

# SITECAST CONCRETE STRUCTURAL SYSTEMS

The initial choice of a sitecast concrete framing system is most often based on the desired spans or column spacings of the structure and on the expected magnitude of the in-service loads on the building. The following systems are listed in order of increasing spans, load capacity, and cost:

- One-Way Solid Slab
- Two-Way Flat Plate
- Two-Way Flat Slab
- One-Way Joist
- Waffle Slab
- One-Way Beam and Slab
- Two-Way Beam and Slab

For short-span, light-load conditions, systems from the top of this list are the most economical. For long spans and heavy loads, systems from the bottom of the list may be required.

## POSTTENSIONING

The span ranges of sitecast concrete systems can be increased by

the use of posttensioned reinforcing. Charts for the sizing of post-tensioned systems are included in this section. Posttensioning also substantially reduces the depth of spanning members and may be desirable where total floor-to-floor heights must be kept to a minimum. The extensive use of post-tensioning in a concrete structure may limit the ease with which such a structure can be modified in the future, since penetrations in slabs and beams must not interrupt the continuity of the reinforcing or surrounding concrete. This may make posttensioning an undesirable choice for buildings where significant change in program or structure must be anticipated.

## ARCHITECTURAL SITECAST CONCRETE CONSTRUCTION

The inherent fire-resistive qualities of concrete construction allow con-

crete systems to remain wholly or partially exposed in a finished building. Furthermore, the process by which concrete is formed on site, and its monolithic and plastic qualities as a finished product give this material unique architectural potential. For these reasons, the choice of a concrete framing system may have significant architectural implications that should be considered early in the design process. Factors to consider in the architectural use of sitecast concrete include: the added cost and difficulty of achieving acceptable levels of finish quality and dimensional accuracy with exposed concrete, the ease of integrating building mechanical and electrical services into the exposed structure, and the potential aesthetic qualities of the various construction elements and systems. If an extensive use of architectural concrete is being considered for a project, the necessary consultants should be sought out at the earliest possible time, as the use of architectural concrete will have a major impact on the design and construction of the building.

# SITECAST CONCRETE COLUMNS

## CONCRETE STRENGTH AND COLUMN SIZE

The top chart on the facing page is based on a concrete strength of 5000 psi (35 MPa). Higher-strength concretes may be used to reduce the required column size. For other concrete strengths, multiply the indicated column size by the amount in the table to the right:

## COLUMN SIZE AND CONCRETE SLAB SYSTEMS

For the two-way slab systems in the table to the right, column size may be limited by the depth of the slab. For further information see the pages indicated.

## ECONOMICAL CONCRETE COLUMN DESIGN

Column sizes should change as little as possible throughout a building. Column strength can be varied where required by changing the strength of the concrete mix or by adjusting the amount of steel reinforcing. Where size increases cannot be avoided, increasing only one dimension of a column at a time, in even 2-in. (50-mm) increments, is usually preferred.

Column locations should be continuous to the building foundation. Where columns on floors above cannot be supported directly below, large transfer beams are required.

Column placements should be as uniform and ordered as possible. Irregular column placements prevent the use of the most economical forming methods.

Rectangular or square columns should conform to standard orthogonal alignments. Deviations from the normal complicate formwork where the column and the slab meet.

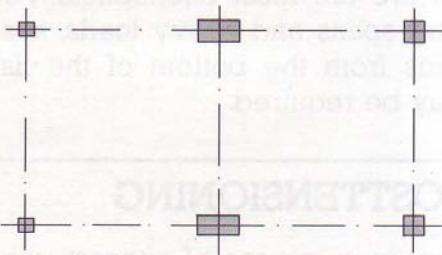
## FIRE-RESISTANCE RATINGS FOR SITECAST CONCRETE COLUMNS

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

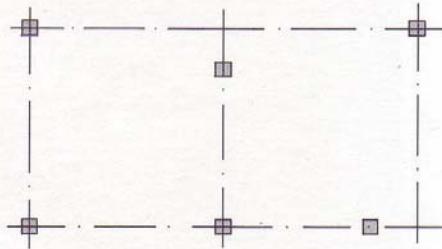
To achieve a 4-hour rating, a concrete column must be at least 14 in. (356 mm) in minimum dimension. For a 3-hour rating, the minimum dimension is 12 in. (305 mm). For 2 hours, a column must be at least 10 in. (254 mm) on a side, and for 1 hour, 8 in. (203 mm).

Concrete Strength	Multiply Column Size by
3000 psi (21 MPa)	1.20
7000 psi (48 MPa)	0.95
9000 psi (62 MPa)	0.80
11,000 psi (76 MPa)	0.75

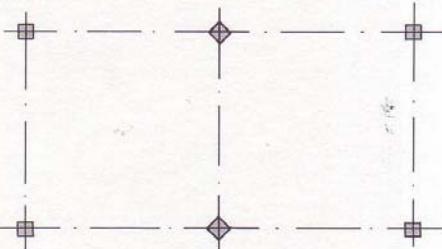
Systems	Pages
Sitecast Concrete	116–117
Two-Way Flat Plate	
Sitecast Concrete	118–119
Two-Way Flat Slab	
Sitecast Concrete	120–121
Waffle Slab	



## VARIATIONS IN COLUMN SIZE

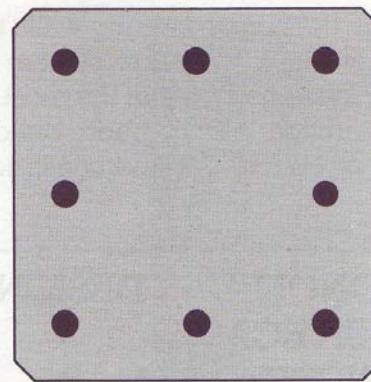
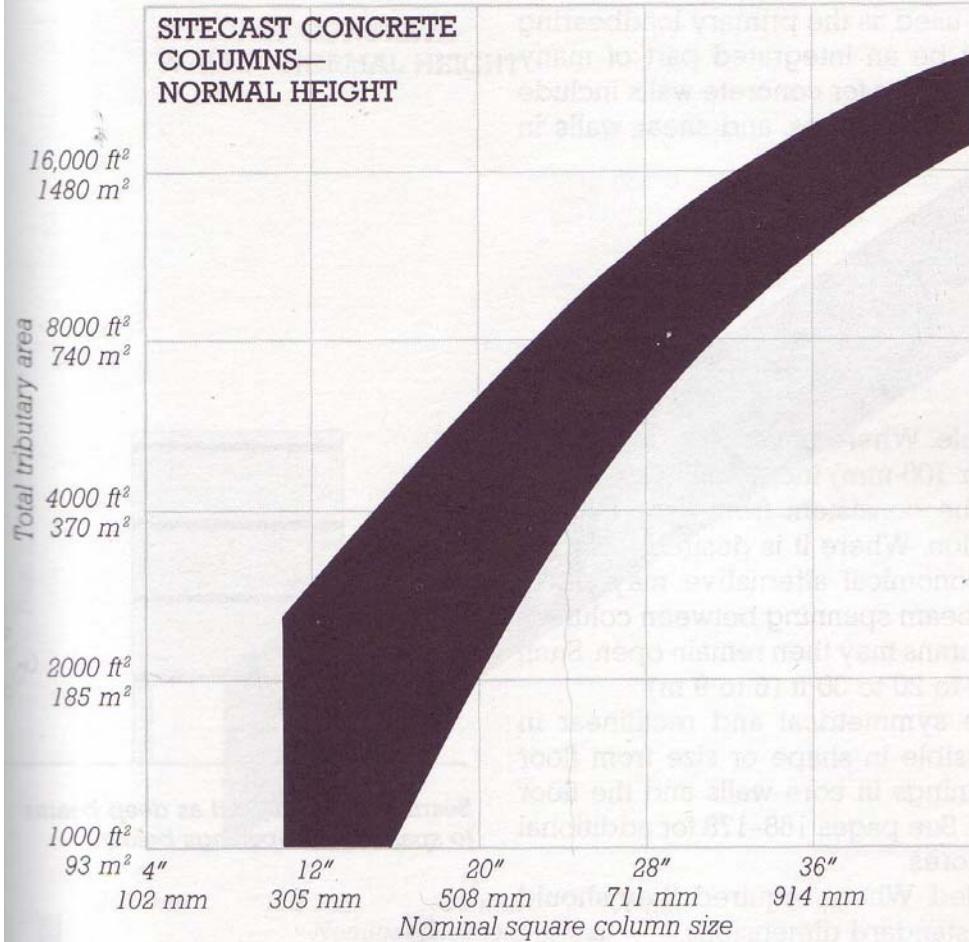


## IRREGULAR COLUMN PLACEMENTS



## IRREGULAR COLUMN ALIGNMENTS

# SITECAST CONCRETE COLUMNS

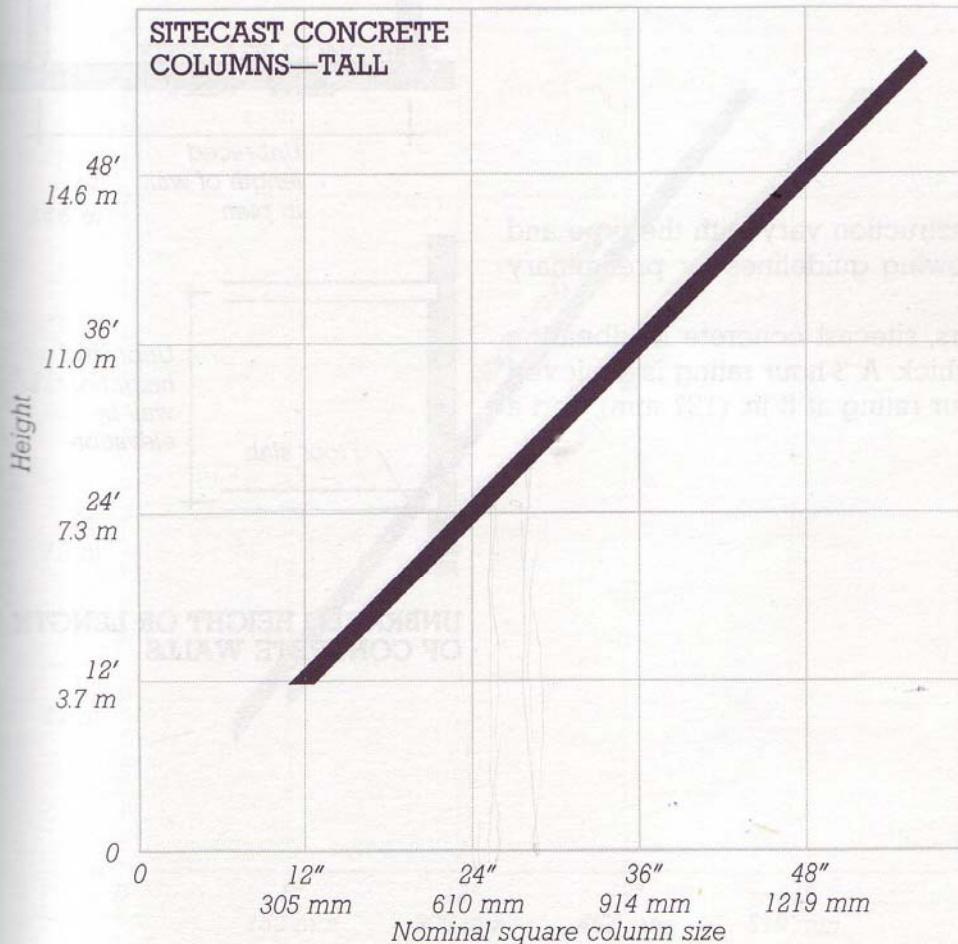


The top chart is for sitecast concrete columns up to 12 ft (3.7 m) in height between floors. For normal loads, read toward the left in the solid area. For high loads, read toward the right.

- For round columns, increase the indicated column diameter by 25%.
- For rectangular columns, select a column of equivalent area.
- Actual column size is equal to the nominal column size less  $\frac{1}{2}$  in. (13 mm).
- Total tributary area* is the total area of roofs and floors supported by the column.

The bottom chart is for columns with unbraced heights greater than 12 ft (3.7 m). Use the larger of the two sizes indicated by both charts on this page.

- For rectangular columns, read from this chart using the least dimension of the column.
- For round columns, read from this chart using the diameter of the column.



# SITECAST CONCRETE WALLS

Sitecast concrete bearing walls may be used as the primary loadbearing element in a structural system or may be an integrated part of many other systems. Some of the most common uses for concrete walls include construction below grade, building structural cores, and shear walls in steel or concrete frame construction.

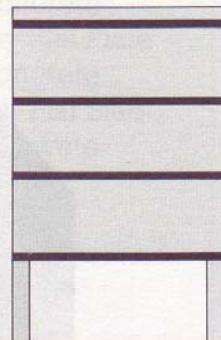
## ECONOMICAL DESIGN OF SITECAST CONCRETE WALLS

Vary wall thicknesses as little as possible. Where necessary, changes in thickness should be in 2- or 4-in. (50- or 100-mm) increments.

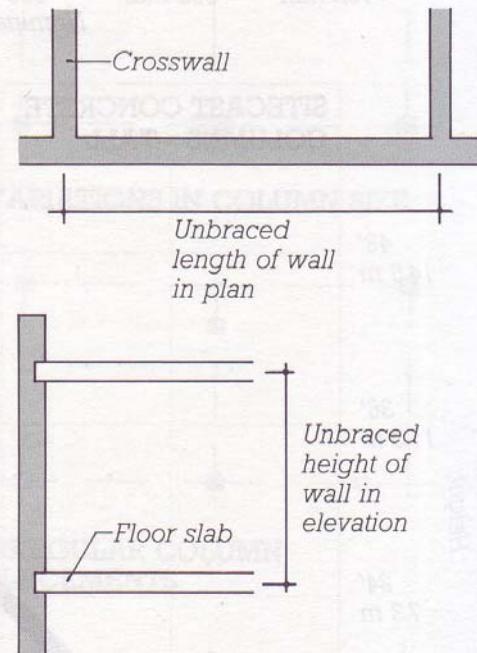
Loadbearing wall locations should be consistent from floor to floor and continuous to the building foundation. Where it is desirable to omit bearing walls on a lower floor, an economical alternative may be to design the wall above to act as a deep beam spanning between columns at each end. The space between the columns may then remain open. Such wall-beams may economically span up to 20 to 30 ft (6 to 9 m).

Concrete building cores should be symmetrical and rectilinear in shape and should vary as little as possible in shape or size from floor to floor. The locations and sizes of openings in core walls and the floor should also be as consistent as possible. See pages 168–178 for additional information on the design of building cores.

The use of pilasters should be avoided. Where required, they should be regularly spaced and of consistent, standard dimensions.



Bearing walls may act as deep beams to span across openings below.



UNBRACED HEIGHT OR LENGTH OF CONCRETE WALLS

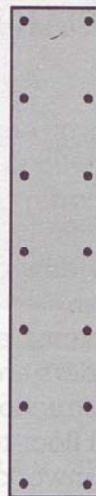
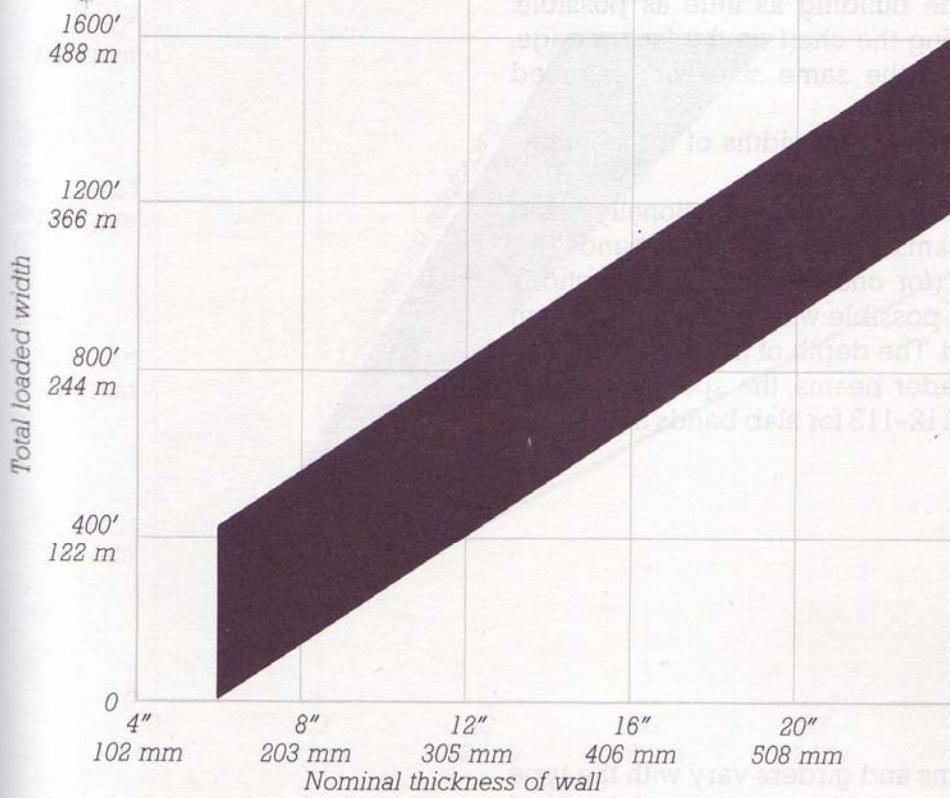
## FIRE-RESISTANCE RATINGS FOR SITECAST CONCRETE WALLS

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

For a fire-resistance rating of 4 hours, sitecast concrete loadbearing walls must be at least 6.5 in. (165 mm) thick. A 3-hour rating is achieved at a thickness of 6 in. (152 mm), a 2-hour rating at 5 in. (127 mm), and a 1-hour rating at 3.5 in. (89 mm).

# SITECAST CONCRETE WALLS

SITECAST CONCRETE  
WALLS—NORMAL HEIGHT



The top chart is for concrete load-bearing walls up to 12 ft (3.7 m) in height between floors. For normal loads, read toward the top in the indicated area. For high loads, read toward the bottom.

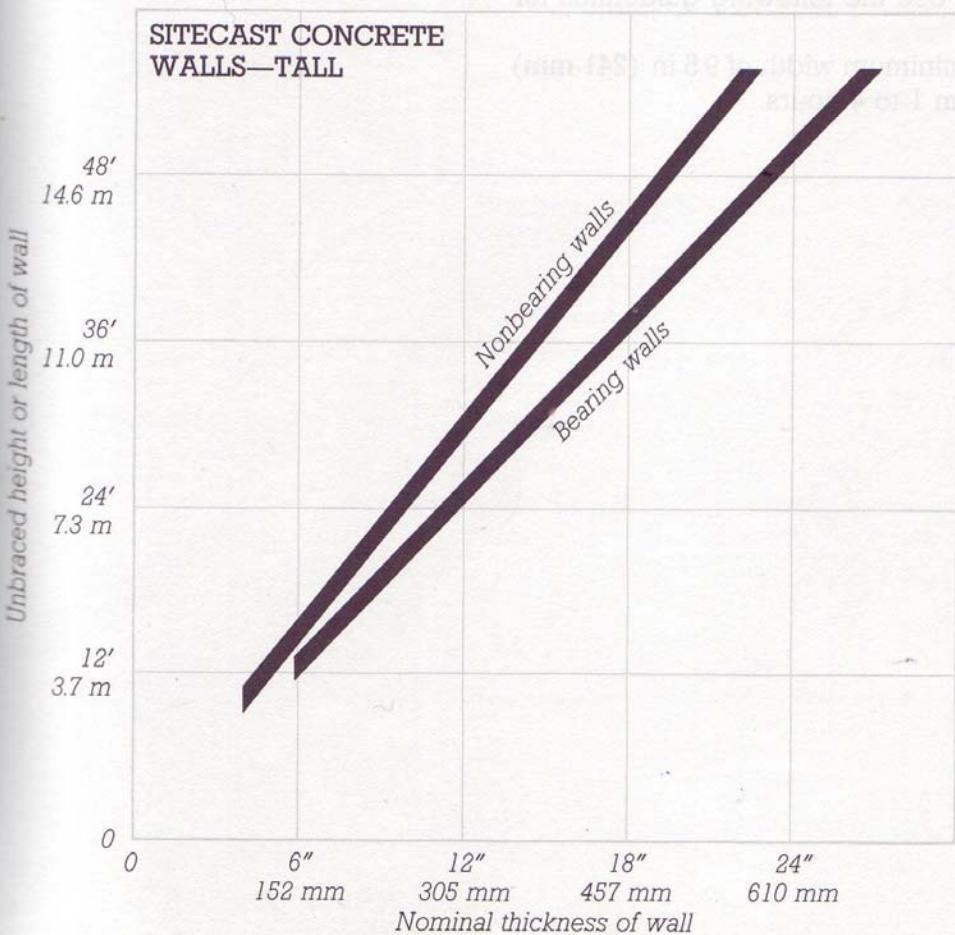
Actual wall thickness is equal to the nominal thickness less  $\frac{1}{2}$  in. (13 mm).

*Total loaded width* is one-half the span of one floor supported by the wall multiplied by the number of floors and roof above the wall.

The bottom chart is for bearing walls taller than 12 ft (3.7 m) between floors and for nonbearing walls. Read along the solid line for the appropriate wall type. For tall bearing walls, use the larger of the sizes indicated by both charts on this page. For nonbearing walls, refer to this chart only.

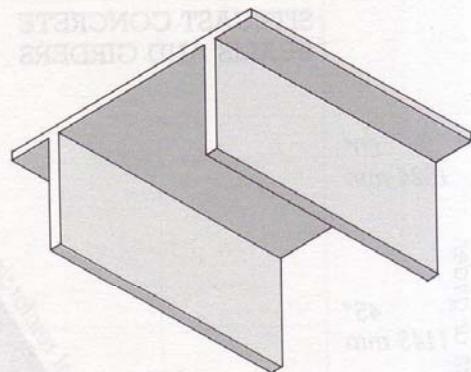
*Unbraced height or length of wall* is the vertical distance between floors or the horizontal distance between pilasters or cross-walls, whichever is less. (See the lower diagram on the facing page.)

SITECAST CONCRETE  
WALLS—TALL



# SITECAST CONCRETE ONE-WAY SOLID SLAB

One-way solid slab construction supported by bearing walls is the least expensive sitecast concrete framing system for short spans and light loads. It is a popular concrete system for multiple dwelling building types such as apartments or hotels, where the regular spacing of bearing walls is easily coordinated with the layout of the small, uniformly arranged rooms typical of these buildings.



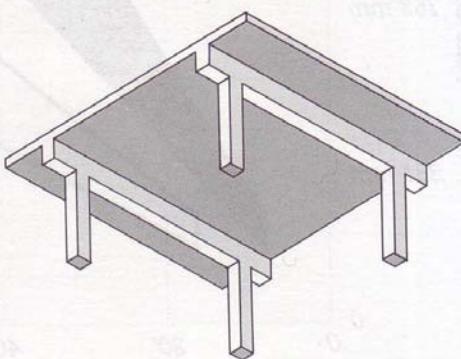
ONE-WAY SOLID SLAB WITH BEARING WALLS

## ONE-WAY BEAM AND SLAB SYSTEMS

The addition of beams and girders to one-way solid slab construction can increase the load capacity and span range of the system and eliminate the need for regularly spaced walls in the building plan. The increased complexity of beam and girder systems, however, makes these one of the most expensive of all sitecast concrete systems to construct. One-way beam and slab construction is usually economical only where long spans or high loads must be accommodated, such as with industrial uses or in areas of high seismic risk.

Slab bands can be an economical alternative to conventional deeper beams when beams are used. Savings in total floor-to-floor heights are possible with the reduced beam depths, and formwork costs are reduced. The depth of the slab itself may be reduced as well, since with the broader beams, the span of the slab between the beams is lessened.

Maximum repetition of standard sizes increases the economy of slab and beam systems. Wherever possible, beam depths should be sized for the longest spans, and then the same depths should be used throughout. Beam widths and spacings, slab depths, and column sizes and spacings should also vary as little as possible within the structure.

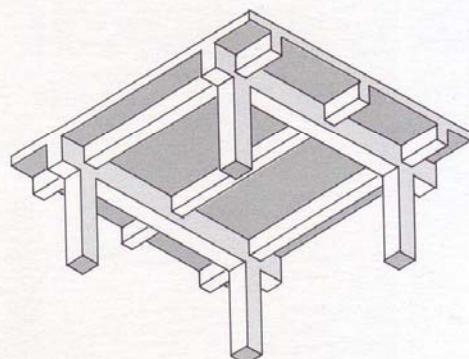


ONE-WAY SOLID SLAB WITH BEAMS

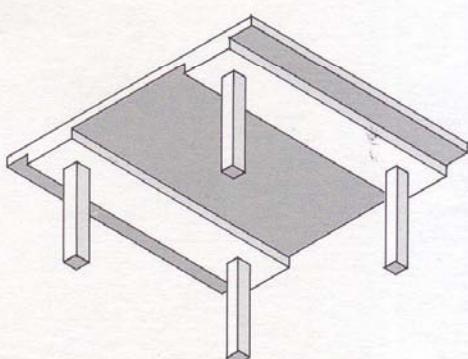
## FIRE-RESISTANCE RATINGS FOR ONE-WAY SOLID SLAB CONSTRUCTION

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

To achieve a 3-hour fire-resistance rating, a solid slab must be at least 6.5 in. (165 mm) thick. For a 2-hour rating, the minimum thickness is 5 in. (127 mm), for 1½ hours, 4.5 in. (114 mm), and for 1 hour, 3.5 in. (89 mm).



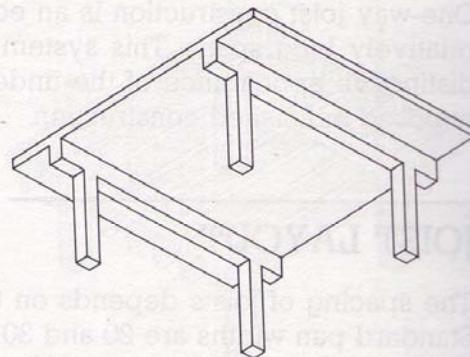
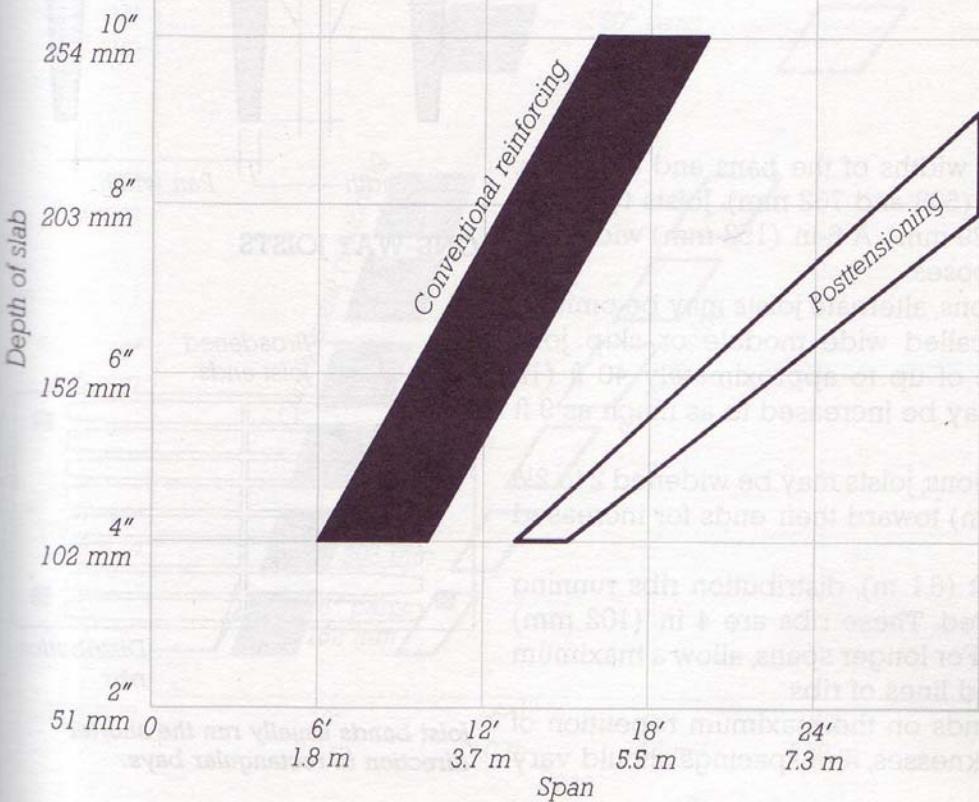
ONE-WAY SOLID SLAB WITH BEAMS AND GIRDERS



ONE-WAY SOLID SLAB WITH SLAB BANDS

# SITECAST CONCRETE ONE-WAY SOLID SLAB

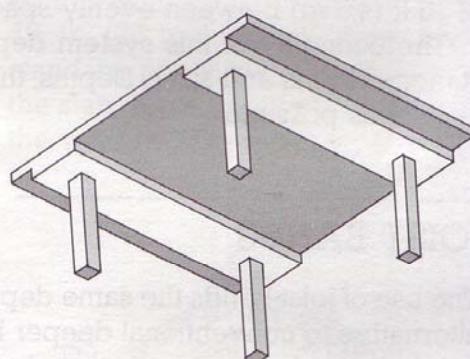
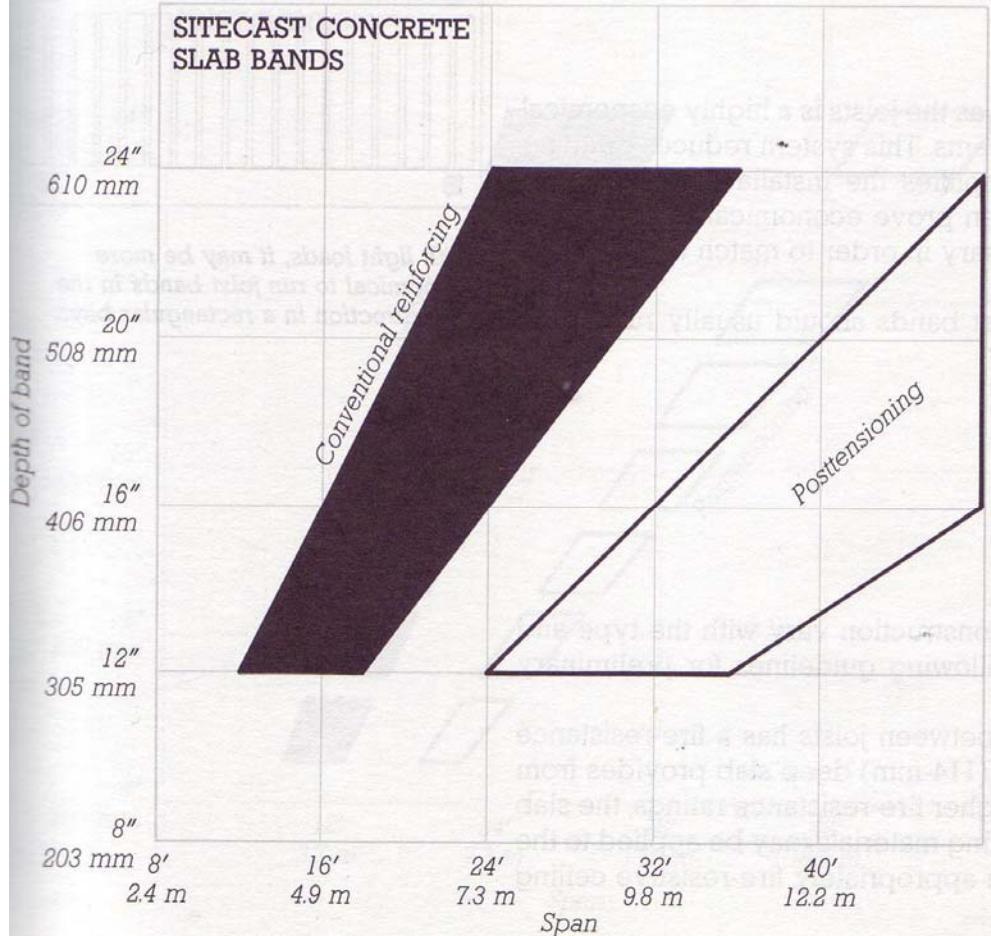
**SITECAST CONCRETE  
ONE-WAY SOLID SLAB**



The top chart is for sitecast concrete one-way solid slab construction, either conventionally reinforced or posttensioned. For light to medium loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- Size slab depth up to the nearest  $\frac{1}{2}$  in. (10 mm).
- For the sizing of concrete beams, see pages 128-129.

**SITECAST CONCRETE  
SLAB BANDS**



The bottom chart is for concrete slab bands—deep, wide beams that can be used with one-way solid slab construction. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- Size beam depths to the nearest inch (25 mm) and widths to the nearest foot (300 mm).
- Typical widths for slab bands range from one-sixth to one-third of the span of the slab between the beams. For slab bands that are relatively deep or that span short distances, choose a narrow width. For those that are relatively shallow or that span long distances, choose a wide width.

# SITECAST CONCRETE ONE-WAY JOISTS

One-way joist construction is an economical system for heavy loads or relatively long spans. This system is also sometimes desirable for the distinctive appearance of the underside of the slab, which may be left exposed in finished construction.

## JOIST LAYOUT

The spacing of joists depends on the widths of the pans and the joists. Standard pan widths are 20 and 30 in. (508 and 762 mm). Joists typically range in width from 5 to 9 in. (127 to 229 mm). A 6-in. (152-mm) wide joist may be assumed for preliminary purposes.

In medium- and light-load applications, alternate joists may be omitted for greater economy. This system, called wide module or skip joist construction, is economical for spans of up to approximately 40 ft (12 m). In some instances, joist spacing may be increased to as much as 9 ft (2.7 m).

In long-span or heavy-load applications, joists may be widened 2 to 2½ in. (50 to 65 mm) over the last 3 ft (1 m) toward their ends for increased capacity.

For joist spans of greater than 20 ft (6.1 m), distribution ribs running perpendicular to the joists are required. These ribs are 4 in. (102 mm) wide and the same depth as the joists. For longer spans, allow a maximum of 15 ft (4.6 m) between evenly spaced lines of ribs.

The economy of this system depends on the maximum repetition of standard forms and sizes. Depths, thicknesses, and spacings should vary as little as possible.

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## JOIST BANDS

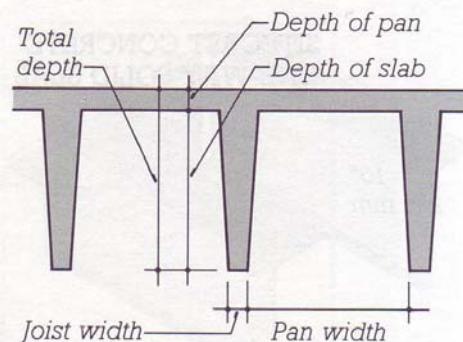
The use of joist bands the same depth as the joists is a highly economical alternative to conventional deeper beams. This system reduces building height, speeds construction, and simplifies the installation of building utilities. In some instances it may even prove economical to use a joist system deeper than otherwise necessary in order to match the required depth of the joist bands.

With rectangular column bays, joist bands should usually run in the shorter direction.

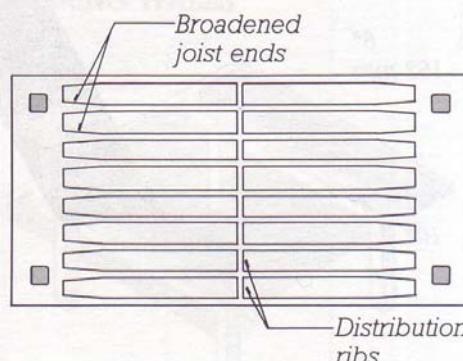
## FIRE-RESISTANCE RATINGS FOR ONE-WAY JOIST CONSTRUCTION

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

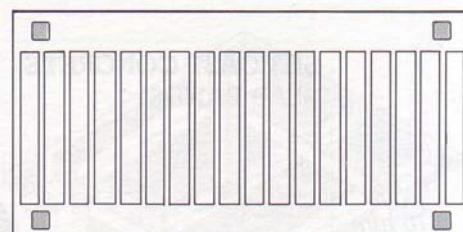
A slab that is 3 in. (76 mm) deep between joists has a fire-resistance rating of from 0 to 1½ hours. A 4½-in. (114-mm) deep slab provides from 1½ to 3 hours of fire protection. For higher fire-resistance ratings, the slab thickness may be increased, fireproofing materials may be applied to the underside of the joists and slab, or an appropriately fire-resistant ceiling may be used.



## ONE-WAY JOISTS



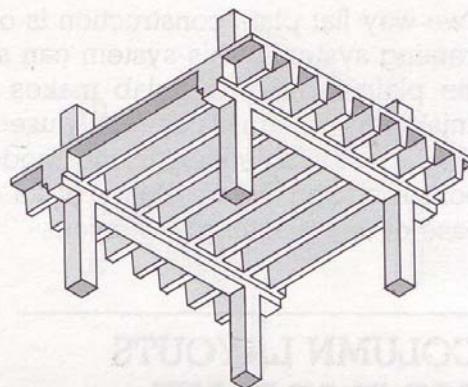
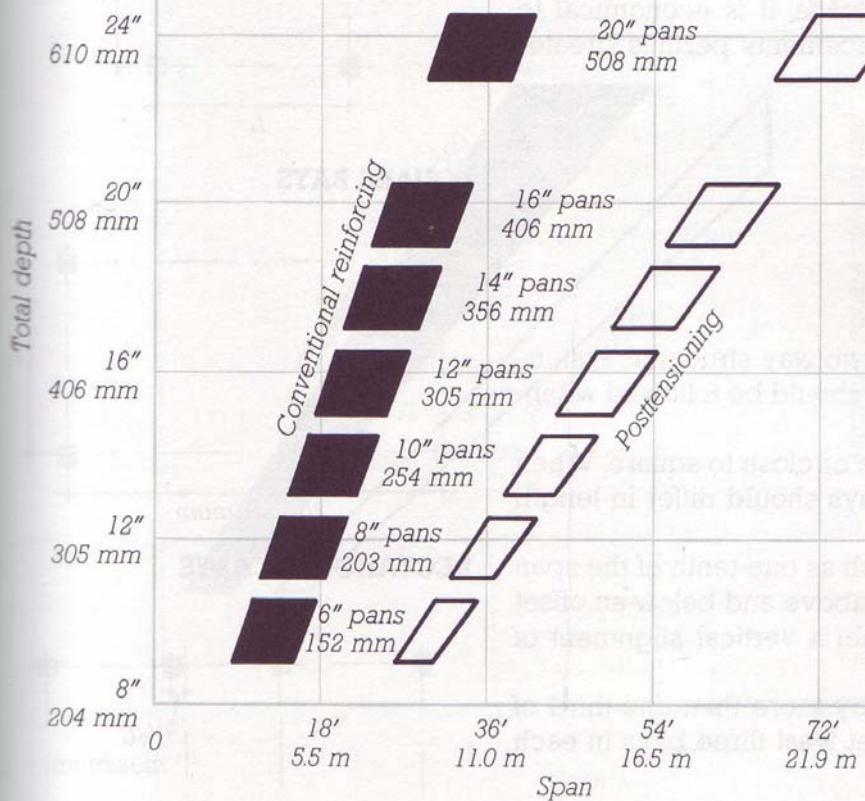
*Joist bands usually run the shorter direction in rectangular bays.*



*With light loads, it may be more economical to run joist bands in the long direction in a rectangular bay.*

# SITECAST CONCRETE ONE-WAY JOISTS

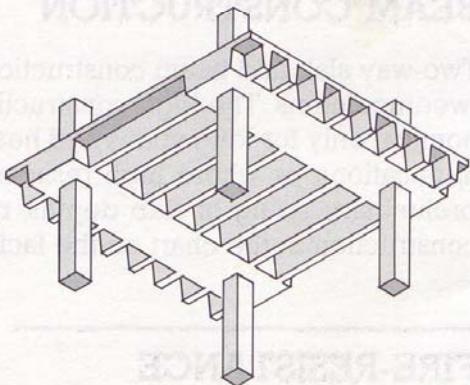
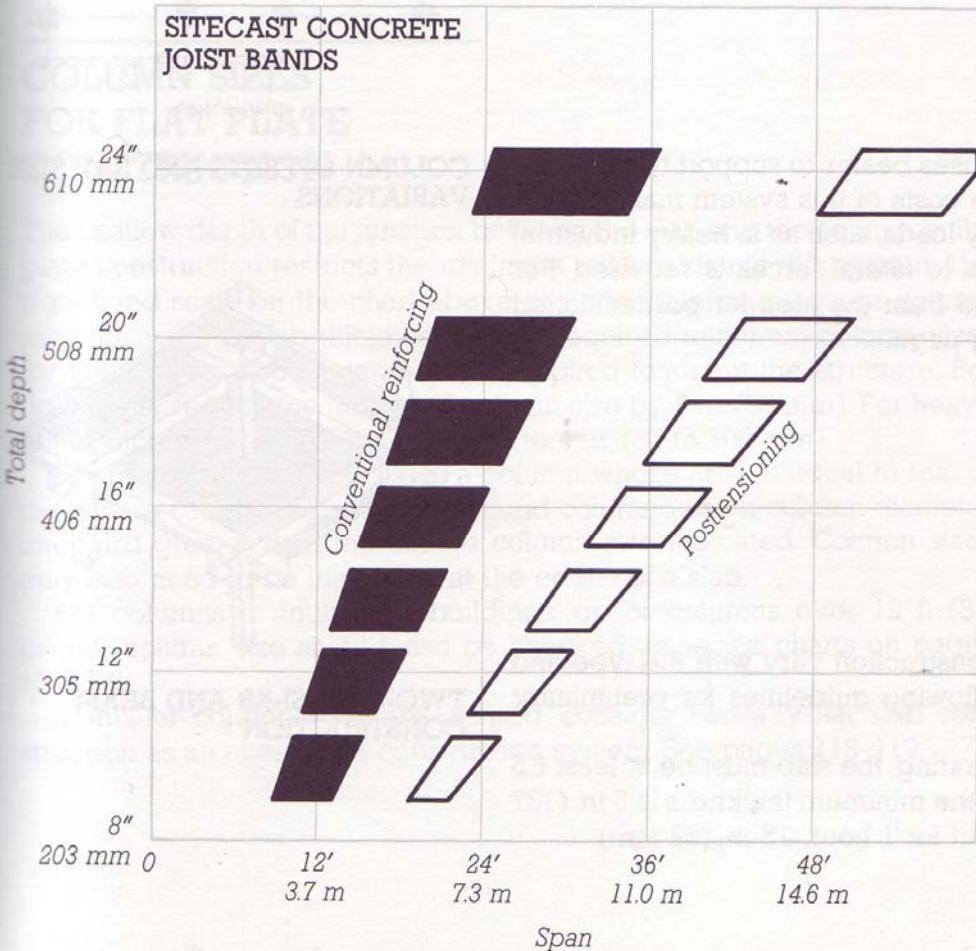
SITECAST CONCRETE  
ONE-WAY JOISTS



The top chart is for sitecast concrete one-way joist construction, either conventionally reinforced or posttensioned. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

□ Total depth is measured from the bottom of the joist to the top of the slab. (See the diagram on the facing page.) Depths are indicated on the chart for slabs of from 3 to 4½ in. (76 to 114 mm) deep with standard pan sizes. The choice of the slab depth usually depends on the required fire-resistance rating for the system.

SITECAST CONCRETE  
JOIST BANDS



The bottom chart is for concrete joist bands—deep, wide beams used with the one-way joist system. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

□ Whenever possible, use a joist band of the same depth as the joists.

□ Typical widths for joist bands range from 1 to 6 ft (0.3 to 1.8 m).

# SITECAST CONCRETE TWO-WAY FLAT PLATE

Two-way flat plate construction is one of the most economical concrete framing systems. This system can span farther than one-way slabs, and the plain form of the slab makes it simple to construct and easy to finish. This system is commonly used in apartment and hotel construction, where it is well suited to the moderate live loads, it is economical to construct, and the flexibility of its column placements permits greater ease of unit planning and layout.

## COLUMN LAYOUTS FOR FLAT PLATE CONSTRUCTION

For maximum economy and efficiency of the two-way structural system, the following guidelines on column placement should be followed whenever possible:

Column bays are most efficient when square or close to square. When rectangular bays are used, the sides of the bays should differ in length by a ratio of no more than 2:1.

Individual columns may be offset by as much as one-tenth of the span from regular column lines. (Columns on floors above and below an offset column must also be equally offset to maintain a vertical alignment of columns.)

Successive span lengths should not differ by more than one-third of the longer span. Slabs should also span over at least three bays in each direction.

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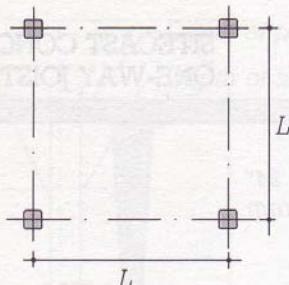
## TWO-WAY SLAB AND BEAM CONSTRUCTION

Two-way slab and beam construction uses beams to support the slab between columns. The high construction costs of this system make it economical only for long spans and heavy loads, such as in heavy industrial applications, or where high resistance to lateral forces is required. For preliminary sizing of slab depths, read from the area for posttensioned construction in the chart on the facing page.

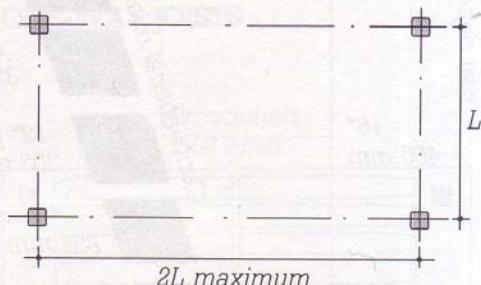
## FIRE-RESISTANCE RATINGS FOR TWO-WAY FLAT PLATE CONSTRUCTION

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

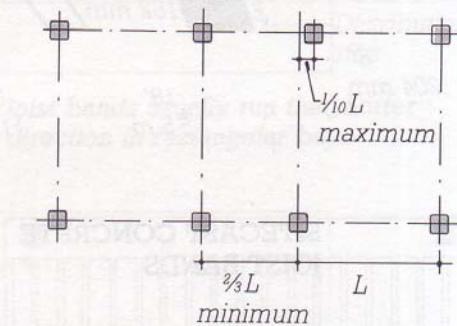
To achieve a 3-hour fire-resistance rating, the slab must be at least 6.5 in. (165 mm) thick. For a 2-hour rating, the minimum thickness is 5 in. (127 mm), for 1½ hours, 4.5 in. (114 mm), and for 1 hour, 3.5 in. (89 mm).



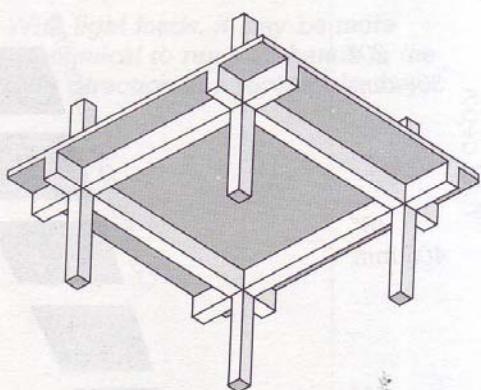
SQUARE BAYS



RECTANGULAR BAYS

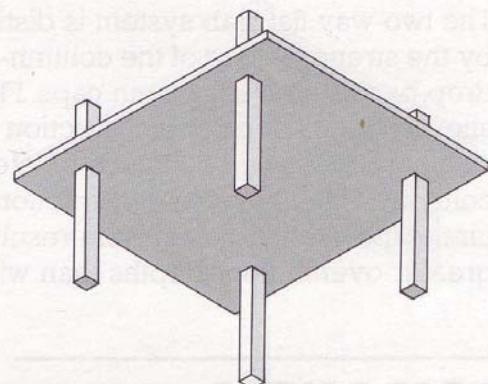
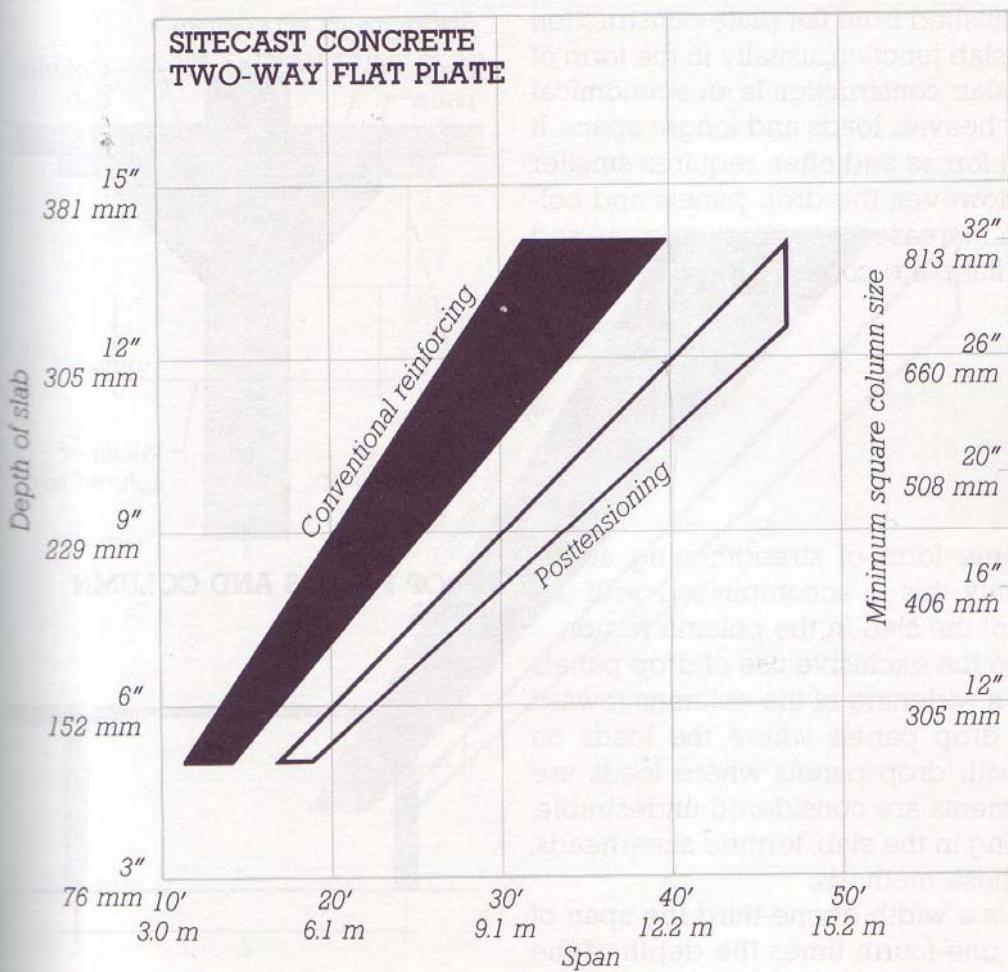


COLUMN OFFSETS AND BAY SIZE VARIATIONS



TWO-WAY SLAB AND BEAM CONSTRUCTION

# SITECAST CONCRETE TWO-WAY FLAT PLATE



This chart is for sitecast concrete flat plate construction, either conventionally reinforced or posttensioned. For medium to light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

For rectangular column bays, use the span of the longer of the two sides of the bay in reading from this chart.

Size slab depth to the nearest  $\frac{1}{2}$  in. (10 mm).

## COLUMN SIZES FOR FLAT PLATE CONSTRUCTION

The shallow depth of the junction between the slab and the column in flat plate construction restricts the minimum column size in this system. The right-hand scale on the chart above provides minimum square column sizes for various slab thicknesses. The required minimum column sizes for this system also depend on the applied loads on the structure. For light loads, reduce the indicated column size by 2 in. (50 mm). For heavy loads, increase the column size by 2 to 4 in. (50 to 100 mm).

For rectangular columns, use a column whose area is equal to that of the square column indicated. For round columns, use a column diameter one-third greater than the square column size indicated. Column sizes may also need to be increased at the edges of a slab.

For columns in multistory buildings, or for columns over 12 ft (3.7 m) tall, column size should also be checked using the charts on pages 106-107.

If smaller column sizes are desired, consider two-way flat slab construction as an alternative construction system. See pages 118-119.

# SITECAST CONCRETE TWO-WAY FLAT SLAB

The two-way flat slab system is distinguished from flat plate construction by the strengthening of the column-to-slab junction, usually in the form of drop panels and/or column caps. Flat slab construction is an economical alternative to flat plate construction for heavier loads and longer spans. It also has increased resistance to lateral forces and often requires smaller columns than flat plate construction. However, the drop panels and column caps used in this system result in increased construction costs and greater overall floor depths than with flat plate construction.

## DROP PANELS, COLUMN CAPS, AND SHEARHEADS

All flat slab construction requires some form of strengthening at the column-to-slab junction. Most commonly this is accomplished with the addition of drop panels, a deepening of the slab in the column region.

There are a number of alternatives to the exclusive use of drop panels in flat slab construction. Column caps, a widening of the columns toward their tops, may be used in place of drop panels where the loads on the slab are light, or in conjunction with drop panels where loads are very high. Where all such formed elements are considered undesirable, special arrangements of steel reinforcing in the slab, termed shearheads, may be an acceptable alternative to these methods.

The minimum size for drop panels is a width of one-third the span of the slab and a total depth of one and one-fourth times the depth of the slab. For heavy loads, panels may increase in width and span.

For maximum economy, keep all drop panels the same dimensions throughout the building. The difference in depth between the slab and the drop panels should be equal to a standard lumber dimension. The edges of drop panels should be a minimum of 16 ft 6 in. (5.0 m) apart to utilize standard 16-ft (4.9-m) lumber in the formwork.

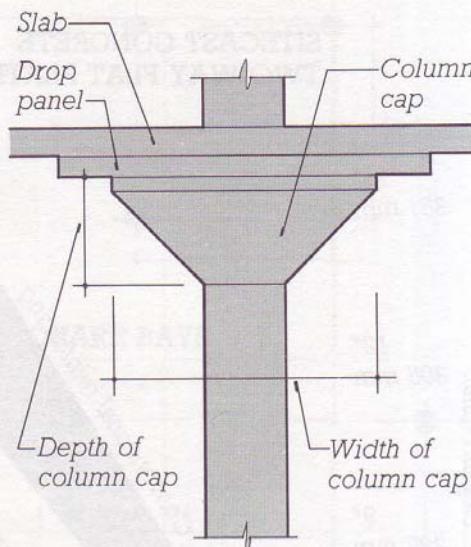
When column caps are used, their overall width should be eight to ten times the slab depth. Column caps are commonly either tapered or rectangular in profile, but should be approximately half as deep as their width at the top.

The addition of beams to flat slab construction can increase the load capacity and span range of the system, though with increased costs.

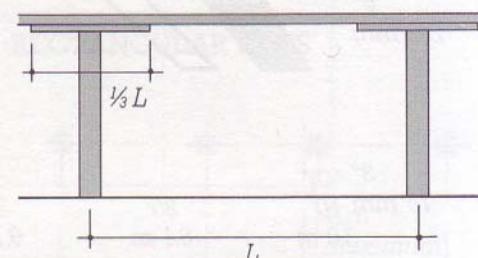
## FIRE-RESISTANCE RATINGS FOR TWO-WAY FLAT SLAB CONSTRUCTION

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

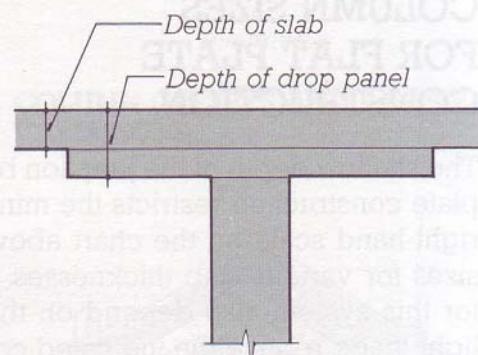
To achieve a 3-hour fire-resistance rating, the slab must be at least 6.5 in. (165 mm) thick. For a 2-hour rating, the minimum thickness is 5 in. (127 mm), for 1½ hours, 4.5 in. (114 mm), and for 1 hour, 3.5 in. (89 mm).



**DROP PANELS AND COLUMN CAPS**

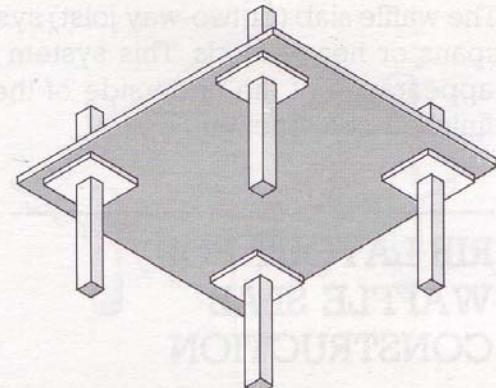
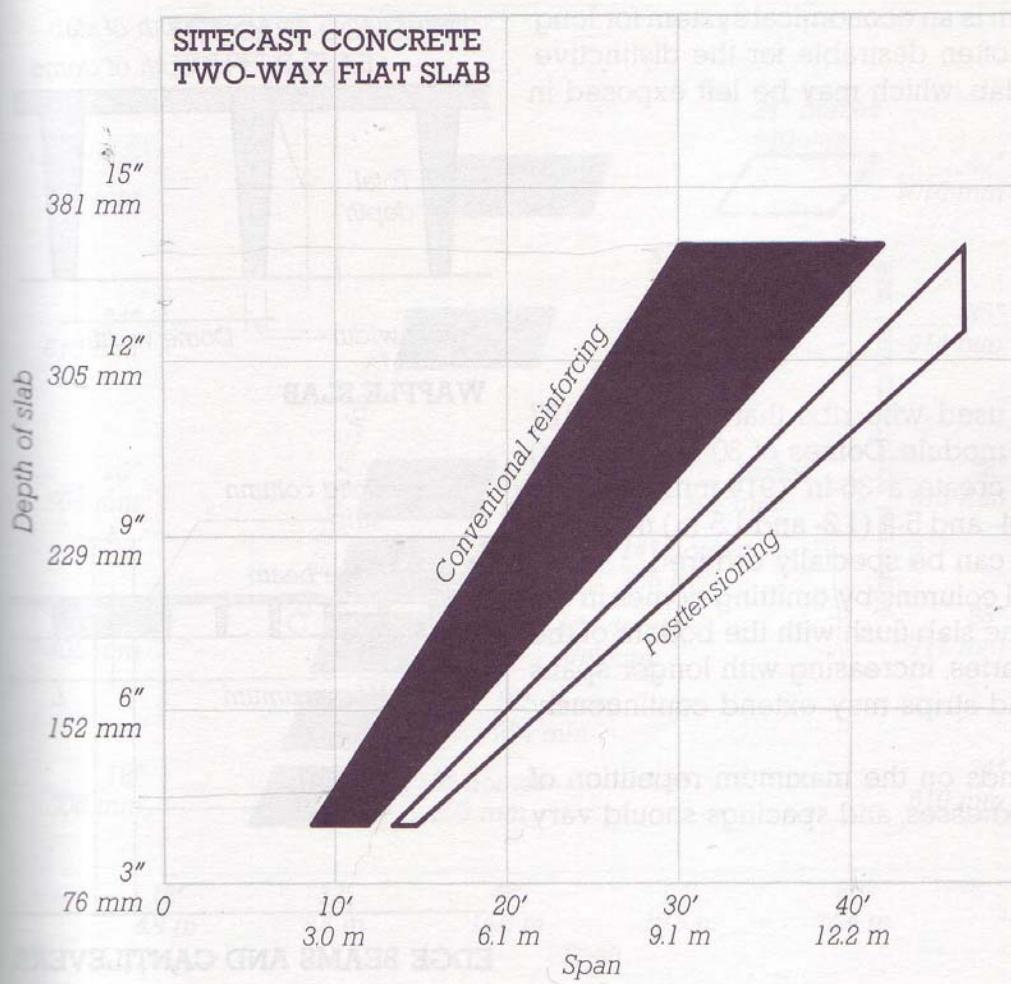


**DROP PANEL WIDTH**



**DROP PANEL DEPTH**

# SITECAST CONCRETE TWO-WAY FLAT SLAB



This chart is for concrete two-way flat slab construction, either conventionally reinforced or posttensioned. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- For rectangular column bays, use the span of the longer of the two sides of the bay in reading from this chart.
- Size slab depth to the nearest  $\frac{1}{2}$  in. (10 mm).

## COLUMN SIZES AND LAYOUTS FOR FLAT SLAB CONSTRUCTION

For light to moderate loads, use a minimum square column size of 12 in. (300 mm) for preliminary design. For heavier loads, larger columns or the addition of column caps may be required. Column size may be increased by 4 to 12 in. (100 to 300 mm) for extremely heavy loads.

For rectangular columns, use a column whose area is equal to that of the recommended square column size. For round columns, use a column diameter one-third greater than the recommended square column size. Column sizes may also need to be increased in multistory buildings or for columns taller than 12 ft (3.7 m). See pages 106–107 for checking column sizes for these conditions.

For maximum economy and efficiency of the two-way structural system, column layouts for flat slab construction should adhere to the same guidelines as those described for flat plate construction. Column bays should be approximately square, and column offsets from regular lines should be minimized. See page 116 for a complete discussion of these guidelines.

# SITECAST CONCRETE WAFFLE SLAB

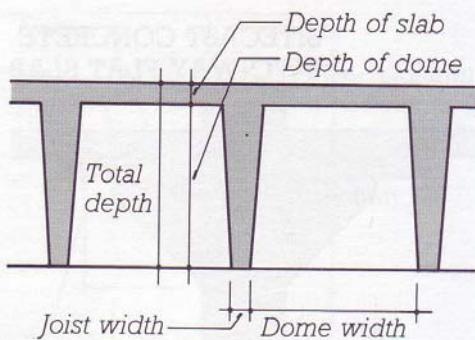
The waffle slab (or two-way joist) system is an economical system for long spans or heavy loads. This system is often desirable for the distinctive appearance of the underside of the slab, which may be left exposed in finished construction.

## RIB LAYOUT FOR WAFFLE SLAB CONSTRUCTION

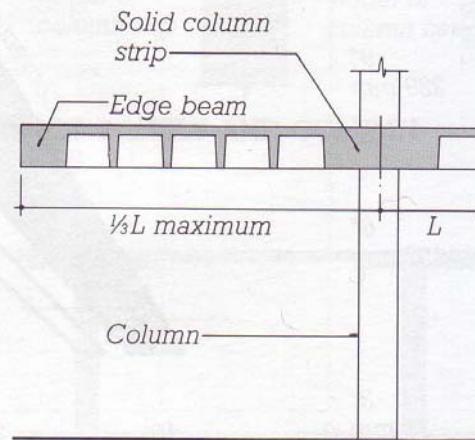
Standard 19-in. (483-mm) domes are used with ribs that are 5 in. (127 mm) wide to create a 24-in. (610-mm) module. Domes of 30 in. (762 mm) are used with 6-in. (152-mm) ribs to create a 36-in. (914-mm) module. Standard domes are also available for 4- and 5-ft (1.2- and 1.5-m) modules, and other square or rectangular sizes can be specially ordered.

Solid heads must be created over all columns by omitting domes in the vicinity of each column and pouring the slab flush with the bottom of the ribs. The number of domes omitted varies, increasing with longer spans and heavier loads. In some cases solid strips may extend continuously between columns in both directions.

The economy of this system depends on the maximum repetition of standard forms and sizes. Depths, thicknesses, and spacings should vary as little as possible.



## WAFFLE SLAB



## EDGE BEAMS AND CANTILEVERS

120

## EDGE CONDITIONS

When the slab ends flush with the edge columns, the area between the outermost rib and the slab edge is filled solid to create an edge beam. The slab may also cantilever beyond the columns by as much as one-third of a full span. In this case, both an edge beam and a solid strip running between the edge columns may be required.

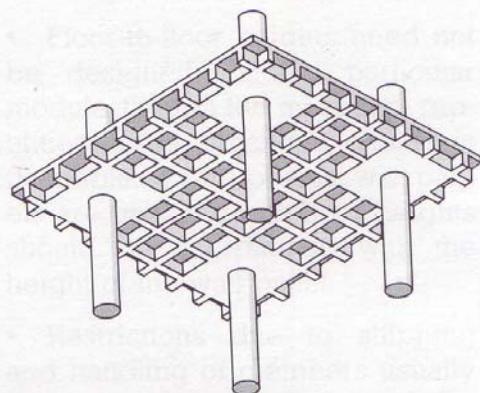
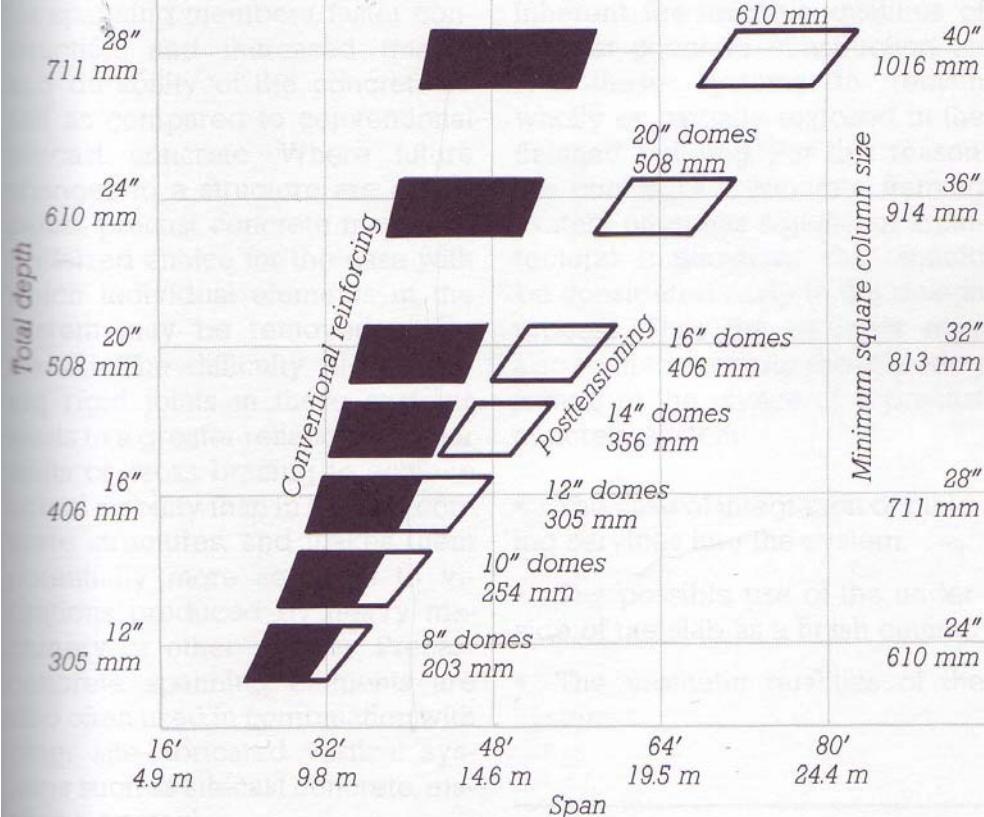
## FIRE-RESISTANCE RATINGS FOR WAFFLE SLAB CONSTRUCTION

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

A 3-in. (76-mm) slab thickness between ribs gives a fire-resistance rating of 0 to 1 hour. A 3½-in. (89-mm) thickness gives 1 hour, a 4½-in. (114-mm) thickness gives 1½ hours, and a 5-in. (127-mm) thickness gives 2 hours. For higher fire-resistance ratings, the slab thickness may be increased further, fireproofing materials may be applied to the underside of the ribs and slab, or an appropriately fire-resistant ceiling may be used.

# SITECAST CONCRETE WAFFLE SLAB

SITECAST CONCRETE  
WAFFLE SLAB



This chart is for concrete waffle slab construction, either conventionally reinforced or posttensioned. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

For rectangular bays, use the average of the spans of the two sides of the bay when reading from this chart.

Total depth is the sum of the depth of the ribs and the slab. (See the diagram on the facing page.) Depths are indicated on the chart for slabs from 3 to 4½ in. (76 to 114 mm) deep with standard pan sizes. The choice of the slab depth usually depends on the required fire-resistance rating for the system. See the facing page for fire-resistance information.

## COLUMN SIZES AND LAYOUTS FOR WAFFLE SLAB CONSTRUCTION

In waffle slab construction, minimum column size is dependent on the overall thickness of the slab. The right-hand scale on the chart above provides minimum square column sizes for various slab thicknesses. For light loads, reduce the indicated column size by 2 to 4 in. (50 to 100 mm). For heavy loads, increase the indicated column size by 4 to 12 in. (100 to 300 mm).

For rectangular columns, use a column whose area is equal to that of the square column indicated. For round columns, use a column diameter one-third greater than the square column size indicated.

For columns in multistory buildings or for columns over 12 ft (3.7 m) tall, column size should also be checked using the charts on pages 106–107.

For maximum economy and efficiency of the two-way structural system, column layouts for waffle slab construction should adhere to the same guidelines as those described for flat plate construction. Column bays should be approximately square, and column offsets from regular lines should be minimized. See pages 116 for a complete discussion of these guidelines.

# PRECAST CONCRETE STRUCTURAL SYSTEMS

Precast prestressed concrete framing systems are characterized by reduced depths and deflections for spanning members, faster construction, and increased quality and durability of the concrete itself as compared to conventional sitecast concrete. Where future changes to a structure are anticipated, precast concrete may be a preferred choice for the ease with which individual elements in the system may be removed or replaced. The difficulty of fabricating rigid joints in these systems leads to a greater reliance on shear walls or cross bracing to achieve lateral stability than in sitecast concrete structures, and makes them potentially more sensitive to vibrations produced by heavy machinery or other sources. Precast concrete spanning elements are also often used in combination with other site-fabricated vertical systems such as sitecast concrete, masonry, or steel.

## SELECTING A PRECAST CONCRETE FRAMING SYSTEM

The initial choice of a framing system should be based on the desired spanning capacity or column spacings of the system and the magnitude of the expected loads on the structure. The following precast concrete systems are listed in order of increasing spans, load capacity, and cost:

- Solid Flat Slab
- Hollow Core Slab
- Double Tee
- Single Tee

For short spans and light loads, select a system from the top of the list. For longer spans and heavier

loads, systems toward the bottom of the list are required.

As with sitecast concrete, the inherent fire-resistive qualities of precast concrete construction allow these systems to remain wholly or partially exposed in the finished building. For this reason, the choice of a concrete framing system often has significant architectural implications that should be considered early in the design process. Thus the designer may also wish to consider the following factors in the choice of a precast concrete system:

- The ease of integration of building services into the system.
- The possible use of the underside of the slab as a finish ceiling.
- The aesthetic qualities of the system.

## LAYING OUT A PRECAST CONCRETE SYSTEM

The economy of precast concrete construction depends on the maximum repetition of standard elements and sizes. Use the following guidelines for preliminary layout of a precast concrete structure to assure maximum economy:

- In the direction of the span of the deck members, use a modular dimension of 1 ft (0.3 m). If a wall panel has been selected, use the width of the panel as the modular dimension.
- In the direction transverse to the span of the deck members, use a module of 8 ft (2.4 m). If a deck member has been selected, use the width of the member as the modular dimension.

- Floor-to-floor heights need not be designed to any particular module, though the maximum repetition of the dimension chosen is desirable. Where precast wall panels are used, floor-to-floor heights should be coordinated with the height of the wall panel.

- Restrictions due to shipping and handling of members usually limit span lengths to from 60 to 80 ft (18 to 24 m) maximum. Further transportation restrictions on depths of elements usually limit bay widths to between 24 and 40 ft (7 and 12 m) where girders are used.

In general, any design features that require unique structural elements, excessive variations in the sizes of elements, alterations in structural configuration, or deviation from the standard dimensions of the system should be avoided. Where the maximum flexibility of layout with precast concrete elements is desired, solid flat slabs or hollow core slabs may be preferred for their shorter spans and the greater ease with which they may be sawn after casting to conform to irregular conditions.

## PROJECT SIZE

The economy of precast concrete construction also depends on the size of the construction project. The following figures are approximate minimum project sizes for which the production of precast concrete elements may be economical:

- 10,000 ft<sup>2</sup> (1000 m<sup>2</sup>) of architectural wall panels, or,
- 15,000 ft<sup>2</sup> (1500 m<sup>2</sup>) of deck or slab members, or,
- 1000 linear feet (300 m) of girders, columns, or pilings.

# PRECAST CONCRETE COLUMNS

Precast concrete columns are typically combined with precast concrete beams in a post and beam configuration. Unlike in sitecast concrete systems, the fabrication of rigid joints in a precast concrete frame is difficult and rarely done. Instead, shear walls or diagonal bracing are normally incorporated into the framing system in order to stabilize the structure against lateral forces.

Precast concrete columns are usually reinforced conventionally. Pre-stressing may be used to reduce stresses on the column during transportation and handling or when significant bending or buckling stresses may be expected in service.

## STANDARD SIZES AND SHAPES OF PRECAST CONCRETE COLUMNS

Precast concrete columns are commonly available in square sizes from 10 to 24 in. (254 to 619 mm). Rectangular sections are also produced, although available sizes will vary with the supplier. For projects using over approximately 1000 linear feet (300 meters) of columns, a greater range of cross sections and sizes may be produced economically.

Columns in lengths of up to approximately 60 ft (18 m) can be transported easily. Columns of up to approximately 100 ft (30 m) in length can be shipped with special arrangements that may affect the overall economy of the system.

For ease of casting, columns with corbels should be restricted to corbels on two opposite sides, or at most, on three sides.

As with all precast concrete elements, precast columns should be as consistent as possible in dimensions and layout in order to achieve maximum economy.

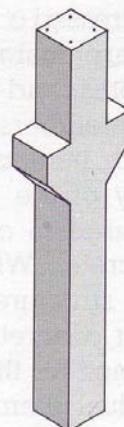
## CONCRETE STRENGTH AND COLUMN SIZE

The top chart on the facing page is based on a concrete strength of 5000 psi (34.5 MPa). Higher-strength concretes may be used to reduce the required column size. For higher concrete strengths, multiply the indicated column size by the amount in the table to the right:

## FIRE-RESISTANCE RATINGS FOR PRECAST CONCRETE COLUMNS

Fire-resistance ratings for concrete construction vary with the type and density of concrete used. Use the following guidelines for preliminary design:

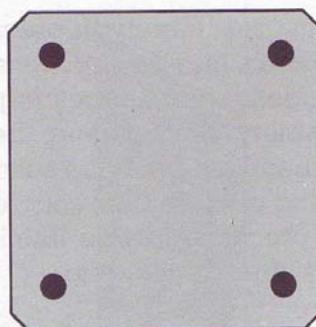
Precast columns must be at least 14 in. (356 mm) in minimum dimension to achieve a 4-hour fire-resistance rating. For a 3-hour rating, the minimum dimension is 12 in. (305 mm). For 2 hours, a column must be at least 10 in. (254 mm) on a side.



PRECAST CONCRETE COLUMN WITH TWO CORBELS

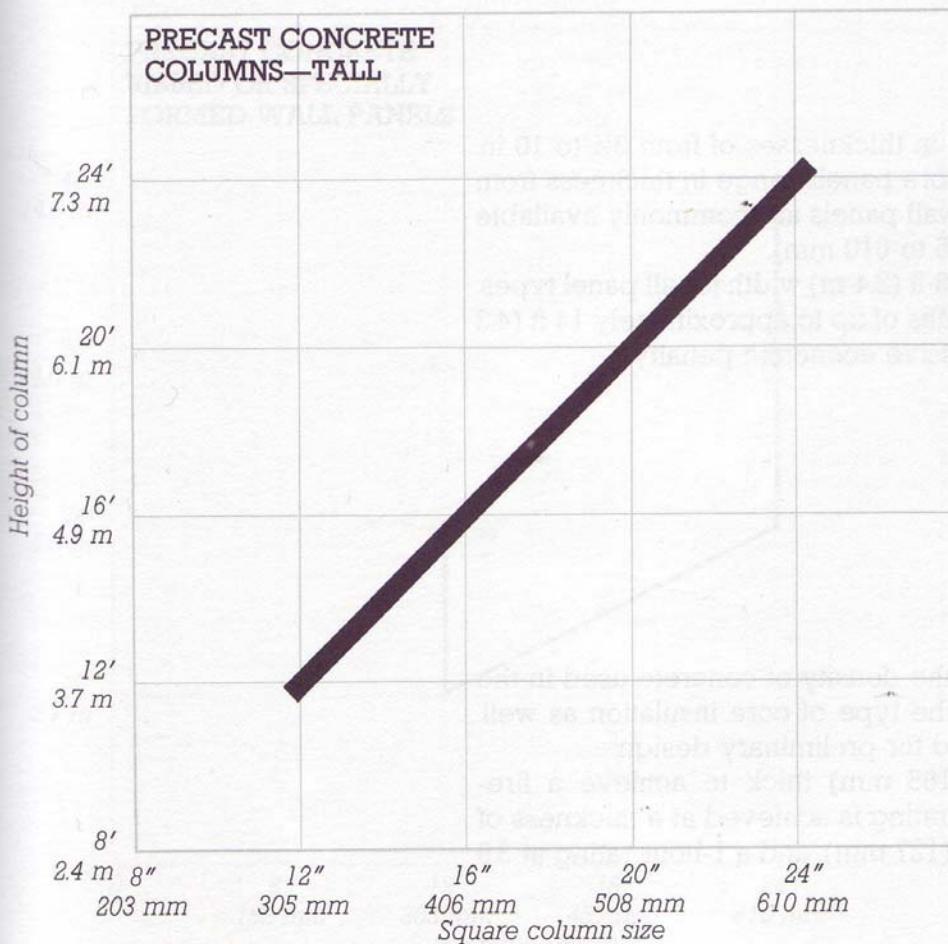
Concrete Strength	Multiply Column Size by
7000 psi (48 MPa)	0.95
9000 psi (62 MPa)	0.80
11,000 psi (76 MPa)	0.75

# PRECAST CONCRETE COLUMNS



The top chart is for square precast concrete columns of up to 12 ft (3.7 m) in height between floors. For normal loads, read toward the top in the indicated areas. For high loads, read toward the bottom.

- For rectangular columns, select a column of equivalent area.
- Actual column size is equal to the nominal column size.
- Total tributary area* is the total area of roofs and floors supported by the column.



The bottom chart is for columns with unbraced heights of greater than 12 ft (3.7 m). Use the larger of the two sizes indicated by both charts on this page.

- For rectangular columns, read from this chart using the least dimension of the column.

# **PRECAST CONCRETE WALL PANELS**

There is great variety in precast concrete wall panel types and applications. Panels may be prestressed or conventionally reinforced; they may be loadbearing or nonbearing; they may or may not contribute to the lateral stability of a building; they may be flat, ribbed, or more intricately shaped; and they may be solid, hollow, or a sandwich of concrete with an insulating core. Precast concrete wall panels may be used in conjunction with a precast concrete framing system or with other framing systems, such as steel or concrete.

## **PANEL TYPES**

Flat panels may be one to two stories high. Ribbed panels may be one to four stories high.

Wall panels may also be formed in a great variety of original shapes. The design of such panels depends on specialized knowledge of precasting methods. When the use of such panels is planned, the necessary consultants should be sought out early in the design process. For the preliminary sizing of these panels, use the chart for ribbed panels on the facing page. Loadbearing wall panels such as these may be used in buildings of up to approximately 16 to 20 stories in height.

Panels with openings usually may not be prestressed. Panels without openings may be prestressed to reduce thickness or to limit stresses in the panels during transportation and handling.

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## **126 SIZES OF PRECAST CONCRETE WALL PANELS**

Solid panels are commonly available in thicknesses of from  $3\frac{1}{2}$  to 10 in. (89 to 254 mm). Sandwich or hollow core panels range in thickness from  $5\frac{1}{2}$  to 12 in. (140 to 305 mm). Ribbed wall panels are commonly available in thicknesses of from 12 to 24 in. (305 to 610 mm).

For preliminary design, assume an 8-ft (2.4-m) width for all panel types. With special provisions, panels in widths of up to approximately 14 ft (4.3 m) may be transported without excessive economic penalty.

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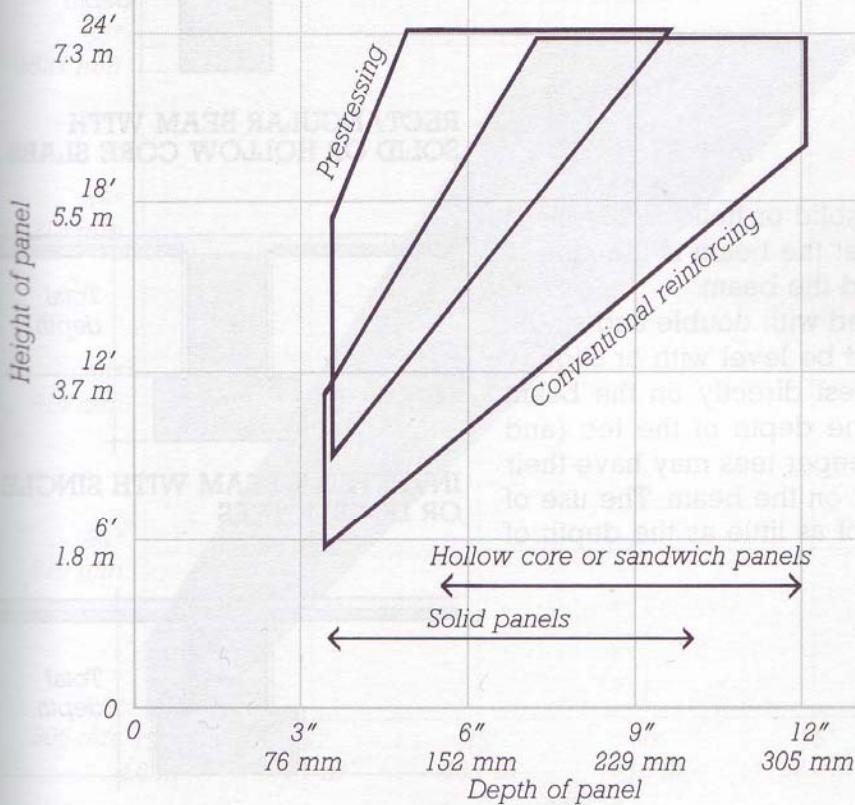
## **FIRE-RESISTANCE RATINGS FOR PRECAST CONCRETE WALL PANELS**

Fire-resistance ratings will vary with the density of concrete used in the panel, and in sandwich panels, with the type of core insulation as well. The following guidelines may be used for preliminary design:

Panels must be at least 6.5 in. (165 mm) thick to achieve a fire-resistance rating of 4 hours. A 3-hour rating is achieved at a thickness of 6 in. (152 mm), a 2-hour rating at 5 in. (127 mm), and a 1-hour rating at 3.5 in. (89 mm).

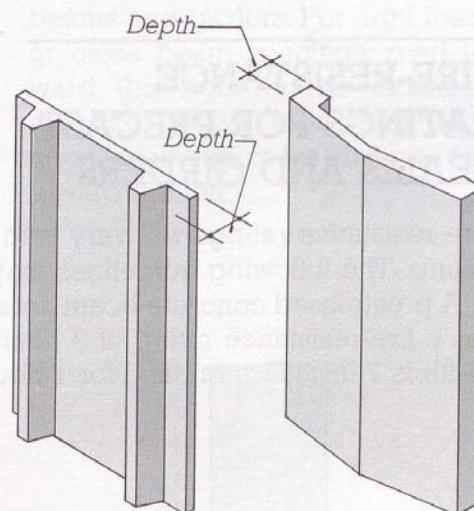
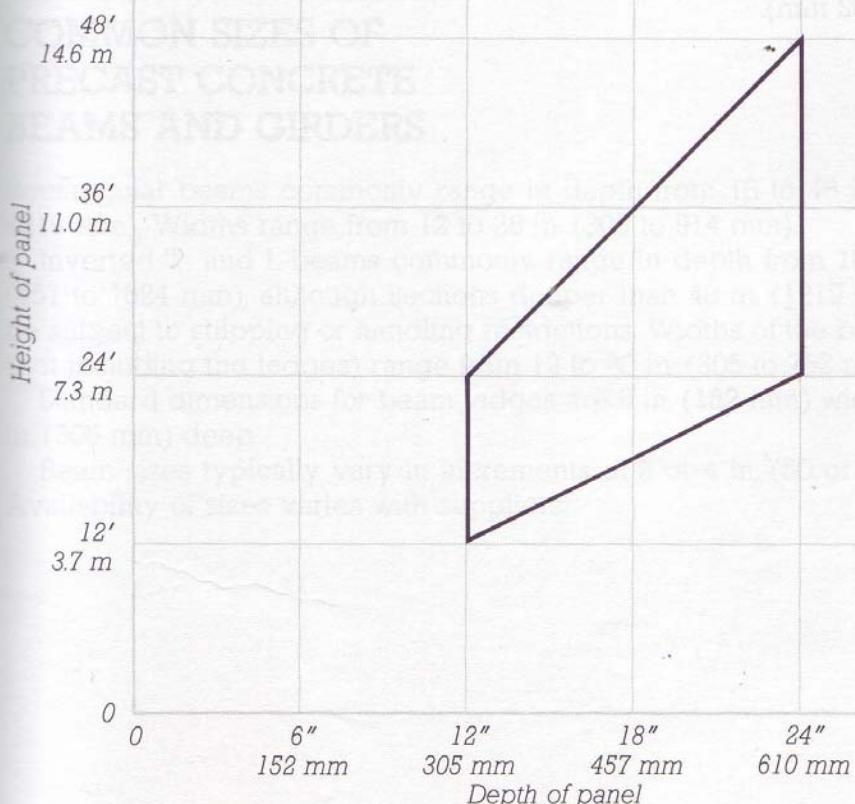
# PRECAST CONCRETE WALL PANELS

## PRECAST CONCRETE FLAT WALL PANELS



The top chart is for flat precast concrete wall panels, either prestressed or conventionally reinforced. For nonbearing panels, read toward the left in the indicated areas. For loadbearing panels, read toward the right.

## PRECAST CONCRETE RIBBED OR SPECIALLY FORMED WALL PANELS



The bottom chart is for precast concrete wall panels formed with ribs, stems, or other stiffening features. For nonbearing or prestressed panels, read toward the left in the indicated area. For load-bearing panels, conventionally reinforced panels, or panels with integral window openings, read toward the right.

*Depth of panel* is the total depth of the panel and any stiffening features.

For the preliminary design of spandrel panels, use the distance between columns for the height indicated on either chart.

# PRECAST CONCRETE BEAMS AND GIRDERS

Precast prestressed concrete girders are commonly used to carry all varieties of precast concrete decking elements between columns or bearing walls. They can be used in any building type where precast concrete construction is to be considered.

## TOTAL DEPTH OF FLOOR SYSTEMS

Rectangular beams are commonly used with solid or hollow core slabs resting on top of the beam. Total floor depth at the beam is the sum of the depths of the slab (and topping, if any) and the beam.

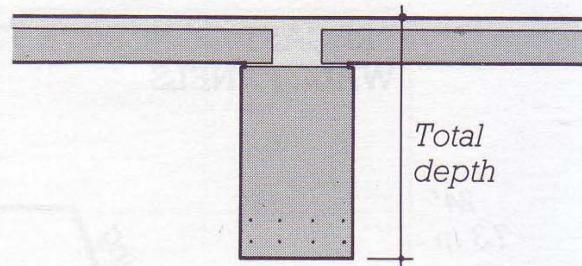
Inverted T- and L-beams are commonly used with double and single tees. When erected, the top of the tees should be level with or slightly above the top of the beam. When the tees rest directly on the beam ledge, the total floor depth at the beam is the depth of the tee (and topping, if any) plus the depth of the ledge. Deeper tees may have their ends notched or "dapped" so as to rest lower on the beam. The use of dapped tees may result in total floor depths of as little as the depth of the tee itself plus any topping.

## FIRE-RESISTANCE RATINGS FOR PRECAST BEAMS AND GIRDERS

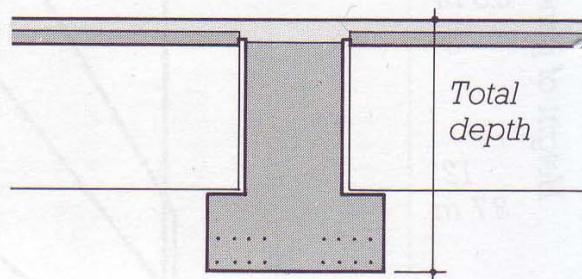
128

Fire-resistance ratings will vary with the density of concrete used in the beams. The following guidelines may be used for preliminary design:

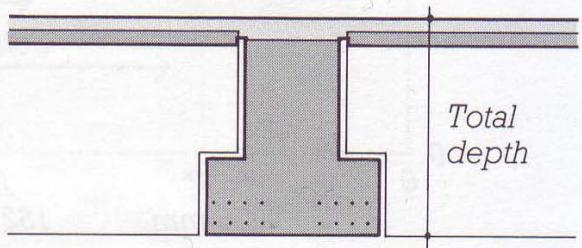
A prestressed concrete beam not smaller than 9.5 in. (241 mm) in width has a fire-resistance rating of 3 hours. For a 2-hour rating, the minimum width is 7 in. (178 mm), and for 1 hour, 4 in. (102 mm).



RECTANGULAR BEAM WITH SOLID OR HOLLOW CORE SLABS

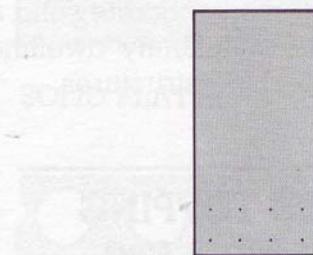
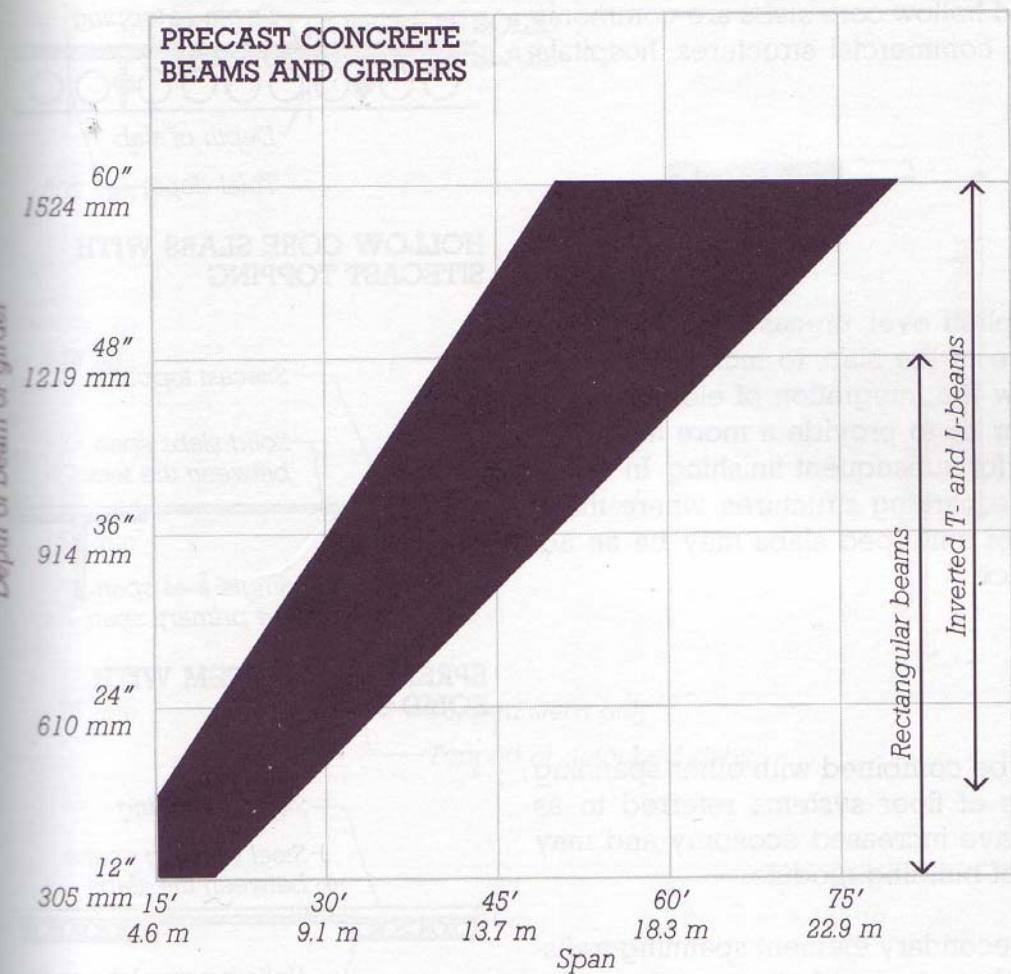


INVERTED T-BEAM WITH SINGLE OR DOUBLE TEES

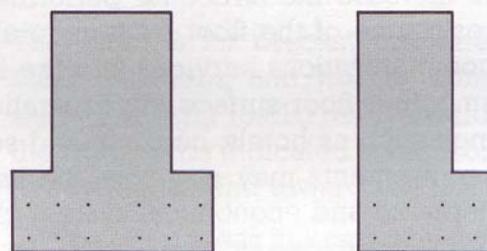


INVERTED T-BEAM WITH DAPPED TEES

# PRECAST CONCRETE BEAMS AND GIRDERS



RECTANGULAR BEAM



INVERTED T- AND L-BEAMS

This chart is for precast concrete beams and girders. For light loads or close beam spacings, read toward the right in the indicated area. For heavy loads and large beam spacings, or for girders, read toward the left.

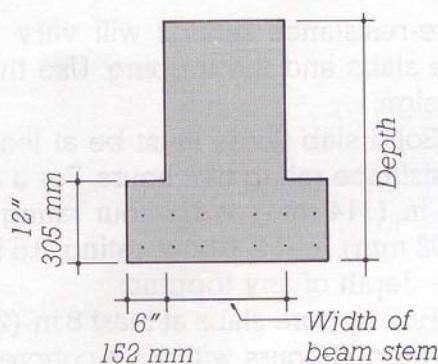
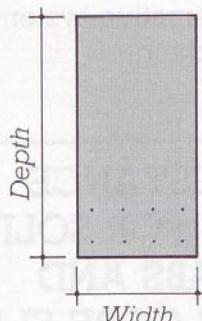
## COMMON SIZES OF PRECAST CONCRETE BEAMS AND GIRDERS

Rectangular beams commonly range in depth from 18 to 48 in. (457 to 1219 mm). Widths range from 12 to 36 in. (305 to 914 mm).

Inverted T- and L-beams commonly range in depth from 18 to 60 in. (457 to 1524 mm), although sections deeper than 48 in. (1219 mm) may be subject to shipping or handling restrictions. Widths of the beam stem (not including the ledges) range from 12 to 30 in. (305 to 762 mm).

Standard dimensions for beam ledges are 6 in. (152 mm) wide and 12 in. (305 mm) deep.

Beam sizes typically vary in increments of 2 or 4 in. (50 or 100 mm). Availability of sizes varies with suppliers.



# PRECAST CONCRETE SLABS

Precast prestressed concrete solid and hollow core slabs are commonly used in hotels, multifamily dwellings, commercial structures, hospitals, schools, and parking structures.

## CONCRETE TOPPING ON PRECAST SLABS

Sitecast concrete topping is often applied over precast concrete slabs to increase the structural performance of the slab, to increase the fire resistance of the floor system, to allow the integration of electrical and communications services into the floor, or to provide a more level and smoother floor surface in preparation for subsequent finishing. In buildings such as hotels, housing, and some parking structures, where these requirements may not exist, the use of untopped slabs may be an acceptable and economical system choice.

## SPECIAL SYSTEMS

Both solid and hollow core slabs may be combined with other spanning elements to create several variations of floor systems referred to as *spread systems*. These systems can have increased economy and may allow greater flexibility in the choice of building module.

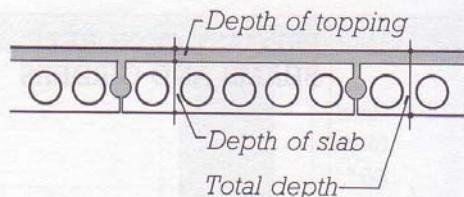
- 130
- Either slab type may be used as a secondary element spanning transversely between longer spanning single tees, double tees, or channels.
  - Hollow core slabs can be spread from 2 to 3 ft (0.6 to 0.9 m), with corrugated steel decking spanning between the slabs. This system is usually topped. Where many floor penetrations are expected, this is an especially attractive system due to the ease of creating openings through the steel decking.

## FIRE-RESISTANCE RATINGS FOR SOLID FLAT SLABS AND HOLLOW CORE SLABS

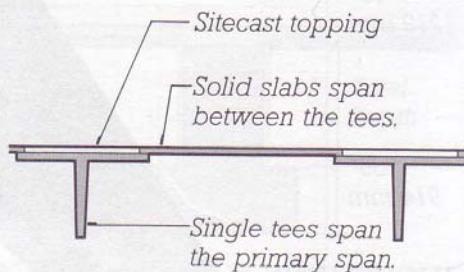
Fire-resistance ratings will vary with the density of concrete used in the slabs and the topping. Use the following guidelines for preliminary design:

Solid slab floors must be at least 5.5 in. (140 mm) thick to have a fire resistance rating of 3 hours. For a 2-hour rating, the required thickness is 4.5 in. (114 mm). A 1½-hour rating requires a minimum thickness of 4 in. (102 mm), and a 1-hour rating, 3.5 in. (89 mm). These thicknesses include the depth of any topping.

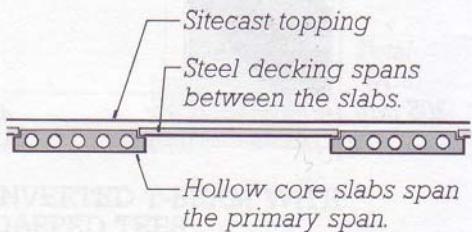
Hollow core slabs at least 8 in. (203 mm) deep achieve a fire-resistance rating of 2 hours without a concrete topping. With the addition of a 2-in. (50-mm) topping, the rating rises to 3 hours.



HOLLOW CORE SLABS WITH SITECAST TOPPING

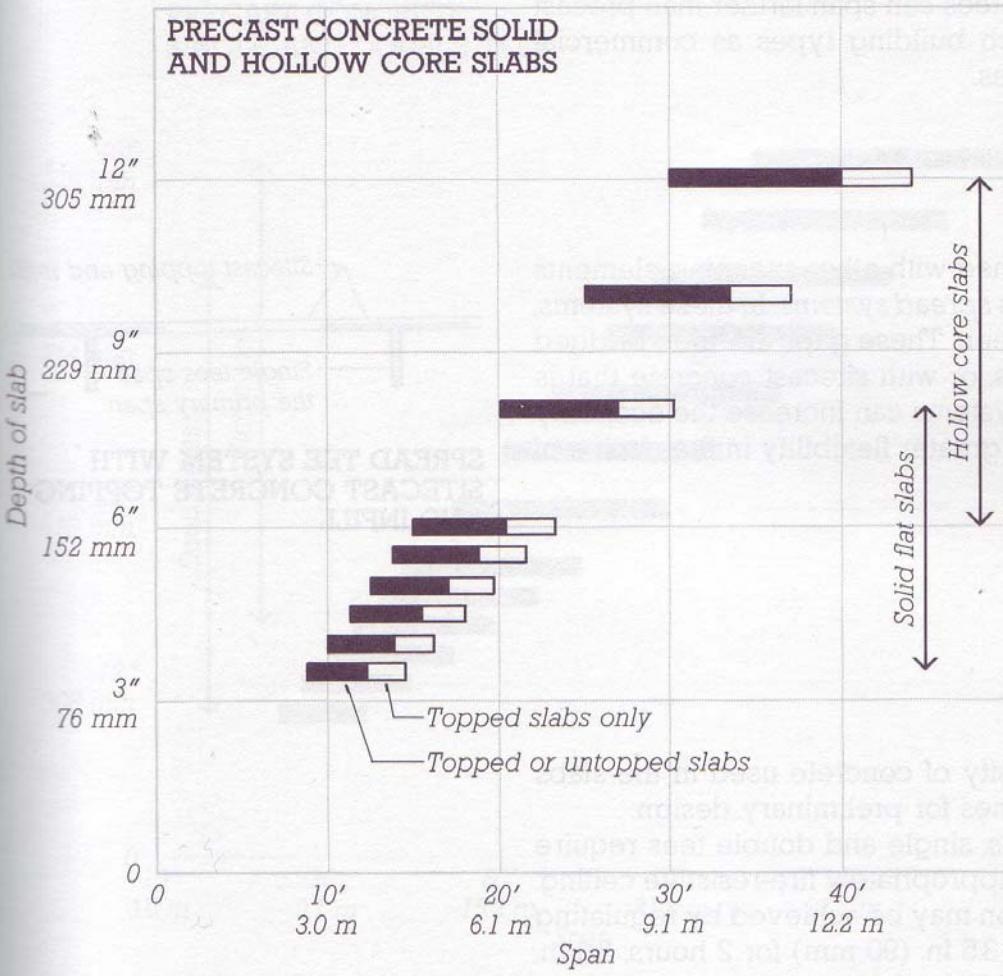


SPREAD TEE SYSTEM WITH SOLID SLABS

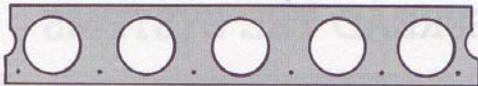


HOLLOW CORE SLAB SPREAD SYSTEM

# PRECAST CONCRETE SLABS



**SOLID FLAT SLAB**



**HOLLOW CORE SLAB**

This chart is for precast concrete solid flat slabs and hollow core slabs. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

The open areas indicated on the chart are for slabs with an added sitecast concrete topping only. The solid areas are for either topped or untopped slabs. The depths indicated on the chart are for the slabs alone, without any additional topping. Where a topping is used, add 2 in. (50 mm) to the indicated depths for preliminary design. See the facing page for further information on the use of concrete toppings.

## COMMON SIZES OF SOLID AND HOLLOW CORE SLABS

Solid flat slabs come in depths from  $3\frac{1}{2}$  to 8 in. (89 to 203 mm). For depths of 6 in. (152 mm) and above, however, hollow core slabs are usually more economical. Typical widths are 8 to 12 ft (2.4 to 3.7 m).

Hollow core slabs come in depths from 6 to 12 in. (152 to 305 mm). Typical widths are 2 ft, 3 ft 4 in., 4 ft, and 8 ft (0.6, 1.0, 1.2, and 2.4 m).

Availability of sizes varies with suppliers.

# **PRECAST CONCRETE SINGLE AND DOUBLE TEES**

Precast prestressed single and double tees can span farther than precast slabs and are commonly used in such building types as commercial structures, schools, and parking garages.

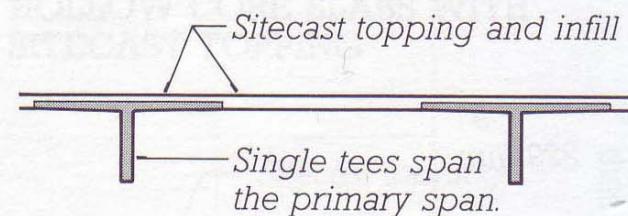
## **SPREAD TEE SYSTEMS**

Single and double tees may be combined with other spanning elements to create framing systems referred to as *spread systems*. In these systems, the tees are erected with spaces between. These gaps are then bridged with precast solid or hollow core slabs, or with sitecast concrete that is poured as part of the topping. These systems can increase the economy of long-span structures and may allow greater flexibility in the choice of building module.

## **FIRE-RESISTANCE RATINGS FOR SINGLE AND DOUBLE TEES**

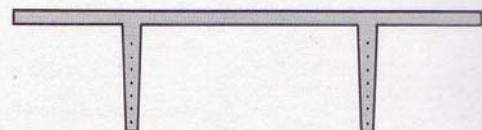
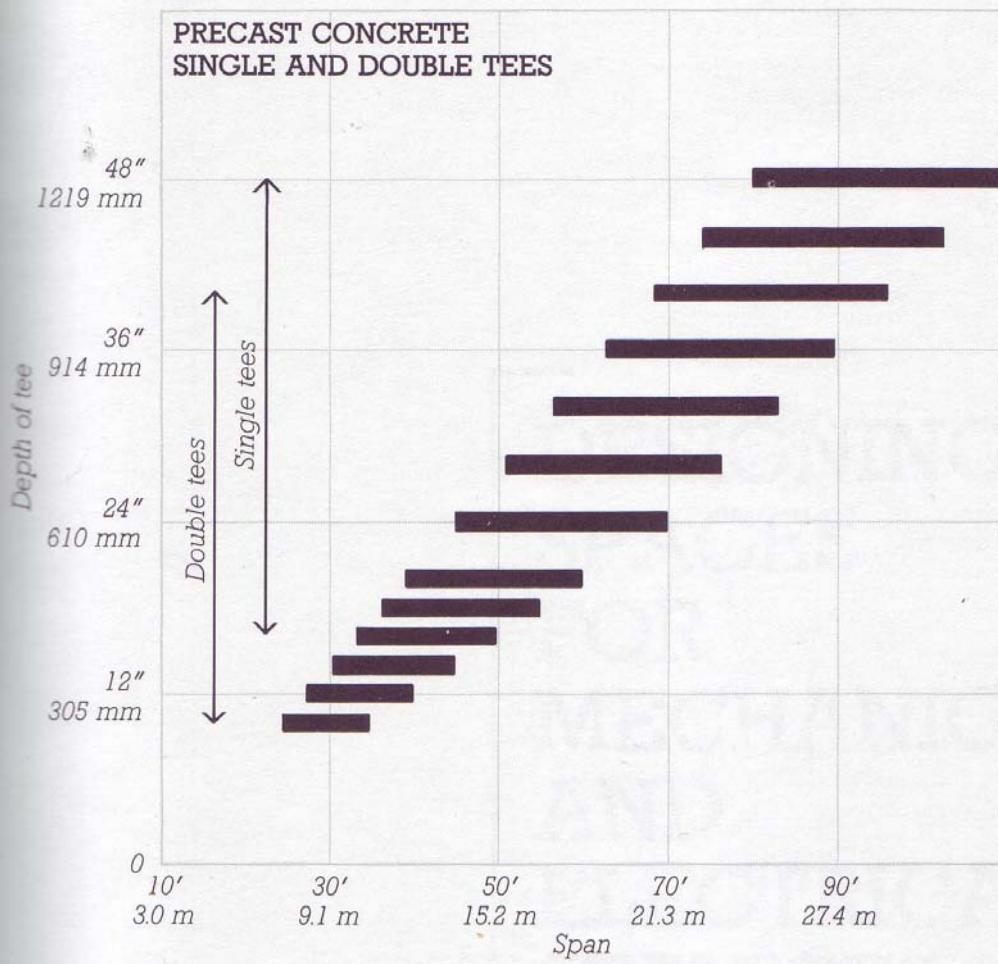
Fire resistance will vary with the density of concrete used in the slabs and topping. Use the following guidelines for preliminary design:

For a fire-resistance rating of 3 hours, single and double tees require applied fire-protection materials or an appropriately fire-resistant ceiling. For ratings of 2 hours and less, protection may be achieved by regulating the thickness of the concrete topping: 3.5 in. (90 mm) for 2 hours, 3.0 in. (75 mm) for 1½ hours, and 2.0 in. (50 mm) for 1 hour.

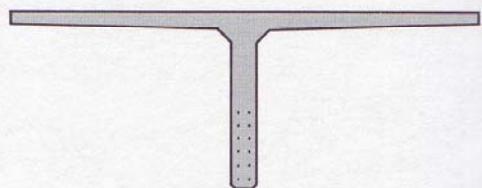


**SPREAD TEE SYSTEM WITH SITECAST CONCRETE TOPPING AND INFILL**

# PRECAST CONCRETE SINGLE AND DOUBLE TEES



DOUBLE TEE



SINGLE TEE

This chart is for precast concrete single and double tees. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

□ Because they do not require temporary support against tipping, double tees are easier and more economical to erect than single tees. Their use is preferred wherever possible.

□ Double tees are most commonly used with a concrete topping. For preliminary purposes, add 2 in. (50 mm) to the depths indicated on the chart. Roof slabs and deep single tees may not need to be topped.

## COMMON SIZES OF PRECAST SINGLE AND DOUBLE TEES

Double tees come in widths of 4, 8, 10, and 12 ft (1.2, 2.4, 3.0, and 3.7 m). Common depths are from 10 to 40 in. (254 to 1016 mm).

Single tees come in widths of 6, 8, 10, and 12 ft (1.8, 2.4, 3.0, and 3.7 m). Common depths are from 16 to 48 in. (406 to 1219 mm).

Tees longer than 60 to 80 ft (18 to 24 m) may be less economical because of increased transportation and handling costs.

Availability of sizes varies with suppliers.