This article mainly focuses on the importance of Formwork codes and the key points to be taken into account in Design of Formwork and most of points presented are the key extracts from various available Formwork code of practice.

Why is code of practice for formwork required?

The Formwork Code of Practice is to give hands-on guidance about ways to manage the formwork in terms selection of materials, design, assembly, and dismantling procedures and mitigating / informing the risk associated with that and also to minimize failures. Because failures or unsafe formwork practice will cause financial losses, accidents some time which involves fatal, time loss etc. Certainly the losses in time and money that go along with construction mishaps are strong motivators for safe activity.

If there is a specification or codal procedures for formwork, we can follow the same for doing the things in a proper manner.

So, if there is a code of practice, we can:

(a) do what the code says
(b) do all of the following:

- Adopt and follow another way that gives the same level of protection against the risk
- Take reasonable precautions
- Exercise proper diligence.

Need For Formwork Codes

- Since formwork is a temporary installation it is not given adequate importance even though it has a vital bearing on cost, quality and speed
- The codal provisions should have minimum requirement which will create confidence in the owner
- Formwork & forming practice require a minimum specification to ensure that the structure is constructed satisfactorily
- Additional specification depending on complexity of the job and tolerances need to be specified by the consultants

International Standards

- ACI SP-4 (R14) - Formwork for concrete.
- Construction Industry Research and Information Association (CIRIA) reports on concrete pressure on formwork, striking times, recommendations etc.,
- CAN/CSA - S269.3 (R2008) - Canadian standard on formwork
- AS3610 & SAA 1509 - 2010 - Australian standards for Formwork
- EN12812 - European Standard on performance requirement and general design.

Indian Standards

- IS - 14687 - 1999 (Reaffirmed 2005), Indian Standard - False work for Concrete Structures - Guidelines
- The other code available for reference "IRC 87 - 2011 - Guidelines on formwork, falsework and temporary structures.
- The above codes do not elaborate on design factors and special applications when compared to the treatise of International codes. Hence - Formwork not given due importance in India.
- Methodology and design approvals are not sacrosanct.
- Age old methods still followed in the construction.

Purpose of Standardization & codes

- To promote good engineering practice
- To improve workplace and overall safety during various activities of construction.
- To ensure good quality of concrete and surface finish.
- To improve speed and economy.
- To create awareness in the industry about formwork.
- To get due importance as that of permanent structure design
- To have a reference for various agencies involved

Formwork Scenario in India

Formwork is an important enabling work, which has to keep pace with the modernization of concrete construction. The entry of global formwork players and also development of indigenous formwork helped the owners / developers / structural consultant to work towards high rise structures, monolithic construction in concrete. There is an increase in the presence of Global system formwork players in India and now the client / owners / con-
tractors are aware of the system formwork and its advantages.

The earliest formwork systems made use of wooden poles and timber runners as it enabled easy forming and making at site. But these wooden planks and timber runners over a period of time and after repeated usage tends to lose their structural and dimensional properties thus posing safety problems.

Many of the accidents take place in RCC construction are associated with improper temporary works and scaffolding. Recently we received an information about a formwork failure in a Metro project, wherein the company used system formwork and still it collapsed. Investigation has started and they are finding out the cause of failure. Either the lack of knowledge of the materials used or the load carrying capacity of the members, poor detailing, non-understanding of construction methods / sequence etc., can lead to such accidents. Keeping pace with modernization, complexity of projects, high rises, availability of latest technology and materials it is not possible to design & erect the formwork using rule of thumb approach without any rational approach in the design of formwork.

Importance of Formwork Design

The Construction Industry is a multifaceted industry, characterized by a broad range of high risk activities and complex work arrangements and “Construction Industry has the largest number of work related deaths than any other industry”.

The inherent risks in the building and construction industry make it one of the priority areas for providing safe environment for Contractors, subcontractors and their workers to face risks from hazards that must be managed to prevent deaths, injuries and illness.

As already stated earlier, Formwork & scaffolding is an important activity which needs to be given major attention when it comes to Safety during Construction. Even though the safety and construction is the responsibility of the builder or contractor, it is necessary that formwork designs and drawings are reviewed and approved. In these cases, the contract document shall clearly specify that the designs and drawing of formwork will be reviewed and approved by Engineer – In-Charge. It is better to write down the work procedures for Shuttering and De-shuttering operations with clearly defined roles and responsibilities, specifications, scheme drawings etc., once most of the shuttering / de-shuttering activities are captured in the paper, it is easier to exercise control and to ensure safe working conditions in site. It is also better to provide a mock-up display of formwork with inbuilt safety features for better understanding for the workers and engineers at site.

Formwork Design

All formwork should be well planned before construction begins. The amount of planning required will depend on the size, complexity, and importance (considering reuses) of the form. Formwork should be designed for strength and serviceability. System stability and member buckling should be investigated in all cases.

After the selection of the proper materials and estimating the load coming on to the forms, the form designer takes up the problem- how to make the form strong enough to carry the anticipated loads, safely, and stiff enough to hold its shape under full load. In order to achieve safety, efficiency and economy, it is better to adopt the rational design i.e., once calculated on the basis of known strengths of materials and the estimated loads rather than empirical design. For extremely heavy loading and special types of construction, a complete and precise structural design of formwork would be required.

Even though there are increasing numbers of new materials are being introduced for forming, the basic support is provided in majority of cases by timber, plywood, steel or aluminum members, same general principles can be applied for other materials whose strength properties are known.

Common Assumptions & Design Calculations

Simplifications

Greater accurate design is not frequently used in formwork design and going into detailed design will take and waste time. Because precise calculation of bending moments is not required as we will have so many assumptions for loads, lateral concrete pressure, quality of materials, workmanship at site etc., Some of the simplifying assumptions are:

1) Generally all loads are assumed as uniformly distributed loads on sheathing, Secondary & Primary members, unless it is mandated for accurate loadings for complex & critical structure.
2) Beams supported over three or more spans are regarded as continuous
3) Strength of nailed connections is neglected in determining the size of main form member. This does not apply when considering splices, braces, brackets, etc.

Generally design of formwork even though it is a temporary structure, the same design Principles used for permanent structure will be used with some assumptions. The formwork usually supports loads for short duration only until the permanent structure gets its strength to support itself. Formwork stands on its own weight for stability except in certain cases where it is exposed to conditions like wind etc., Formwork Components are to be repeated & reused without losing its structural properties, but will be assessed case to case basis.

Approximate design checks should be carried out for simple formwork system for normal Structures and also simple rule of thumb checks also necessary. Formwork design for complex structures to be checked with more accurate design principles computer aided Structural analysis like STAAD etc., Some of the branded system formwork suppliers have their own Design calculation aids, Charts & tables which will be used as a ready reckoner while design of formwork.

It is the responsibility of the formwork designer to ensure that he has all the information required to complete the design. However, information on all factors affecting a design will not necessarily be available at an early stage, so wherever assumptions to be made should be done and later on it can be cross-checked and the design can be amended.

All materials and equipment used in formwork construction must be fit for the intended purpose and meet design specifications. Materials and equipment must be manufactured in accordance with a quality assurance system that ensures compliance with the design specification.

How a formwork is designed

Estimate the load
Form the design basis
Estimate the permissible stresses
Analyze & design each component

**Basic Information required**

Formwork design whether it is Simple or complex requires certain information prior to commencing of design. It is also the responsibility of the formwork designer to ensure that he has all relevant input to complete the schemes and the design. In case of any missing details, the same has to be sought from the relevant person. Most of the branded system formwork company before submitting quote or before preparation of schemes & design will have format to be filled by the contractor / client containing project details etc., which are required as input. Any missing information assumptions can be made and to be re-checked before releasing “Good for Construction formwork schemes”.

- All details and GA drawings, construction schedule, relevant specification
- Types of finish
- Through ties allowed or not. Water retaining structures requires water barrier ties.
- Method of placing of concrete- Pump, crane bucket etc.,
- Deshuttering time or if it is Post tensioned means the time for deshutting
- Rate of concrete pouring
- Pour sequence
- Capacity of batching plant.
- Type of cement, retarders etc.,
- Available formwork materials and their status.
- Date of submittals required

**Basic formwork systems –Design consideration**

A formwork designer or engineer may provide certification of a ‘basic formwork system’. A basic formwork system is understood as the formwork for a floor, wall or column.

**A basic formwork system includes**

- standard formwork frames which have a known tested loading capacity spaced at no more than the recommended distances apart for a normal floor thickness with secondary & Primary member and sheathing on top of them, and
- specially manufactured and designed formwork systems with proprietary formwork components and rated load calculations in line with the manufacturers’ specifications.

**A basic formwork system is limited by the following conditions:**

- The height of the formwork must not be greater than or equal to 6 metres to the soffit of the new floor from the supporting floor.
- Walls and columns must not be greater than 6 metres free standing from the floor on which the formwork will be supported.

Where any of these conditions occur, the system is classified as a ‘non-basic formwork system’, and this code requires that an engineer is the only person who may certify such a formwork system.

**Non-basic formwork systems –Design consideration**

Formwork systems which exceed the description of a ‘basic formwork system’ are, categorised as ‘non-basic formwork systems’. As per BS 5975 an engineer is the only person who may certify:

- the design of all temporary or permanent formwork structures categorised as ‘non-basic formwork systems’, and
- any back propping used for either basic formwork systems or non-basic formwork systems.

As per the code, non-basic formwork systems include formwork structures higher than three frames or 6 metres (or three times the least base width).

**Formwork drawings & Detailing**

Formwork drawings must explain

- plans, elevations and sections to show the general arrangement of the formwork and to identify and locate all members and components including bracing
- the maximum point loadings to be applied
- the component types and spacings
- the maximum stirrup head & base jack extensions
- the secondary & primary supporting member type, the dimensions and spacings
- the prop sizes and maximum extensions
- the methods for tying the structure together and spacing between ties (if required)
- the plywood layout.

Where eccentric loading is to be applied to U-heads (i.e. Primary members s are positioned to one side of the U-head), the formwork drawings must state that this is permitted.

After completion of the formwork design, detailed Formwork scheme to be prepared so that the site Engineers / labourers can directly do the shuttering work as per that.

Preparing formwork scheme with more details like Assembly / making of panels, spacings, construction Joints, etc., will be helpful to the site to plan for the exact requirement of formwork and saves enormous construction time as you will be planning the activities properly.

A formwork drawing should be like a pictorial representation of elements and their assembly, wherein workmen understands and completes their tasks as designed. Branded system formwork players gives isometric / 3D views to supplement and also to make the site persons to visualize the formwork job.

Useful check list for details to be incorporated in the formwork drawings

1) Sequence to concrete placement.
2) Sequence of form removal, back propping, repropping etc.,
3) Anchorages, form ties, braces spacing and tying of diagonal bracings
4) Requirement of opening for vibrator
5) Construction joints, expansion joints details
6) Camber or adjusted elevations to compensate deflections
7) Bottom precast sill under shores for heavy loadings
8) Formwork release agents
9) Recheck with Structural drawings
10) Check for the Construction joints, expansion joints required / permitted as per structural drawings
11) Any special patterns or grooves requirement as per Architectural drawings.
12) Precautions in supporting members for permanent Shuttering along with the formwork
13) Check to be made for release / loosening of supports for shell / dome structures as proper deflection
14) Sequence of de-shuttering is necessary to have proper stress pattern in the structure
15) Essential provision for specialized construction techniques such as taking the boom placer, concreting
16) Equipment such as boom placer / crane to be taken along with the self climbing equipment.
17) Embedded parts, openings, any MEP works requirements to be checked.

Verification of Formwork design

Verification that the formwork structure complies with the design of the formwork system must be documented and provided. A construction check list can be used to assist in this process. Relying solely upon such a checklist will not be sufficient to verify compliance.

The verification and documentation that a design has been complied with may be delegated to a ‘competent person’ on site.

A competent person, if not an engineer or formwork designer, must have appropriate training and knowledge to perform onsite inspections of the formwork system. This delegated person needs to be experienced in formwork construction and be competent in reading drawings and be able to certify that the formwork structure satisfies the details on the formwork drawings, specifications and any other formwork documentation. A competent person who is not a formwork designer or engineer must not authorise variations to the design. A competent person must ensure the remedial action has occurred prior to the concrete pour including any items referred to an engineer for certification and modified as instructed by an engineer.

A pre-pour inspection & the check list should be a part of any quality control system.

The final pre-pour inspection report should be signed jointly by the Formwork Engineer / Site engineer and a Quality Control engineer.

Lack of Attention to Formwork Details

Even when the basic formwork design is soundly conceived, small differences in assembly details may cause local weakness or overstress loading to form failure. This may be as simple as insufficient nailing, or failure to tighten the locking devices on metal shoring, tie rods, nuts etc., Other details that may cause failure are:

- Inadequate provisions to prevent rotation of beam forms where slabs frame into them on the side.
- Inadequate anchorage against uplift for sloping form faces.
- Lack of bracing or tying of corners, stop ends, or other places where unequal pressure is found.
- Stripping procedures for special structures like domes, cantilevered structures etc.,
- Failures have occurred in pre-stressed bridges, due to non-consideration of post tensioning effects on the staging towers adjacent to the pier supports.

Some of the checklist and the commonly found defects in formwork systems

Foot / Base plates

(a) not levelled in or eccentrically placed
(b) inadequate load-carrying capacity of the ground and uneven bedding
(c) deterioration with time (e.g. Due to weather conditions)
(d) deterioration of load-carrying capacity of the ground, (e.g. washouts)
(e) crushing due to inadequate load distribution from vertical and horizontal members.

Horizontal supports

(a) inadequate lateral and torsional bracing, (e.g. Between
telescopic props, centres carrying heavy loads over long spans, steel props supporting heavy loads at, or near, maximum extension and between towers supporting independent spans)
(c) horizontal members not centrally placed in Stirrup heads / U heads.
(d) inadequate supports to cantilevers, [e.g. Struts supporting deep beam sides on the outer face of the structure]
(e) inadequate support to prevent overturning of deep principal members because stirrup head or fourway heads often omitted
(f) bolted timber connections not staggered creating tendency to split out.

Vertical supports
(a) inadequate bracing during erection
(b) support not plumb
(c) inadequate lateral ties and/or vertical and plan bracing
(d) no ties between standards at point of loading (most important where telescopic props are being supported)
(e) adjustable steel props with nails, mild-steel bolts and reinforcing bars used in place of correct pins
(h) top and bottom plates of steel props

General
(a) excessive tolerances in construction
(b) failure to check tightness of bolts, wedges, etc.
(c) failure to control vertical rate of placement of concrete
(d) failure to control placement of concrete, causing uneven loading of forms
(e) inadequate allowance for uplift of concrete under inclined forms
(f) inadequate allowance for the effects of vibration on joints
(g) inadequate allowance for stresses induced by prestressing, temperature and moisture movements
(h) no allowance for wind loading
(i) no allowance for the effect of vibration on ties, struts, braces, and wedges
(j) unrealistic assessment of stresses due to over-simplification of design assumptions
(k) unequal load distribution between two or more members carrying a common load

Premature stripping of forms, premature removal of shores, and careless practices in reshoring can produce catastrophic results. Even though de-shuttering is the last operation, but it is the first and most important aspect which to be taken into consideration by the designer and the site engineer. A formwork designer should keep in mind about ease of de-shuttering, plant & equipment availability while preparation of the scheme. The time for formwork removal or reproppering removal should be based on both the specification compliance, codal provisions and field assessment.

Conclusion

Formwork takes more than 50 percent of RC construction time. The cost of formwork varies between 15 to 25% of the Reinforced concrete structure cost. Proper engineered system formwork should be specified upon in the tenders to attain good formwork practice, Safe working conditions and to get quality and durable concrete structure, otherwise it will not only lead to poor quality structures but also wasting of resources like materials, manpower and time which in turn affects construction delay and cost escalation of projects.

First step of compliance is to follow the codal guidelines. By their nature, codes set for minimum standards in order to protect workers and the public, but they can give no absolute guarantee of safety. There are too many other work place practices and conditions that affect the balance between safe and unsafe conditions. However, once a failure has occurred investigators will certainly check whether the codal provisions were followed or violated. So, it’s better to keep in touch with changing requirements in codes and standards, recognizing that they are always necessary but not always sufficient for safety.

Major formwork players publish a lot of information on formwork usage, assembly, work procedures etc., in their websites which a person can access and can practice at site. So, non-availability of detailed Indian codes or specification for formwork should not be an excuse for inferior/improper formwork practices. In order to bring the standard of constructions in India to International levels, the consultants should specify, systemise and implement the right formwork system for the projects and also the standardization body of India also to look to bring in more detailed Code of Formwork practice in India to suit the available materials / system and formwork practices in India.

References
3) AS3610 - 2010 - Australian standards for Formwork for Concrete