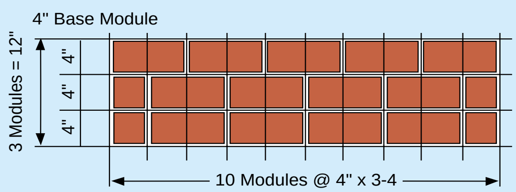
To enhance construction productivity and economy, horizontal and vertical elements can be isolated as separate design priorities. But viewing the building frame as a tote/ project may reveal many additional opportunities to streamline the construction process, accelerate production and reduce costs.

Modular Dimensions

Virtually all construction materials, not just formwork but glass, HVAC, interior finishing materials and masonry as well, are sized in multiples of a nominal 4 inches. Concrete block and brick are typical examples, as in Figure 36. Consequently, designing according to this base module inevitably means less cutting, piecing and waste material.

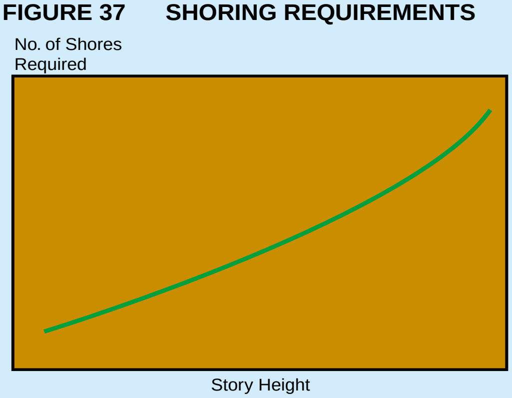
FIGURE 36 THE MODULAR BRICK SYSTEM



Story Height

The capacity of temporary shoring decreases exponentially as the distance between levels increases. Minimizing story height permits use of fewer pieces of shoring material and less labor to erect and dismantle. (Figure 37)

FIGURE 37 SHORING REQUIREMENTS

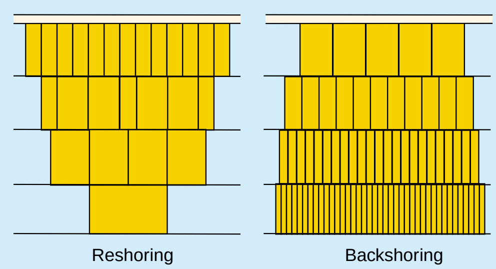


If spacing between floors is constant, the same vertical shoring materials can be recycled from one level to the next. If spacing varies, additional shoring must be procured and adjusted to fit. Likewise, all wall and column forms must be adjusted for variations in story spacing.

Form Removal Specifications

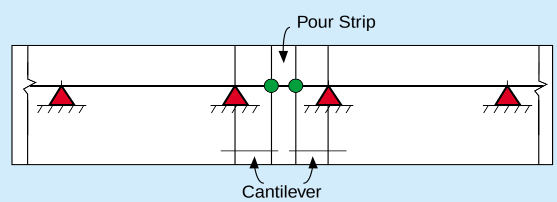
Typically, a building endures the greatest loads it will ever carry during construction, when fresh concrete elements have not fully cured and reached their design strength. Consequently, timing the removal of temporary shoring is a critical issue. For reasons so complex as to be beyond the scope of this manual, the designer's specifications for form and shoring removal can have a very significant impact on the speed of construction, shoring requirements, and as a result, cost. In the worst-case (Figure 38) the extreme-cost condition known as backshoring may be caused inadvertently by mix-timing form removal.

FIGURE 38 RESHORING VS. BACKSHORING



Where pour-strips are used (time-delayed pours to allow for shrinkage in long or posttensioned structures) the backshoring condition may be avoided by designing the slabs adjacent to the pour strips as cantilevers. The pour-strip is designed as simple span, as in Figure 39.

FIGURE 39 POUR STRIP



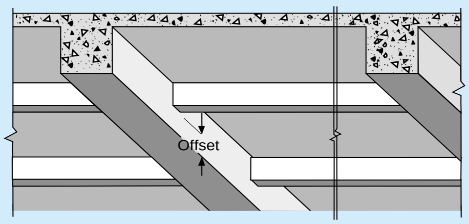
Designing a pour strip as a simple span supported by cantilevers, avoids costly backshoring condition.

In general, dual specifications facilitate the construction process: time specification for stripping vertical elements (e.g.: 12 hours after pouring) and a strength specification for stripping horizontal elements (e.g.: 75% of design strength). (See ACI 301, 4.5) This approach provides flexibility to the builder, without diminishing design control.

Level Floor Soffits

Any drop below the soffit elevation of a framing system, whether for a deep beam (Figure 40) or a drop panel in a flat slab, is a discontinuity of the basic formwork framing. It interrupts production as crews stop one basic formwork framing system at that point, and piece-and-fit to start and finish another.

FIGURE 40 VARYING SOFFITS



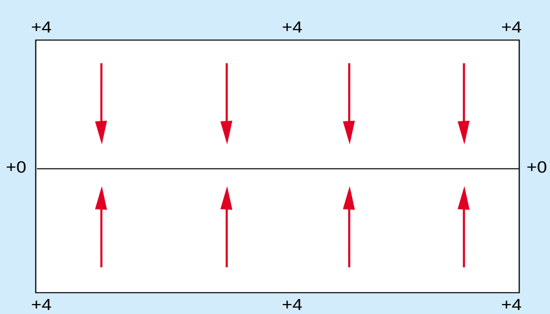
Permanent Slopes For Drainage

Four methods are available to design sloped surfaces (typically for drainage).

a. *Top-surface slope* — Much preferred due to its considerably lower cost, this method maintains a constant soffit elevation and consequently, is faster to form. It is achieved either by varying slab thickness or with fills. This slope method and method (b) below may require a higher-quality roof membrane than other roof designs. But even with its added cost, the total cost of these methods is much less than methods (c) and (d) below.

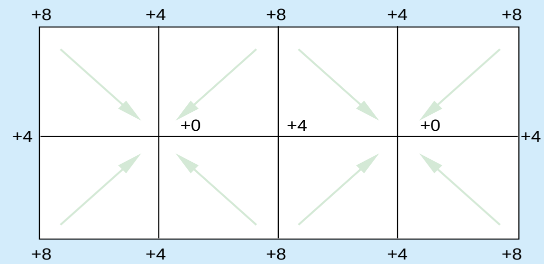
b. *One-way slope — top and bottom surfaces* (Figure 41) — To reduce deadload and save permanent materials, bottoms of slabs may be sloped to parallel the top. This is more costly than method (a). Positioning the deck at varying elevations is labor-intensive. (Beams should also be sloped to parallel the slab, to avoid variable beam depth.)

FIGURE 41 ONE-WAY SLOPE



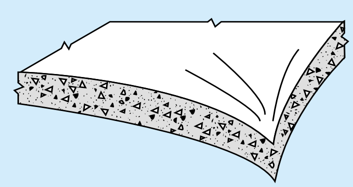
c. *Two-way slope—top and bottom surfaces* (Figure 42)—This design is an extreme-cost option and almost always can be avoided. With ridges and valleys running in two directions, two-way sloping impedes formwork productivity, with stop-start disruption at each change of slope direction.

FIGURE 42 TWO-WAY SLOPE



d. *Warps* (Figure 43)—Of all slope designs, warps are the most extreme impediment to formwork productivity. Forming the curved surfaces requires intricate, expensive carpentry and precision installation. If at all possible, alternative designs should be considered instead.

FIGURE 43 WARP



Top and Bottom Surfaces are Curved

Camber to Offset Floor Deflection

Typically, cambered slabs are not structural necessities, sufficient stiffness can be designed into floor framing systems to keep deflection within tolerances. This also avoids forming costs associated with camber. If camber is a design imperative, it may be specified much like the sloped surfaces previously discussed: as one-way, two-way, or warped. Again like slopes, costs are progressively higher as complexity increases, with warps at the extreme.

Construction Joint Location A concrete structure normally is built in progressive stages. (Figure 44) However, to facilitate high-production recycling of equipment and manpower, some latitude in the precise location of construction joints (Figure 45) is desirable. The permissible locations for construction joints should be indicated on the construction drawings, to save time on the job and help ensure a quality structure. The contractor may then select the most efficient sequencing for the construction method to be used. The designer should approve all construction joint locations prior to commencement of the work. Once established, these locations should be communicated to all parties involved in formwork, concrete and reinforcement.

FIGURE 44 SEQUENCING AND RECYCLING

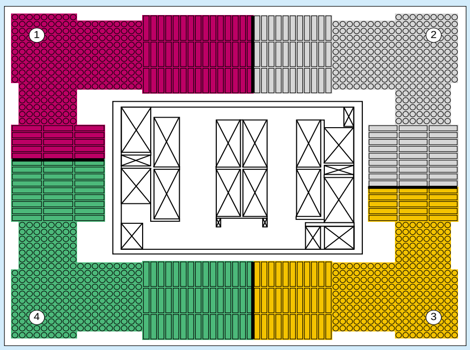
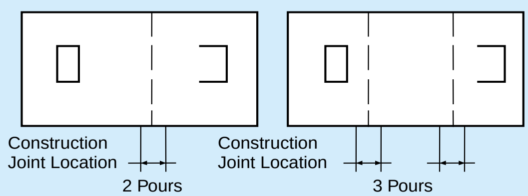


FIGURE 45 CONSTRUCTION JOINT LOCATIONS



Floor Penetrations

Penetrations for electrical and plumbing require careful planning. Pipe sleeves, electrical boxes and other attachments to forms (Figure 46) can impede stripping of framework. Double sleeving

FIGURE 46 ATTACHMENTS TO FORMWORK

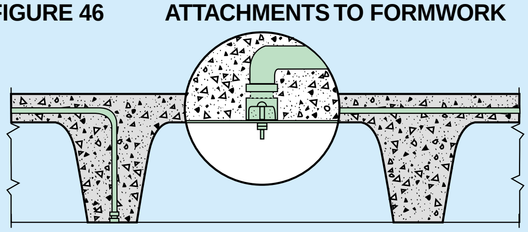


FIGURE 47 DOUBLE SLEEVING FOR BLOCKOUTS

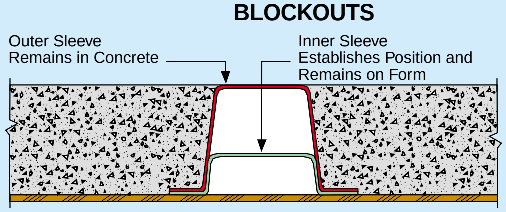
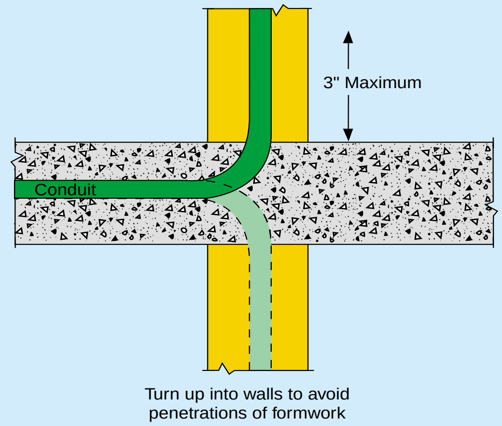


FIGURE 48 PENETRATIONS

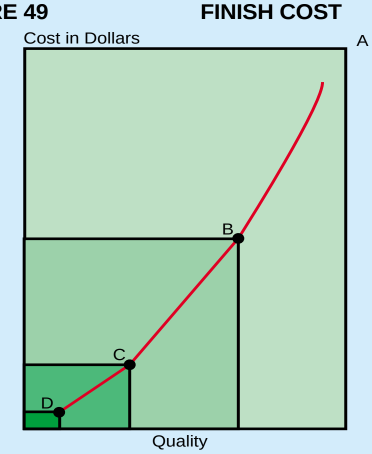


for block-outs (Figure 47) speeds construction, especially for flying forms. Piping and conduit that turn up from the slab into a partition wall (Figure 48) are less expensive than those which turn downward, because a penetration of formwork is thus avoided.

Concrete Finish

The more rigid the specification for concrete finish, the higher its production cost, as in Figure 49. To achieve economy, the lowest acceptable level of quality should be specified. As-cast architectural concrete (ACI 347-78, Chapter 5) is the most expensive to form. When an exposed concrete finish is being considered, its cost should be weighed against surfacing alternatives ranging from sandblasting or speckling and painting to brick, ceiling tile, wall fabric or marble. This comparison may show exposed or architectural concrete to be cost-acceptable.

FIGURE 49 FINISH COST



Permitted irregularities in formed surfaces

Type of Irregularity	Class of Surface			
	A	B	C	D
Gradual	1/8"	1/4"	1/2"	1"
Abrupt	1/8"	1/4"	1/4"	1"