STRUCTURAL LAYOUT

If your structure does nothing more than support the building, it is being underutilized.

—Edward Allen

Before beginning to lay out the structural system, the design-related characteristics of the components should be considered.

PRELIMINARY CONSIDERATIONS

BEARING WALLS

Bearing walls are best used to support loads uniformly distributed along their length, including slabs and closely spaced joists. Because beams and girders introduce concentrated loads, they are seldom supported by bearing walls; columns are commonly used instead. Where concentrated loads must be supported by a bearing wall, the wall should be strengthened in that location by adding reinforcement or by thickening the wall into a pilaster.

The placement of bearing walls in plan is dictated by their role as supporting elements. Because of this, it is essential to plan the spacing and placement of the walls in careful coordination with the building's functions. Because economic considerations require that the arrangement of bearing walls be as uniform as possible, this makes bearing walls more attractive for building types such as schools, apartments, and motels.

Regularly spaced bearing walls may act as shear walls to contribute lateral stability. They may be used alone if they are arranged in both directions. If they are oriented in one direction only, other members (such as bracing or rigid column connections) can be used to provide lateral stability. Shear walls should be well distributed in plan and placed as symmetrically as possible, especially in taller buildings.

Openings can be made in bearing walls by installing headers (beams) over the opening. For greater plan flexibility, beams and columns can be used in combination with bearing walls (Figure 18.1).

As a general rule, in multistory buildings, the walls should align above one another. However, it may be possible to open up the ground-floor plan (for a lobby, for example) by designing the wall on the second floor as a deep beam to transfer loads to perimeter columns on the first floor (Figure 18.2).

COLUMNS

Columns may be used to support either beams (and trusses) or slabs (including decking and joists). Because columns do not tend to enclose space, they have less impact than bearing walls on the
planning of building spaces. This makes columns a good choice where
the interior spaces of the building do not follow a repetitive struc-
tural module or where rooms are irregular in shape or size. Col-
umns provide the maximum openness in the plan and allow the
interior space configuration to be changed by moving nonstructural
partitions. When used with beams, columns are practical over a
greater range of spans and bay proportions.

Steel and site-cast column-and-beam systems can provide lat-
eral support by behaving as a rigid frame. This requires that joints
be rigid. (It is difficult to achieve rigid joints in precast concrete
and timber framing, and other means of lateral support must be used.)
Rigid frames are desirable because they cause little interference with
the plan and services of a building. However, rigid frames are most
efficient with regular bay spacing. Generally, rigid frames necessi-
tate deeper beams and heavier columns than would be required with
a comparable braced frame or shear walls. Rigid frames are not well
suited for tall spaces or very long spans.

When used with beams, columns must be located on the
centerline of the beams. Column spacing can vary up to the span-
ning capacity of the beam, although it is most economical to utilize a
regular grid spacing.

BEAMS
Beams may be laid out in one or both directions with joists, slab, or
decking spanning between them (Figure 18.3). For rectangular struc-
tural grids where joists and beams are used, it is usually more eco-
omical for beams to span in the shorter direction and joists in the
longer. Where slabs and beams are used, the slabs usually span in
the shorter direction and beams in the longer (Figure 18.4).

FLAT PLATES
Flat plates are two-way slabs that are supported by columns only
without the use of beams. (The term flat plate, as it is being broadly
used here for preliminary design purposes, includes all flat, two-
way structures such as waffle slabs and space frames, as well as the
flat concrete plate.) The absence of beams permits greater plan flex-
bility, allowing columns to be placed in irregular patterns. It also
frame braces may be used to increase lateral resistance.

The most economical column arrangement for flat plates is a square grid. However, much greater flexibility is possible in a column arrangement with only moderate cost increases, making this combination particularly suited for irregular and free-form plans. However, with the exception of space frames, the shallow depth of the plate limits the system to relatively short spans (Figure 18.5).

**SYSTEM SELECTION**

The first step is to select one or more alternative framing systems based on the project design criteria. This should be done very early in the schematic design phase, recognizing that the decision might change later. Figure 18.6 shows various design criteria and the structural types most suitable for them.

*Structural design should be a two-way street, giving and taking with form and space until an optimum synthesis is achieved.*

—Edward Allen

Figure 18.3: Beam layouts: (a) one-way beam and slab, and (b) two-way girder and beam.

Figure 18.4: Efficient span directions for (a) joists and beams, and (b) slab and beams.

Figure 18.5: Flat plates (a) are most economical using square column bays and (b) are well suited for irregular shapes and column spacing.
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**RATIONALE**
- Inherently fire-resistive construction
- Simple, site-fabricated systems
- Systems without beams in roof or floors
- Precast-concrete systems without ribs
- Short-span, one-way, easily modified
- Quickly erected; avoid site-cast concrete
- Easily formed or built on site
- Highly prefabricated; modular components
- Lightweight, easily formed or prefabricated
- Precast, site-cast concrete; steel frames
- Strong; prefabricated; lightweight
- Capable of forming rigid joints
- Lightweight, short-span systems
- Systems without rigid joints
- Multipurpose components
- Systems that inherently provide voids
- Two-way, long-span systems
- Long-span systems

Figure 18.6: Framing system selection chart.