A Brief intro to code concerns

Issues affecting superstructure

Professionals & Codes

- Professionals are licensed with a societal trust to ***protect the health safety and welfare of the general public***
- To fulfill this public trust, builders, architects, engineers and building officials have developed performance guidelines for meeting life safety obligations in the design and construction of buildings

Codes…for every region

- UBC - The uniform building code, published by the International Conference of Building Officials
- BOCA - The BOCA code, published by the Building Officials Code Administrators
- SBCCI - Southern Building Code Congress International

- These are mostly superceded at this time

A Unified Code

- IBC 2000 - Written by BOCA, ICBO & SBCCI will begin to be adopted during the year 2000, will resolve some of the regional code differences & conflicts….except for..
- NFPA - National Fire Protection Administrators, authors of the fire code used in most government funded projects.

The general idea of codes

- Keep the building's life safety infrastructure intact long enough to evacuate the building's occupants and allow fire fighters a relatively safe environment to fight the fire…(limit collapse during firefighting)

Key Strategies of the Code

- The ***taller*** a building is, the longer it's construction has to survive a fire…(to give occupants time to climb down a stair, In the first World Trade Center bombing, it took occupants over ***three hours*** to walk down 100 or so stories!)
- The ***bigger*** a building is in area, the longer it's construction has to survive a fire…(to give occupants time to make their ways to exits and evacuate the building)

Key Strategies of the Code..2

- The less ambulatory the occupants are, the better the longer the building's life safety infrastructure has to survive intact in a fire. So Hospitals, Nursing homes, Asylums, prisons, where the occupants are not free or not able to walk out of the building must be built to ***survive longer*** in a fire.

Implications

- This means the better a building is built, the bigger and taller it can be… or that it can be used for less ambulatory people.
- Generally the code considers building construction as falling into two general categories, Combustible (can burn) and Non-Combustible (can't burn)

Process

- Most codes follow a similar process, asking the designer to
  - First categorize the kind of use planned for the building into and OCCUPANCY type.
  - Next categorize the CONSTRUCTION type planned to meet the height, and area given by the project's program, site, and conceptual design
  - Next specify the quality of the construction in the number of HOURS each assembly will survive during a fire, based on approved tests (U.L., Factory Mutual….)

Allowable Height & Area table

- Most codes will have a table or matrix listing the occupancy type on the left, and asking the designer to read across to the right to match up the height and area allowed for that occupancy with the projects programmatic requirements.

Height & Area table

Area per floor

Non-combustible **Combustible**

Height (feet)		Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Group	H / A	UL	160’	65’	55’	65’	55’	65’	50’	40’
A1	H	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
B	H	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

•So in this example, a type B occupancy, with a design program requiring 40,000 square feet on a site small enough to require a 4 story building could be built like a type IV HT building.
•If we only considered area per floor, the type V-A would work allowing up to 18,000 square feet per floor….but type V-A is limited to 3 floors in height so, we move left to the next construction type, type IV-HT….but being heavy timber, its not so useful for the office building, we move over to the left one more and find type III-B which is big enough per floor, and allows 4 floors. So we work to type III - B requirements.

Let’s see that again..

Non-combustible **Combustible**

Height (feet)		Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Group	H / A	UL	160’	65’	55’	65’	55’	65’	50’	40’
A1	H	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
B	H	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

•First, we look at the concept for the office building, in this case the program calls for 40,000 s.f. and the site is driving a 4 story concept.

•Next we look at the type ‘B’ occupancy for office building

Step two...

Non-combustible — Combustible

Height (feet)		Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Group	H / A	UL	160’	65’	55’	65’	55’	65’	50’	40’
A1	H	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
B	H	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

•Next, knowing the building will be 4 story and 40,000 square feet, we know it is 10,000 square feet per floor.

•Checking the ‘A’ row in the ‘B’ occupancy we find that type V - A allows 18,000 s.f. per floor, plenty for our application

Step three...

Non-combustible — Combustible

Height (feet)		Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Group	H / A	UL	160’	65’	55’	65’	55’	65’	50’	40’
A1	H	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
B	H	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

•Now we check the allowable height for Type V - A and find that it allows 3 stories….not enough for our project.

•So we keep looking...

Step Four

Non-combustible — Combustible

Height (feet)		Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Group	H / A	UL	160’	65’	55’	65’	55’	65’	50’	40’
A1	H	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
B	H	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

• We move to the left (the direction of more fire resistive construction) and find type IV-HT allows enough area per floor (36,000) s.f. and enough height (5 stories)

•But the HT behind the Type IV designation means we would have to build out of heavy timber, which limits materials, opportunity for systems integration, and acoustical qualities in order to preserve the fire resistive nature of Heavy Timber construction.

•So we keep looking….

Step Five

Non-combustible | Combustible

Height (feet)		Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Group	H / A	UL	160'	65'	55'	65'	55'	65'	50'	40'
A1	H	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
B	H	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

- Again we move to the left (the direction of more fire resistive construction) and find type III - B allows enough area per floor (19,000) s.f. and enough height (4 stories)
- So Type III - B is our Construction Type for construction for the project.

The lowest construction type allowed

Non-combustible | Combustible

Height (feet)		Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Group	H / A	UL	160'	65'	55'	65'	55'	65'	50'	40'
A1	H	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
B	H	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

It is common to work the project into the lowest allowable construction type when the architectural idea does not drive the selection of the superstructure. This reduces cost and provides a little more detailing flexibility during design development

What does it mean????

- So it looks like Type III - B will work for us. What does that mean in terms of the materials for beams, columns, walls, roofs, partitions and the fire protection of each?
- In the IBC, Table 601 describes the fire resistance ratings (in hours) for each building element.

Ratings for construction types

Building Element	Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Structural Frame (incl col. girders, trusses)	3	2	1	0	1	0	HT	1	0
Bearing walls int. Bearing walls ext.	3 3	2 2	1 1	0 0	2 1	2 0	2 1/HT	1 1	0 0
Non-Bearing Walls / partitions	SEE	TABLE	602	AND	SECTION	603			
Floor construction Including supporting beams & joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	1-1/2	1	1	0	1	0	HT	1	0

•This table gives the required ratings for each construction element.
•A building is rated by its weakest element! So even if the structural frame was poured concrete (type 1 construction) if the floor was not protected, the weakness of the floor in fire would drag the whole building down to a type IIB, IIIB or VB. (where it may be too big, too tall, or the wrong occupancy to pass inspection!)

Ratings for construction types

Building Element	Type I A	Type I B	Type II A	Type II B	Type III A	Type III B	Type IV HT	Type V A	Type V B
Structural Frame (incl col. girders, trusses)	3	2	1	0	1	0	HT	1	0
Bearing walls int. Bearing walls ext.	3 3	2 2	1 1	0 0	2 1	2 0	2 1/HT	1 1	0 0
Non-Bearing Walls / partitions	SEE	TABLE	602	AND	SECTION	603			
Floor construction Including supporting beams & joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	1-1/2	1	1	0	1	0	HT	1	0

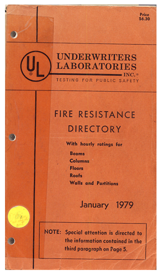
•Now that we have a construction type selected (III B), we need to determine the required fire protection ratings for each element.
•Our Type III - B construction shows 0 hours of protection required for every building element except interior bearing walls

Ethics, Morals, Conscience

- So, not having a required rating for many of the building components is good news and bad news.
- Good news because all we have to do is maintain noncombustibility and we meet the code.
- Bad news because we know that the building structure can fail pretty quickly during a fire. Steel begins seriously losing strength at 1200 degrees, and most fires hit 1600 degrees in the first 10 minutes!
- So what to do, It’s not hard to protect the steel with a layer of drywall, and even though it’s not required, it will help the columns and trusses last longer.
- Sprinkling can many times give the owner a reduced insurance rate that can offset the cost of the system over the life of the mortgage.

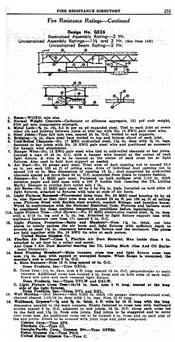
What makes a rating?

- The hours of protection offered by fire protecting materials to building elelments have been established by full scale fire testing of various component assemblies by testing labs like UL, or Factory Mutual.



Testing to failure

- A testing lab like U.L. will construct a full scale assembly to the manufacturer's (who pays for the test) specification.
- Then U.L. will expose it to fire on one side, recording temperature, deformation, smoke contribution, while loading the assembly to its design load, until it fails.
- U.L. reports the performance in its fire resistance handbook.



FIRE RESISTANCE DIRECTORY 255

Fire Resistance Ratings—*Continued*

Design No. G526
Restrained Assembly Rating—2 Hr.
Unrestrained Assembly Ratings—1½ and 2 Hr. (See Item 14B)
Unrestrained Beam Rating—2 Hr.

1. Beam—W10X21 min size.
2. Normal Weight Concrete—Carbonate or siliceous aggregate, 151 pcf unit weight. 3700 psi min compressive strength.
3. Metal Lath—⅜ in. rib, 3.4 lb per sq yd expanded steel. Tied to each joist at every other rib and midway between joists at side lap with No. 18 SWG galv steel wire.
4. Steel Joists—Type 8J2 min size, spaced 24 in. O.C. welded to end supports.
5. Bridging—½ in. diam steel bars welded to top and bottom chord of each joist.
6. Cold-Rolled Channels—No. 17 MSG cold-rolled steel, 1½ in. deep with ½ in. legs, fastened to bar joists with No. 18 SWG galv steel wire and positioned as necessary for hanger wire attachment.
7. Hanger Wire—No. 12 SWG galv steel wire tied to cold-rolled channels or bar joists. Located a max of 48 in. O.C. with a hanger wire located at the corner of each light fixture. A wire is to be located at the center of each cross tee at light fixtures. Also used to hold duct support as needed.
8. Air Duct—No. 20 gauge galv steel. Total area of duct opening not to exceed 56.5 sq in. per each 100 sq ft of ceiling area. Area of individual duct opening not to exceed 118 sq in. Max dimensions of opening 12 in.; duct supported by cold-rolled channels spaced not more than 60 in. O.C. suspended from joists in trapeze fashion.
9. Damper—No. 14 MSG galv steel. Protected on both surfaces with 1/16 in. thick asbestos paper and held open with a 160 F fusible link (bearing the UL Listing Mark). Damper to overlap duct outlet min 1 in.
10. Air Boots—No. 21 MSG galv steel, 40 by 6 by 3½ in. high. Installed on both sides of light fixtures, attached to fixtures with tabs at ends of air boots.
11. Light Fixtures Recessed—Fluorescent lamp type, No. 22 MSG steel housing 24 by 48 in. size. Spaced so that their area does not exceed 25 sq ft per 100 sq ft of ceiling area. Fixtures fitted with flexible steel conduit, conduit fittings, and junction boxes. Wired in conformance with the National Electrical Code. Fixtures and ballasts must be considered for these ambient temperature conditions before installation.

Specifying

- The tested assemblies are then available for specifying by architects and engineers.
- These specifications are ***very*** specific, U.L. records the kinds of screws, any wire ties, and all products in the assembly.
- It is the position of U.L. that any change in the specification would mean an unpredictable level of performance in the field.
- So what is specified must be what's built…but isn't always.

Specifics on Systems & Materials

- As we review different construction systems and materials we will make special note of the code's expectations for the performance of those materials….and how the design & construction industry meet the performance requirements.

Egress

- Promoter P.T. Barnum is said to have charged people 25 cents to enter a darkened room and "See the Egress."
- Once in the darkened room, the people could only see a dim light over a door with a sign on it saying "This way to the Egress."
- Upon opening the door and walking through they found themselves on the street!

- Egress is the term applied to the various means (corridors, stair enclosures, stairs) *to be used as a means of escape in the event of a fire or other disaster in the building*.

Some key IBC Definitions

- Area of Refuge: Area where persons unable to use stairways can remain temporarily to await instructions or assistance during emergencies
- Corridor: An enclosed exit access component that defines and provides a path of egress travel to an exit.
- Exit: That portion of a means of egress system which is separated from other interior spaces of a building by fire resistance rated construction and opening protectives as required to provide a protected path of egress travel between the exit access to the exit discharge including exit doors, exit enclosures, exit passageways

How Many People?

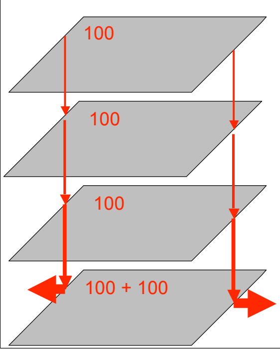
- The IBC offers the choice of two processes for determining the number of people *(occupants)* in the building.
  - The first method is to determine the actual number of people in the space.
  - This is easier to do in a building with fixed seating (auditorium) than in say an open office space where, the density varies over time.
  - The second method is to refer to the Maximum Floor Area per Occupant table, find your use type, divide the number of gross square feet per occupant in the table into your project's gross square footage to arrive at the number of occupants in the building, or per floor.

Occupant load table …excerpted

Occupancy	Floor Area in Square Feet per occupant
Assembly without fixed seats	
Concentrated (chairs)	7 net
Standing space	5 net
Unconcentrated (tables and chairs)	15 net
Business Areas	100 gross
Dormitories	50 gross
Educational	
Classroom Area	20 net
Vocational Areas (shops)	50 net
Library	
Reading Area	50 net
Stack Area	100 gross

So our Business Occupancy would take the program area (40,000 s.f.) and divide it by 100 s.f. to determine we have 400 occupants

Egress convergence



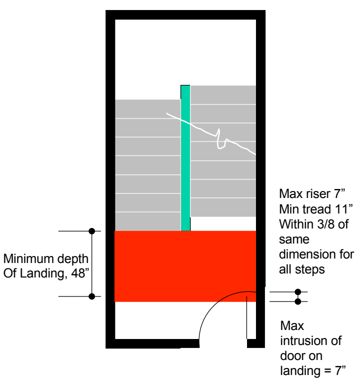
- As the occupants from a floor above exit through lower floors, they don't impact the exit size for the floor the pass through, but the exit size cannot get smaller.
- But when exits converge at a floor, like the ground floor where they leave the building, the occupant load for the ground floor must take into account the occupant load of the floor immediately above.
- First floor, 10,000 s.f. = 100 occ + 100 from second, 200 occupants

How wide does that make the exit?

- The IBC reads "The total width of the means of egress in inches shall not be less than the total occupant load served multiplied by"
  - .3 for stairs in unsprinkled buildings
  - .2 for corridors, other egress components in unsprinkled buildings

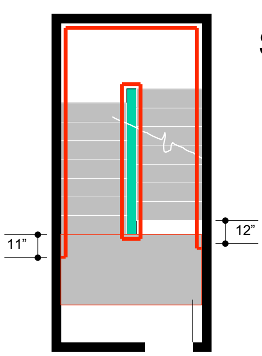
  - .2 for stairs in sprinkled buildings
  - .15 for other components in sprinkled buildings
- So our top floor stair in our unsprinkled example could be no less than 100 x .3 or 30 inches…not nearly wide enough to meet minimums of the IBC or ADA
- So the code continues to read "nor less than specified elsewhere in this code" so it let's itself out of an apparent contradiction

Stairways



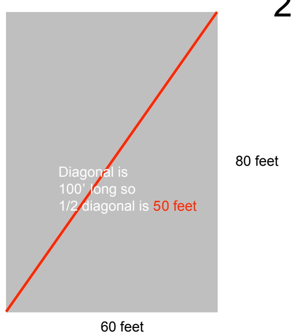
- Two required
- Fully enclosed with 2 hour fire rated construction
- Minimum stair width 48"
- Max stair width without intermediate railing = 5'
  Minimum headroom 80" from nosing line
- Max height between landings = 12'-0"

Stairways…cont'd



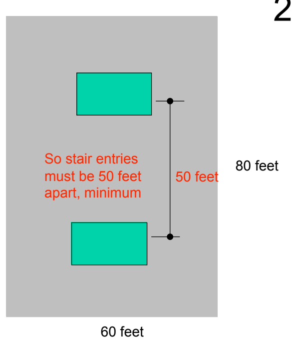
- Handrail height 34" - 38"
- Handrails required both sides. 1-1/4 to 2" dia, 1-1/2" from wall (clear)
- Handrails must extend 12" beyond top riser, and one tread (11"min) beyond bottom tread

2 exit spacing



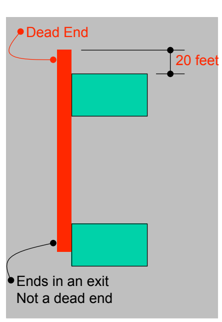
- Exits cannot be closer than 1/2 the maximum diagonal distance of the floor plate

2 exit spacing



- So in this example, the exit stairs could not be placed closer than 50 feet apart
- Maximum travel distances would be for this type 'B' building
  - 200 feet without sprinklers
  - 250 feet with sprinklers
- What would be the maximum stair spacing in a sprinkled type 'B' building?

Dead End Corridors



- A corridor not ending in an exit is considered a *dead end corridor*
- Dead end corridors are limited to 20 feet in length in most occupancies.
- In occupancy group B with a sprinkled building, the dead end can be extended to 50 feet long.

On your way to the exit...

- DO NOT plan the egress path to exit through another tenants space
- DO NOT plan the egress path to exit through storage spaces, kitchens, mechanical rooms…or other high hazard occupancies.

- But exiting through a non hazardous accessory space is acceptable, as long as there is a clear path discernable to the exit.

& in housing

- One egress window per bedroom is required.
- Minimum width is 20 inches
- Minimum height is 24 inches
- Minimum area is 5.7 square feet.
- Maximum height above floor is 44 inches

- (20x24=480 sq. in. or 3.33 s.f.)

Some fine print

- Area allowed in table 503 is area *per floor* so a two story building would double the total allowable area…
- Sometimes this allowable area per floor is not enough given the program area, and site conditions affecting how many floors can be built (example: a zoning height limit)

Increasing area

- Section 506 of the IBC allows modifications to the area values in table 503.
- Increases in the allowable area can be earned through the addition of a fire sprinkler system or by having a large (>25%) proportion of the building perimeter facing an open space (permanently deeded as such and accessed by an approved fire lane or street) or *public way* (usually a street, alley or other publicly deeded right of way)

Formula for increasing area

$$A_a = A_t + \left[\frac{A_t I_f}{100}\right] + \left[\frac{A_t I_s}{100}\right]$$

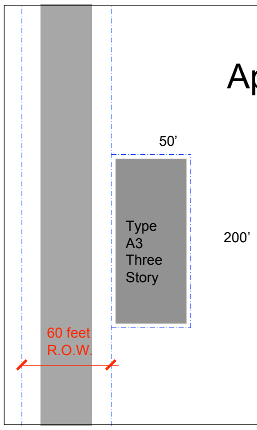
- A_a • Allowable Area
- A_t • Area listed on table 503
- I_f • Area increase from frontage on public way (506.2)
- I_c • Area increase due to sprinkler protection

Calculating increase for frontage

$$I_f = 100\left[\frac{F}{P} - 0.25\right]\frac{W}{30}$$

Note: w/30 cannot exceed 1.0 unless qualifications for unlimited area are met

- I_f • Percent Area increase due to frontage
- F • Building perimeter fronting on a public way having 20 feet of minimum width
- P • Perimeter of entire building
- W • Minimum width of public way or open space



Applied

- This type A3 occupancy building has 500 feet of perimeter
- 200' feet of perimeter face the street, which is in a 60 foot wide R.O.W.
- The rest of the perimeter faces property lines within a few feet.

Plug it in

$$I_f = 100\left[\frac{200}{500} - 0.25\right]\frac{60}{30}$$

$$I_f = 100\left[.4 - 0.25\right]\ 1$$ (A3 Occupancy doesn't qualify for unlimited area)

$$I_f = 100\left[0.15\right]\ 1$$ (A3 Occupancy doesn't qualify for unlimited area)

$$I_f = 15$$ This works out to a 15% Area increase in this example

Plug in to the Area Increase formula

$$A_a = 15{,}500 + \left[\frac{15{,}500 \times 15}{100}\right] + \left[\frac{A_t\ I_s}{100}\right]$$

$$A_a = 15{,}500 + \left[\frac{232{,}500}{100}\right] + \left[\frac{A_t\ I_s}{100}\right]$$

$$A_a = 15{,}500 + \left[2{,}325\right] + \left[\frac{A_t\ I_s}{100}\right]$$

$$A_a = 17{,}825$$

Frontage effect

- This Area increase allowed by the *frontage* of the building on an open space or public way has increased the allowable area per floor to 17,825 s.f.
- Section 506.3 also allows an area increase for installing an approved automatic sprinkler system. The tabular area can be increased by 200% for multi-story buildings and 300% for single story buildings.

Plug in the Sprinkler Increase formula

$$A_a = 15{,}500 + \left[\frac{15{,}500 \times 15}{100}\right] + \left[\frac{15{,}500 \times 200}{100}\right]$$

$$A_a = 15{,}500 + \left[\frac{232{,}500}{100}\right] + \left[\frac{3{,}100{,}00}{100}\right]$$

$$A_a = 15{,}500 + \left[2{,}325\right] + \left[31{,}000\right]$$

$$A_a = 48{,}825$$

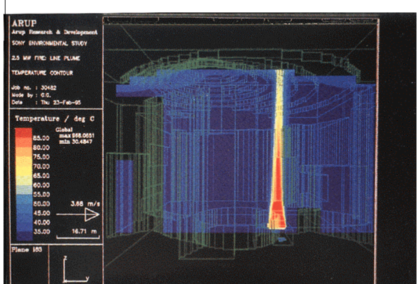
Sprinkler advantage

- Now, with the sprinkler area increase, the allowable area per floor is 48,825 square feet. Quite a difference from the initial allowable area of 15,500 s.f.

Some last points about fire

– Fire
– Three elements are necessary for a
  • fuel
  • heat
  • oxygen

Learning about fire

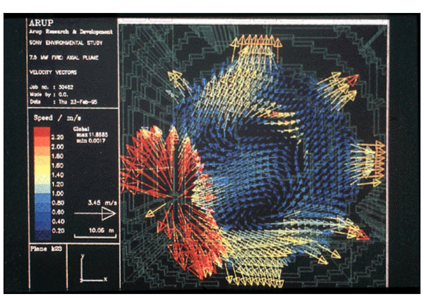


Computational Fluid Dynamic (CFD) modelers are being used to understand the behavior of fire in buildings

This model of an atrium in Berlin has a “virtual fire” burining

The CFD modeler calculates the heat, speed and direction of air movement in the space

Learning about fire



The Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) leads research in fire science and fire engineering

http://www.bfrl.nist.gov/

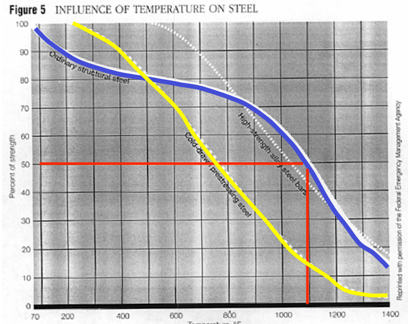
Fire temperatures

- In a fire, temperatures vary, but 1000 to 2000 degrees Fahrenheit are common.
- A temperature difference of 650 degrees between the ceiling and floor are common. (stay low)
- Around the time when the temperature hits 1500 degrees, the superheated gases given off by materials and furnishings explodes sending out a fireball which moves at over 20 feet per second.
- This fireball event, called flashover by firefighters has sufficient force to blow out most window assemblies, (hence no windows in stairs and corridors)

Steel and Fire

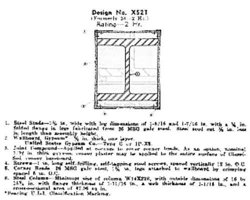
- Steel doesn't burn but will lose 90% of its strength by the time fire hits 1400 degrees.
- But up to 1100 degrees, the steel retains up to 50% of its strength. So as architects, we try to keep steel cool, usually by insulating, but strategies for steel protection will be discussed in the steel chapter.

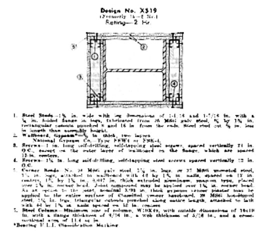
Figure 5 INFLUENCE OF TEMPERATURE ON STEEL



Steel & Fire

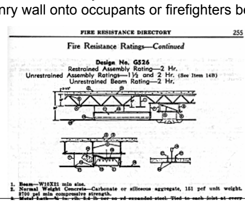
- Thicker steel conducts heat away from the fire source and keeps temperature lower.
- This is why the UL tests for heavier steel sections require less insulation than the thinner sections.





Steel and more fire

- A lightweight steel web joist (bar joist) can collapse within 5 to 15 minutes when exposed to 1100 degree heat.
- Steel will elongate 1 inch for each 10 feet of length at 1000 degrees.
  - This can eccentrically load a column, or literally push over a masonry wall onto occupants or firefighters below.



Wood and Fire

- As wood burns, it produces a layer of charcoal at a rate of approx. 1/40th inch per minute.
- Small members (2x4...) burn through rapidly.
- In larger members (heavy timber) the charcoal layer acts as insulation to protect the interior of the member from fire and allow it to keep much of its structural capacity.
- This is why Type 4 construction allows more height and area then Type 5 and even more than some Type 3 constructions.

Concrete and fire

- Concrete protects the reinforcing steel inside by transferring heat through its mass.
- Moisture in concrete turns to steam in a fire and will spall the surface off, sometimes exposing the reinforcing steel to the fire.
- A minimum of 2 inches of concrete should cover all reinforcing steel.
- Structural precast concrete members usually depend on prestressed steel tendons for strength.
- These tendons are made of a type of steel which loses strength faster than mild steel rebars, and don't recover their strength when the fire is out. Tendons are permanently damaged by temperatures over 800 degrees.

Plastics and smoke

- Plastics are extremely flammable, they are principle contributors to the combustible gases making up a flashover, their melting and dripping flaming drops spreads fire.
- Smoke production by vinyl and urethanes (most furnishings, some thermal insulation) will reduce visibility to less than 6 feet in less than 1 minute.
- Smoke production by wood will reduce visibility to less than 16 feet in less than 1 minute.

People and fire

- People
- comfort zone 60 to 80 degrees
- tolerable for 1 hour 140 to 150 degrees (maximum survivable breathing temperature)
- intolerable in 25 minutes 210 to 220 degrees
- intolerable in 15 minutes 240 to 250 degrees
- intolerable in 5 minutes 270 to 280 degrees
- irreversible injury in 30 seconds 350 to 360 degrees
  - Common fire temperatures 1000 to 2000 degrees