section 1109
- Signage, Section 1110

There are too many requirements to talk about in detail in this guide, as well as numerous exceptions. However, we will look at three IBC sections that contain a wealth of information: Dwelling units and sleeping units, Section 1107; Accessible routes, Section 1104; and Parking and passenger loading facilities, Section 1106.

Dwelling Units and Sleeping Units

One of the questions we asked previously was, "What's the difference between Accessible units and Type A and Type B dwelling or sleeping units?" Let's look at what the IBC says.

Accessible Units and Type A and Type B Dwelling or Sleeping Units

As mentioned earlier, IBC Section 1102.1 gives us the following definitions.

- An accessible unit is *a dwelling unit or sleeping unit that complies with this code and the provisions for Accessible units in ICC A117.1.*
- A Type A unit is *a dwelling unit or sleeping unit designed and constructed for accessibility in accordance with this code and the provisions for Type A units in ICC A117.1.*
- A Type B unit is *a dwelling unit or a sleeping unit designed and constructed for accessibility in accordance with this code and the provisions for Type B units in ICC A117.1, consistent with the design and construction requirements of the federal Fair Housing Act.*

There are major differences between these three types of dwelling units — too numerous to detail here. Basically, the requirements for Type A units are more rigorous than for Type B units, and the requirements for Accessible units are more rigorous than Type A units. You can find a complete comparison of the requirements for the three types of units in a 21 page document on the Web at: www.nfpa.org/assets/files/PDF/ANSIMatrixA117.pdf.

So why does the code list three different types of accessible dwelling units? Because different occupancy types need different levels of accessibility in order to meet the needs of the disabled population. We'll look at how this affects Groups I and R occupancies shortly. But first let's be clear on what Section 1107.2 says:

- Where the code calls for Accessible dwelling units, their design and construction must meet the requirements of Chapters 1 though 9 of the ICC A117.1 standard.
- Where the code calls for Type A dwelling units, they can comply with either the requirements for Type A dwelling units or Accessible dwelling units.
- Where the code calls for Type B dwelling units, they can comply with the requirements for Type B dwelling units, Type A dwelling units or Accessible dwelling units.

In other words, if the code calls for a particular type of dwelling unit, you can always build up to a higher standard for accessibility, but you can't step it down to a lesser accessibility standard. However, when building to a higher standard, there's also the matter of cost to consider:

- Accessible dwelling units are often the most costly to build and have the greatest design limitations.
- Type A dwelling units can also be costly to build, but have more design flexibility.
- Type B dwelling units may be the least costly to build, present the fewest hurdles and give you the most flexibility in design.

You'll probably want to limit the number of Accessible and Type A units to the minimum required by the code, so let's look at what the code calls for.

There are some general requirements for all three types of dwelling and sleeping units. And some requirements are specific to occupancy type: Group I, Institutional, and Group R, Residential. Other occupancy types don't include dwelling or sleeping units.

General Dwelling and Sleeping Unit Requirements

Rooms and spaces available to the general public or serving Accessible units, Type A, or Type B units must also be accessible (see Section 1107.3). These include:

- Toilet and bathing rooms
- Kitchens
- Living rooms
- Dining rooms
- Outside areas like patios, terraces and balconies

There must be at least one accessible route that connects the accessible building entrance with the primary entrance of each Accessible unit, Type A or Type B unit. The same route must connect any interior or exterior spaces that serve the dwelling units; see Section 1107.4. As usual, there are exceptions. If the accessible route would have a slope greater than 1 in 12 or if physical barriers or legal restrictions prevent the installation of an accessible route, then a vehicular route, with parking at the end of the route meeting Section 1106, is permitted. There are also exceptions involving exterior decks, balconies or patios that are part of Type B units. Be sure and review this section of the code for details.

Group I Dwelling and Sleeping Unit Requirements

There are specific requirements for:

- Group I-1, Assisted-living facilities, etc.
- Group I-2, Nursing homes, Hospitals and Rehab facilities
- Group I-3, Prisons, etc.

Group I-1, Assisted-living Facilities, etc.

Group I-1 includes:

- Assisted-living facilities
- Convalescent homes

Number of Dwelling Units	Number of Accessible Units Required
1 through 25	1
26 through 50	2
51 through 75	3
76 through 100	4

Figure 23-1 Group I-1 Required accessible units per dwelling units

- Halfway houses
- Care facilities
- Social rehab facilities
- Alcohol and drug centers providing 24-hour care for 16 or more people

All dwelling units must meet Type B requirements, at a minimum, and at least 4 percent (but no less than 1) of the dwelling units must be Accessible units; see Section 1107.5.1.

So, Group I-1 facilities with up to 25 dwelling units must have at least one Accessible unit. Facilities with 50 dwelling units must have two Accessible units, because 4 percent of 50 units equal two units. But what if the facility has somewhere between 26 and 49 units?

Here's how to figure the required number of accessible units. If you have 35 units, one Accessible unit would represent only $^{1}/_{35^{th}}$ (or 2.9 percent) of the total number of units. This doesn't meet the 4 percent requirement. Look at Figure 23-1. Once you have more than 25 units, having only one Accessible unit puts the building below the mandatory 4 percent, so you must add another Accessible unit. If you have over 50 units, having only two Accessible units again drops the proportion below 4 percent, so you add one more. A rule of thumb is: If 4 percent of the number of dwelling units results in a number containing a fraction, you must round up to the next highest number of Accessible units.

What if you're planning to build a large facility? Then include a number of units up to, but not more than, one of the magic numbers: 50, 75, 100, etc. This allows you to optimize the number of Accessible units, and saves you money, since Accessible units are usually more expensive to build than Type B units.

Group I-2, Nursing Homes, Hospitals and Rehab Facilities

Group I-2 includes nursing homes, hospitals and rehab facilities. But for accessibility purposes, the codes break them down into three distinct subgroups. We'll discuss nursing homes first.

Nursing Homes — In nursing homes with four or more dwelling units, all units must be at least of Type B construction. And at least 50 percent must be Accessible units (Section 1107.5.2). That means that for every two dwelling units, at least one must be an Accessible unit. Figure 23-2 illustrates only up to 12 units, but the regulation applies to any number of units that you're building. If you have an odd number of dwelling units, you must provide the next highest number of Accessible units. For instance, if you have 35 dwelling units, multiply 35 by 50 percent to get 17½ units, which you would round up to 18 Accessible units. You can't round it down.

Hospitals — In general-purpose hospitals, psychiatric, detox or residential care/assisted living facilities, all units must meet at least Type B requirements. And at least 10 percent must be Accessible units (Section 1107.5.3). So for every 10 dwelling units, at least one must be an Accessible unit. If you build something in between 10 and 20 dwelling units, or in between 20 and 30 dwelling units, etc., you must round up the number and provide the higher number of Accessible units. For instance, if you have 25 dwelling units, multiply 25 by 10 percent to get 2½ units, which rounds up to 3 Accessible units. See Figure 23-3.

Rehabilitation Facilities — Rehab facilities specialize in treating people with limited mobility.

Number of Dwelling Units	Number of Accessible Units Required
1 or 2	1
3 or 4	2
5 or 6	3
7 or 8	4
9 or 10	5
11 or 12	6

Figure 23-2 Group I-2 nursing homes, 50 percent must be Accessible

Number of Dwelling Units	Number of Accessible Units Required
1 through 10	1
11 through 20	2
21 through 30	3
31 through 40	4
41 through 50	5
51 through 60	6

Figure 23-3 Group I-2 hospitals, etc., Accessible units per dwelling units

So it's not surprising that the code requires 100 percent of the dwelling units be Accessible units (see Section 1107.5.4).

Group I-3, Prisons, etc.

Detention facilities with more than five inhabitants — like prisons and reformatories — that restrain the movement of their inhabitants, must have at least 2 percent of their dwelling units Accessible (Section 1107.5.5). See Figure 23-4. There's no requirement that other units be either Type A or Type B units. There are special requirements for holding cells, if you're planning to build a jail or a prison.

Group R Dwelling and Sleeping Unit Requirements

There are specific requirements for all four Group R occupancies. We'll look at each separately.

Number of Dwelling Units	Number of Accessible Units Required
1 through 50	1
51 through 100	2
101 through 150	3
150 through 200	4

Figure 23-4 Group I-3, Prisons, etc., Accessible units per dwelling units

TABLE 1107.6.1.1 ACCESSIBLE DWELLING AND SLEEPING UNITS		
TOTAL NUMBER OF UNITS PROVIDED	MINIMUM REQUIRED NUMBER OF ACCESSIBLE UNITS ASSOCIATED WITH ROLL-IN SHOWERS	TOTAL NUMBER OF REQUIRED ACCESSIBLE UNITS
1 to 25	0	1
26 to 50	0	2
51 to 75	1	4
76 to 100	1	5
101 to 150	2	7
151 to 200	2	8
201 to 300	3	10
301 to 400	4	12
401 to 500	4	13
501 to 1,000	1% of total	3% of total
Over 1,000	10, plus 1 for each 100, or fraction thereof, over 1,000	30, plus 2 for each 100, or fraction thereof, over 1,000

Figure 23-5 Group R-1 Accessible dwelling and sleeping units

Group R-1, Hotels, Motels and Boarding Houses

For commercial hotels, motels and boarding houses used most often for transient residents, the number of Accessible units is shown in IBC Table 1107.6.1.1 (Figure 23-5), and covered in Section 1107.6.1.

This table also includes the number of roll-in showers you must provide. The showers must include a permanently-mounted shower seat.

If the building is intended only for transitory occupants, there's no requirement to provide either Type A or Type B dwelling units. But if the building has four or more dwelling units intended to be used as permanent residences, then those dwelling units must be designed as Type B units.

Group R-2, Apartment Houses, Monasteries, Convents, etc.

In facilities with four or more dwelling units in a single structure, every dwelling unit must be at least a Type B unit. Where there are more than 20 dwelling units, at least 2 percent of those must be Type A units (Section 1107.6.2.1). See Figure 23-6.

Number of Dwelling Units	Number of Type A Units Required
21 through 50	1
51 through 100	2
101 through 150	3
150 through 200	4

Figure 23-6 Group R-2, Type A units per dwelling units

Group R-2, Boarding Houses, Dormitories, Fraternity and Sorority Houses

In facilities with four or more dwelling units in a single structure, every dwelling unit must be at least Type B construction (Section 1107.6.2.2). Also, you must supply a number of Accessible units; refer to Table 1107.6.1.1 (Figure 23-5) for specifics.

Group R-3, Residential Occupancies Other Than R-1, R-2 and R-4

In facilities with four or more dwelling units in a single structure, every dwelling unit must meet at least Type B requirements (Section 1107.6.3).

Group R-4, Residential Care Facilities with Between 6 and 16 Inhabitants

At least one of the dwelling units must be an Accessible unit. The remaining dwelling units must be at least Type B units (Section 1107.6.4).

Exceptions for the Number of Type B Dwelling Units

Most Group I and R occupancies have exceptions allowing the number of Type B dwelling units to be reduced under certain circumstances. These include:

- Structures without elevator service
- Multistory units
- Elevator service to the lowest story with units
- Site impracticality
- Design flood elevation

Refer to Section 1107.7 for the details.

Accessibility Routes

I once visited a state park where the restroom facilities were accessible — at least according to the signs. Then I noticed a row of concrete wheel bumpers that completely blocked access. I took a picture and sent it to the proper state agency. They never acknowledged my letter, but the problem was corrected. A local authority that enforces the rules also has to follow the rules. In this case, Section 1104.6 says that security bollards, etc. must not block a required accessible route.

The full requirements for accessibility routes are covered in Section 1104. At least one accessible route must be provided between accessible buildings, facilities, elements and spaces on the same site. This isn't required if the only means of access between them is by vehicle, with no pedestrian access. Inside a building that's required to be accessible, there must be an accessible route to each part of the building. If only one route is provided, it can't pass through kitchens, storage rooms, restrooms, closets or similar spaces. In multistory buildings, at least one accessible route must connect each accessible level. Section 1104.4 gives a few exceptions to this.

To many builders, these accessibility requirements may seem like a nuisance. But if you or someone in your family were disabled, you'd think differently. And, one day you may be disabled, simply due to old age. It happens to anyone who lives long enough! These regulations are a small price to pay to allow access to everybody.

Parking and Passenger Loading Facilities

Section 1106.1 says you must include a minimum number of accessible parking spaces in a parking lot. These requirements are shown in IBC Table 1106.1, Figure 23-7.

When you count the total number of parking spaces, don't include spaces used only for buses, trucks, delivery vehicles or law enforcement vehicles.

TABLE 1106.1
ACCESSIBLE PARKING SPACES

TOTAL PARKING SPACES PROVIDED	REQUIRED MINIMUM NUMBER OF ACCESSIBLE SPACES
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1,000	2% of total
1,001 and over	20, plus one for each 100, or fraction thereof, over 1,000

Figure 23-7 Accessible parking spaces

Provide at least one van-accessible parking space for each six accessible parking spaces, or fraction of six spaces; see Section 1106.5. This might raise the question, "What's the difference between an accessible parking space and a van-accessible parking space?" Section 502.2 of the ICC A117.1 standard says that both must be 96 inches wide. So there's no difference in the actual parking spaces required. But there *is* a difference in the access aisles you must provide next to the parking space. Section 502.3 says that access aisles for cars must be 60 inches wide. For vans they must be 96 inches wide. And, van-accessible spaces need to have 98 inches minimum overhead clearance as well.

It's best to scatter accessible parking spaces throughout the parking area. Remember to locate them on the shortest route to the nearest accessible entrance to a building or facility. Unless it's unavoidable, don't put them where the route of travel crosses traffic lanes. If the route of travel *must* cross traffic, there must be a designated, marked crosswalk.

There's a conflict of interest for shopping mall parking lots. Fire regulations require a fire lane next to the building, and disabled parking can't be in a fire lane, so chances are they'll *have* to be across traffic lanes. Some traffic engineers think that marked crosswalks are dangerous because people put too much faith in stripes on the pavement — painted stripes won't stop a car. However, awareness on the part of both drivers and those using the crosswalks is always a necessary element of safety. And that includes small children — no one should think they're safe in a crosswalk or that they can cross any traffic lane without first looking carefully in all directions!

If you provide passenger drop-off and loading zones, one zone in every 100 feet must be accessible. These zones must also have signs and be located on a direct route to an accessible route of travel; see Section 1106.7 and Chapter 5 of the ICC A117.1 standard.

Special Occupancy Parking Requirements

Finally, there are some parking space occupancy-specific requirements for particular Group R and I occupancies.

Groups R-2 and R-3

At least 2 percent (and not fewer than one space) of the parking spaces must be accessible for R-2 and R-3 occupancy buildings that are required to have Accessible units or Type A or Type B dwelling units; see Section 1106.2.

Hospital Outpatient Facilities

In hospital parking lots, 10 percent of the parking spaces serving outpatient facilities must be accessible (Section 1106.3).

Rehabilitation Facilities

At rehab facilities, there must be a minimum of 20 percent (and at least one) accessible parking spaces serving the facility (Section 1106.4).

Accessible Means of Egress

We discussed Accessible Means of Egress back in Chapter 16, but for more complete information, refer to IBC Section 1007. Study it carefully if the subject applies to any building you're constructing.

We've just had a brief synopsis of the requirements of the IBC for accessibility, as well as a brief introduction to the ICC A117.1 standard. These provide you with a basic overview of the major requirements. To make sure you're in full compliance, get a copy of the ANSI A117.1 standard (it has many very good illustrations and explanations) and study Chapter 11 of the IBC and Section 1007 in detail.

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Getting the Last Word

Inspectors, like all people, come with different backgrounds and temperaments. But there's one thread that runs through nearly all the inspectors I've known. They all worked in or around construction before pinning on an inspector's badge. Most had a career as a contractor or designer, or worked in the trades. And some are still pretty good craftsmen. With their backgrounds, it's inevitable that inspectors carry around opinions about what makes professional quality work — and what is and what isn't up to par.

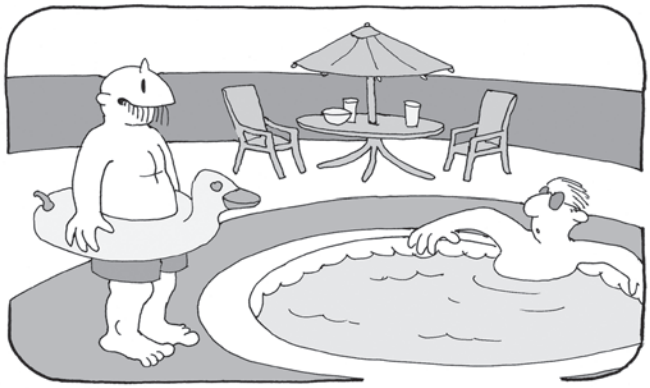
Opinions on craftsmanship are entirely separate from code compliance and should have no bearing on an inspector's job, which is checking for code violations. But people have opinions, and building inspectors are people, so occasionally you're going to get some free advice. I recommend listening to advice offered by an inspector — out of courtesy, if nothing else.

I'm kind of old fashioned. I think getting fatherly advice from an inspector should be considered a compliment. That usually means the inspector thinks the contractor is worth the time and effort and will care enough to listen. Remember what I said back in Chapter 1: Make the inspector part of your team. Together you're going to put up a building everyone can be proud of.

As an inspector, I offered advice when I thought it would do some good. One time I was inspecting a new residential job. The home reflected quality work, except for one thing that caught my eye: The trim around the entry opening had been butted in square — not mitered. I mentioned this to the contractor, and he jumped all over me for exceeding my authority. He was right. But his sensitivity on this subject was obvious. "Who's going to notice or care?" he asked. "Certainly not the people who'll buy this house."

"Probably every builder in town is going to know about this," I assured him with a smile, "because I'm the biggest loudmouth in the department. When finish carpentry like that goes into a nice house like this, it makes a good story. I like to share good, humorous stories with my buddies. I'll bet there'll be at least a dozen contractors and inspectors who'll hear this one before sundown tonight." We left it at that. But when I did the final inspection several weeks later, the same contractor was there. This time the trim corners had the neatest miter job you've ever seen. I didn't say anything. But I ran my fingers over the joints and gave him a little nod of approval. He didn't say anything either. He shrugged, shoved his hands deep into his pockets and gave me a sheepish grin.

That contractor jumped several points on my opinion scale. From that day, I looked forward to checking his jobs. Maybe he felt the same way. Anyhow, we never exchanged another cross word.



"I'm here to inspect your hot tub."

CHAPTER 24

Miscellaneous Items

This chapter covers some items that don't fall neatly into any of the previous chapters. They include:

- Temporary use of public property
- Permanent use of public property
- Agricultural buildings
- Prefabricated buildings
- Sound transmission control
- Swimming pools, spas and hot tubs

These are among the most frequently amended sections of the codes adopted by states and local governments. Always check local codes for amendments that apply where you're building.

Temporary Use of Public Property

Permanent use of public property isn't usually allowed by the building code or local zoning ordinances. Almost any building that's going to stay put can't be on public property. How about fences, barricades and shelters used during construction or demolition? They're considered temporary structures. They can be built on public property. But your local authority might require a special permit for the use of the public property. Structures built for fairs, exhibitions and carnivals are considered temporary.

Most temporary structures used during construction or demolition are for the public's safety and protection. You can use part of the sidewalk in front of a job site. Just leave pedestrians a walkway at least 4 feet wide, with a durable walking surface. If you need to use the whole sidewalk, it's okay to detour pedestrians into the street. But you must provide a 4-foot walkway, with railings at least 42 inches high on both the traffic side and the construction side, and a strong barricade that directs vehicles away from the pedestrian path; see IBC Sections 3306.2 to 3306.4. You must also provide lighting during dark hours.

If construction is more than 8 feet high, you'll need barriers between the construction site and the walkway; see IBC Section 3306.5

TABLE 3306.1 PROTECTION OF PEDESTRIANS		
HEIGHT OF CONSTRUCTION	DISTANCE FROM CONSTRUCTION TO LOT LINE	TYPE OF PROTECTION REQUIRED
8 feet or less	Less than 5 feet	Construction railings
	5 feet or more	None
More than 8 feet	Less than 5 feet	Barrier and covered walkway
	5 feet or more, but not more than one-fourth the height of construction	Barrier and covered walkway
	5 feet or more, but between one-fourth and one-half the height of construction	Barrier
	5 feet or more, but exceeding one-half the height of construction	None

For SI: 1 foot = 304.8 mm.

Figure 24-1 Pedestrian protection

and Table 3306.1 (Figure 24-1). Openings in the barrier must have doors that are normally closed. Check Section 3306.6 for barrier design details.

Cover the walkways if the construction is more than 8 feet high and the distance from the construction to the lot line is less than one-quarter of the construction height, or 5 feet, whichever is more. The details for covered walkways are given in Section 3306.7.

Temporary use of public property for a site shed, fence, or the handling or storage of materials is covered in Sections 3308.1 and 3308.2. Don't block public transport loading and unloading areas, or obstruct areas within 20 feet of a street intersection. Make sure there are still adequate sight lines to traffic signals. And make sure there's easy access to:

- Utility poles
- Standpipes
- Fire hydrants
- Fire or police alarm boxes
- Catch basins
- Manholes

Don't interfere with the free flow of water in a gutter. Be careful when mixing or handling mortar, concrete, or other material on public property. This work can damage public property or create a nuisance.

Permanent Use of Public Property

Permanent use of public property usually addresses projections over the property line. Cornices, architectural features, eave overhangs and exterior private balconies that extend past the floor area are governed by IBC Section 704.2. We'll look at this section first.

Projections in Type I or II buildings must be of noncombustible materials, but in other buildings they can either be noncombustible or combustible. But if you use combustible materials where protected openings are required, they must be 1-hour fire-resistant or heavy timber.

Projections have size limitations. They can't extend more than 12 inches into an area where openings are prohibited, but if the distance from the point where protected openings are required to the lot line is less than 36 inches, the maximum is one-third that distance.

Encroachments into the Public Right-of-Way

Other permanent uses of public property, including stairs, columns and awnings, are identified in IBC Chapter 32, which covers four general categories.

Below Grade

Only street wall footings or their supports at least 8 feet below grade can extend up to 12 inches beyond the street lot line. See Section 3202.1.1.

Above Grade but Below 8 Feet in Height

Most encroachments above grade and under 8 feet high are prohibited. There are exceptions for steps, some architectural features and awnings, as you can see in Section 3202.2. Doors and windows can't open or extend into the public right-of-way. Steps can't project more than 12 inches. They must be guarded by an approved means at least 3 feet high, or by columns or pilasters. Columns or pilasters, including any bases or moldings, can't project more than 12 inches. Other architectural features are limited to a 4-inch projection. Awning valances can't extend below 7 feet from the public right-of-way.

Between 8 Feet and 15 Feet Above Grade

Above 8 feet but below 15 feet, you have more flexibility for items like the following:

- Awnings
- Canopies
- Marquees
- Signs
- Windows
- Balconies
- Architectural features
- Mechanical equipment

See Section 3202.3 for more details. Awnings, canopies, marquees and signs can't extend from the building by more than two-thirds of the sidewalk width. Stanchions or columns supporting awnings, etc. must be placed within 2 feet of the curb line.

You're allowed to project windows, balconies, architectural features or mechanical equipment from the lot line by 1 inch for every inch above 8 feet. For example, if the bottom of your window is 10 feet above the public right-of-way, it can project by 24 inches. The maximum allowable projection up to 15 feet above the public right-of-way is 48 inches or 4 feet. So, using this formula, you'll reach the maximum projection at 12 feet.

More Than 15 Feet Above Grade

Above 15 feet, almost anything goes! IBC Section 3202.3.3 says that projections shall not be limited. Of course, they still have to meet the requirements of IBC Section 704.2, previously discussed.

Finally, if you're planning to install a pedestrian walkway *over* a public right-of-way, get permission from your local authority. It must be at least 15 feet above the public right-of-way (see Section 3202.3.4).

Awnings and Canopies

More requirements for awnings, canopies and marquees can be found in IBC Sections 3105, 3106 and 1607.11.2.4.

Remember the old-fashioned striped canvas awnings above the windows on old-time city streets? They were common in towns across the United States. Then they came to be considered fire hazards, and virtually ceased to exist. In fact, the UBC didn't even recognize them because of their potential fire danger. Now they've become popular again. Awnings have to be 8 feet high or more, but their valances can be as low as 7 feet above the public right-of-way.

Awnings have to withstand wind or other lateral and live loads (Sections 3105.3 and 1607.11.2.4). Today, awning canopies must be fire-resistant, with a flame spread index over 25.

Marquees

A marquee is a different animal. It can't be more than 3 feet thick when it extends more than two-thirds the distance from the building to the curb. If it extends less than two-thirds of that distance, it can be as thick as 9 feet. See Section 3106.2. If a marquee includes a skylight, it has to conform to the requirements of IBC Chapter 24 (see Chapter 22 of this book).

TABLE C102.1 BASIC ALLOWABLE AREA FOR A GROUP U, ONE STORY IN HEIGHT AND MAXIMUM HEIGHT OF SUCH OCCUPANCY							
I		II		III and IV		V	
A	B	A	B	III A and IV	III B	A	B
ALLOWABLE AREA (square feet)[a]							
Unlimited	60,000	27,100	18,000	27,100	18,000	21,100	12,000
MAXIMUM HEIGHT IN STORIES							
Unlimited	12	4	2	4	2	3	2
MAXIMUM HEIGHT IN FEET							
Unlimited	160	65	55	65	55	50	40

For SI: 1 square foot = 0.0929 m^2.
a. See Section C102 for unlimited area under certain conditions.

Figure 24-2 Group U basic allowable areas

Any water that collects on a marquee can't be allowed to flow over the sidewalk; it must be drained directly to the gutter or storm sewer (IBC Section 3201.4).

A marquee can't obstruct the operation of any exterior standpipe, the passage of stairways, the exit from the building, or the maintenance of street lights. Section 3106.4 gives the details. There was a requirement in the UBC that a marquee couldn't extend within 2 feet of the curb to prevent damage by tall trucks parking at the curbside. Even though it's no longer mentioned in the code, it's still a good idea. But remember, Section 3202.3.1 restricts a marquee's extension to less than two-thirds the distance from the building to the curb if the lowest height of the marquee is less than 15 feet. Most marquees will be less than 15 feet in height at the lowest point. In that case, the two-thirds of the sidewalk limit will probably prevent damage from tall trucks.

Marquees must be made of noncombustible material and be supported entirely by the building; see Section 3106.5.

Agricultural Buildings

The IBC covers agricultural buildings in Appendix C. They're classified as Group U, Utility buildings, and include the following uses (see Section C101.1):

- Livestock shelters or buildings, including shade structures and milking barns
- Poultry buildings or shelters
- Barns and sheds
- Storage of equipment and machinery used exclusively in agriculture
- Horticultural structures, including detached production greenhouses and crop protection shelters
- Stables and grain silos

The allowable areas and maximum heights of agricultural buildings are much greater than other building types, and the exit requirements are also more relaxed. Table C102.1 (Figure 24-2) gives basic allowable areas for the different construction types.

The area of a one-story agricultural building is unlimited if it's surrounded by at least 60 feet of open space on all sides. A two-story agricultural building is also unlimited if it's fully sprinklered (see Sections C102.2 and C102.3).

The normal requirements for exits apply except that, in an agricultural building, at least one exit is required for each 15,000 square feet and the maximum travel distance to an exit can't exceed 300 feet; Section C104.1.

Be careful with any mixed occupancy. Remember that the most restrictive occupancy applies to any mixed-occupancy building. Appendix C doesn't cover residences, private garages, or commercial or partly commercial buildings.

Prefabricated Buildings

These include almost everything from small metal tool sheds to large barns and equipment storage buildings. Many smaller structures are exempt from permit requirements. IBC Section 105.2 says one-story detached accessory buildings having 120 square feet in floor area, or less, don't require a permit.

Prefabricated buildings of more than 120 square feet, or parts of buildings, are covered in IBC Section 1703.7. When you apply for a permit to construct a prefab building, you have to submit a report that includes:

- Assembly details, with a description of the assembly and the components
- How the assembly is evaluated
- Test results and data showing code compliance

The building official evaluates the report and usually issues a permit, since most modern prefab steel and aluminum buildings meet code requirements. The inspector checks the footings and foundations, the connections to the foundations, the bolt patterns, bracing, etc. in addition to the interior improvements in these structures (sanitation, insulation, interior finish). If your prefab structure is extra large, the building official may need to see the results of testing to determine its durability and weather resistance. Typical uses for prefabricated buildings are workshops and garages, storage for motor homes, campers, airplanes, classic cars, and motorcycles. Agricultural uses include storage of machinery, hay, grain, and livestock.

Sound Transmission Control

Requirements for sound transmission control are provided in the IRC, Appendix K. The code applies to *wall and floor-ceiling assemblies separating dwelling units including those separating adjacent townhouse units…* The aim is to protect occupants from noisy neighbors. Read these sections and the applicable ASTM standards. They'll guide you through code compliance. But it's tough to prove compliance or noncompliance for apartment buildings. Sometimes only a sound engineer using a battery of equipment can prove compliance.

Section AK102.1 says you must build walls and floor/ceiling assemblies to the ASTM E 90 standard. The standard requires an airborne sound transmission class of at least 45. To meet this you'll need to make sure that all penetrations and openings for *piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts are sealed, lined, insulated or otherwise treated to maintain the required ratings.*

In addition, Section AK103.1 says to build all *floor/ceiling assemblies between dwelling units or between a dwelling unit and a public or service area within the structure* to the ASTM E 492 standard. They must also meet an impact insulation class rating of at least 45.

Check to see if your jurisdiction has adopted these code requirements. If it has, ask the building inspector what you have to do to comply. If you're building to the IBC, check Section 1207. Those requirements are stricter.

Swimming Pools, Spas and Hot Tubs

Neither code has much to say about the construction of swimming pools, spas and hot tubs. But the IRC does require that they be designed and constructed to the following standards:

- In-ground pools, ANSI/NSPI-5: Section AG103.1
- On-ground and above-ground pools, ANSI/NSPI-4: Section AG103.2
- Permanent spas and hot tubs, ANSI/NSPI-3: Section AG104.1
- Portable spas and tubs, ANSI/NSPI-6: Section AG104.2

The codes focus on barriers, entrapment protection and electrical requirements: see Appendix G of the IRC and IBC Section 3109.

IRC Appendix G is mainly concerned with the barriers and safety devices around a pool

or spa, rather than the pool itself. This section refers to pools, spas and hot tubs installed on the lots of one- or two-family dwellings (Section AG101.1). It excludes apartment building or commercial pools, and appears to exclude pools for townhouses. The code includes spas, hot tubs and swimming pools (both indoor and outdoor), under a single heading — swimming pools. Section AG102 gives this definition:

Swimming pool. *Any structure intended for swimming or recreational bathing that contains water over 24 inches (610 mm) deep. This includes in-ground, above-ground and on-ground swimming pools, hot tubs and spas.*

Swimming Pool Barriers

IRC Section AG105.2 gives details for barriers installed around an outdoor swimming pool. I'll just give the highlights here.

The barrier must be at least 48 inches above grade. The bottom of the barrier must be within 2 inches of grade on the side of the barrier that faces away from the pool. For an above-ground pool, you can either install the barrier at grade level or at pool-top level. If you mount the barrier on the above-ground pool structure, the bottom of the barrier must be within 4 inches of the pool structure.

Here are some other requirements:

- Openings in the barrier must be small enough to prevent passage of a 4-inch-diameter sphere.
- Solid barriers without openings, like masonry or stone walls, must be smooth except for tooled masonry joints. You can't have indentations or protrusions that would make the wall easy to climb.
- If the barrier has horizontal and vertical members, like picket fencing, the requirements vary if the tops of the horizontal members are more or less than 45 inches apart. If horizontal members are more than 45 inches apart, the spacing between vertical members can't be more than 4 inches. If less than 45 inches, the spacing between vertical members can't be more than 1¾ inches and the horizontal members must be on the pool side so they can't become footholds for uninvited guests, such as neighborhood kids. In either case, if there are decorative cutouts in the vertical members, the spacing inside the cutouts can't be more than 1¾ inches wide.
- For chain link fences, the maximum mesh size is 2¼ inches.
- Lattice barriers can't have openings larger than 1¾ inches.
- Access gates must open away from the pool and be self-closing and self-locking. If you install the self-latching device less than 54 inches from the bottom of the gate, there are additional requirements you must meet.
- If the residence itself is part of the barrier, the pool must be protected by a powered safety cover, or any opening from the house must have an audible alarm device indicating whenever the door and/or screen are opened. As an alternative, the door must be self-closing and self-latching. If any of this applies to you, read all the details in Item 9.2 of this section.
- If the structure of an above-ground pool is used as the barrier, or the barrier is mounted on top of the pool structure, the ladder or steps used for access must be secured, locked, or removed to prevent access.

A 48-inch barrier won't keep all children out, but it will protect toddlers, and slow down the rest. Children are the reason openings in any barrier have to be so small — to keep the little ones from climbing over. The code assumes that any child big enough to climb over a 4-foot fence should be able to climb out of a pool.

Entrapment Protection

There's another critical safety measure that must be implemented for a swimming pool, spa or hot tub. You must provide entrapment protection at suction outlets. This is a very serious subject. Children are for some reason drawn to

explore where water is being sucked down, and small children can become caught in the suction and held underwater. There have been accidents and high-profile lawsuits because of inadequate safeguards. Section AG106 covers the main requirements. In effect, all pool and spa suction outlets must be covered by an approved method, with the exception of surface skimmers.

There are additional requirements regarding these systems. Check the following sections for more information:

- Atmospheric vacuum relief system required, Section AG106.3
- Dual drain separation, Section AG106.4
- Pool cleaner fittings, Section AG106.5

Read these sections carefully if you're planning to install a pool. A pool subcontractor should be familiar with all the requirements. But as the primary contractor, the ultimate responsibility lies with you — so you should know the code.

Electrical Requirements

The electrical requirements for residential swimming pools are covered in Chapter 41 of the IRC. Believe me, there are a lot of them. Be very careful when you have water and electricity in close proximity to each other. Check the regulations if you're planning to install a pool. Again, you'll probably want to call in the experts. It's better to be safe than sorry.

Permits

You need a permit for any in-ground pool or above-ground pool with water 24 inches deep or more. However, you don't need a permit for an above-ground prefab pool with less than 24 inches of water; see IRC Section 105.2. The IBC, also in Section 105.2, gives the same exemption for Group R-3 occupancies for an above-ground prefab pool with less than 24 inches of water and less than a 5,000-gallon capacity. All other occupancies require a permit for any kind of swimming pool.

Finding Additional Code Information

Those are all of the miscellaneous items I'm going to cover here. The Building Code is divided into two volumes, the IBC and the IRC. Both of them are over 600 pages long. I couldn't possibly cover every requirement and every miscellaneous item in this one book. But I hope I've given you information on the most common subjects. If I haven't covered a topic as thoroughly as you'd like, get a copy of the ICC CD-ROM entitled *The Designer Collection*. It includes:

International Building Code®

International Residential Code®

International Fire Code®

International Existing Building Code®

International Energy Conservation Code®

ANSI/ICC Standard A117.1, Accessible and Usable Buildings and Facilities

The CD-ROM comes with a search feature. Simply type in a topic, word or phrase. You'll find every mention of that item in the particular code you've selected. This is much easier than looking through the code books, and you won't miss any references to that topic in the codes. It'll also help you avoid mistakes. That's it — good luck!

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How to Use the *Contractor's Guide to the Building Code CD*

Inside the back cover is a CD with all the material in the book, including the figures and tables, with a search feature that will let you find the topic you need at the touch of a key.

To start, insert the *Contractor's Guide to the Building Code CD* into your computer's CD-ROM drive.

The CD is designed to work best with Acrobat Reader 6. If you have version 5 or lower, or no version at all, you'll be asked if you want to update to or install Acrobat Reader 6.0. To install, click on the Acrobat Reader link and follow the instructions on the screen.

If you have Adobe Acrobat Reader 6.0 or later already installed, the program should automatically start. The *Contractor's Guide to the Building Code PDF* will be displayed. You can now navigate through all the chapters and information included in the book.

The minimum computer and internet browser requirements for Adobe's Acrobat Reader 6 are:

1) Pentium-class processor,
2) Windows XP Professional, Home Edition or Tablet PC Edition; Windows ME; Windows 2000 Professional SP2; Windows NT Workstation 4.0 SP6; Windows 98 Second Edition,
3) 32 MB of RAM (64 MB recommended),
4) 80 MB of available hard disk space,
5) 800 x 600 monitor resolution,
6) Microsoft Internet Explorer 5.01 or later, Netscape Navigator 7.0 or later, or America Online 6.0 or later.

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Practical References for Builders

2006 *International Residential Code*

Replacing the *CABO One*- and *Two-Family Dwelling Code*, this book has the latest technological advances in building design and construction. Among the changes are provisions for steel framing and energy savings. Also contains mechanical, fuel gas and plumbing provisions that coordinate with the *International Mechanical Code* and the *International Plumbing Code*.
604 pages, 8½ x 11, $76.50

Also available: **2003 *International Residential Code*, $72.50**
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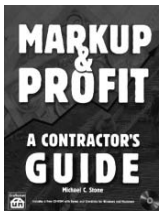
2000 *International Residential Code* on interactive CD-ROM, $48.00

Markup & Profit: A Contractor's Guide

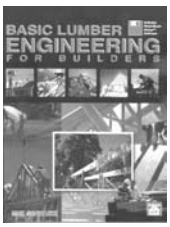


In order to succeed in a construction business, you have to be able to price your jobs to cover all labor, material and overhead expenses, *and* make a decent profit. The problem is knowing what markup to use. You don't want to lose jobs because you charged too much, and you don't want to work for free because you charged too little. If you know how to calculate markup, you can apply it to your job costs to find the right sales price for your work. This book gives you tried and tested formulas, with step-by-step instructions and easy-to-follow examples, so you can easily figure the markup that's right for *your* business. Includes a CD-ROM with forms and checklists for your use. **320 pages, 8½ x 11, $32.50**

Contractor's Index to the 1997 Uniform Building Code

Finally, there's a common-sense index that helps you quickly and easily find the section you're looking for in the UBC. It lists topics under the names builders actually use in construction. Best of all, it gives the full section number and the actual page in the UBC where you'll find it. If you need to know the requirements for windows in exit access corridor walls, just look under Windows. You'll find the requirements you need are in Section 1004.3.4.3.2.2 in the UBC — on page 115. This practical index was written by a former builder and building inspector who knows the UBC from both perspectives. If you hate to spend valuable time hunting through pages of fine print for the information you need, this is the book for you.
192 pages, 8½ x 11, Loose-leaf, $20.00

Basic Lumber Engineering for Builders



Beam and lumber requirements for many jobs aren't always clear, especially with changing building codes and lumber products. Most of the time you rely on your own "rules of thumb" when figuring spans or lumber engineering. This book can help you fill the gap between what you can find in the building code span tables and what you need to pay a certified engineer to do. With its large, clear illustrations and examples, this book shows you how to figure stresses for pre-engineered wood or wood structural members, how to calculate loads, and how to design your own girders, joists and beams. Included FREE with the book — an easy-to-use limited version of NorthBridge Software's *Wood Beam Sizing* program.
272 pages, 8½ x 11, $38.00

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Updated means of egress and interior finish requirements, comprehensive roof provisions, seismic engineering provisions, innovative construction technology, revamped structural provisions, reorganized occupancy classifications and the latest industry standards in material design.
674 pages, 8½ x 11, $100.00.

Also available: **2003 *International Building Code*, $96.50**

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A spiral-bound, quick reference to the 2006 *International Residential Code* that is filled with easy to read and understand code requirements for every aspect of residential construction. This user-friendly guide through the morass of the code is packed with illustrations, tables, and figures, to illuminate your path to inspection and approval.
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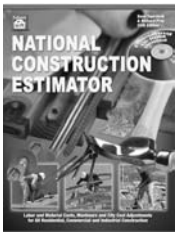
A comprehensive guide to the *International Plumbing* and *Fuel Gas Codes* that explains the intricacies of the code in easy-to-understand language. Packed with plumbing isometrics and helpful illustrations, it makes clear the code requirements for the installation methods and materials for plumbing and fuel gas systems. Includes code tables for pipe sizing and fixture units, and code requirements for just about all areas of plumbing, from water supply and vents to sanitary drainage systems. Covers the principles and terminology of the codes, how the various systems work and are regulated, and code-compliance issues you'll likely encounter on the job. Each chapter has a set of self-test questions for anyone studying for the plumber's exam, and tells you where to look in the code for the details. Written by a former plumbing inspector, this guide has the help you need to install systems in compliance with the *IPC* and the *IFGC*.
312 pages, 8½ x 11, $37.00

National Construction Estimator



Current building costs for residential, commercial, and industrial construction. Estimated prices for every common building material. Provides man-hours, recommended crew, and gives the labor cost for installation. Includes a CD-ROM with an electronic version of the book with *National Estimator*, a stand-alone *Windows*™ estimating program, plus an interactive multimedia video that shows how to use the disk to compile construction cost estimates.
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Contractor's Plain-English Legal Guide

For today's contractors, legal problems are like snakes in the swamp — you might not see them, but you know they're there. This book tells you where the snakes are hiding and directs you to the safe path. With the directions in this easy-to-read handbook you're less likely to need a $200-an-hour lawyer. Includes simple directions for starting your business, writing contracts that cover just about any eventuality, collecting what's owed you, filing liens, protecting yourself from unethical subcontractors, and more. For about the price of 15 minutes in a lawyer's office, you'll have a guide that will make many of those visits unnecessary. Includes a CD-ROM with blank copies of all the forms and contracts in the book.
272 pages, 8½ x 11, $49.50

Code Check Building

Here is a condensed guide to commonly cited *IRC* code violations in the construction of one- and two-family dwellings. Designed to be used on-site for quick reference, this easy-to-read, completely illustrated flipchart will help you quickly find out if buildings meet recent code requirements for foundations, framing, exterior and interior walls, fireplaces and chimneys. **32 pages, 8½ x 11, $16.95.** Published by Taunton Press

Concrete Manual

Filled with illustrations, diagrams, and photographs, this essential code resource covers every aspect of concrete. Shows how to pour, how to affect strength, how to affect durability, how to avoid cracks and blemishes, types of aggregates, types of sealants, formwork requirements, proportioning the concrete mixture, how to test and control concrete, slabs on gound, finish and curing, precast and prestressed concrete, steel reinforcing, and special concrete techniques. Includes a FREE CD-ROM for searching text and copying images.
340 pages, 8½ x 11, $73.00

2003 *International Residential Code* Study Companion

Understand the 2003 *IRC*. To pass inspection, you have to build to Code. But hunting through the Code to find the rules, and then trying to understand them, can be a challenge. The 2003 *International Residential Code* Study Companion is guaranteed to make the job easier. It tells you the code section, quotes it, then explains it in plain English. Best of all, there's a large, clear illustration showing exactly how the work must be done.
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Construction Codes & Inspection Handbook

This gigantic compilation of code requirements simplifies understanding of quality assurance, code compliance, and inspection approval for commercial and industrial construction. It explains where and how most code defects occur and how to locate and correct them. You'll find almost 600 practical checklists, tables, charts and calculations to save you time and money by making sure that your projects pass code the first time. Covers *IBC*, *NEC*, *IPC*, *IFGC* and the *IZC* codes with large, clear illustrations of what the codes require for site work, concrete, masonry, carpentry, structural steel, doors and windows, finishes, thermal and moisture protection, piping systems, mechanics, electrical, and OSHA regulations. It's hard to imagine a more complete resource for architects, builders, engineers, and code officials. **640 Pages, 8½ x 11, $59.95.** Published by McGraw-Hill.

Stained Concrete Interior Floors

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Shows how to frame any type of roof in common use today, even if you've never framed a roof before. Includes using a pocket calculator to figure any common, hip, valley, or jack rafter length in seconds. Over 400 illustrations cover every measurement and every cut on each type of roof: gable, hip, Dutch, Tudor, gambrel, shed, gazebo, and more.
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Basic Engineering for Builders

This book is for you if you've ever been stumped by an engineering problem on the job, yet wanted to avoid the expense of hiring a qualified engineer. Here you'll find engineering principles explained in non-technical language and practical methods for applying them on the job. With the help of this book you'll be able to understand engineering functions in the plans and how to meet the requirements, how to get permits issued without the help of an engineer, and anticipate requirements for concrete, steel, wood and masonry. See why you sometimes have to hire an engineer and what you can undertake yourself: surveying, concrete, lumber loads and stresses, steel, masonry, plumbing, and HVAC systems. This book is designed to help you, the builder, save money by understanding engineering principles that you can incorporate into the jobs you bid.
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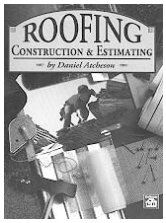

Installation, repair and estimating for nearly every type of roof covering available today in residential and commercial structures: asphalt shingles, roll roofing, wood shingles and shakes, clay tile, slate, metal, built-up, and elastomeric. Covers sheathing and underlayment techniques, as well as secrets for installing leakproof valleys. Many estimating tips help you minimize waste, as well as insure a profit on every job. Troubleshooting techniques help you identify the true source of most leaks. Over 300 large, clear illustrations help you find the answer to just about all your roofing questions. **432 pages, 8½ x 11, $38.00**

Troubleshooting Guide to Residential Construction

How to solve practically every construction problem — before it happens to you! With this book you'll learn from the mistakes other builders made as they faced 63 typical residential construction problems. Filled with clear photos and drawings that explain how to enhance your reputation as well as your bottom line by avoiding problems that plague most builders. Shows how to avoid, or fix, problems ranging from defective slabs, walls and ceilings, through roofing, plumbing & HVAC, to paint.
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JLC Guide to Moisture Control

Water can be a building's worst enemy, which is why we try so hard to keep it out of our homes and living spaces. The editors of the *Journal of Light Construction* have brought together leading experts to write this book on controlling practically all forms of moisture damage in residential buildings. It explains the mysteries of vapor barriers, provides innovative solutions for keeping basements and crawl spaces dry, and shows fool-proof methods for flashing windows and doors so that they won't let in storm water. Also gives storm-proof stucco details as well as tips for keeping paints and stain on exterior wood. Provides leak-free flashing techniques for both steep and low-slope roofs and plans for low-cost whole-house ventilation that work incredibly well.
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Guide to Stamped Concrete

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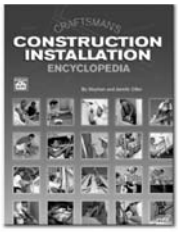
142 pages, 8½ x 11, $45.00

Craftsman's Construction Installation Encyclopedia



Step-by-step installation instructions for just about any residential construction, remodeling or repair task, arranged alphabetically, from *Acoustic tile* to *Wood flooring*. Includes hundreds of illustrations that show how to build, install, or remodel each part of the job, as well as manhour tables for each work item so you can estimate and bid with confidence. Also includes a CD-ROM with all the material in the book, handy look-up features, and the ability to capture and print out for your crew the instructions and diagrams for any job.
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Framing with steel has obvious advantages over wood, yet building with steel requires new skills that can present challenges to the wood builder. This book explains the secrets of steel framing techniques for building homes, whether pre-engineered or built stick by stick. It shows you the techniques, the tools, the materials, and how you can make it happen. Includes hundreds of photos and illustrations, plus a FREE download with steel framing details and a database of steel materials and manhours, with an estimating program. **320 pages, 8½ x 11, $39.75**

Drafting House Plans

Here you'll find step-by-step instructions for drawing a complete set of home plans for a one-story house, an addition to an existing house, or a remodeling project. This book shows how to visualize spatial relationships, use architectural scales and symbols, sketch preliminary drawings, develop detailed floor plans and exterior elevations, and prepare a final plot plan. It even includes code-approved joist and rafter spans and how to make sure that drawings meet code requirements.
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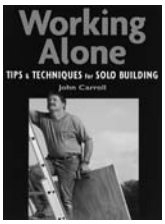
Blueprint Reading for the Building Trades

How to read and understand construction documents, blueprints, and schedules. Includes layouts of structural, mechanical, HVAC and electrical drawings. Shows how to interpret sectional views, follow diagrams and schematics, and covers common problems with construction specifications. **192 pages, 5½ x 8½ , $16.75**

Builder's Guide to Drainage & Retaining Walls

Creating an adequate drainage system is the critical first step in most construction projects. Retaining walls are integral to the design plan, when used to achieve level grade. These two topics are interrelated, and this book provides a complete introduction to doing both right. Here you'll find the data you need on average rainfall and runoff requirements so you can figure gutters, downspouts and roof drainage, and install appropriate waterproofing and damp-proofing in basements and crawlspaces. The book gives details for determining slope drainage, doing the grading, complying with street drainage requirements, and dealing with lots with septic systems. Many types of retaining wall are covered, including modular unit walls, bin and crib walls, and more. Also provides tables for estimating concrete quantities for both poured-in-place and masonry and concrete walls. Includes detailed recommendations for retaining walls in most of the situations you're likely to encounter. Includes a CD-ROM that brings you the entire book in an Adobe PDF file, for jobsite reference and quick word search. (This file has no print capability.) A second PDF file includes 100 sample details you can print and carry along on jobs. **294 pages, 8½ x 11, $59.95**

Working Alone



This unique book shows you how to become a dynamic one-man team as you handle nearly every aspect of house construction, including foundation layout, setting up scaffolding, framing floors, building and erecting walls, squaring up walls, installing sheathing, laying out rafters, raising the ridge, getting the roof square, installing rafters, subfascia, sheathing, finishing eaves, installing windows, hanging drywall, measuring trim, installing cabinets, and building decks. **152 pages, 5½ x 8½ , $17.95**

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344 pages, 8½ x 11, $54.75

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Residential Construction Performance Guidelines

Created and reviewed by more than 300 builders and remodelers, this guide gives cut-and-dried construction standards that should apply to new construction and remodeling. It defines corrective action necessary to bring all construction up to standards. Standards are listed for sitework, foundations, interior concrete slabs, basement and crawl spaces for block walls and poured walls, wood-floor framing, beams, columns and posts, plywood and joists, walls, wall insulation, windows, doors, exterior finishes and trim, roofs, roof sheathing, roof installation and leaks, plumbing, sanitary and sewer systems, electrical, interior climate control, HVAC systems, cabinets and countertops, floor finishes and more.
120 pages, 6½ x 8½, $39.95. Published by: NAHB Remodelers Council

Contractor's Guide to Change Orders

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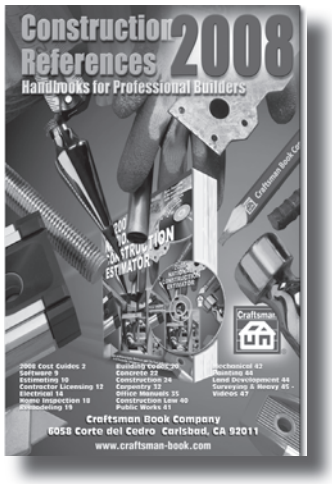

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