APPENDIX B

Preliminary Sizing of Structural Members

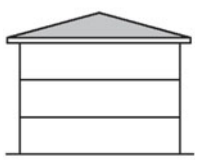
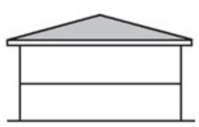
APPENDIX OUTLINE

The information provided in this appendix is valid only for approximate sizing of structural members during the sketch design (SD) or initial design development (DD) stages of conventional buildings. A structural engineer should be consulted for final member sizes.

CONVENTIONAL WOOD LIGHT FRAME (WLF) BUILDINGS

Wall Framing

Approximate Stud Size and Spacing

Number of stories	Stud size	Stud spacing	
3 stories	2 × 6	16 in. o.c.	
2 stories	2 × 6 2 × 4	16 in. o.c. 12 in. o.c.	
1 story	2 × 4	24 in. o.c.	

1. Stud size and spacing are for approximately 10-ft-high studs. For tall walls, such as those used in double-height spaces, doubled studs and (or) closer stud spacing may be required.
2. In cold climates, the stud size may be governed by insulation requirements. For example, 2 × 6 studs may be necessary where 2 × 4 studs are structurally adequate.
3. In high-wind regions, the exterior walls may require larger studs and (or) closer spacing or doubled studs.

FLOOR FRAMING

Lumber Joists—Approximate Span Capabilities

	Joist spacing		
Joist size	**12 in. o.c.**	**16 in. o.c.**	**24 in. o.c.**
2 × 6	11 ft	10 ft	9 ft
2 × 8	15 ft	13 ft	11 ft
2 × 10	19 ft	17 ft	14 ft
2 × 12	23 ft	20 ft	16 ft

I-Joists—Approximate Span Capabilities

	I-joist spacing		
I-joist depth	**12 in. o.c.**	**16 in. o.c.**	**24 in. o.c.**
$9\frac{1}{2}$ in.	18 ft	16 ft	14 ft
$11\frac{7}{8}$ in.	21 ft	19 ft	15 ft
14 in.	24 ft	20 ft	17 ft
16 in.	28 ft	24 ft	19 ft

Trussed Joists—Span Capabilities

Unlike lumber or I-joists, trussed joists are custom manufactured for a project and are not trimmable. Typical spacing of trussed joists = 24 in. o.c.

$$\textbf{Approx. joist depth} = \frac{\textbf{joist span}}{\textbf{18}}$$

Example

If joist span = 30 ft, approximate joist depth = (30 × 12)/18 = 20 in.
Because trussed joists are made of 2 × 4 lumber, the width of joists is $3\frac{1}{2}$ in.

ROOF FRAMING

Sawn Lumber Rafters—Approximate Span Capabilities

	Rafter spacing		
Rafter size	**12 in. o.c.**	**16 in. o.c.**	**24 in. o.c.**
2 × 6	14 ft	13 ft	12 ft
2 × 8	19 ft	18 ft	15 ft
2 × 10	25 ft	22 ft	18 ft

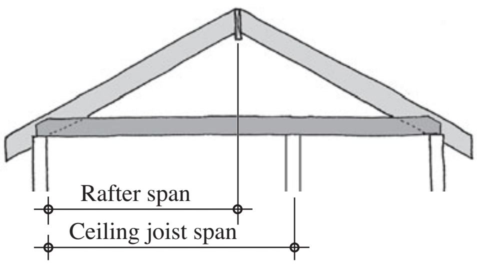
The above table applies to a roof live load (or snow load) ≤20 psf and a light roof cover (such as asphalt shingles). If the snow load exceeds 20 psf and (or) the roof cover is heavier (such as clay or concrete tiles), the span capability of a given rafter size will be smaller.

Sawn Lumber Ceiling Joists—Approximate Span Capabilities

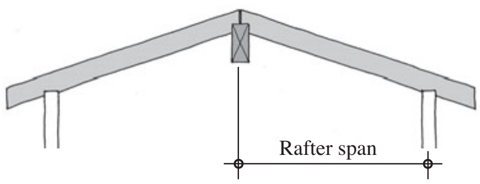
	Joist spacing		
Joist size	**12 in. o.c.**	**16 in. o.c.**	**24 in. o.c.**
2 × 6	18 ft	16 ft	14 ft
2 × 8	24 ft	22 ft	18 ft
2 × 10	—	—	22 ft

The above table applies to an uninhabitable attic without storage.

A dash (—) indicates that the span capability exceeds 26 ft—the maximum sawn lumber length available.



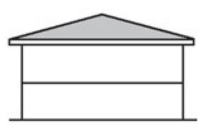
Because the span of a hip or valley rafter is larger than the common rafters, hip or valley rafters are generally one size larger than the common rafters. Thus, for 2 x 8 common rafters, a hip or valley rafter is generally 2 x 10.



CONVENTIONAL COLD-FORMED STEEL FRAME (CFSF) BUILDINGS

Wall Framing

Approximate Stud Size and Spacing

Number of stories	Stud size	Stud spacing	
2 stories	550S162–33 350S162–43	24 in. o.c. 16 in. o.c.	
1 story	350S162–33	24 in. o.c.	

Stud size and spacing are based on sheet steel with a yield strength of 33 ksi. The other commonly used yield strength is 50 ksi (see Chapter 17).

550S162–33 implies a stud (joist or rafter) with a web depth of 5.5 in. and a flange width of 1.625 in., made of 33-mil (0.033-in.)-thick sheet steel (see Chapter 17).

1. Stud size and spacing are for approximately 10-ft-high studs. For tall walls, such as those used in double-height spaces, larger stud size and (or) thicker sheet steel or closer spacing of studs may be required.

2. In cold climates, the stud size may be governed by insulation requirements. For example, 550S162 studs may be necessary where 350S162 studs are structurally adequate.
3. In high-wind regions, the exterior walls may require larger studs, studs made of thicker sheets, or higher yield strength.

Floor Framing

Joists—Approximate Span Capabilities

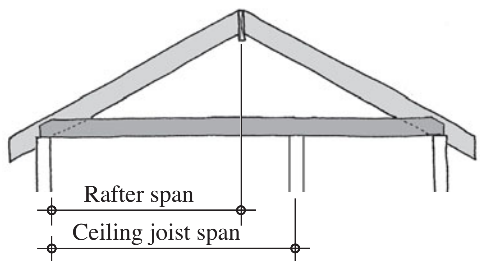
Joist size	Joist spacing	
	16 in. o.c.	24 in. o.c.
550S162–54	11 ft	10 ft
800S162–54	15 ft	13 ft
1000S162–54	18 ft	17 ft
1200S162–54	21 ft	18 ft

1. For a given joist size, the span capability can be increased by increasing the sheet thickness. Commonly used sheet thicknesses for joists are 33, 43, 54, 68, and 97 mil.
2. The span capabilities given here are for the intermediate sheet thickness of 54 mil.

Roof Framing

Rafters—Approximate Span Capabilities

Rafter size	Rafter spacing	
	16 in. o.c.	24 in. o.c.
550S162–54	18 ft	15 ft
800S162–54	24 ft	20 ft
1000S162–54	28 ft	23 ft
1200S162–54	30 ft	25 ft



1. The above table applies to a roof live load (or snow load) ≤20 psf and a light roof cover (such as asphalt shingles). If the snow load exceeds 20 psf and (or) the roof cover is heavier (such as clay or concrete tiles), the span capability of a given rafter size will be smaller.
2. For a given rafter size, the span capability can be increased by increasing the sheet thickness. Commonly used sheet thicknesses for rafters are 33, 43, 54, 68, and 97 mil.
3. The span capabilities given here are for the intermediate sheet thickness of 54 mil.

Ceiling Joists—Approximate Span Capabilities

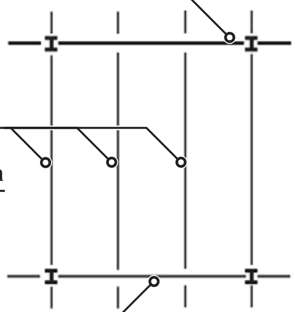
Joist size	Joist spacing	
	16 in. o.c.	24 in. o.c.
550S162–54	18 ft	15 ft
800S162–54	20 ft	18 ft
1000S162–54	21 ft	19 ft
1200S162–54	23 ft	20 ft

1. The above table applies to an uninhabitable attic without storage.
2. For a given joist size, the span capability can be increased by increasing the sheet thickness. Commonly used sheet thicknesses for rafters are 33, 43, 54, 68, and 97 mil.
3. The span capabilities given here are for the intermediate sheet thickness of 54 mil.

STRUCTURAL STEEL FRAME BUILDINGS

FLOORS AND ROOFS

W-section Girders and Beams



Girder

W-section beam

Approx. depth = $\frac{\textbf{Span}}{\textbf{22}}$

Typical spacing of beams = 8 to 12 ft

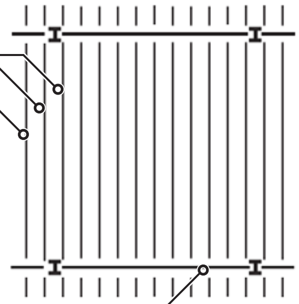
W-section girder

Approx. depth = $\frac{\textbf{Span}}{\textbf{16}}$

but not less than beam's depth

Nominal Depths of W-Sections in inches
44, 40, 36 33, 30, 27, 24, 21 18, 16, 14, 12, 10, 8, 6, 4

Girders and K-series joists



K-series joists

Approx. depth = $\frac{\textbf{Span}}{\textbf{20}}$

Typical spacing of joists
= 2 to 4 ft (for floors)
= 4 to 6 ft (for roofs)

W-section girder or joist girder

Approx. depth = $\frac{\textbf{Span}}{\textbf{16}}$ (for W-section girder)

Approx. depth = $\frac{\textbf{Span}}{\textbf{14}}$ (for joist girder)

Standard Depths of K-Series Joists in inches
8, 10, 12, 14, 16, ...30

Example 1

Determine the approximate depths of the beams and girders for the floor of Figure 19.5.

Solution

The maximum span of the girder is 26.5 ft. Therefore, approximate girder depth = $(26.5 \times 12)/16 = 19.9$ in., or 20 in. The nearest W-section is W21. Hence, use a W21 girder.

The maximum beam span is 30 ft. Therefore, approximate beam depth = $(30 \times 12)/22 = 16.4$ in. Hence, use a W16 beam.

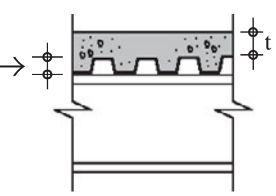
COLUMNS

Interior Columns

To approximate the size of an interior column, compute the total floor area supported by the column on all floors and then select the column size from the following table.

Column size	Maximum floor area on all floors
8 in. x 8 in.	2,000 sq. ft
10 in. x 10 in.	3,000 sq. ft
12 in. x 12 in.	4,500 sq. ft
14 in. x 14 in.	6,000 sq. ft

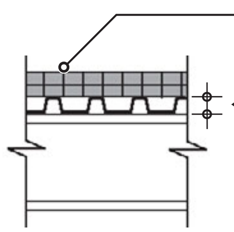
Composite Floor Decks



Approx. deck depth = 2 in.

Approximate thickness of concrete (t) above deck
4 in. for 2-h fire-rated floor
3 in. for 1-h fire-rated floor

Roof Decks



Thickness of rigid insulation = 3 in. to 6 in. depending on the climate

Approx. deck depth = 1-1/2 in.

Exterior Columns

Although the floor area supported by an exterior column is less than that of an interior column, exterior columns will generally support (exterior) walls, which generally are not supported by interior columns. Therefore, exterior columns may be assumed to be the same size as interior columns.

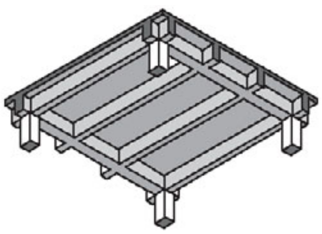
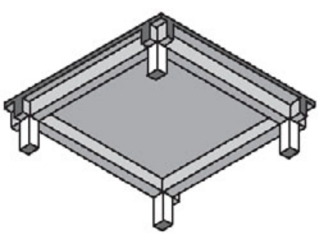
Example 2

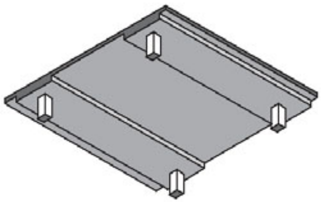
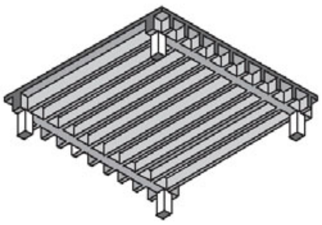
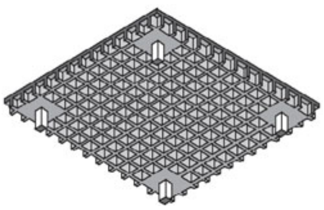
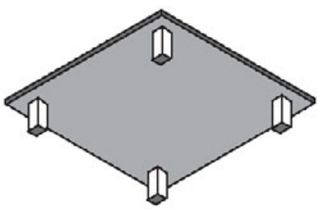
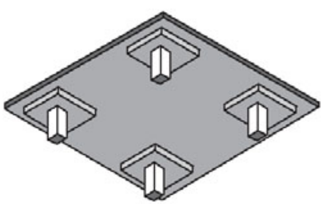
If the building in Figure 19.5 is five stories tall, determine the approximate size of the columns.

Solution

We will base the column size on the maximum floor area supported by an interior column. The largest bay size is $(30.0 \times 26.5) = 795$ ft^2. The total area on all five floors is $5(795) = 3{,}975$ ft^2. From the table above, an approximate column size is a W12 column (web depth approximately 12 in.).

SITE-CAST CONCRETE FRAME BUILDINGS

 **Beam and Girder-Supported One-Way Solid Slab**	*Reinforced Concrete* *Girder* $\textbf{Approx. depth} = \frac{\textbf{span}}{\textbf{12}}$ Width = 0.6 (depth) *Beam* $\textbf{Approx. depth} = \frac{\textbf{span}}{\textbf{15}}$ Width = 0.6 (depth) *Slab* $\textbf{Approx. thickness} = \frac{\textbf{span}}{\textbf{24}}$ Typical distance between beams = 8 ft to 15 ft	*Posttensioned Concrete* *Girder* $\textbf{Approx. depth} = \frac{\textbf{span}}{\textbf{18}}$ Width = 0.6 (depth) *Beam* $\textbf{Approx. depth} = \frac{\textbf{span}}{\textbf{20}}$ Width = 0.6 (depth) *Slab* $\textbf{Approx. thickness} = \frac{\textbf{span}}{\textbf{40}}$ Typical distance between beams = 15 ft to 25 ft	Span for girder is clear distance between columns, and span for beams is clear distance between girders. Depth of girder or beam includes thickness of slab. Span for slab is clear distance between beams. As far as possible, girder and beam depths should be the same. Therefore, the girder should span along the shorter direction. Round beam and girder widths and depths to whole inches. Round slab thickness to $\frac{1}{2}$ inch, not less than 4 in. Slab thickness may be governed by fire-resistance requirements.
 **Two-way Solid Slab**	*Reinforced Concrete* *Beam* $\textbf{Approx. depth} = \frac{\textbf{span}}{\textbf{15}}$ Width = 0.6 (depth) *Slab* $\textbf{Approx. thickness} = \frac{\textbf{span}}{\textbf{36}}$ Typical column spacing = 8 ft to 25 ft	*Posttensioned Concrete* *Beam* $\textbf{Approx. depth} = \frac{\textbf{span}}{\textbf{20}}$ Width = 0.6 (depth) *Slab* $\textbf{Approx. thickness} = \frac{\textbf{span}}{\textbf{48}}$ Typical column spacing = 25 ft to 30 ft	Span for beams is clear distance between columns. Span for slab is the longer of the two clear distances between beams. Round beam width and depth to whole inches. Round slab thickness to $\frac{1}{2}$ inch, not less than 4 in. Slab thickness may be governed by fire-resistance requirements. As far as possible, distance between columns in both directions should be the same.

 **One-Way Band Beam Slab**	*Reinforced Concrete* *Beam* **Approx. depth** = **2.0 to 2.5 (slab thickness)** Width = 0.25 to 0.3 (center-to-center beam spacing) *Slab* **Approx. thickness** = $\frac{\textbf{span}}{\textbf{24}}$ Typical column spacing = 25 ft to 30 ft	*Posttensioned Concrete* *Beam* **Approx. depth** = **2.0 to 2.5 (slab thickness)** Width = 0.25 to 0.3 (center-to-center beam spacing) *Slab* **Approx. thickness** = $\frac{\textbf{span}}{\textbf{40}}$ Typical column spacing = 30 ft to 40 ft	Span for slab is clear distance between beams. Round beam width and depth to whole inches. Round slab thickness to $\frac{1}{2}$ inch. Slab thickness should not be less than 4 in. Slab thickness may be governed by fire-resistance requirements.
 **One-Way Joist Slab**	*Reinforced Concrete* *Beam* **Depth** = **same as joists** Width = 1.75 (joist depth) Joist **Approx. depth** = $\frac{\textbf{span}}{\textbf{18}}$ Width = 5 in. (standard-module pans), 7 in. for wide-module pans *Slab* **Thickness** = **3 in.** (standard-module pans), **4 in.** (wide-module pans) Typical column spacing = 25 ft to 40 ft	*Post-tensioned Concrete* *Beam* **Depth same as joists** = Width = 1.25 (joist depth) Joist (Reinforced Concrete) **Approx. depth** = $\frac{\textbf{span}}{\textbf{18}}$ Width = 5 in. (standard-module pans), 7 in. for wide-module pans *Slab* **Thickness 3 in.** (standard-module pans), **4 in.** (wide-module pans) Typical column spacing = 35 ft to 50 ft	Span for joists is clear distance between beams. Depth of joists or beams includes slab thickness. Round joist depth to pan depth + slab thickness. Slab thickness may be governed by fire-resistance requirements.
 **Two-Way Joist (Waffle) Slab**	*Reinforced Concrete* *Joist* **Approx. depth** = $\frac{\textbf{span}}{\textbf{22}}$ **Width** = **5 in. to 6 in.,** depending on dome size *Slab* **Thickness** = **3 in. to 4 in.** Typical column spacing = 30 ft to 45 ft	*Posttensioned Concrete* *Joist* **Approx. depth** = $\frac{\textbf{span}}{\textbf{30}}$ **Width** = **5 in. to 6 in.,** depending on dome size *Slab* **Thickness** = **3 in. to 4 in.** Typical column spacing = 40 ft to 60 ft	Depth of joists includes slab thickness. Round joist depth to dome depth + slab thickness. Slab thickness may be governed by fire-resistance requirements. The number of domes filled around columns is a function of column spacing, floor load, and dome size. Beams may be used in place of filled domes.
 **Flat Plate**	*Reinforced Concrete* *Slab* **Approx. thickness** = $\frac{\textbf{span}}{\textbf{30}}$ Typical column spacing = 15 ft to 20 ft	*Posttensioned Concrete* *Slab* **Approx. thickness** = $\frac{\textbf{span}}{\textbf{40}}$ Typical column spacing = 20 ft to 25 ft	Slab span is (longer) clear distance between columns. As far as possible, distance between columns in both directions should be the same. Slab thickness may be governed by fire-resistance requirements.
 **Flat Slab**	*Reinforced Concrete* *Slab* **Approx. thickness** = $\frac{\textbf{span}}{\textbf{35}}$ Typical column spacing = 20 ft to 30 ft	*Posttensioned Concrete* *Slab* **Approx. thickness** = $\frac{\textbf{span}}{\textbf{45}}$ Typical column spacing = 30 ft to 45 ft	Slab span is (longer) clear distance between columns. As far as possible, distance between columns in both directions should be the same. Slab thickness may be governed by fire-resistance requirements.

Columns

Column size depends on various factors, such as the total floor area supported by the column, concrete strength, amount of reinforcement, column height, and whether the column is part of the lateral load resistance system of the building. For conventional buildings in which the lateral load is resisted by shear walls, the following rule of thumb may be used for the approximate size of an interior column:

$$\text{Area of column} = \frac{\text{total floor area supported by column}}{10 \text{ to } 20 \left(\text{depending on concrete strength}\right)} \text{ not less than 10 in. in any direction}$$

As far as possible, column size should be the same for interior and exterior columns and from floor to floor. Note that the amount of reinforcement and the concrete strength in a column can be increased toward the lower floors.

Example: Determine the column size required for a square reinforced-concrete column at the ground floor of a building supporting 1,000 ft^2 at each floor. Number of floors = 4.

Solution:

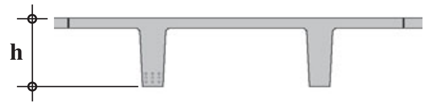
$$\text{Area of column} = \frac{4{,}000}{10} = 400 \text{ in.}^2$$

Hence, approx. column size = 20 in. × 20 in.

PRECAST, PRESTRESSED CONCRETE MEMBERS

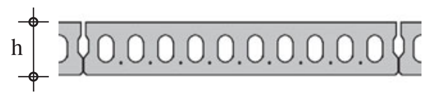
Double-T Units

Approx. depth, $h = \dfrac{\text{Span}}{28}$



Hollow-core slabs

Approx. depth, $h = \dfrac{\text{Span}}{40}$



LOAD-BEARING MASONRY AND CONCRETE BUILDINGS

Reinforced-Concrete Masonry Bearing Walls in Residential (e.g., Apartment and Hotel) Buildings

8-in.-thick, CMU walls for up to 8-floor-high buildings.

10-in.-thick CMU walls for 11- to 15-floor-high buildings.

12-in.-thick CMU walls for 16- to 20-floor-high buildings.

Upper floors in 10-in.- or 12-in.-thick wall structures may be constructed of 8-in.-thick walls.

Reinforced-Concrete Masonry Bearing Walls in Single-Story, Long-Span Structures (e.g., Gymnasiums)

10-in.- or 12-in.-thick CMU walls, depending on the span.

Site-Cast Reinforced-Concrete Bearing Walls in Residential Buildings

6-in.-thick site-cast reinforced-concrete walls for up to 20-floor-high buildings.

Precast-Concrete Tilt-Up Walls

The thickness of tilt-up walls in a single-story building can be approximated by dividing the wall height by 48 (not less than 6 in.). For two- or three-story buildings, slightly thicker walls may be needed.