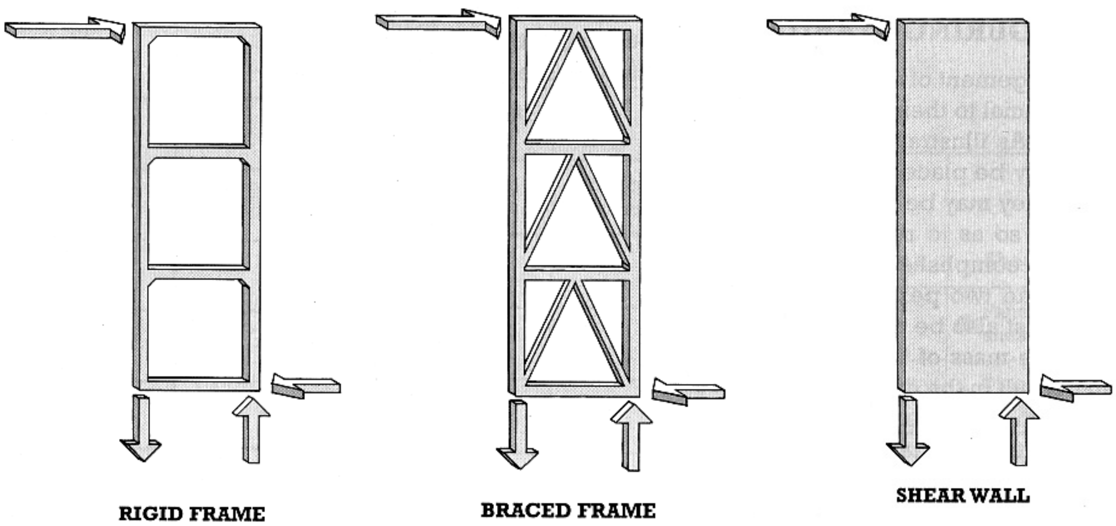
Structural Planning

Design Issues

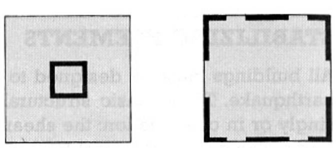
(Reference: The Architect's Studio Companion, 3rd ed., Allen & Iano, Wiley, 2002)

Lateral Stability: Wind forces and inertial forces due to ground acceleration are two types of lateral loads buildings must be designed to resist. Without resisting elements or systems, the buildings will move a little, a lot, or suddenly. Stability is the ability to flex and not suddenly "snap" or in other words, the ability to remain in the configuration intended to transfer load.

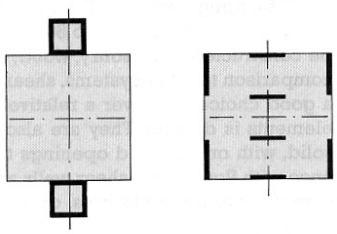
- Resisting systems include *shear walls, braced frames* and *rigid frames:*



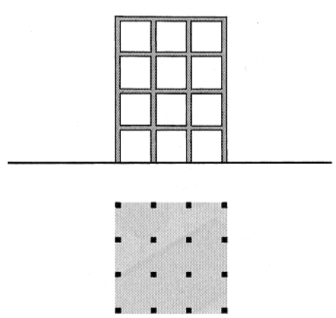
- Configurations are important for the systems to be effective. Symmetrical or balanced arrangements are the most effective for resisting the lateral forces from all directions.



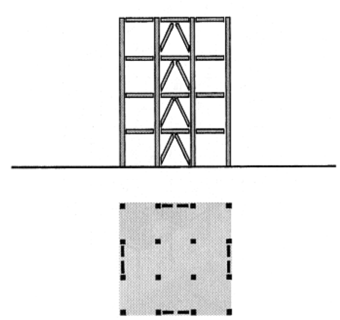
Stabilizing elements may be placed within the interior or at the perimeter of a building.



Stabilizing elements should be arranged in a balanced fashion.

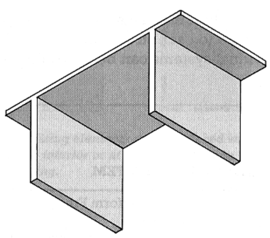


Rigid frame structures require no additional bracing or shear walls, as shown in this elevation and plan.

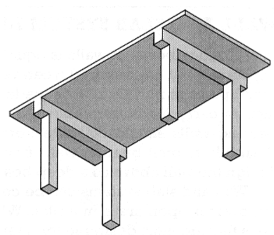


The locations of braced frames or shear walls must be considered in relation to the elevation and plan of the building.

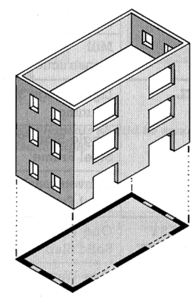
Vertical Load Resistance: Load bearing walls, columns and frames are examples of vertical load resisting elements. They can support a variety of horizontal spanning elements, such as beams and slabs. The order, or modular placement, becomes important, and uniform arrangements are economical. Load bearing walls can also function as shear walls to resist lateral loads. They are commonly constructed of reinforced concrete or masonry.



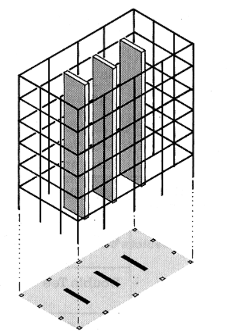
WALL AND SLAB SYSTEMS
(shown from below)



COLUMN AND BEAM SYSTEMS
(shown from below)

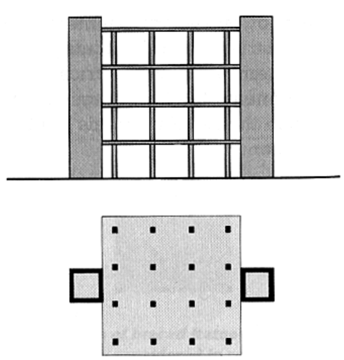


Shear walls may be arranged in a box form to resist lateral forces from all directions.

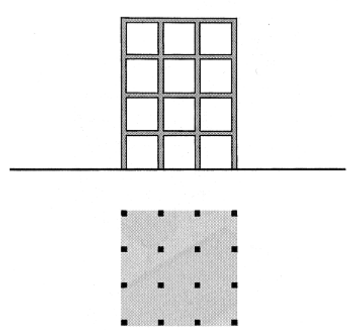


When combined with other stabilizing mechanisms, shear walls may be arranged so as to resist forces in only one direction of a building.

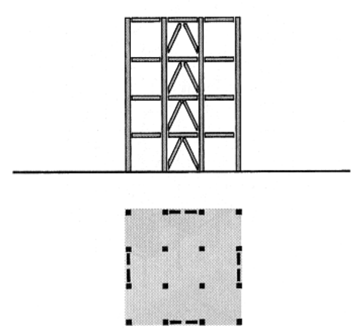
Horizontal Load Resistance: The combination of vertical and horizontal load resistance is dependant upon construction materials and size or utility of spaces. Slabs can act as diaphragms to transmit loads to the columns, shear wall or frames. They are commonly constructed of reinforced concrete. Rigid frames are commonly steel or monolithically cast reinforced concrete.



Shear walls are commonly used with column and slab systems. In this elevation and plan, the shear walls are shown incorporated into a pair of vertical cores.



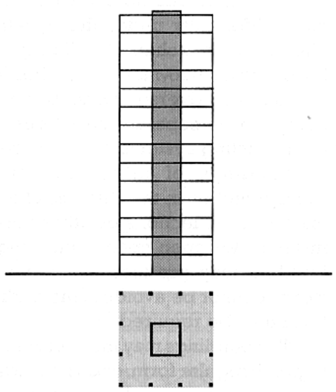
Rigid frame structures require no additional bracing or shear walls, as shown in this elevation and plan.

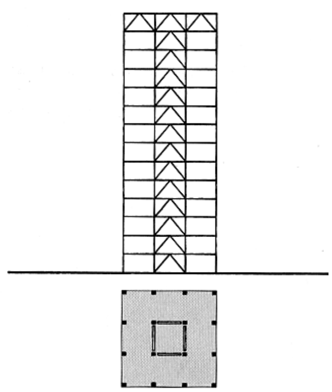


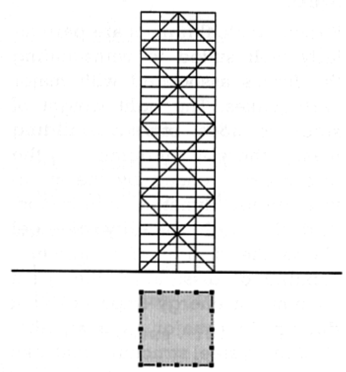
The locations of braced frames or shear walls must be considered in relation to the elevation and plan of the building.

<u>Multistory Design Issues</u>**:** As a building gets taller, it is exposed to more wind load that it must resist laterally. It also increases in mass at each story, which makes the inertial forces from ground acceleration very complex. The behavior of a structure under these types of loads is dependant upon the arrangement of the masses and the stiffness and placement of the horizontal and vertical load resisting elements.

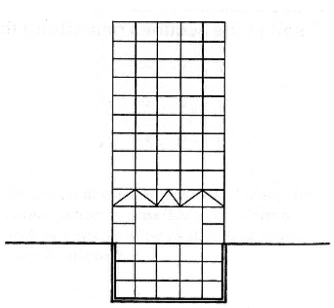
Cores are quite common to increase stiffness vertically. *Unfortunately, they can't provide effective horizontal load transfer, and should not be relied on as the sole lateral resistant mechanism!* Exterior bracing or tube formations, such as the Sears Tower in Chicago, are other multistory configurations to resist lateral loads.

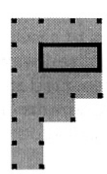

RIGID CORE

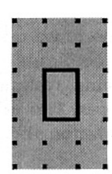

BRACED CORE WITH HAT TRUSS

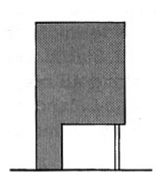

BRACED FRAME TUBE

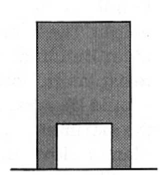
Vertical and horizontal "discontinuities" contribute to irregular or poor lateral response. Vertical discontinuities include "cut-outs" in stories, or changes in plan vertically, while horizontal continuities include problems such as "soft stories" which have different stiffness from the rest of the structure, and unbalanced placement of shear walls.

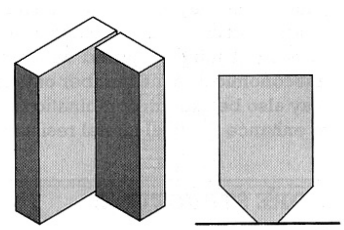

Transfer beams or trusses may be used to interrupt vertical loadbearing elements where necessary.

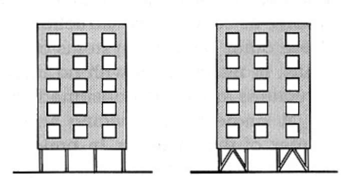

UNBALANCED PLAN


BALANCED PLAN


UNBALANCED SECTION


BALANCED SECTION


Discrete building masses should be structurally independent. Inherently unstable building masses should be avoided.


Discontinuities in the stiffness of structures at different levels should be avoided, or additional stabilizing elements may be required.

Structural Plans and Grids (Reference: Construction Graphics, 1st ed., Bisharat, Wiley, 2004)

Foundation

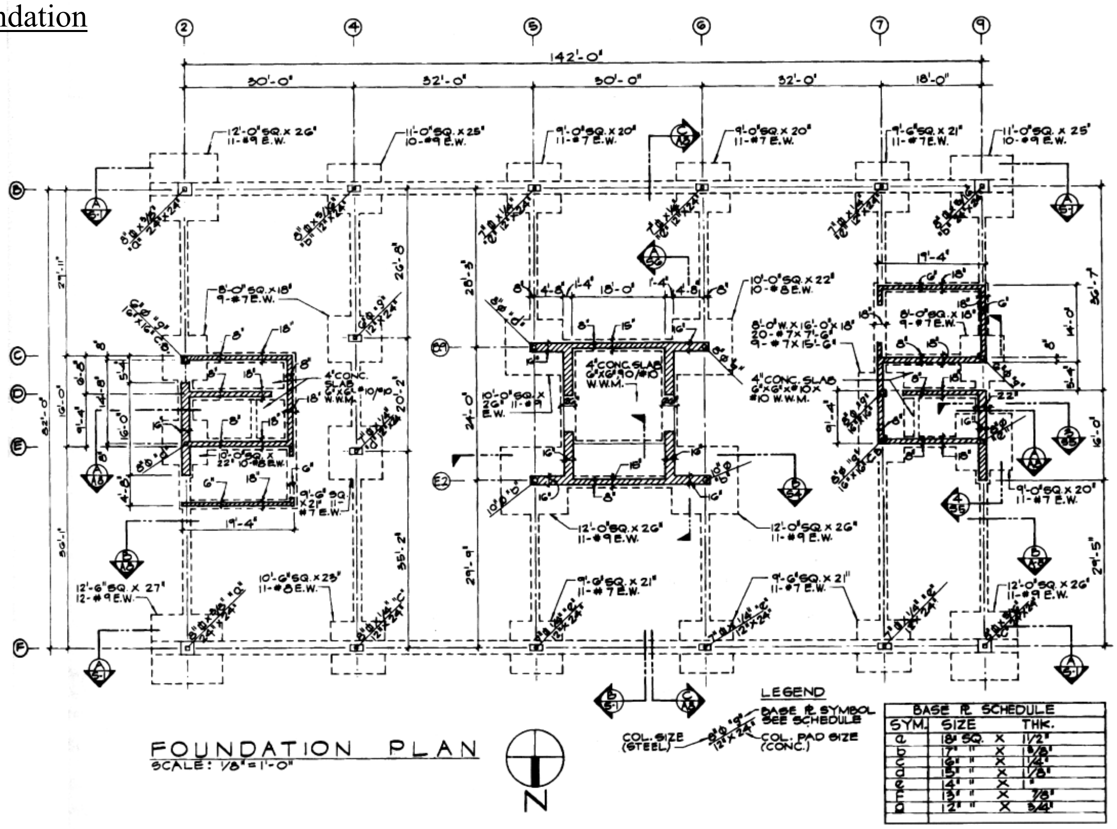


Figure 7.4 This foundation plan uses a grid referencing system, though not the one promoted by the National CAD Standard. Note the idiosyncrasies in this drawing: north is normally the top of the page. (From *The Professional Practice of Architectural Working Drawings*, 2nd edition, by Osamu Wakita and Linde, Richard, John Wiley & Sons, Inc., 1995. Used with permission of John Wiley & Sons, Inc.)

Footing Detail

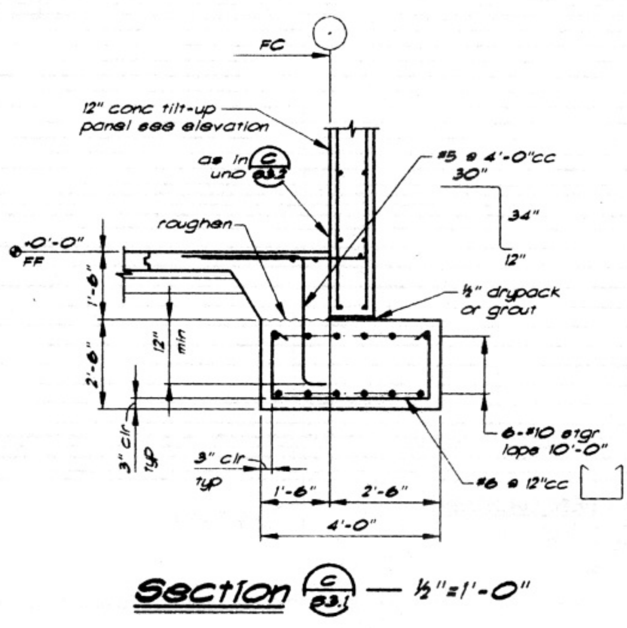


Figure 8.5b Footings are often depicted in wall sections on subsequent sheets, but in this instance the engineer is showing just a footing section, denoted C S3.1 on the plan in 8.5a.

Steel

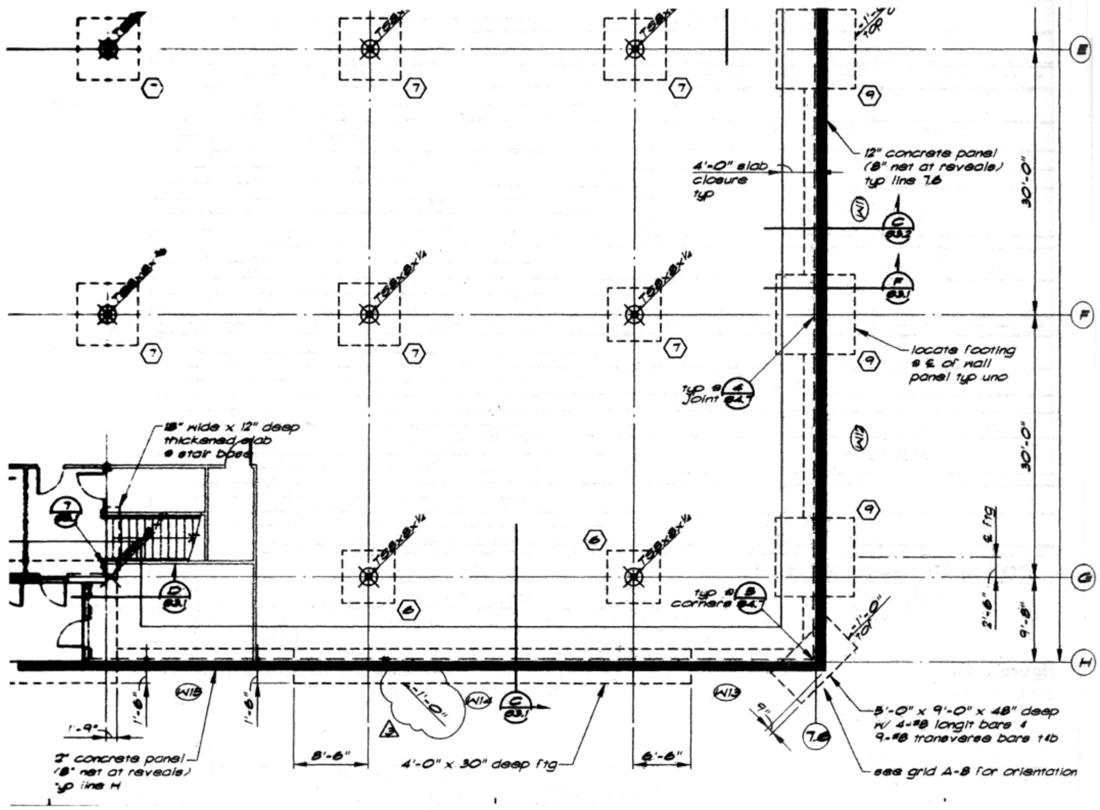


Figure 8.5a Drawings of structural steel framing systems begin with the foundation plan, which is where the columns and footings that carry the frame are described. (Drawing courtesy of Buehler and Buehler Structural Engineers.)

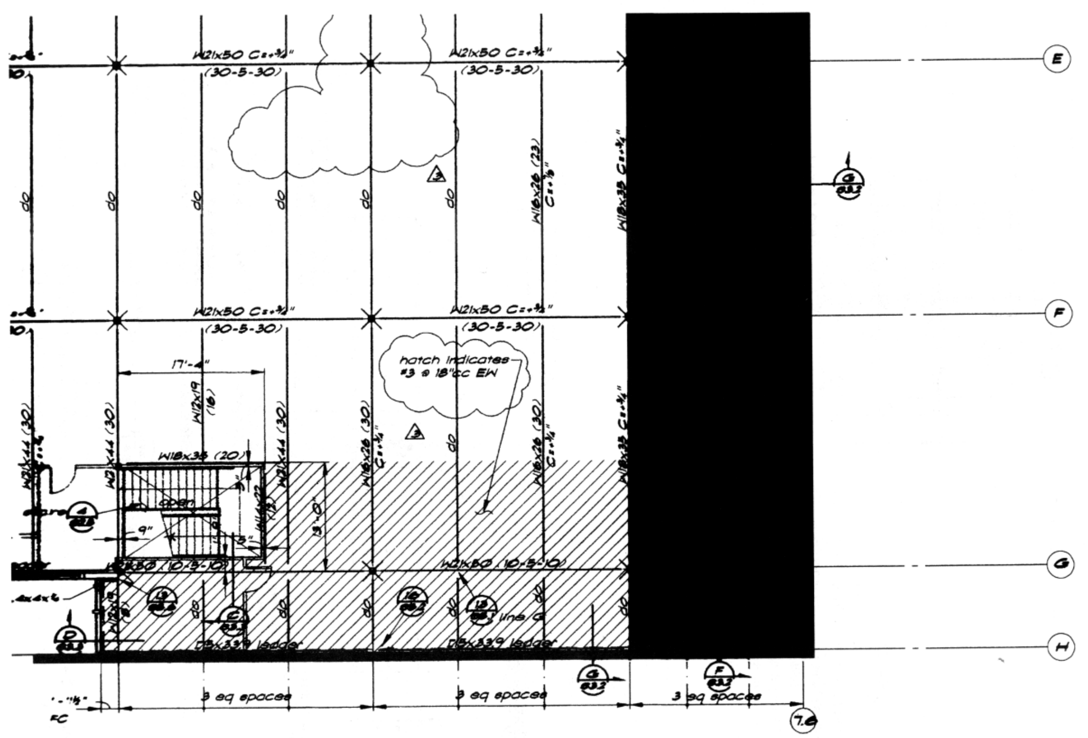
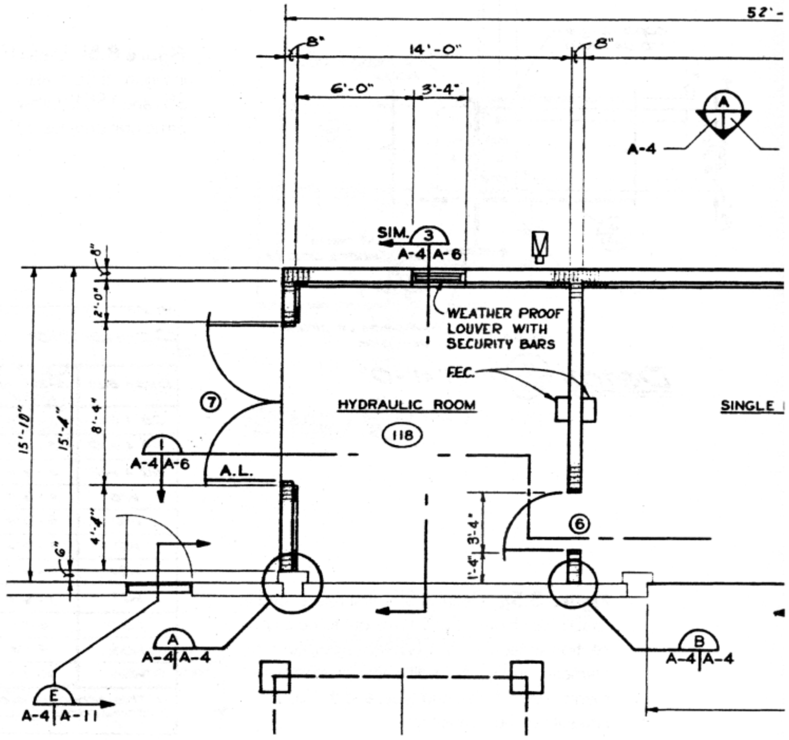


Figure 8.5c The first floor framing plan commonly shows column locations and lists girders and beams by size. The floor deck is also described on the plan. The girder designation W21 × 50 C = + 3/4" (above gridline F) and 30-5-30 (below gridline F) is, respectively, the girder size and camber and number of headed stud anchors required in each third of the beam (left, center, right). The beam designation is slightly different (see lines perpendicular to girder lines): Above the beam line following the beam size is the number of headed stud anchors to be uniformly distributed between columns on the top of the beam, with the camber listed below the beam line. (Drawing courtesy of Buehler and Buehler Structural Engineers.)

Reinforced Masonry

Figure 8.6a In this partial floor plan for a reinforced masonry structure, the wall descriptions are very simple. Note the conservative use of the masonry symbol and the consequent uncluttered appearance of the drawing. The split-bubble referencing system used throughout these drawings directs the reader's attention to several details, depicted on other pages as well as the page on which they originate. Details 1 A-4/A-6 and 3 A-4/A-6 are building sections; details A and B A-4/A-4 are details of the connection to existing concrete columns; and detail E A-4/A-11 is a roof connection detail. In the upper right part of the drawing is the reference to an exterior elevation (A A-4/A-5).



Timber

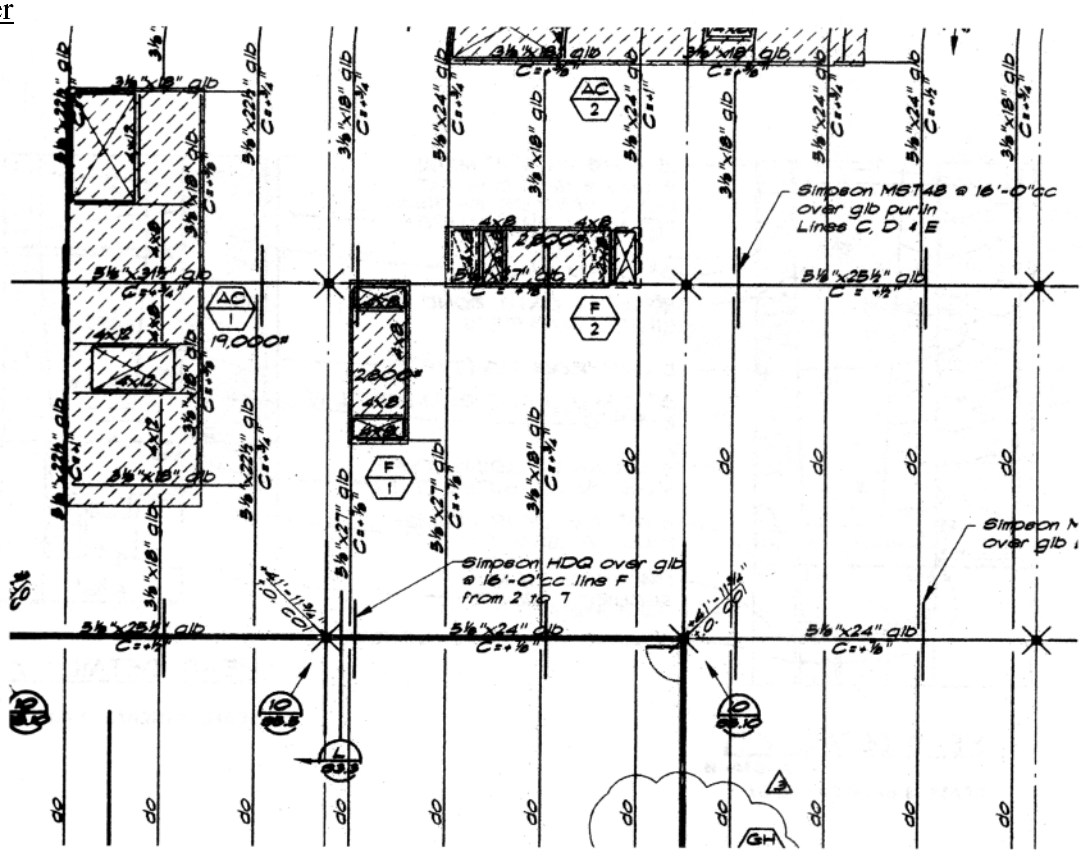


Figure 8.7a This partial roof framing plan shows the glued-laminated girder and beam system. Note the weight of AC unit 1 and how the structural engineer has addressed the additional loading where mechanical equipment is supported by the roof. (Drawing courtesy of Buehler and Buehler Structural Engineers.)

Common Span Lengths and Depths:

from Structures, 6th ed., Schodek & Bechthold, Pearson/Prentice Hall, 2007

Span Range by System

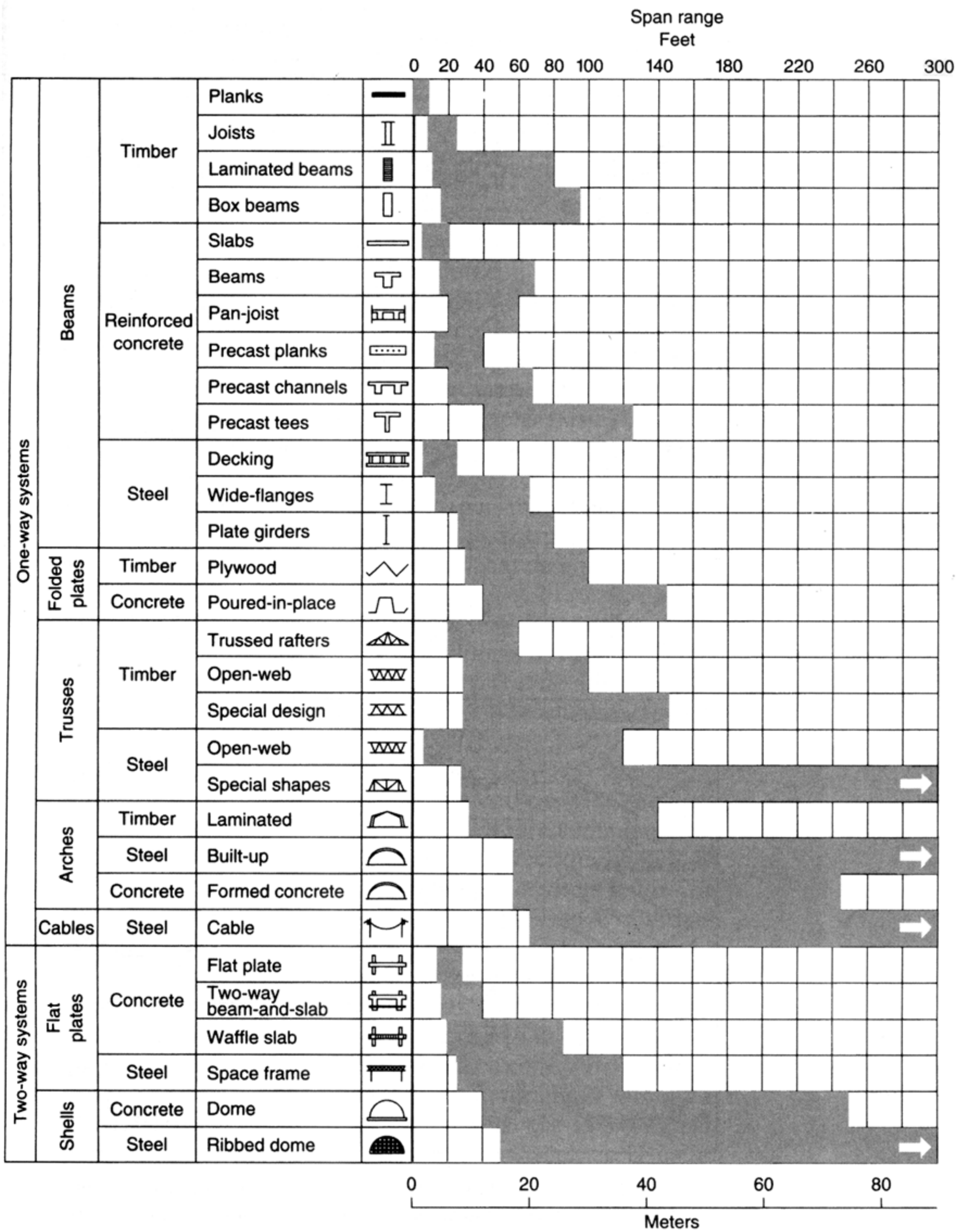


FIGURE 13.12 Approximate span ranges of different systems. (See also more detailed charts in Chapter 15.)

Timber

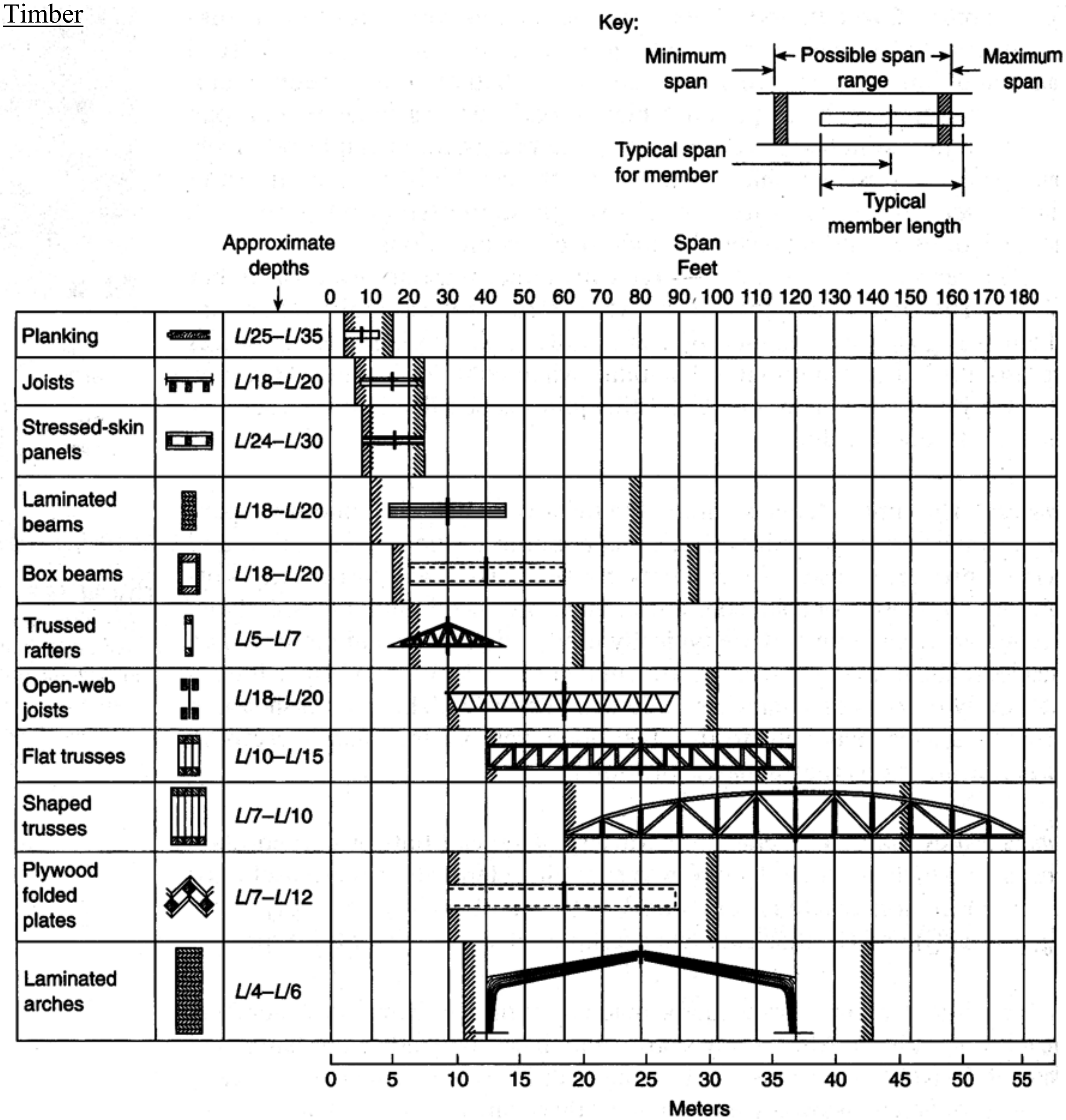


FIGURE 15.4 Approximate span ranges for timber systems. So that typical sizes of different timber members can be compared, the diagrams of the members are scaled to represent typical span lengths for each of the respective elements. The span lengths that are actually possible for each element are noted by the maximum and minimum span marks.

<u>Reinforced Concrete</u>

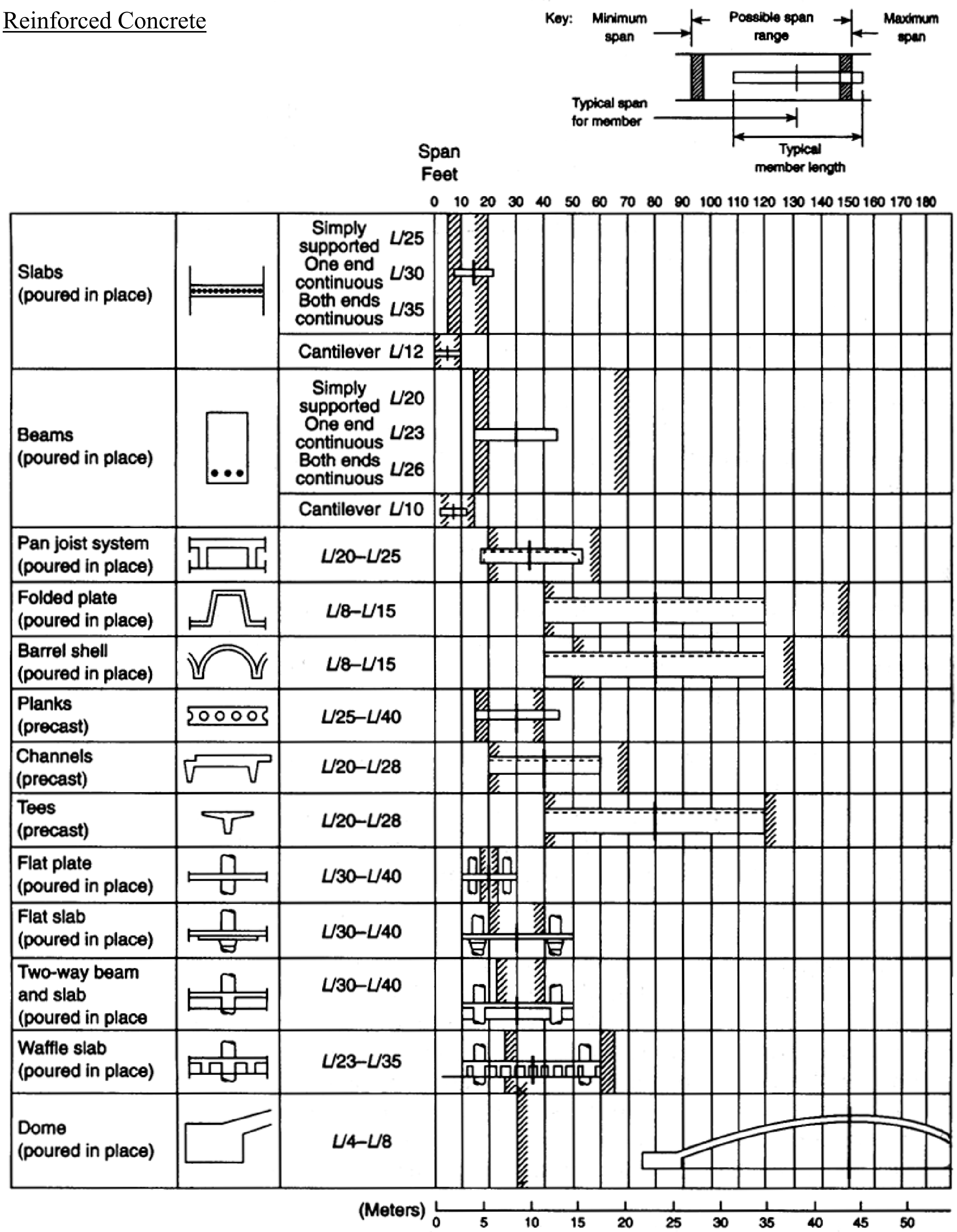


FIGURE 15.6 Approximate span ranges for reinforced-concrete systems. So that typical sizes of different members can be compared, the diagrams of the members are scaled to represent typical span lengths for each of the respective elements. The span lengths that are actually possible for each element are noted by the maximum and minimum span marks.

<u>Steel</u>

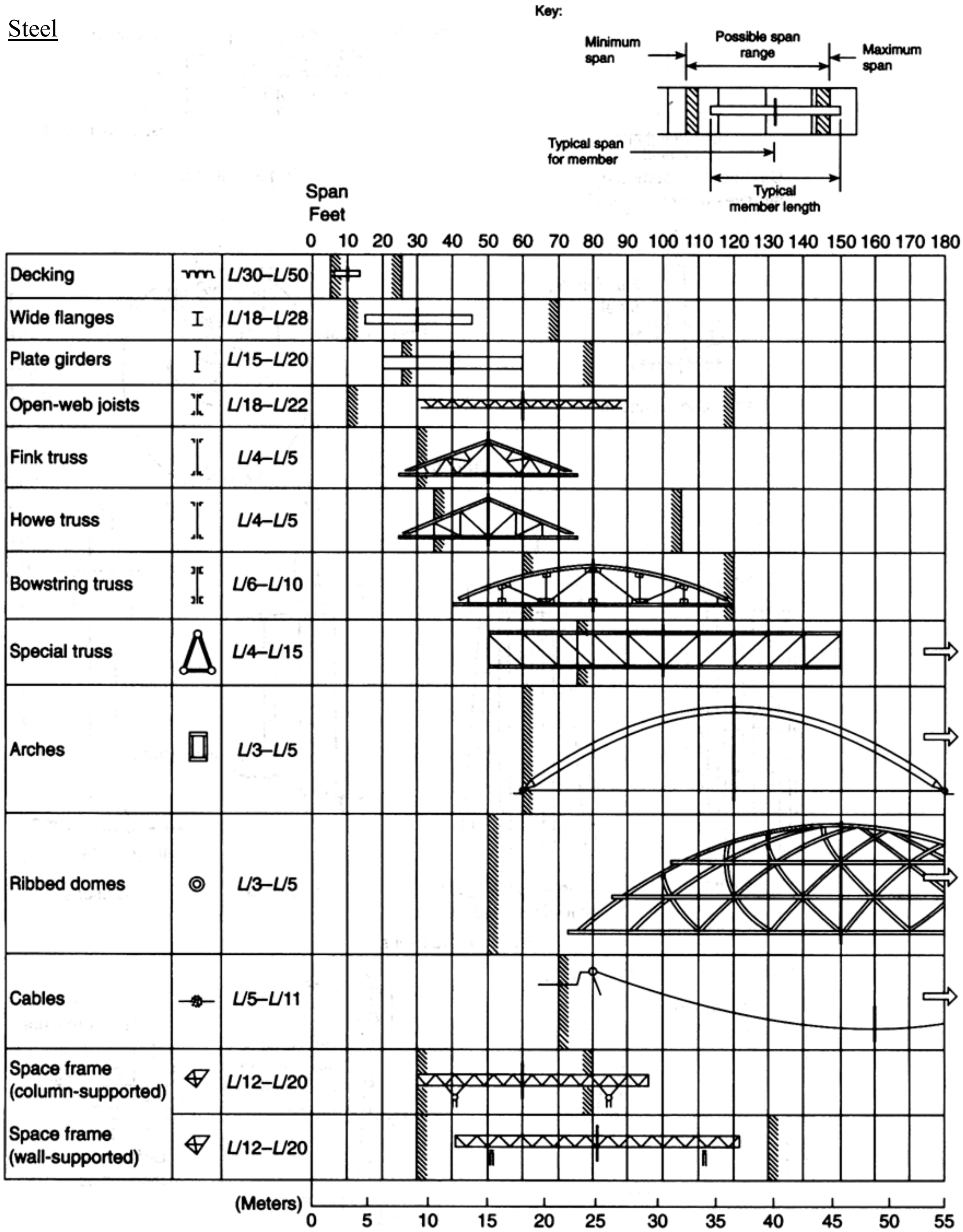


FIGURE 15.9 Approximate span ranges for steel systems. So that typical sizes of different members can be compared, the diagrams of the members are scaled to represent typical span lengths for each of the respective elements. The span lengths that are actually possible for each element are noted by the maximum and minimum span marks.