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18

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

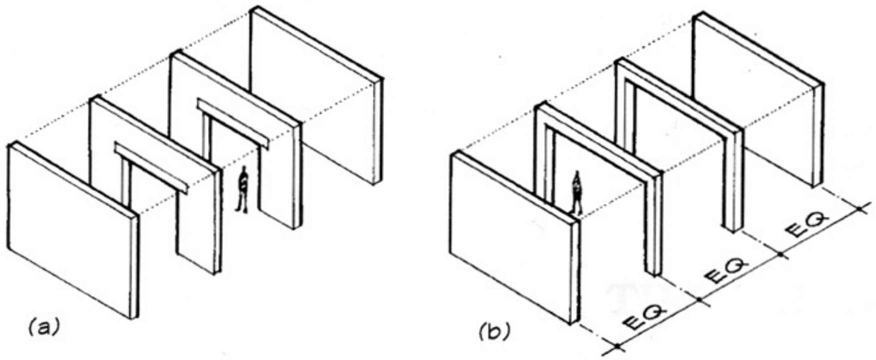

Figure 18.1: Opening up bearing-wall plans: (a) openings can be created in walls using headers, and (b) beams and columns can be combined with bearing walls.

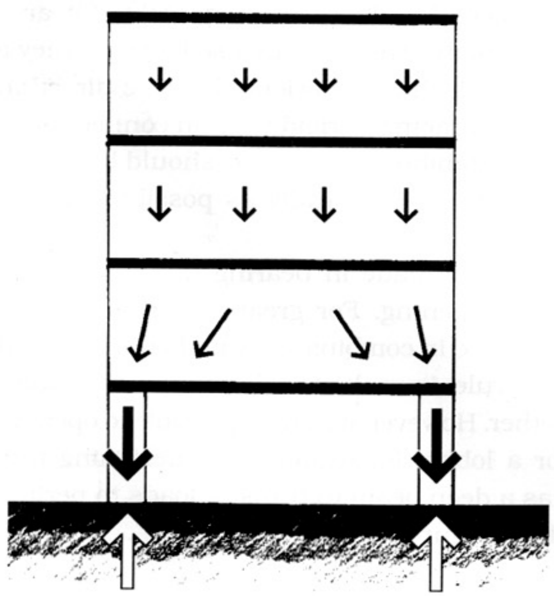

Figure 18.2: Bearing walls may act as deep beams to span across an opening below.

planning of building spaces. This makes columns a good choice where the interior spaces of the building do not follow a repetitive structural module or where rooms are irregular in shape or size. Columns 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 lateral 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 necessitate 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 spanning 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 structural grids where joists and beams are used, it is usually more economical 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 flexibility, allowing columns to be placed in irregular patterns. It also

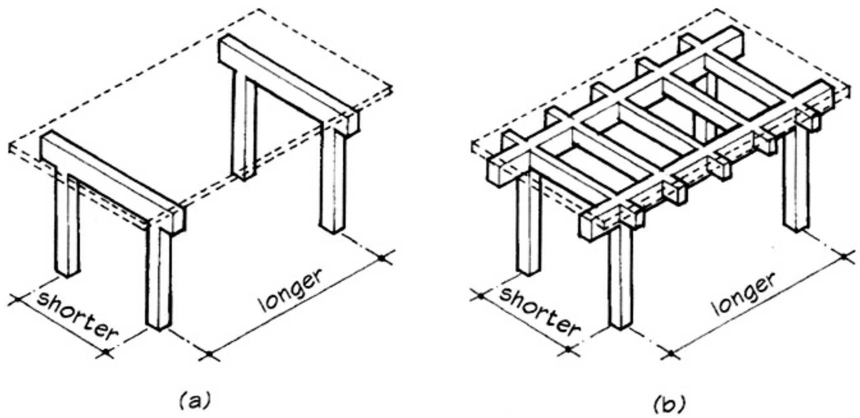

Figure 18.3: Beam layouts: (a) one-way beam and slab, and (b) two-way girder and beam.

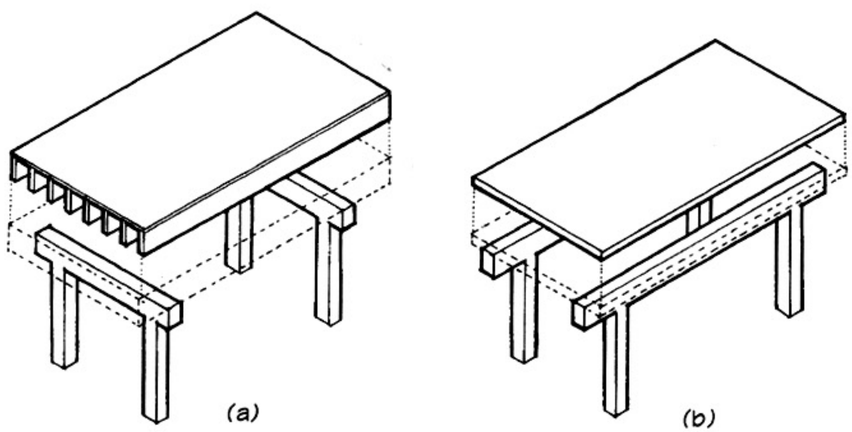

Figure 18.4: Efficient span directions for (a) joists and beams, and (b) slab and beams.

reduces the total structural depth required while simplifying construction techniques.

The rigid connection between the plate and supporting columns can provide the required lateral resistance. This may require increased plate depth as well as heavier columns. Alternatively, shear walls or 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*

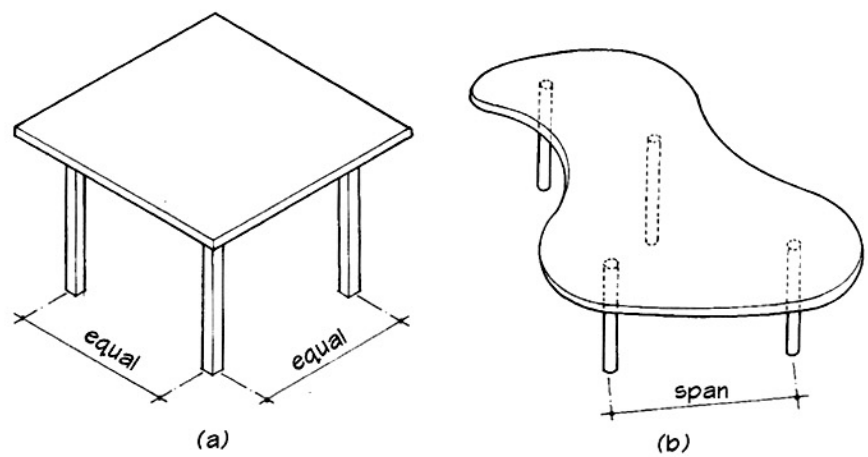

Figure 18.5: Flat plates (a) are most economical using square column bays and (b) are well suited for irregular shapes and column spacing.

DESIGN CRITERIA	Light-frame timber	Heavy-frame timber	Masonry bearing wall	Steel frame (hinge connections)	Steel frame (rigid connections)	Steel open-web joists	Steel space frame	Steel decking	Site-cast concrete: one-way slab	Site-cast concrete: two-way plate	Site-cast concrete: two-way slab	Site-cast concrete: one-way joists	Site-cast concrete: waffle slab	Precast concrete: solid slab	Precast concrete: hollow-core slab	Precast concrete: single tee	Precast concrete: double tee	RATIONALE
Exposed, fire-resiant construction		■	■						■	■	■	■	■	■	■	■	■	Inherently fire-resistive construction
Irregular building form	■		■						■	■	■							Simple, site-fabricated systems
Irregular column placement										■	■		■					Systems without beams in roof or floors
Minimize floor thickness									■	■				■	■			Precast-concrete systems without ribs
Allow for future renovations	■	■	■	■	■	■	■	■	■			■		■	■			Short-span, one-way, easily modified
Permit construction in poor weather	■	■		■	■	■	■	■						■	■	■	■	Quickly erected; avoid site-cast concrete
Minimize off-site fabrication time	■		■						■	■	■	■	■					Easily formed or built on site
Minimize on-site erection time		■		■	■	■		■						■	■	■	■	Highly prefabricated; modular components
Minimize low-rise construction time	■	■		■	■	■		■										Lightweight, easily formed or prefabricated
Minimize medium-rise construction time				■	■	■		■	■	■	■	■	■	■	■	■	■	Precast, site-cast concrete; steel frames
Minimize high-rise construction time				■	■	■		■										Strong; prefabricated; lightweight
Minimize shear walls or diagonal bracing			■		■				■	■	■	■	■					Capable of forming rigid joints
Minimize dead load on foundations	■	■		■	■	■	■	■										Lightweight, short-span systems
Minimize damage due to foundation settlement	■	■		■		■		■						■	■	■	■	Systems without rigid joints
Minimize the number of separate trades on job	■		■															Multipurpose components
Provide concealed space for mech. services	■					■	■								■			Systems that inherently provide voids
Minimize the number of supports							■											Two-way, long-span systems
Long spans						■	■									■		Long-span systems

Figure 18.6: Framing system selection chart.