Section 2. Structural Framing in Reinforced Concrete

One of the main attractions of reinforced concrete is its “plasticity”: It can be built conveniently in any shape. A reinforced concrete structure can be assembled using any combination of planar (shells, walls, slabs) and linear (columns, girders) elements. It offers a multiplicity of options to creative architects (Fig. 2-1) and engineers (Figs. 1-6, 1-7).

Figure 2-1. Reinforced Concrete Structure in Japan.

Reinforced concrete offers options in economy too. The simplest reinforced concrete building structure, in terms of geometry, is one composed of footings, columns, and flat plates. As an assembly invented by C. A. P. Turner, this type of structure is called a flat plate (Fig. 2-2) or a flat slab (Fig. 2-3) if the columns have capitals. The flat plate and the flat slab are economical because they require smaller investment in formwork than do other structural configurations in reinforced concrete, because they permit clean ceilings, and because structural elements do not interfere with conduits.

Figure 2-2. Flat-Plate Structure
Perhaps the most critical component of the flat-plate structure is the connection between the slab and the columns. This connection can be improved with the use of capitals and drop panels. Capitals are often used in parking and industrial structures requiring larger spans and heavier loads.

As an alternative to the use of capitals, and to increase the stiffness and strength of the flooring system, a series of parallel beams can be cast to support the slabs.
A combination of beams and joists can also be used to produce strong and stiff floors if the increases in the costs of formwork and labor are not prohibitive.

Another option to stiffen and strengthen a slab is to support it with beams running along column lines in two perpendicular directions (dark-color and light-color beams in Figure 2-6). These beams are connected to columns to form frames that add lateral strength and stiffness to the structure.
In this system, load acting on a slab panel, an area defined by bounding column centerlines on four sides, is resisted by beams running in two directions (dark and light beams in Figure 2-6). This type of slab is called a “two-way” slab in reference to the fact that load is transmitted from the slab to the beams in two directions (Figure 2-7a). In slabs supported by beams parallel to one another, the load is transferred from the slab to beams in a single direction (Figure 2-7b). Slabs with beams running in a single direction, whether they have joists or not, are, therefore, called “one-way” slabs.1

The strength and lateral stiffness provided by frames are necessary to resist wind, blast, soil, and earthquake loads. Depending on the expected magnitude of lateral loads, the addition of shear walls (Figure 2-8) may be necessary.

1 It is of interest to note that historical development followed a different course. Initially, structural framing was based on beam-and-post combinations in timber. Introduction of iron and steel emphasized the use of one-way construction where the load was carried in one direction at a time, from the floor planks to the girders, from the girders to the columns. The first experiments in reinforced concrete used the same system. The two-way slab followed. The flat plate, construction without girders, had to be invented much later.
Both vertical loads, such as self weight and weight of building contents and occupants, and lateral loads, such as loads generated by wind or earthquake, need to be transferred to the foundation. Foundations may consist of a single reinforced concrete mat or a series of footings. Footings may or may not be connected by grade beams (Figure 2-9) depending on soil conditions.

![Figure 2-9. Foundation](image)

Production of a good framing concept for a structure requires selection of the appropriate structural system having the proper proportions. It is wise to have an idea of the right proportions of the structural elements before undertaking calculations for design. How do we develop an idea of the right proportions? Simply by looking at structures and observing their proportions!

The following are guidelines for selection of preliminary proportions. They are not absolutes. The proportions of building structures vary from place to place depending on local demands and experience. It is good to realize that physics is universal but engineering is local. Existing structures are the best source of information on proper proportions.

1. The depth of a typical continuous reinforced concrete beam is L/12.
   (L = span length in inches)

2. The width of a typical reinforced concrete beam is h/2.
   (h = beam depth)

3. The height of a reinforced concrete column is 4 to 7 times the depth of its cross section.
4. The thickness of a two-way concrete slab ranges from L/30 – L/36.
   (L = span length in inches)

5. The thickness of a one-way concrete slab without joists is L/20 – L/24.
   (L = span length in inches)

6. The unit weight of a reinforced concrete building is 150-200 psf.

Questions

1) What is the function of grade beams?

2) Select preliminary dimensions for a beam of a frame with 30-ft spans.