

2.1 Introduction:

This chapter provides information related to the importance of economy, safety structures, planning and designing the formwork system as an integral part of the process of designing and constructing concrete structures. There are decisions that must be made during the design process that will have major impacts.

This chapter also deals with formwork materials, accessories and systems. Materials generally used in formwork are Timber, Steel and Plastics with different types and classifications. The systems used can be a combination of two materials. Selection of materials suitable for formwork should be based on maximum economy to the contractor, consistent with safety and the quality required in the finished work.

Formwork system can be generally classified as Vertical Systems (wall and column) and Horizontal Systems (slab and beam). The material serving as the contact face of forms is known as sheathing and it is used in both the vertical and horizontal systems.

2.2 Formwork Requirements:

Formwork is made from different materials, and requires great skill and experience in its manufactures.

To produce concrete forms that meet all job requirements, the construction engineer must understand the characteristics, properties, and behaviors of the materials used; be able to estimate the loads applied to the forms; and be familiar with the advantages and shortcomings of various forming systems.

In designing and building formwork, four major objectives must be considered:

1. Economy:

The main materials of the reinforced concrete work are concrete, reinforcement and formwork, so the total cost can be approximately distributed among the three items. Economy should be considered when planning the formwork for a concrete structure. It involves many factors; including the cost of materials, the cost of labor in making, erecting, and removing the forms and the cost of equipment required to handle the forms. Economy also includes the number of reuses of the form materials, the possible salvage value of the forms for use elsewhere, and the cost of finishing concrete surfaces after the forms are removed. A high initial cost for materials, such as steel forms, may be good economy because of the greater number of uses that can be obtained with steel so steel formwork has replaced wood formwork to some degree, although the use of wood is still substantial because of its availability and ease of fabrication.

Design of the proposed formwork for a given project usually will enable the job planner to determine, in advance of construction, what materials and methods will be the most economical.

Forms must be built efficiently, minimizing time and cost in the construction process and schedule for the benefit of both the contractor and the owner. Forms must be simple to erect & dismantle and modular dimensions should be used.

Economy in formwork design depends partly on the ingenuity and experience of the form designer, whether a contractor or an engineer. Judgment with respect to the development of a forming system could both expedite a project and reduce costs. Although forms may be job built, many proprietary forming systems are available.

In addition a large proportion of the cost of conventional formwork is related to formwork labor costs. Significant cost saving could be achieved by reducing labor costs.

In the design of concrete structures, the common approach is to select the minimum size of structural members and the least amount of steel to sustain

the design loads. The perception is “the least amount of permanent materials in the structure will result in the least cost.” To achieve the most economical design, the designer should analysis each individual member to make certain that it is not heavier, wider, or deeper than its load requires. This is done under the pretense that the minimum size and least weight result in the best design.

2. Quality:

Forms must be designed and built with sufficient stiffness and accuracy so the size, shape, position, and finish of the cast concrete are attained within the required tolerances.

The quality of the formwork itself has a direct impact on safety, accidents, and failures. Correctly designed formwork will ensure that the concrete maintains the desired size and shape by having the proper dimensions and being rigid enough to hold its shape under the stresses of the concrete.

The quality of the resulting concrete is dictated by the quality of formwork materials and workmanship. Many concrete-related problems such as discoloration, stains, and dusting are attributed to concrete formwork. Also, some deformed concrete surfaces are due to deformed formwork systems caused by repetitive reuse and inadequate support of formwork. Also joints that are insufficiently tight will leak cement paste. The surface of the concrete will thus be disfigured by fins of the cement paste, and honeycombing may result adjacent to the leaking joints.

Final shape of the formwork in contact with the concrete should be so arranged and jointed as to produce a concrete surface of good appearance. Wires, nails, screws, and form surface flaws must not be allowed to disfigure the concrete surface.

In some cases a provision of special form lining may be necessary to achieve the desired surface finished.

3. Safety:

Formwork operations are risky, and workers are typically exposed to unsafe working conditions. Partial or total failure of concrete formwork is a major contributor to deaths, injuries, and property damages within the construction industry.

Forms must be built with sufficient strength and factors of safety so they are capable of supporting all dead and live loads without collapse or danger to workers and to the concrete structure.

Contractors are generally responsible for stability and safety of concrete formwork. Also they are guided by several federal, state, and local codes and regulations that regulate formwork safety. Most of these documents provide general guidelines for safety but provide no guarantee against failure. Contractors typically are trying to achieve fast removal of formwork elements without compromising the safety and integrity of structures.

A floor formwork system filled with wet concrete has its weight at the top and is not inherently stable. As a result, one of the most frequent causes of failure is from effects that induce lateral forces or displacement of supporting elements; therefore, inadequate cross-bracing or horizontal bracing is one of the most frequently involved factors in formwork failure. Also vibration is one factor that can trigger failure through inadequate bracing.

In addition formwork failures result from faulty formwork structural design, inadequate shoring and reshoring, improper construction practices during construction, unstable support or mudsills, and insufficient concrete strength to sustain the applied load after construction. The failure at one point in the formwork that can become an extensive collapse through chain reaction.

So Formwork should be designed by an engineer or by someone who has sufficient knowledge of forces and resistance of form materials.

The safety of workers is a concern of all parties: owners, designers, and contractors. Safety is everyone's responsibility, including workers in the field, supervisors, and top management. There are many risks in the process of erecting and dismantling forming systems. Every precaution should be taken to ensure a safe working environment.

- **Safety in formwork requires that the forms be:**

a- Strong: To ensure the safety of the structure and the protection of the workers, it is essential that formwork be designed to carry the full load and side pressures from freshly placed concrete, together with construction traffic and any necessary equipment.

b- Sound: The materials used to construct the forms must be of the correct size and quantity, of good quality, and sufficiently durable for the job.

c- Avoid Deflection: Deflection is the most important consideration for design of formwork, the limit for deflection varies according to class of the work. For simply supported spans, this limit is not more than $\text{span}/360$.

4. Speed and Time:

Speed of construction is defined as the rate in which concrete building is raised and can be expressed in terms of number of floors erected per week or months. Speed of construction can be also measured in terms of inches or millimeters of concrete poured per hour. Formwork operations can control the pace of construction projects. Formwork is typically supported by several levels of shores and reshores that carry the loads until the concrete gains enough strength to support its own weight and all other externally applied loads. Shores are vertical members made of wood that support recently built concrete that have not developed full design strength. On the other hand, reshoring occurs when the original shoring is removed and replaced in such a manner as to avoid deflection of the cured concrete. As a result, several floors may be blocked, preventing the progress of any other construction activities. Faster formwork cycle from erection to stripping would allow for faster removal of shoring and reshoring and faster overall project progress.

Reuse of a form is only fully efficient if the form can be stripped and rebuilt without too much labor time or damage to the form.

2.3 Formwork Types:

Formwork components can be assembled in a wide variety of systems for casting many structural shapes. The terms **formwork** and **falsework** are often used in combination.

Formwork system can be generally classified as Vertical Systems (wall and column) and Horizontal Systems (slab and beam). The material serving as the contact face of forms is known as sheathing and it is used in both the vertical and horizontal systems.

2.3.1 Formwork Horizontal Systems:

Horizontal formwork systems are used to temporarily support horizontal concrete work such as concrete beams and slabs.

Formwork systems for horizontal concrete work can be also classified into two main categories: hand-set systems and crane-set systems. Conventional wood systems and conventional metal systems are classified as hand-set systems. In hand-set systems, different formwork elements can be handled by one or two laborers.

Conventional wood system includes formwork for slabs, beams, and foundations. The system is generally built of lumber or a combination of lumber and plywood. Formwork pieces are made and erected in situ. For stripping, conventional wood systems are stripped piece by piece, then cleaned, and may be reused a few times.

Flying formwork systems, column-mounted shoring systems, and tunnel formwork are classified under crane-set systems. In crane-set systems, adequate crane services must be available to handle formwork components.

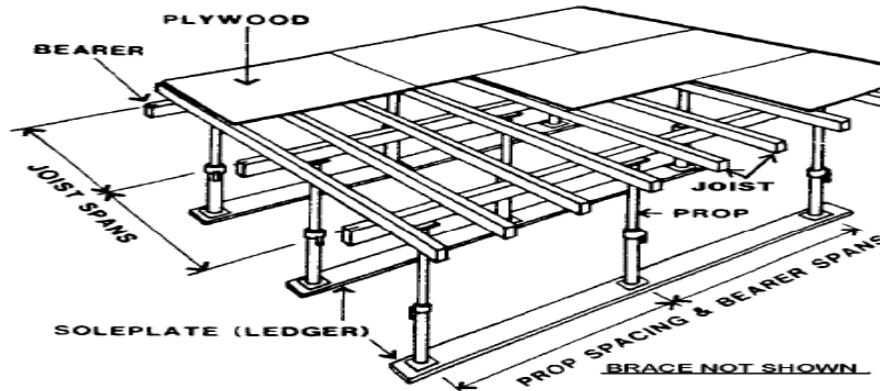
2.3.1.1 Formwork for Concrete Slabs (soffit formwork):

Conventional wood systems for horizontal concrete work are made of plywood or lumber sheathing for decking. The thickness of plywood or lumber is determined by structural analysis and is a function of the applied loads, type of wood or plywood, and the spacing between sheathing supporting elements. Plywood is preferred over lumber sheathing because it provides a smooth concrete surface that requires minimum finishing effort.

Sheathing is supported by horizontal members called joists or runners (primary beams). Joists are made from dimension lumber spaced at constant intervals that are a function of applied loads and the type of lumber. It is a recommended practice to round down the calculated joist spacing to the lower modular value.

Joists are supported by another set of horizontal members perpendicular to the joists, called stringers (bearer or secondary beams). The stringers are supported by vertical members called shores (PROP). Shores are rested on heavy timbers, called mudsills, to transfer the vertical loads to the ground. In the case where a slab-on-grade exists, shores are rested directly on them.

Vertical timber shores can be replaced by the scaffold type, which has been proven to be more efficient because of its high number of reuses and its height, which means that no splicing is typically required. The scaffold-type shoring system consists of two vertical steel posts with horizontal pipe between them at regular intervals. Adjustable screw jacks are fitted into the steel posts at both ends.



Standard slab formwork

Figure (2.1) A typical arrangement of soffit formwork and falsework.

2.3.1.2 Formwork for Concrete Beams:

Formwork for beams consists of a bottom and two sides (open through section) in addition to their supporting elements. The bottom is typically made of ply wood or lumber sheathing. The bottom is supported by and fastened to horizontal joists. Beam sides are also made of plywood or lumber sheathing.

The supports need to be maintained to the soffit and also provide lateral support to the sides. In timber this is done by the use of a head tree across the top of a vertical member. Metal panels are used with corner pieces, but timber head trees are needed for vertical support.

Once the bottom of the beam form is constructed and leveled, one side of the beam is erected first with holes drilled into it for installing the tie rods. Tie rods are steel rods that hold the two sides of the beam together. After the first side of the beam form is erected, the reinforcement is placed inside the beam and then the other side of the beam is erected. Tie rods are then inserted into all holes and the wales on both sides of the beam. The tie rods' function is to resist the horizontal pressure resulting from the freshly placed concrete and thus keep the sides of the beams in their proper location. Tie rods are fastened to the sides of the beam and also to vertical wales and clamps.

To further support the two sides of the beam and hold them together, additional temporary spreaders are fastened at the top of the beam sides at regular distances. Temporary spreaders may be made from wood or steel.

Beam forms must be designed and constructed to safely support the vertically applied dead loads and live loads as described above.

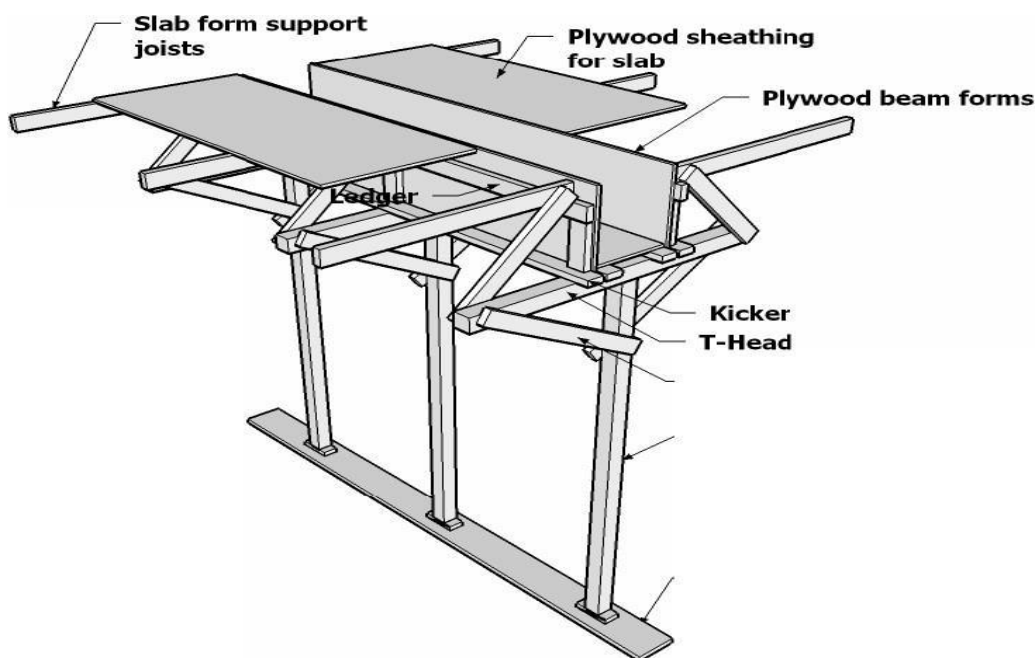


Figure (2.2): illustrates the basic wood member arrangements for a beam forms

2.3.2 Formwork Vertical Systems:

Vertical formwork systems are those used to form the vertical supporting elements of the structure such as columns and walls. The functions of the vertical supporting systems are to transfer the floor loads to the foundation and to resist the lateral wind and earthquake loads.

2.3.2.1 Formwork for Column Systems:

Column-form materials tend to vary with the column shape. Wood or steel is often used with square or rectangular columns. Round column forms, more typically pre-manufactured in a range of standard diameters, are available in steel, paperboard, and fiber-reinforced plastic. Square and rectangular forms are composed of short-span bending elements contained by external ties or clamps.

Round column forms are more structurally efficient because the internal concrete pressures can be resisted by a hoop membrane tension in the form skin with little or no bending induced. Round, single-piece glass-fiber-reinforced plastic tubes with a single joint can be removed from the column without cutting. They are held together with either bolts or clamps. Round paperboard tubes are single-use forms that are stripped by unwrapping and then discarded. They can be cut to the exact length needed, and sections of the tube can be adapted to making partial column sections (e.g., half-round, quarter-round).

Steel column forms have built-in bracing for short heights so the only external bracing required serves to keep the column plumb and for taller columns. Both half-round and rectangular panel units are available in various section heights that can be connected vertically to form tall columns. Round steel forms are generally used for larger columns and bridge piers.

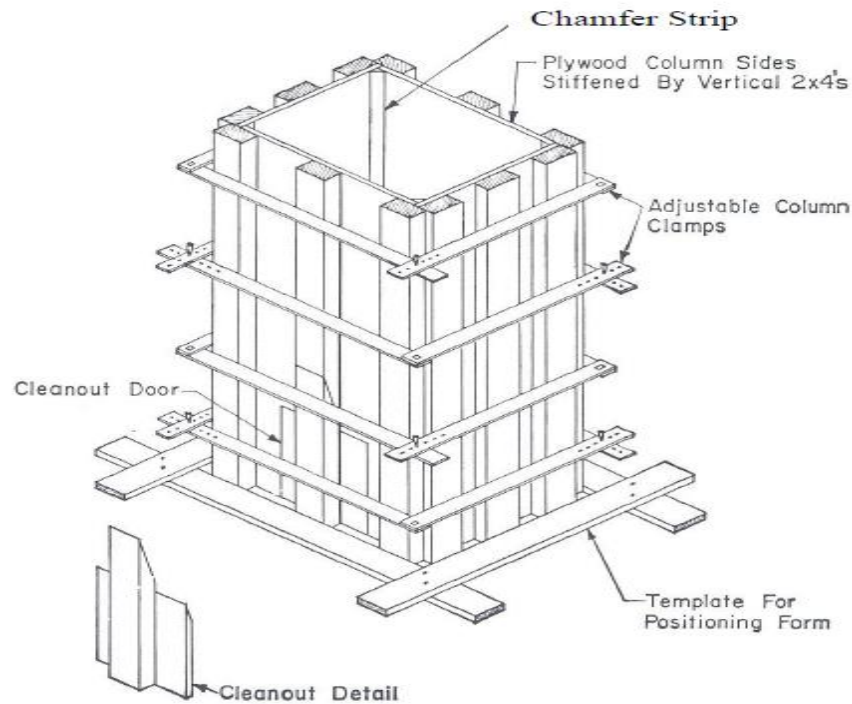


Figure (2.3): Column forms

2.3.2.2 Formwork for Wall System:

Wall forms principally resist the lateral pressures generated by fresh concrete as a liquid or semi-liquid material. The pressures can be quite large; certainly many times the magnitude of live loads on permanent floors. Thus, wall form design often involves closely spaced and well-supported members. As mentioned, the contact surface of the wall form is referred to as sheathing. Studs are vertical supporting members to which sheathing is attached. Wales are long horizontal members (usually double) used to support the studs. The studs and wales are often wood, steel, or aluminum beam-like elements. Commercial form suppliers are innovative in devising elements as well as hardware for connections. The wall form members are sometimes oriented with the stud members placed horizontal rather than vertical, and the wales are run vertical. The wales are in turn supported on washer plates or other bearing devices attached to form ties.

A concrete form tie is a tensile unit connecting opposite sides of the form and providing a link forequilibrium. Form ties are usually steel, although some fiber-reinforced plastic ties are also available.

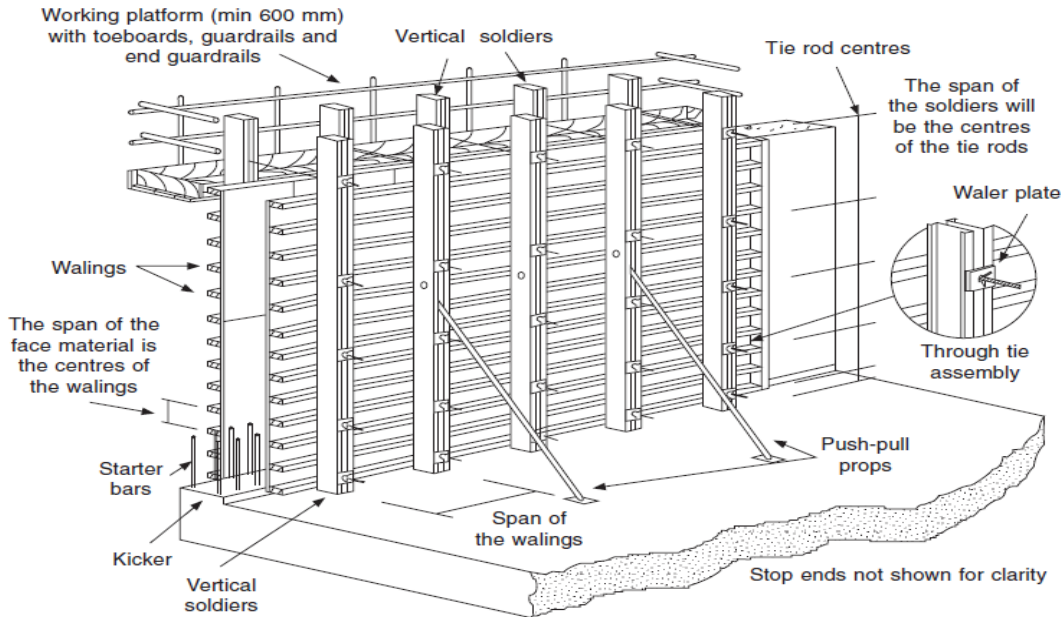


Figure (2.4) A typical arrangement of double-faced wall formwork.

2.3.3 Falsework systems:

2.3.3.1 Shoring:

In multistory concrete building construction a process called shoring and reshoring is used.

Shores are vertical or inclined support members designed to carry the weight of the formwork, concrete, and construction loads above. Shoring systems may be made of wood or metal posts. The simplest type of vertical shore is a piece of timber with special hardware attached to the top to facilitate joining to the stringers with a minimum of nailing. Metal shore-jack fittings may be placed at the lower end of the shore to allow some adjustment for exact height.

Reshores are shores placed snugly under a concrete floor so future loads imposed from construction at the highest level can be shared over sufficient floors to carry the dead and live loads safely.

In some multistory construction, this process is varied slightly. **Backshores** are shores placed snugly under a concrete slab or structural member after the original forms and shores have been removed from a small area without allowing the slab or member to deflect or support its own weight or existing construction loads from above.

Preshores are added shores placed snugly under selected panels of a deck forming system before any primary (original) shores are removed. Preshores and the panels they support remain in place until the remainder of the bay has been stripped and backshored, a small area at a time.

Scaffolding system is an elevated platform to support workmen, tools, and materials. In concrete work, heavy-duty scaffolding is often adapted to double as shoring. Basic scaffold-type shoring is made from tubular steel frames. End frames are assembled with diagonal bracing, locking connections, and adjustable bases to create a shoring tower. These may have flat top plates, U-heads, or other upper members for attaching to supported forms.

Shoring systems produced by some manufacturers include a drop-head mechanism. The systems include panels, beams, and a shore with a top plate that is in direct contact with the concrete slab underside. When the drop-head mechanism is released, the beams and panels can be lowered and removed while the shore stays in place. This allows rapid reuse of the panels and beams while the shore continues to support the early-age, low-strength slab. Overall, this approach allows rapid reuse of components, increasing speed of construction and reducing forming materials needed. Keeping the shores in place longer under the most recently placed slab also increases safety. After appropriate slab strength gain to support the slab self-weight and construction loads, the slab is activated by releasing the shores and then resnugging them to act as reshores.

Centering is a specialized temporary vertical support used in construction of arches, shells, and space structures where the entire temporary support is

lowered (struck or decentered) as a unit to avoid introduction of injurious stresses in any part of the structure. Shores that are supported on the ground must have a temporary footing (termed, in formwork, a mudsill) that is of adequate strength and size. The mudsill may be a plank, wood grillage, or precast pad, depending on the loads and ground conditions.

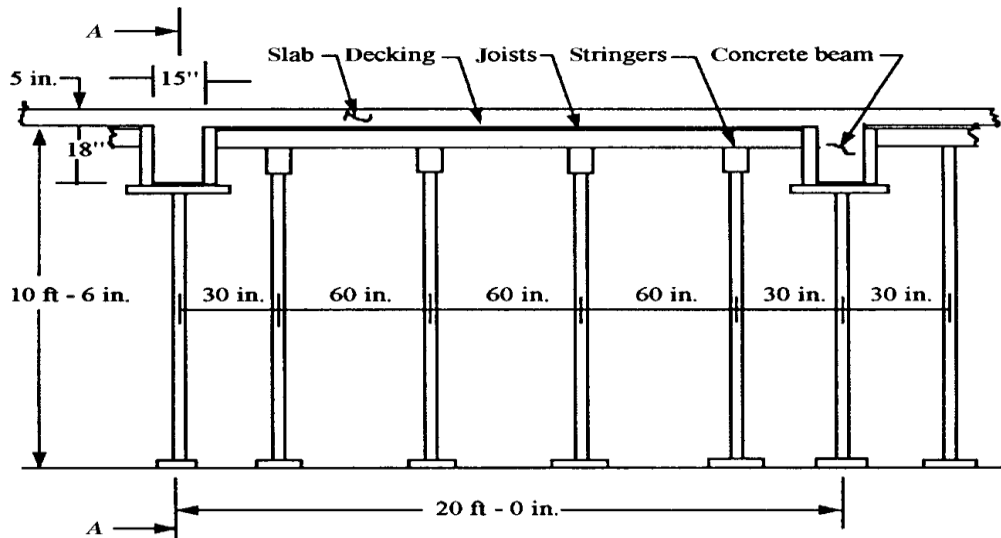


Figure (2.5): shoring system.

2.3.3.2 Bracing and lacing:

A brace is any structural member used to support another, always designed for compression loads and sometimes for tension under special load conditions. The formwork system should be designed to transfer all horizontal loads to the ground or to completed construction in such a manner as to ensure safety at all times. Diagonal bracing should be provided in vertical and horizontal planes where required to resist lateral loads and to prevent instability of individual members.

Form braces are frequently made of wood or steel. Commercial steel pipe braces in various diameters and wall thicknesses and load-rated for adjustable lengths are popular. Buckling strength of braces is always a primary design consideration.

Horizontal lacing can be considered in design to hold in place and increase the buckling strength of individual shores and reshores or backshores. Lacing should be provided in whatever directions are necessary to produce the correct slenderness ratio (l/r) for the load supported, where (l = unsupported length) and (r = least radius of gyration). The braced system should be anchored to ensure stability of the total system. This can be accomplished with bolts, nails, and a variety of commercial devices, depending on the materials involved. When attaching braces to the ground, a buried or above-ground concrete mass known as a deadman is sometimes used.

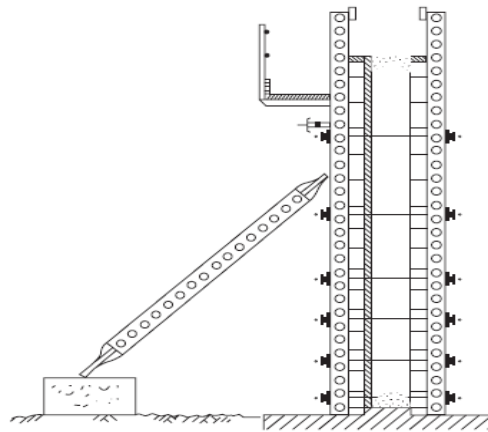


Figure (2.6): Propping of wall formwork (deadman).

2.4 Formwork Materials:

The selection of materials suitable for formwork should be based on the price, safety during construction, and the quality required in the finished product. Approval of formwork materials by the engineer/architect, if required by the contract documents, should be based on how the quality of materials affects the quality of finished work. Where the concrete surface appearance is critical, the engineer/architect should give special notice and make provision for preconstruction mockups.

Materials used for the construction of concrete formwork range from traditional materials such as Timber, steel, aluminum, and plywood to nontraditional materials such as fiberglass. The systems used can be a combination of two materials. Wood products are the most widely used material for formwork. The objective of this section is to introduce Timber as an important material for formwork.

Permanent forms are any form that remains in place after the concrete has developed its design strength. The form may or may not become an integral part of the structure. Metal deck forms are used in floor and roof slabs cast over steel joists or beams.

2.4.1 Timber:

Timber is widely used for many construction applications including concrete formwork. Timber is harvested from trees and is classified as hardwood and softwood. *Hardwood* comes from trees that have broad leaves such as oaks, maples, and basswood. *Softwood* comes from trees that have needlelike leaves such as pines, cedars, and firs. Softwoods are most commonly used in construction of formwork.

Timber is suitable for constructing concrete forms is available in a variety of sizes, grades, and species groups. The form designer should determine what is economically available before specifying a particular grade or species group

of timber for constructing the forms. Timber is commonly available material and has excellent strength, weight and cost factor.

A special type of timber is known as plywood. It is used extensively for formwork for concrete, especially for sheathing (the material serving as the contact face of), decking, and form linings.

The relatively large sheets of plywood have reduced the cost of building and at the same time have provided smooth surface. That reduces cost of finishing of concrete surfaces, availability in a variety of thicknesses and lengths, and ease of handling during construction.

Plywood is a manufactured wood product consist a number of veneer sheets, or plies Type of plywood can be grouped as exterior and interior. For formwork the exterior plywood is used. Adhesive used to bond the piles in manufacturing of exterior plywood is watertight and gives maximum number of reuses. The plywood industry manufactures special plywood called Ply form specifically for use in forming concrete structures.

2.4.2 Metals:

The initial cost of metal formwork is more than timber formwork but the number of reuses of metal formwork is higher than that of timber. In long run metal formwork can be economical. In heavy construction works metal formwork may require a lifting mechanism to handle the formwork panels or props.

Steel sheet formwork has the problem of rusting also. To avoid rusting, in every use the surfaces should be oiled with an appropriate releasing agent. In metal formwork usage, the metal sheets are prepared as panels of standard sizes. This brings the difficulties of erecting irregular dimensions of formwork.

For certain uses, forms made of steel have several advantages over forms made of other materials. They can provide adequate rigidity and strength. Steel or aluminum or magnesium is the most widely used metals

2.4.2.1 Steel:

The major advantages of steel sections in formwork are the ability of steel to form longer spans and its indefinite potential for reuse when handled with reasonable care. Steel sections are used in the fabrication of different formwork components, namely:

- (1) Steel panel forms.
- (2) Horizontal and vertical shores.
- (3) Steel pan and dome components used for joist and waffle slabs.
- (4) Steel pipes for formwork bracing.

Other heavy forms and formwork are also made of steel, such as bridge formwork. Steel is used for formwork when other materials are impossible to use because of their low strength. Steel forms are typically patented, and allowable loads are generally published by the manufacturers.

2.4.2.2 Aluminum:

Aluminum stems from have lighted weight which reduces handling costs and offsets its higher initial material cost. When compared to steel panels, aluminum panels used for ganged forms weight approximately 50% less. The major problem with aluminum forms is corrosion: Pure aluminum is attacked chemically by wet concrete. Aluminum alloys have proven to be very successful in resisting corrosion.

Support trusses fabricated with aluminum alloys have been effectively used for flying forms. These forms are lightweight and allow large lengths of deck forms to be moved easily. Cast aluminum alloy molds have also been used successfully to form ornamental concrete products. Aluminum wall forms have also been used to produce textures on the surfaces of concrete walls.

Forms made from aluminum are in many respects similar to those made of steel. However, because of their lower density, aluminum forms are lighter than

steel forms, and this is their primary advantage when compared with steel. Because the strength of aluminum in handling, tension, and compression is less than the strength of steel, it is necessary to use larger sections when forms are made of aluminum. Because wet concrete can chemically attack aluminum, it is desirable to use aluminum alloys in resisting corrosion from the concrete.

2.4.3 Glass-Reinforced Plastic:

Forms fabricated from glass-reinforced plastic have good strength, light weight, and high number of reuses. Glass-reinforced plastic also produces high-quality concrete finishes. Glass-reinforced plastic forms are very flexible and can form complex or nonstandard shapes with little capital investment.

Plastic formwork could be reinforced or un-reinforced. Plastic is reinforced by glass fibers. Reinforced plastics are specially produced for a specific formwork type. Un-reinforced plastics are produced in sheet form with smooth or textured surfaces. Plastic formwork is lighter but less durable than metal formwork.

To fabricate glass-reinforced plastic forms, models of plaster, wood, or steel are prepared to the exact desired dimensions. The model is then waxed, polished, and sprayed with a parting agent to prevent sticking of the resin to the master pattern. Glass mat is then fitted over the model and thoroughly saturated with a brushcoat of polyester resin. When the resin has set and the heat dissipated, another layer of glass mat and polyester resin is added, and this process is repeated until the desired thickness of the fiberglass sheet is achieved.

Another method to build glass-reinforced plastic forms is through the use of a spray gun to apply the resin to chopped strands of fiberglass, which are used as the reinforcing material.

To increase the number of potential reuses with any of the methods of fabrication mentioned, an extra thickness of resin is molded into the contact surface or additional stiffening and supports are added by means of built-up ribs, wood struts, steel rods, or aluminum tubing.

The two major problems associated with glass-reinforced plastic forms are attack by alkalis in the concrete and form expansion because of exposure to hot sun or heat from hydration of cement.

2.5 Accessories:

2.5.1 Form ties:

A form tie is a tensile unit connecting opposite sides of the form and providing a link for equilibrium or used to hold concrete forms against the active pressure of freshly placed plastic concrete. In general, it consists of an inside tensile member and an external holding device, both made to specifications of various manufacturers. These manufacturers also publish recommended working loads on the ties for use in form design.

Form ties are usually steel, although some fiber-reinforced plastic ties are also available. The ties come in a wide range of types (Figure 2.4) and tension working capacities rated by the manufacturer. Snap ties, loop ties, and flat ties are single-use ties, usually of relatively low capacity (1500 to 3200 lb) that are twisted and snapped off a specified distance back from the concrete surface. Coil ties, she bolts, and he bolts are examples of ties where some parts are left embedded within the cast wall and some parts can be reused. The taper tie, a tapered rod threaded on each end, is completely removed and reused. The tension capacity of heavy ties can range upward to over 60,000 lb. Some of the ties have built-in provisions for spacing the forms a definite distance apart; this is particularly true of single-use ties if this feature is ordered. An alternative means of maintaining the correct inside distance is by means of a **spreader**, a strut (usually of wood) inserted inside the forms that can be retrieved with an attached rope or wire when the concrete placement reaches that level.

2.5.2 Form anchors:

Form anchors are devices used to secure formwork to previously placed concrete of adequate strength. The devices normally are embedded in the concrete during placement. The actual load-carrying capacity of the anchors depends on their shape and material, the strength and type of concrete in which they are embedded, the area of contact between concrete and anchor, and the depth of embedment and location in the member. Manufacturers publish design data and test information to assist in the selection of proper form anchor devices.

2.5.3 Form hangers:


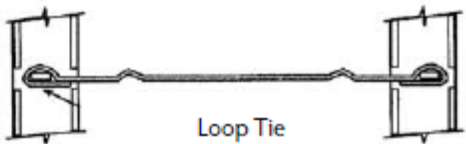


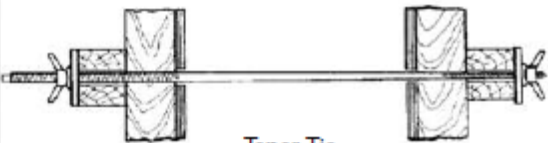
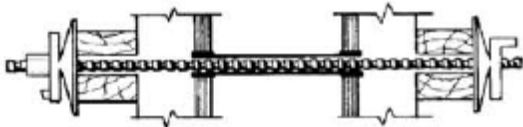
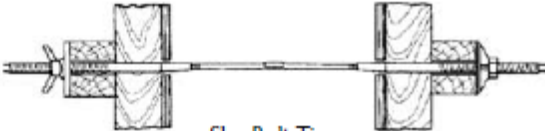

Form hangers are devices used to suspend formwork loads from structural steel, precast concrete, or other members

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2.5.4 Side form spacers:

A side form spacer is a device that maintains the desired distance between a vertical form and reinforcing bars. Both factory-made and job-site fabricated devices have been successfully used.

FIGURE (2.7) Examples of form ties: (From Hurd, M.K., *Formwork for Concrete*, 7th ed., SP-4, American Concrete Institute, Farmington Hills, MI, 2005.)

One-Piece Ties		Used to secure and space modular panel forms Available in several configurations Notched for breakback Safe Loads 1500, 2250, and 3000 lb
		Secures and spaces prefabricated modular forms Notched for a 1-in. breakback Crimp is anti-turn feature Safe Loads: 2250 and 3000 lb
		Used for job-built forms, lighter construction May have cone spreader and waterseal washer Notched for 1-in. breakback Safe Loads: 2250 and 3350 lb
		Long lengths supplied for cutting as desired on the job Custom colors available Cut off flush with surface of hardened concrete Safe Loads: 3000, 7500, and 25,000 lb
		Used where specs require or permit complete removal of tie from concrete Tie is reusable Safe Loads: 7500 to 50,000 lb
		Standard 20-ft lengths cut to meet project requirements Double nuts may be needed for higher load capacities Bar is reusable Safe Loads: 10,000 to 32,500 lb
Internally Disconnecting Ties		Heavy duty, with reusable end bolts No internal spreader, but external spreader bracket available Safe Loads: 4900 to 64,000 lb Up to 155,000 in High-Strength Steel
		Designed for medium to heavy construction With or without cone spreaders Bolts reusable Safe Loads: Two-strut, 3000 to 13,500 lb; Four-strut, 9000 to 27,000 lb

2.5.5 Recommendations:

The recommended factors of safety for ties, anchors, and hangers are given in Table (3.1).

The rod- or band-type form tie, with a supplemental provision for spreading the forms and a holding device engaging the exterior of the form, is the common type used for light construction.

The threaded internal disconnecting type of tie (also called through tie) is more often used for formwork on heavy construction, such as heavy foundations, bridges, power houses, locks, dams, and architectural concrete. Removable portions of all ties should be of a type that can be readily removed without damage to the concrete and that leaves the smallest practicable holes to be filled. Removable portions of the tie should be removed unless the contract documents permit their remaining in place. A minimum specification for form ties should require that the bearing area of external holding devices be adequate to prevent excessive bearing stress in form lumber.

Form hangers should support the dead load of forms, weight of concrete, and construction and impact loads. Form hangers should be symmetrically arranged on the supporting member and loaded, through proper sequencing of the concrete placement, to minimize twisting or rotation of the hanger or supporting members.

Form hangers should closely fit the flange or bearing surface of the supporting member so that applied loads are transmitted properly.

Where the concrete surface is exposed and appearance is important, the proper type of form tie or hanger will not leave exposed metal at the surface. Otherwise, noncorrosive materials should be used when tie holes are left unpatched, exposing the tie to the elements.