

Dear Reader,

Formwork systems are among the key factors determining the success of a construction project in terms of speed, quality, cost and safety of works. Aiming purely at speed often contradicts the achievement of other quality targets. Problems such as misalignment, misplacement, deflective concrete or holding up other works causing serious interruption can occur.

An effort is made in this issue to give a broad treatment to this vast, intricate and interesting subject viz. ***“Formwork in Construction”***

We hope you find the mailer informative and useful. Happy Reading!!



Issue Highlights

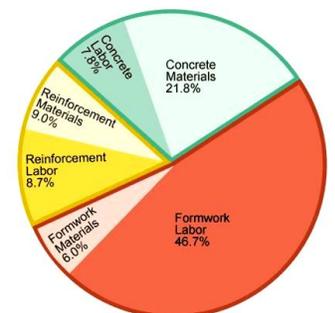
- Formwork and Formwork Systems
- Requirements of a Good Formwork
- Formwork Failures
- Necessary Precautions
- Formwork Removal

Introduction

Formwork is the temporary structure that enables moulding of concrete into desired shape, holds it in the correct position until it has hardened sufficiently and is able to support the loads imposed on it. The structural system of temporary supports that holds the formwork in position is termed as false work. Formwork is also an effective means of curing when it is left in place. The operation of removing the formwork is known as stripping. Stripped formwork can be reused. Reusable forms are known as panel forms and non-usable ones are called stationary forms.

The erection of formwork is a time consuming process and cost of formwork (material+labour) could sometimes be as high as 50% of the cost of the concrete structure. The failure of formwork systems during construction, causing monetary and time loss, sometimes grave injuries and death, are not uncommon. Efficient design of these temporary structures play critical role in reducing the cost and ensuring safety.

Formwork can be made out of Timber, Plywood, Steel, Aluminium, Precast Concrete, Ferro-cement or Fibre glass, used separately or in combination depending upon the nature and size of the work. Steel and Aluminum forms have the advantage over the other types as those can be repetitively used whereas Aluminium forms are lighter and thus enhance the productivity. For small works, timber is the most commonly used formwork material. The disadvantage with timber formwork is that it can warp, swell and shrink. Fibre glass forms are used in cast-in-situ construction such as slabs or members involving curved surfaces. Generally, precast concrete or ferro-cement formwork forms an integral part of the member and would not be removed.



Classification of Formwork and Formwork systems:

Different types of construction require the use of different types of formworks. The strength of the building components, the speed at which building is constructed, and the cost of construction will depend to a great extent upon the appropriateness of formwork used in the construction.

Formwork can be classified according to a variety of categories, relating to the differences in sizes, location of use, construction materials, nature of operation, or simply by the brand name of the products. Major formwork systems are as follows:

- 1. Traditional Timber Formwork Systems:** A combination of plywood and timber are used to create these traditional/conventional formwork systems at the construction location. Moisture resistant particleboards are often used as a substitute for plywood for making formworks of this type. Use of traditional formwork for larger/ complicated architectural structures, might result in major delays since producing intricate shapes is difficult with conventional systems.



- 2. Re-Usable Plastic/PVC/Aluminium Formwork Systems:** This type of formwork can be used repeatedly for constructing different types of structures/components. These systems are modular, interlocking and are simple to use as compared to other types. Houses built under mass housing schemes often utilize this type of formwork as they are robust and lightweight. They help to incredibly lower the cost of construction because of high number of repetitions possible.

- 3. Table form/Flying form systems:** A table form/flying form is a large pre-assembled formwork and falsework unit, often forming a complete bay of suspended floor slab. It offers mobility and quick installation for construction projects with regular plan layouts or long repetitive structures and hence is highly suitable for flat slab, and beam and slab layouts. It is routinely used for Residential flats, Hotels, Offices, Commercial buildings etc. The system requires enough space around the new construction to fly the table unit beyond the building line on everyday use. The supporting slab must be capable of carrying high loads at bearing locations; back propping may be needed underneath the slab.



- 4. Jump form Systems:** In this system, the formwork supports itself on the concrete cast earlier; so does not rely on support or access from other parts of the building or permanent works. Jump form system (including systems often described as climbing form), is suitable for construction of multi-storey vertical concrete elements in high-rise structures such as Shear walls, Core walls, Lift shafts, Stair shafts, etc. These are constructed in a staged process. It is a highly productive system designed to increase speed and efficiency while minimizing labour and crane time. Systems are normally modular and can be joined to form long lengths to suit varying construction geometries.

- 5. Slip form Systems:** Slip form is similar in nature and application to jump form, but the formwork is raised vertically in a continuous process. It is a method of vertically extruding a reinforced concrete section and is suitable for construction of core walls in high-rise structures – lift shafts, stair shafts, towers, etc. It is a self-contained formwork system and can require little crane time during construction. This is a formwork system which can be used to form any regular shape or core. The formwork rises continuously, at a rate of about 300mm per hour, supporting itself on the core and not relying on support or access from other parts of the building or permanent works. Commonly, the formwork has three platforms. The upper platform acts as a storage and distribution area while the middle platform, which is the main working platform, is at the top of the poured concrete level. The lower platform provides access for concrete finishing.





6. Permanent Insulated Formwork Systems: Insulating concrete forms (ICF) are typically used to construct permanent insulated formwork systems. Such formwork is usually assembled at the construction site. Once the concrete has been cured, this formwork stays in place. It is much stronger than other types of formworks and also enhances the speed of construction. Acoustic and thermal insulation offered by such formworks are higher compared to other types.

Selection of Appropriate Formwork and System

The selection and application of formwork, particularly for large-scaled and complex projects, depend on the following factors:

1. Design Related

- a. The shape of the building (block-shaped, awkward shaped etc.)
- b. Design of the external wall (shape, architectural finishes etc.)
- c. Internal Layout (simple framed structure, several interior load-bearing walls etc.)
- d. Structural Forms (Buildings with core shafts, flat slabs, regular shear walls etc.)
- e. Consistency in Building dimensions (non-standard dimensions and changing dimensions of structural components)
- f. High head-room, Large spans etc.

2. Construction Related

- a. Site Complexities (Exceptionally small or large sites, sloped or very crowded sites, proximity to sensitive structures, etc.)
- b. Required speed of work.
- c. Desired repeatability of formwork.
- d. Area or Volume of cast per pour.
- e. Availability of accurate construction plan/arrangement.
- f. Type and number of lifting and transporting equipment available.
- g. Involvement of other construction techniques like post-tensioning, prefabrication etc.
- h. Possibility of alternative designs from buildability considerations.

Requirements of a good Formwork:

- Should be strong enough to withstand all types of dead and live loads; resist the pressure of the fresh concrete without damage or excessive deflection.
- Should be rigidly constructed, efficiently propped, braced both horizontally and vertically, so as to retain its shape and to avoid bows/bulges outside the tolerances specified for the work.
- Should be constructed accurately to ensure correct surface levels, dimensions and true to its shape.
- Joints should be closed/sealed to prevent the loss of cement slurry and matrix from the concrete (as this can cause ragged edges, hydration staining and honeycombing, which in turn can affect strength, durability and result in poor off-form finishes).
- Formwork material should not warp or get distorted when exposed to the environment.
- Should be robust to allow repeated stripping, storing and erection and also permit removal of various parts in desired sequences without any damage to the concrete.
- Should rest on firm base.
- Should be economic, easily available and suitable for reuse.



Adequately braced formwork

The formwork is to be constructed such that the tolerances on the shapes, lines and dimensions shown in the drawing shall be within the limits given below: (Clause 11.1, IS: 456-2000)

Sl.No.	Item	Tolerances
a)	Deviation from specified dimensions of cross-section of columns and beams	+10 mm -5 mm
b)	Deviation from dimensions of Footings: 1. Dimensions in plan 2. Eccentricity 3. Thickness	+50mm -10mm 0.02 times the width of the footing in the direction of deviation but not more than 50mm +50 mm -10 mm Or ± 0.05 times the specified thickness, whichever is less.

Formwork should be coated with a form release agent that facilitates easy removal of formwork. This protects concrete surfaces from possible damage due to handling stresses caused during stripping and also improves the surface finish. The release agents may be of barrier type products that simply separate the concrete from the formwork, or more commonly used reactive type products (which react with the concrete constituents to form soap-like products) that prevent the concrete from adhering to the formwork.

Failures of Formwork

Safety must find the first place in the design, construction, erection and stripping of the formwork and scaffolding systems. Builders know from the experiences that it pays to avoid accidents at construction sites. Majority (about 50%) of the accidents at construction sites have been found to be due to failure of formwork or collapses of centering. The accidents have invariably resulted in loss of human lives and property apart from throwing construction schedules out of gear.

Formwork failures may be due to faulty design, faulty materials, faulty construction/erection or a combination. Another interesting aspect of failure is that often the same design or even the same materials might have been used several times without any calamity and in many such cases, an element of chance might have rescued the situation which otherwise might have been a disaster.

ACI 347 states "Formwork failures can be attributed to human error, substandard materials and equipment, omission, and inadequacy in design. Careful supervision and continuous inspection of formwork during erection, concrete placement, and removal can prevent many accidents".

There are number of reasons for formwork failure. Some common construction deficiencies that can lead to formwork failures are:

- Failure to inspect formwork during and after concrete placement to detect abnormal deflections or other signs of imminent failure that could be corrected.
- Insufficient/ineffective nailing, bolting, welding, or fastening.
- Insufficient or improper lateral and diagonal bracing.
- Use of damaged or inferior timber having lower strength than needed.
- Poor Splicing of timber shores.



Recent formwork failure



- Use of prop on prop or overlapping of props.
- Lack of bracing at joints in shores.
- Unstable soil under the shore sole plates; Failure to check tightness of the shores on the floors below.
- Inadequate lateral supports to the shutter plates.
- Improperly secured form ties.
- Inadequately secured wedges for forms and for false work.
- Not taking into consideration vertical rate of placement concrete, lateral pressure on the forms, expected slump, type of vibration used, effect of admixtures, etc.
- Failure to regulate properly the horizontal rate and sequence of placing concrete to avoid unbalanced loading on the formwork.
- Vibrations and shocks arising from the movement.
- Premature removal of supports.
- Failure to construct formwork in accordance with the form drawings.
- Lack of proper field inspection by qualified persons to ensure that form design has been properly interpreted by form builders.



Precautions

Construction procedures should be planned in advance to ensure the safety of personnel and the integrity of the finished structure. Some of the safety provisions that should be considered are:

- Erection of safety signs and barricades to keep unauthorized personnel clear of areas in which erection, concrete placing, or stripping is under way;
- Providing experienced personnel during concrete placement to ensure early recognition of possible form displacement or failure. A supply of extra shores or other material and equipment that might be needed in an emergency should be readily available;
- Provision for adequate illumination of the formwork and work area;
- Inclusion of lifting points in the design and detailing of all forms that will be crane-handled. This is especially important in flying forms or climbing forms. In the case of wall formwork, consideration should be given to an independent work platform bolted to the previous lift;
- Incorporation of scaffolds, working platforms, and guardrails into formwork design and all formwork drawings;
- Incorporation of provisions for anchorage of alternate fall protection devices, such as personal fall arrest systems, safety net systems, and positioning device systems; and
- A program of field safety inspections of formwork.

Checks before concreting

- Forms must be tight enough to hold all the cement slurry. Passing day light through joints is an indication to the contrary. Masking tapes can be used to seal the joints.
- Props are tightened and are truly vertical and braced laterally and diagonally.
- Braces are properly anchored.
- Props should rest on firm base having adequate area to distribute the load without settlement.
- Form surface is free from any oil/grease, paper pieces, wooden chips or other foreign materials sticking to it. The surface should be adequately wetted.



- Forms should be capable of being released without damage to forms and the concrete.
- The release agent on the form surface should be applied uniformly.
- The necessary access and pathways for men, equipment and concrete must be provided.
- Column ties or column clamps are spaced according to design drawings.
- Spacing of ties or clamps is based on a sound assessment of concrete pressure.
- Columns are adequately braced where they are not tied in to a slab-form structure.
- Hazardous soil conditions such as excessive moisture, freezing, and un-compacted soil are reported and discussed with the designer.
- Shoring frames and jacks are located and aligned within tolerances specified on the drawings.
- Shoring frames and jacks are out of plumb no more than 3.5mm in 1m.
- Temporary loads such as rebar are not obviously overloading the system.



Removal of Formwork

Premature removal of formwork is one of the most common causes of failures. This type of failure can lead to a progressive collapse, and is therefore extremely dangerous. Determination of the time of form removal should be based on the resulting effect on the concrete. There should not be excessive deflections, distortions and damage to the concrete during the removal of support or stripping operation. As a general rule, the forms for columns and piers can be removed before forms for beams and slabs.

Clause 11.3 of IS 456:2000 states that Formwork shall not be released until the concrete has achieved a strength at least twice the stress to which concrete may be subjected, at the time of removal of the formwork. The strength referred to shall be that of concrete using the same cement and aggregates and admixture, if any, with the same proportions and cured under conditions of temperature and moisture similar to those existing on the work.

While the above criteria of strength shall be the guiding factor for removal of formwork, in normal circumstances where ambient temperature does not fall below 15°C and where ordinary Portland cement is used and adequate curing is done, following striking period may deem to satisfy the above guidelines. For other cements and lower temperature, the stripping time recommended may be suitably modified.

Sl.No.	Type of Formwork	Minimum period of Striking Formwork
i.	Vertical formwork to columns, walls, beams	16-24 hours
ii.	Soffit formwork to slabs (props to be refixed immediately after removal of formwork)	3 Days
iii.	Soffit formwork to beams (props to be refixed immediately after removal of formwork)	7 Days
iv.	Props to slabs → Spanning upto 4.5 m → Spanning over 4.5 m	7 Days 14 Days
v.	Props to beams and arches → Spanning upto 6 m → Spanning Over 6 m	14 Days 24 Days

Conclusion:

The quality of concrete and the safety of construction to a large extent depend on the type and quality of Formwork, degree of supervision as well as workmanship. The demands on construction have resulted in innovations leading to development of different types of Formwork systems. Engineer has to choose the appropriate systems, which give more techno-economic benefits. In addition it is required to understand the precautions to be taken while erecting the formwork and pouring the concrete. It is important to carryout necessary checks before placing the concrete in to the forms. The time and method of striking off the formwork is another important criterion to be considered. The forms should be released only after the concrete attains sufficient strength to resist the handling stresses and stresses due to the self-load. The forms should be retained for the stipulated period as per codal provisions. Utmost care should be taken while striking off the formwork to avoid damage to the concrete.

As construction is happening at a brisk pace, designers and contractors are finding it prudent to use advanced Formwork systems in-order to ensure speed and quality of construction, safety of the workmen and to fulfil the commitments. The continual growth of construction and its allied activities apart, it is this positive change in the stakeholder's mindset that is taking the Formwork Industry to new heights. What's appreciable is the alacrity with which Indian companies have also started offering advanced Formwork systems.

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