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GUIDELINES FOR FORMWORK, FALSEWORK AND TEMPORARY STRUCTURES

(First Revision)

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INTRODUCTION

The Guidelines for the Design and Erection of Falsework for Road Bridges was first published in March, 1984. The draft of the revised "Guidelines for Formwork, Falsework and Temporary Structures was prepared by B-7 Committee (Personnel given below) and was finalised in their meeting held on 29.9.2010. The draft of the first revision of Guidelines was approved by Bridges Specifications & Standards Committee (BSS) meeting on 25th October 2010.

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These Guidelines were approved by the Executive Committee on 27th October, 2010 and by the Council in the 192nd meeting held at Nagpur on 11th November, 2010, subject to the condition that the comments made thereon should be taken into consideration by the Convenor of Bridges Specifications & Standards Committee and authorised to make any changes necessary in light of the comments made by the members of the Council.

1 SCOPE

These guidelines apply to the design, fabrication, erection, and stripping of Formwork, Falsework and Temporary Structures built mostly from structural materials and used for supporting different types of permanent concrete bridge structures during construction till they become self supporting or built to provide access for doing concrete work, the shoring and scaffolding etc.

Compliance of these guidelines can not confer immunity from legal obligations in the event of failures and casualties.

2 OBJECTIVES

The objective is to design and construct safe and economical formwork and scaffolding system that will support all loads imposed and provide the necessary rigidity to achieve the lines, grades and shapes shown in the working drawings. The basic parameters to be considered as under:

2.1 Quality

2.1.1 The forms and other structures are designed and built accurately so that the desired shape, size, alignment and finish of the cast-concrete is achieved in terms of dimension and strength.

The forms must be built to correct dimensions, must be sufficiently rigid under the construction loads to maintain the designed shape of the concrete within permissible deflections and tolerance limits, must be sturdy and strong enough to maintain large members in alignment, and must be constructed so they can withstand handling and reuse, without losing their dimensional integrity. The formwork must remain in place until the concrete is strong enough to carry its own weight.

2.1.2 The correct material should be chosen. The quality of surface finish of the concrete is affected by the material of the form. A correct combination of form material and oil or other parting compound can contribute in eliminating air holes or other surface imperfections in the cast concrete.

2.2 Safety

Safety should be included in the planning and management of the project and procedures that will assure safety for workmen and structure should be adopted. The following be ensured that:

2.2.1 Forms, Falseworks and Temporary Structures are correctly designed after collection of required data and making sufficient investigations, by rational analysis with adequate safety margins and strong enough for the expected load.

These are supervised during erection and concreting by competent Supervisors who should see that these are constructed exactly as designed, following a safe erection procedure so that no members are temporarily overloaded.

2.2.2 No other loads are ever imposed on them if these have been designed with no allowance for unusual construction loads or eccentric loads due to placing sequence or any such load.

2.2.3 Adequate work area or work platforms with proper method of access have been provided.

2.2.4 Safety signs and barricades have been erected to keep unauthorized personnel clear of areas in which erection or stripping is underway.

2.3 Efficiency

The formwork, falsework and temporary works should be so planned and designed that these can be handled ,erected and dismantled easily and used repeatedly to optimal limits.

2.4 Economy

Economy is one of the main concerns, since formwork cost may be more than 20-30 percent of the cost of concrete structure. No attempt, however, should be made to achieve economy at the cost of quality or safety.

2.4.1 The formwork falsework and temporary structures should be meticulously planned and designed to cater for all the parameters of quality, safety and efficiency and the provisions of codes and specifications such that these are time and cost effective.

2.4.2 Shortcut in design or construction of formwork may endanger quality and safety and should not be attempted.

2.4.3 The design and erection of formwork/falsework should, whereever possible, form an item of contract so that the cost of this item is correctly assessed, executed and supervised.

2.4.4 Coordinated efforts between Engineer/Designer and Contractor can also result in savings in the cost.

2.5 General Relationship and Responsibility

2.5.1 The responsibility of the designer, contractor, and the clients should be decided without ambiguity and the interests and views of all the three should be considered while deciding various parameters for design, specifications and erection with optimum utilization of the skills ,knowledge and resources available at the site.

2.5.2 The system of designing, checking and approval of designs, erection systems and construction methodology should be clearly defined and agreed by all the involved parties.

2.5.3 The various parameters for design, its limitations and permissible tolerances should be finalized after mutual consultation between the involved partied and described in a Design brief to be prepared and agreed before taking up the work.

3 DEFINITIONS

For the purposes of the guidelines, the following terms and definitions apply:

3.1 Base Plate

Metal plate for distributing the load from a standard, raker or other load bearing member.

3.2 Bay Length

Distance between the centers of two adjacent standards measured horizontally.

3.3 Blinding

Layer of lean concrete usually 50 mm to 100 mm thick, put down on soil such as clay to seal the ground and provide a clean level bed for construction work.

3.4 Brace

Tube or structural Member placed horizontally or diagonally with respect to the vertical or cross horizontal members of a scaffold and fixed to them to provide stability.

3.5 Camber

Vertical curvature of a beam or formwork, either formed initially to compensate for subsequent deflection under load, or produced as a permanent effect for aesthetic reasons.

3.6 Coupler

Component used to join members together.

3.7 Erection Drawing

Drawing prepared prior to erection showing the arrangement and details of the falsework structure.

3.8 Falsework

Temporary structure used to support a permanent structure until the structure become self supporting.

3.9 Formwork

Section of the temporary works used to give the required shape and support to poured concrete, which consists primarily of sheeting material (e.g. wood, plywood, metal sheet or plastic sheet) in direct contact with the concrete and other stiffening members that directly support the sheeting.

3.10 Hand Rail

Member incorporated in a temporary structure to prevent the fall of a person from a platform or access way.

3.11 Joint Pin

Adjustable fitting placed in the bore of a tube to connect one tube to another coaxially.

3.12 Joist

Horizontal or sloping beam.

3.13 Lacing

Members that connect together and reduce the unsupported length of compression members.

3.14 Permit to Load

Certificate issued to indicate that the falsework may safely be put to its designed use.

3.15 Prop

Compression member used as a temporary support.

3.16 Re-Propping - Back Propping

System used during the construction operation in which the original props are removed and replaced in a sequence planned to avoid any damage to partially cured concrete.

3.17 Scaffold

Temporary structure that provides access or on which persons work or that is used to support material, plant or equipment.

3.18 Lift

Height of concrete formed and cast in one pour.

3.19 Sole Plate Sill

Timber, concrete or metal spreader used to distribute the load from a standard or base plate to the ground/founding strata.

3.20 Spigot Pin

Pin placed transversely through the spigot and the scaffold tube or frame to prevent the two from coming apart.

3.21 Standard

Vertical or near vertical scaffold tube.

3.22 Stiff Length (of the bearing)

Length of the bearing that cannot deform appreciably in bending.

3.23 Strut

A member in compression.

3.24 Temporary Structures

Parts or the works that allows or enables construction to protect, support or provide access to, the permanent works and which may or may not remain in place at the completion of the works.

3.25 Toe Board

Upstand at the edge of a platform intended to prevent operatives' feet from slipping off the platform.

3.26 Wedge

Two pieces of strong timber or metal that tapers along its length laid one above another with parallel outer faces.

3.27 Shim

A strong piece of timber or metal to adjust the level/length of the member in compression.

3.28 Tier

A unit or frame erected one above another in a vertical direction.

3.29 Yoke

A vertical inverted U shape member generally used in slip form.

4 MATERIALS

4.1 General

The permitted materials for falsework in the context of these guidelines are timber, steel, plywood, concrete, masonry and fibre glass forms.

4.2 Specification for Materials

All the materials shall conform to the specified quality consistent with the intended purpose and actual site conditions as applicable. Where materials or component and their uses are covered by existing IS or IRC Standards as shown in **Table 4.1**, conformity with them subject to the satisfaction of supplementary requirements, if any, arising out of these guidelines shall be ensured.

Table 4.1

Material	Principal use	Minimum size	Specification and design data sources	Remarks
1	2	3	4	5
a) Timber	i) Form, shoring and scaffolding		IS 883	Soft woods of partially seasoned stock are recommended for formwork since fully dried timber swells excessively when it becomes wet and green timber will dry out and warp during hot weather.
	ii) Form for deck soffit, beam sides and other vertical surfaces	25 mm		-do-
	iii) Beam soffit columns side	50 mm 30 mm		-do-
	iv) Props	75 x 100 mm		-do-
	v) Bailies for Shore/ Bracing	75 mm dia Minm.		
b) Ply-wood	Forms and Form linings Sheeting and panels	6 mm	IS 4990	Plywood provides large area of joint free smooth concrete surface, easy in handling, light weight, flexibility of use, capacity to withstand hot and cold climates, no shrinkage cupping or twisting, high resistance to impact load and vibration, as of bonding, reusability.
c) Steel	i) Sheet Plate	Forms and Form linings 3.15 mm with form vibrators	IS 2062 IS 961 IS 1977	Steel forms can stand repetitive use. Note:- Plate thickness may be increased if repetitive use is 500 or more

Contd...

Material	Principal use	Minimum size	Specification and design data sources	Remarks
1	2	3	4	5
	ii) Rolled sections and tubes	Form supports shoring & framing, (i) Angles 50 x 50 x 6 mm (ii) Flats 50 x 6 mm (iii) Tubes 40 mm dia nominal bore with wall thickness 4.05 mm for main members and 25 mm dia for secondary members	IS 961 IS 226 IS 1161 IS 1977 IS 2062	Steel framing and bracing can be used in conjunction with timber and plywood panel system. **Note:** Sections may be increased up if repetitive use is 500 or more
	iij) Proprietary Systems	Forms can be obtained for round, square rectan-gularor polygonal shapes Formwork components such as plates, prop, frames, accessories and trestles, etc.		Design data to be obtained from the manufacturer of the proprietary systems.
	iv) Clamps/ Couplers for tubular centering		IS 2750	
d) Aluminium Alloys		Light weight panels and forming systems shoring and falsework	Manufacturer's data	
e) Fibre Glass	Precast concrete construction and architectural concrete		Manufacturer's data	This material is a glass fibre reinforced plastic product, excellent cast-concrete surfaces can be moulded to any shape without joints or seems
f) Precast Concrete		37 mm		
g) Asbestos cement	Column forms and duct formers			Usually left in position and provides the finished surface.
h) Laminated pressed paper, tubes (Card Board)	Circular column forms, formers for small ducts		Manufacturer's data	
i) Hard board with lining	Form panels and G.I. lining.	Minimum 12 mm thick	-do-	

Contd...

Material	Principal use	Minimum size	Specification and design data sources	Remarks
1	2	3	4	5
j) Plastic, Polyete-rene, Polythe-Lene Polyvinyl chloride	Formliners for decorative concrete		-do-	
k) Rubber	Form lining and void forms		-do-	

Codes:

IS 4990 Specification for Plywood for Concrete Shuttering work.

IS 226 Specification for Structural Steel (Standard Quality)

IS 2062 Specification for Structural Steel (Welding Quality)

IS 961 Specification for Structural Steel (High Quality) IS 1977 Specification for Structural Steel (High Steel)

IS 1161 Specification for Tubes for Structural purposes

Note : The sizes given in **Table 4.1** are only indicative of the minimum requirements and shall be derived from the actual detailed design.

4.3 New Materials

In case any new material is intended to be used that is not specifically covered in the Indian or International codes, but the use of which has been permitted elsewhere, it would be necessary to produce certification from the concerned authorities regarding the successful performance of such materials for 5 repeated uses. Such a certificate shall be supported with details of critical performance parameters and test results.

4.4 Formwork Accessories

For the design of form ties, form anchors and form hangers permissible stress shall conform to the relevant standards as well as design data based on test evidence published by the manufacturers.

4.4.1 *Form ties :* A form tie is a tensile unit adopted for holding concrete forms against the active pressure of freshly placed plastic concrete. Form ties, are also manufactured part of proprietary system.

4.4.2 *Form anchors :* Form anchors are devices used in the securing of formwork to previously placed concrete of adequate strength. The devices normally are embedded in the concrete during placement. Actual load carrying capacity of the anchors depends on the strength of concrete in which they are embedded, the area of contact between the concrete and anchor and the depth of embedment. Manufacturers also publish design data and test information to assist in the selection of proper form anchor devices.

4.4.3 *Form hangers :* Form hangers are often used to suspend formwork from a supporting structure.

4.5 Form Coatings or Release Agents and Sealants for Formwork

4.5.1 *Form coatings :* Form coatings or sealants are usually applied to contact surface either during manufacture or in the field to serve one or more of the following purposes:

a) To seal the contact surface and joints from intrusion of moisture or loss of moisture and cement slurry

b) To alter the texture of the contact surface

c) To improve the durability of the contact surface

d) To facilitate release of form from concrete during stripping

4.5.2 *Release agents :* Form release agents are applied to form contact surfaces to prevent bond and thus facilitate stripping. They may be applied permanently to form materials during manufacture or in the field or may be applied to the form before each use. The release agents shall be checked for compatibility with form surfaces, plastic concrete including admixtures and requirements for the application of further materials to the hardened concrete. They shall be kept off construction joints surfaces and reinforcing steel by applying before the reinforcement is laid. Care shall be taken to ensure that excessive application of release agent does not cause staining of concrete surface or retard curing. Where exposed aggregate work or other type of concrete surface finish is desired, release agents may be designed suitably.

4.5.3 *Form insulation :* These are usually used for protection of concrete in cold weather. These shall be used as per manufacturer's recommendations.

4.5.4 *Sealants :* In order to get smooth concrete surface finish and prevent escape of cement slurry, use of laminated tar paper or similar sealant can be permitted.

4.5.5 *Manufacturer's recommendations :* Manufacturer's recommendations shall be followed in the use of coatings, sealants and release agents, but independent investigation of their performance is recommended before use.

5 INVESTIGATIONS

The following investigations should be done before starting the design and all other data as made available should be verified with the site conditions.

5.1 All Topographical, Geographical and Climatic conditions should be investigated as relevant to design.

5.2 Sufficient Hydraulic and Hydrological investigations should be done to cover the river flow conditions, velocity of flow and discharge and water levels during different periods, any abnormal or sudden discharge which may be released from any Irrigation works in the upstream of construction site, any back flow conditions, tides or wave action, scour pattern during different seasons and flood conditions, any debris or trees flowing in the river.

This needs to be monitored regularly and whereever there are irrigation works upstream there should be continuous communication and alert system with them.

5.3 Adequate Geotechnical/sub soil investigations should be done at the locations of ground support to ascertain the allowable bearing capacity and to decide the type of foundation or support system after due consideration of the scours at those locations and the permissible settlements. Depth of sub-soil water should also be determined.

5.4 Adequate investigations should be done to locate any underground or overhead utility services which may foul with the foundation of the falsework/Temporary structures or the erection/launching or casting systems.

5.5 Detailed investigations should be done to find out the limitations at site because of space and movement restraints, headroom or clearances required, traffic regulation or diversion proposals, lighting and warning signs, regulations for noise control, vibrations or impact effects or environmental issues-pollution of air, soil or water etc.

5.6 Detailed investigations need to be done whenever there are any changes in any of the conditions which will affect the design or the systems of erection etc. being used. The designs/systems could be reviewed and revised, if necessary, adopting the changed data/informations.

5.7 Falsework foundations in general are at a shallow depth. The subsoil investigations should be done keeping this factor in mind.

5.8 Necessary investigation should be done to assess the severity of the seismic effects to assess its implications on the design.

6 DESIGN

6.1 Design Brief

6.1.1 A design brief or design basis note should be prepared first in consultation with all concerned including the owner or the client and those involved in design, fabrication, construction and proof checking etc.

6.1.2 The brief should include all data relevant to the design, design philosophy and construction methodology etc. It is important that it is prepared early to allow sufficient time for all subsequent activities i.e. design, design check, procurement of equipments, construction and erection scheme etc.

6.1.3 The preparation of the brief might involve a large amount of information needed to be collected from various sources before design work can commence or a program for the construction or the temporary works can be drawn up.

6.1.4 Certain information might be of direct relevance to both the Permanent Works designer and the Temporary Works designers, such as site investigation information or where the Temporary Works affect or take support from the permanent works.

6.1.5 The following list indicates the type of information that might be required for the preparation of the brief.

a) Relevant drawings of the permanent works.

b) Relevant clauses from the Specification for the permanent works.

c) Statement of any requirement to design the temporary works in accordance with a particular standard or guidance document.

d) Information on any significant risk associated with the design of the permanent works.

e) Program for the construction of the permanent works.

f) Methodology for construction including the different stages of construction for which design check may be required.

g) Program for the various phases of the design, design check, any external approvals, and procurement and erection of the Temporary Works.

h) The timing for the removal of the Temporary Works in relation to the ability of the Permanent works to be self-supporting.

i) Any requirements for access onto, under, or around the Permanent Works.

j) Any environmental constraints placed on the site by local authorities or other body, for example, a requirement by the local authority to limit noise to certain hours of the day.

k) Climatic and environmental conditions at site, hydraulic parameters, scour conditions, sub soil conditions, space restraints, wherever applicable.

l) Specific requirements for permissible stresses, tolerances, load combination, if in variance with the provisions of the standards being used for design.

m) Expected number of re-use.

n) Standards of safety and quality concerns.

6.1.6 The design brief should be provided to the designer or supplier to carry out the design of the temporary works.

6.1.7 When the design is completed the design brief should be provided to the organization/individual who is to carry out the design check. And also to the construction agency.

6.2 General Considerations

6.2.1 Formworks, Falsework and Temporary Structures shall be designed to meet the requirements of the permanent structure, taking into account the actual condition of materials, environment and site conditions in such a manner to facilitate easy erection and dismantling.

6.2.3 These may be designed in accordance with relevant IRC Codes for design of permanent structures except for loads, load combinations, allowable stresses and deflections which are dealt in this code. If in case any item is not covered in this or other IRC codes, design may alternatively be based on other acceptable references or national/international codes.

6.2.4 Careful attention shall be paid to the detailing of the support/connections and their function so as to reflect and accommodate the behaviour of the structure. Wherever possible, the structure shall be designed in such a manner that any local failures will not lead to progressive failure of false work/temporary structure.

6.3 Loads

6.3.1 These structures shall be designed to cater for the vertical, horizontal and other loads as specified in the subsequent clauses.

6.3.2 *Vertical loads :* Vertical loads shall comprise of Dead load, superimposed load, applicable live load and other loads as detailed below.

6.3.2.1 Dead loads

6.3.2.1.1 Dead load, generally static in nature, occur during the service life of these structures such as, Self-weight of the formwork and falsework, any ancillary temporary work connected to and supported by the falsework structure and permanent structure supported by the falsework.

6.3.2.1.2 Self-weight shall be determined according to Clause **205** of IRC:6 except for the following items for which the unit weights given in the following clause shall apply.

6.3.2.1.3 The following unit weights shall be adopted in the absence of actual measurements:

a)	Wet concrete including reinforcement	26 kN/m^3
b)	Timber-soft wood	6 kN/m^3
c)	Timber-hardwood	7 to 10 kN/m^3
d)	Steel formwork, Aluminium formwork, Combination of steel and ply (sheeting, main and secondary bearers) and other materials.	Actual weight
e)	Scaffold tube (40 NB)	45 N/m

6.3.2.1.4 For falsework composed of scaffold tube fittings, the additional weight of fittings, in absence of actual data may be accounted for by increasing the self-weight of the vertical and horizontal members by 15 percent. Similarly, in the case of falsework built with fabricated frames, the additional weight of fittings may be estimated at 5 percent of the total weight of the frames and bracings.

6.3.2.2 Impact : In absence of data, to cater for impact in precast construction the dead load should be increased by minimum of 10 percent due to weight of precast concrete member.

For cast-in-place concrete construction, impact forces are covered under superimposed loads.

6.3.2.3 Up lift forces : Reduction in self-weight due to submerged portions of structure should be considered in the calculations wherever applicable.

6.3.2.4 Superimposed loads

6.3.2.4.1 Superimposed loads shall include the following :

a) Construction personnel

b) Plant and equipment including the impact and surge - Special consideration shall be given to items of plant which cause vibration to formwork such as form vibrators and prestressing equipment.

c) The static load of the moving item should be increased by 25 percent for mechanically operated equipment, and by 10 percent when using manually operated equipment.

d) **Stacking of materials -** This normally occurs from storage of materials such as shutter plates, Reinforcement and concrete making materials on the falsework prior to concreting. Stacking materials on falsework should be avoided. If it is unavoidable, then the maximum permissible load should be accounted for in the design and clearly indicated in the drawings.

e) **Prestressing loads -** The forces and deformation thereof, of the structure associated with prestressing are often transferred to the supporting falsework. Allowance shall be made in the falsework design to accommodate either the force or the movement involved.

6.3.2.4.2 Depending upon seasonal, geographic and construction factors, snow can accumulate and form into drifts on the permanent and temporary works causing additional loading, this loading shall generally be within 0.75 kN/m^2 and only in exceptional case will this loading be exceeded.

6.3.2.4.3 Impact due to deposition of Concrete - This can be due to the deposition of concrete of forms and secondary girders supporting the forms a design UDL of 3.6 KN/m^2 shall be considered.

6.3.3 *Lateral loads :* The lateral loads shall comprise of:

a) Lateral pressure of fresh concrete
b) Environmental loads - wind, water
c) Earth pressures
d) Earthquake forces
e) Any other load not covered in above

6.3.3.1 Lateral pressure of fresh concrete

6.3.3.1.1 The factors affecting lateral pressure on forms are:

a) Density of concrete
b) Rate of placing
c) Vibrating
d) Temperature of concrete
e) Concrete Slump
f) Method of discharge and compaction
g) Width, depth & shape of section
h) Vertical form height
i) Constituent material of concrete like admixtures, aggregate, cementitious material

6.3.3.1.2 The design pressures may be calculated on the basis of standard literature such as CIRIA report (enclosed in Annexure).

6.3.3.1.3 The design pressure for Self Compacting concrete will be different than for the other concretes. Special literature should be referred to for calculating the pressure from such concrete on the formworks.

6.3.3.1.4 In general a minimum value of 20 kN/m²/m height shall be adopted in the design. This value is valid for the rate of rise of concrete of 1.0 m/h at 25ºC and slump 40 mm without admixtures.

6.3.3.2 Environmental loads

6.3.3.2.1 Wind - In view of temporary nature of falsework it may be designed for wind loads as per IS 875 (Part-3)-1987 but with a return period of 5 years.

6.3.3.2.2 Water - Where it is necessary for falsework supports to be placed in flowing water, the effect of the forces caused by the flow shall be considered. These will include-

a) Water current forces with due consideration for scour, turbulent flow during the construction period

b) Flood level occurring during the period of erection and dismantling of temporary work 2 times the calculated scour will be considered.

c) Increased frontal area, and head of water due to trapped debris-

Where there are successive rows of falsework members exposed to flowing water it is possible that some shielding protection is provided to the downstream members by the upstream. The following factors will contribute to the total force being applied to the falsework in the water :

i) The area of obstruction to the water flow presented by the first line of falsework members;

ii) Any further decrease in the width available for the passage of the water as it passes through the falsework.

iii) The increase in obstruction to the flow that would result from the trapping of debris on the faces of the falsework.

6.3.3.2.3 Trapped debris effect

The accumulation of debris will produce a force on the falsework that may be calculated as for that on a rectangular cofferdam. This force is given by the expression :

$$F_d = 666\, A_d V_w^2$$

where,

A_d = Area of obstruction presented by the trapped debris and falsework (in m²)

V_w = velocity of water flow (m/s)

F_d = force in N

This effect will be dependent up on the rate of flow, the amount and nature of the floating debris, the nature of the obstruction and the depth of water.

6.3.3.2.4 Wave action - When falsework is erected in or adjacent to water, it may be subjected to wave forces. In marine locations this is a probability, but elsewhere it is a possibility that should considered. For further information specialist literature may be referred to.

6.3.3.2.5 Earth pressure - Earth pressure shall be calculated as per IRC:6.

6.3.3.2.6 Earthquake forces

Earthquake forces shall be considered for structures in Zones IV and V Load combinations and permissible stresses shall be as per IRC:6. Response reduction factor R shall be as per IRC:6/Table 7 of IS 1893 (Part 1)-2002 and Importance factor (I) shall be taken as 1.0.

6.3.3.2.7 Any other load not covered in above. Other horizontal forces may result in from the following cases and shall be catered for wherever appropriate.

a) Movements of the permanent structures imposed on the falsework due to effects like prestressing operations.

b) External ties and anchorages.

c) Plant and equipment - Horizontal forces may result due to acceleration of plant moving on falsework. The design should allow for a horizontal force in any of the possible directions of movement equivalent to 10 percent of the static load of the moving item.

d) Horizontal forces may develop if the pumped concrete pipe is supported by falsework though surcharge will usually be smaller. The pipes shall be adequately anchored, specially at bends and the effect of blowing out the line pipe shall also be considered.

The additional force due to the concrete pipeline, Fx (in N), applied to the falsework shall be calculated from the expression:

$$F_x = \quad 0.25\ p\ A_x$$

where,

p is the maximum pressure in the pipeline (in N/mm^2).

A_x is the cross sectional area of the pipeline (in mm^2)

The maximum pressure in the pipeline, P, is dependent up on a number of factors but the following pressures are not likely to be exceeded.

5 N/mm^2, for mechanical pumps

0.7 N/mm^2, for pneumatic placers

6.3.3.2.8 Design values of total lateral load : Certain horizontal forces are identifiable and can be calculated but there may be others which may not either be foreseen or estimated. As such, an amount equal to 1 percent of the total design vertical load of falsework in any direction shall be added to the calculated lateral loads to arrive at the design load.

The design value of the total lateral load however shall not be less than 3.0 percent of the total design vertical load. The point of application of the loading may be assumed at the soffit of the formwork.

6.3.4 *Load combinations*

Various combinations of forces which are likely to be applied on the falsework should be taken into account. An indicative typical arrangement of forces is illustrated in Figure below:

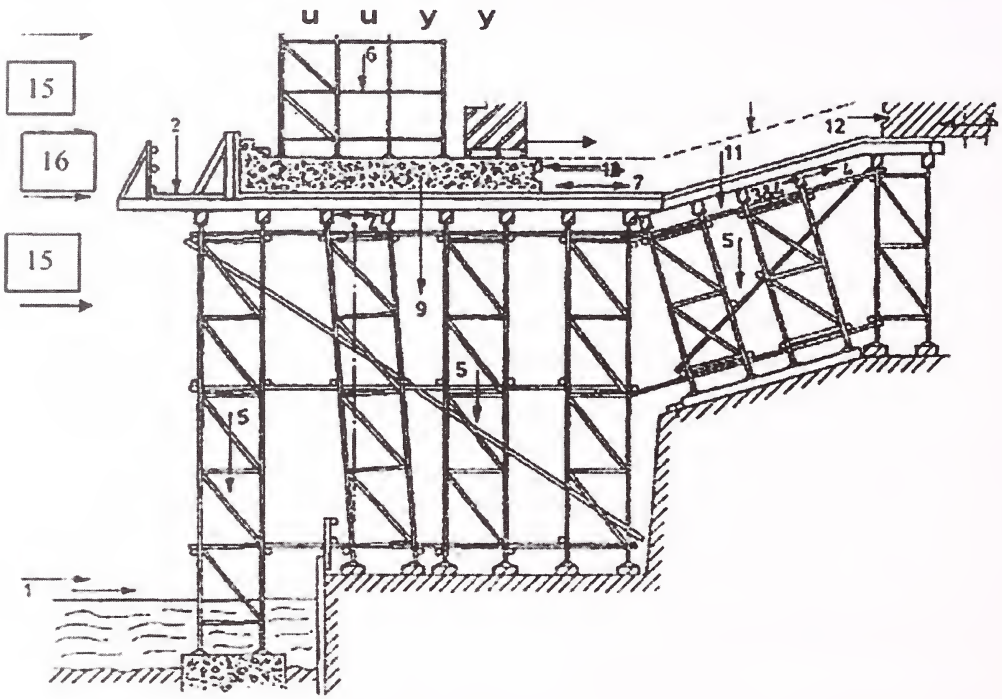

Fig. Typical Force Combinations

Key

1) Water forces
2) Construction personnel
3) Out-of-vertical by design
4) Erection tolerances
5) Self weight of falsework
6) Self weight of later stage of falsework
7) Horizontal friction between concrete and soffit formwork
8) Impact due to motorized bogies/vehicles
9) Weight of already cast concrete
10) Mobile plant load
11) Weight of concrete to be cast

12) Reaction from active concrete pressure against completed work
13) Weight of stacked material
14) Thermal movement forces
15) Wind load on falsework
16) Wind load on formwork

6.3.5 *Permissible stresses*

Basic Permissible stresses shall be taken as below

a) **Timber** - The permissible stresses in timber shall conform to IS 883 or IS 3629.

b) **Steel** - The permissible stresses shall be those as recommended in IRC:24 as appropriate to the steel being used and the use to which it is put.

c) **Tubular sections** - Permissible stresses in tubular sections shall be those as recommended in IS 806.

d) **Masonry** - The permissible stresses shall be those as recommended in IRC:40.

e) **Concrete and Reinforcement** - Permissible stresses shall be as per IRC:21.

f) **Other materials** - Where material chosen is other than those mentioned above, the permissible stresses may be those as recommended by the manufacturer after tests based on relevant material codes. The permissible stresses chosen may also be related to the ultimate strength or to other physical characteristics, and it will be necessary to choose which criteria is critical in light of the form, extent and consequence of any possible failure.

6.3.5.1 Depending upon the condition of the material proposed to be used, suitable reduction factors in the above permissible stresses shall be applied.

6.3.6 *Over-turning*

Factor of safety against over-turning for load combinations other than wind or seismic shall be 1.33 min. For load combinations with wind or seismic or any other exceptional load, same shall be 1.1 min.

6.3.7 *Deflection limits*

In general, the deflection of members in formwork is limited by the tolerances specified for permanent works. In general, the calculated deflection of unsupported areas of form faces shall not exceed 3 mm.

The total deflection shall be such that the maximum dimensional tolerances specified for permanent works in specifications are not exceeded. Where the deflection of the falsework members is greater than permissible tolerances, suitable pre-camber arrangement shall be provided.

6.4 Analysis

6.4.1 *Load transfer systems:* The system which transfers the loads to the falsework shall be examined to ensure that all possible changes in the conditions of load transfer are provided for. Relative deflections between the permanent structure and the falsework including settlement of the foundations may cause high local concentrations of load.

Adjustable or non-adjustable distance pieces, including jacks and similar devices are often used to transfer loads.Capacity of such members shall be checked for a minimum of 3 percent of the vertical load acting horizontally at the load point.

6.4.2 *Special loading conditions:* The design or sequence of construction of the permanent structure may give rise to special, or unusual loading conditions on the falsework. Where this is so, it shall be indicated clearly by the designer/user of such permanent works, so that it may be taken into account in the design of the falsework.

6.4.3 *Reversal of loading:* Reversal of moments and stresses may occur during erection and dismantling of the falsework and shall be accounted for in the design.

6.5 Lateral and Diagonal Bracings

6.5.1 Diagonal bracings in both the longitudinal and lateral directions shall connect the shores or props of the upper and lower bays of the scaffolding tubes at splice or joint as the case may be.

i) The bottom horizontal bracing shall be within 600 mm of the bottom.

ii) Top horizontal bracing shall be within 600 mm from top.

iii) The intermediate horizontal bracings shall be designed to suit the design requirements.

iv) The diagonal bracings shall be at slope between 30º and 60º to the horizontal.

6.5.2 The falsework system shall be designed to transfer all lateral loads to the ground or to completed construction of adequate strength and stiffness in such a manner as to ensure safety at all times. Diagonal bracing must be provided in vertical and horizontal planes for falsework tubes not designed as self standing to provide stiffness and to prevent buckling of individual members. A laterally braced system shall be anchored to ensure stability. Diagonal bracing must be capable of resisting the overturning moment.

6.6 Shores

6.6.1 All shores shall have a firm bearing. Inclined shores shall be braced securely against slipping or sliding. The bearing ends of shores shall be cut square and have a tight fit end splices. Splices shall be secure against bending and buckling. Connections of shore heads to other framing shall be adequate to prevent the shores from falling out when reverse bending causes upward deflection of the forms.

6.6.2 *Timber shores, where used, shall meet the following requirements :*

a) The number of splicing in any shore shall be kept to the minimum. The matching ends of shores to be spliced shall be cut square, for proper seating. Locations of splices should be staggered. The splicing members shall ensure concentric force transfer.

b) All splice fastening shall be adequate.

c) Metal splice pieces of adequate size may be used in place of timber.

d) Lap splice shall be prohibited.

6.7 Proprietary Items

When proprietary forms, shoring or components are used, the manufacturers' recommendations for safe working loads shall be supported by data sheets and test reports for components by an approved testing organization. Necessary details required to be furnished by the manufacturer are given in **Appendix-1**.

6.8 Foundation of Falsework

6.8.1 Where the falsework rests directly on ground, or on permanent structure, it shall be ensured that load is transferred and distributed so as to ensure that total or differential settlements are within acceptable limits. The details of the actual site conditions and the safe bearing pressures for use in the design shall from part of design briefs. Safe bearing capacity of soil shall be arrived based on available data/sound engineering practices.

6.8.2 Falsework supported on permanent structure - Where it is intended to support the falsework on permanent construction, it is essential to determine limitations, if any, which the design of permanent works imposes on the incidence and distribution of load from the falsework. It is essential to determine the strength of the permanent works to receive loading based on the rate of gain of strength and maturity of concrete in the structure. Necessary checks shall be made to ensure the safety of the permanent structure.

6.8.3 Falsework supported on the ground - The loads from the falsework shall be applied to the ground through, distribution members which may be of timber, steel base plate or precast sleepers to ensure proper contact with the ground. Shores of the falsework system shall be centrally placed on the member. These distribution members shall be properly designed for all possible load combinations.

6.8.4 Foundation supports comprising piles or other deep ground insertions shall be designed and installed to specific designs and drawings. Where there is a likelihood of the foundation becoming flooded, foundations shall be designed to safely withstand the direct and indirect consequences of such flooding including scour, undermining or weakening of ground strata.

6.8.5 The slope of the ground can cause stability problems and it is recommended that the slope of the surface on which the falsework rests should not exceed 1 in 6 unless approved by a suitably qualified engineer specializing in geotechnics. The stability of the ground above and below the falsework site should also be considered.

6.8.6 Falsework foundations in general are set at a very shallow depth, compared with those of permanent structures, which brings them within the zone affected by seasonal moisture content changes, frost action, scour, etc. These effects should be duly considered in making investigations as well as in the design.

6.9 Special Requirements for Prestressed Concrete

6.9.1 The structural designer shall indicate special requirements, if any, for prestressed construction. Where required, it may be necessary to provide appropriate means of lowering or removing the formwork before full prestress is applied to prevent damage due to upward deflection of resilient formwork.

6.9.2 The restraint to shrinkage of concrete shall be kept to a minimum and the hogging of members due to prestressing force and the elastic deformation of formwork or falsework shall be considered in the design and removal of the formwork.

6.10 Common Deficiencies in Design

Some avoidable common design deficiencies leading or contributing to failure, are

a) Lack of sufficient allowance in design for special loads as mentioned above.

b) Inadequate/improper shoring.

c) Improper positioning of shores at different levels where high/tall falsework is involved. This may create reversal of stresses.

d) Inadequate provisions (especially where beam hangers are used) to prevent rotation or twisting of beam forms, particularly when slabs frame into them on only one side or slabs of unequal spans frame into beams.

e) Inadequate provision against uplift.

f) Insufficient allowance for unsymmetrical or eccentric loading due to placement sequence.

g) Inadequate design of form ties or clamps.

h) Inadequate protection against scour and effect of Buoyancy where applicable

i) Poor foundation conditions of sites not accounted for in design.

j) Lack of proper adjustment of shims and wedges during concreting.

k) Neglecting horizontal and inclined pressures of concrete on inclined formwork

l) Neglecting concrete buoyancy

m) Not accounting the continuity of the members

n) Omitting dead weight of void forms and Buoyancy effect.

o) Incorrectly assessing the effective length of support towers or struts, or neglecting the possibility of torsion failure.

p) Deformation/extensions of tension components such as ropes , strands, etc. to enable adequate load transfer.

q) Forgetting that the effective weight of anchorages may be reduced by buoyancy when they are set below water table & buoyancy effect. Buoyancy effects on counterweights placed below water table/ flood level.

7 SPECIFICATIONS

7.1 The specifications for different materials used and the item of work shall be the same as given in MORT&H Specifications or relevant IS publication.

7.2 If the specification of a particular item are not available in the above documents then specification provided elsewhere ,if applicable or suitable, may be followed.

7.3 If no specifications are available for a particular item then proper specifications shall be drafted and got approved by the competent authority before starting the work of that item.

7.4 For patented items the specifications as prescribed by the manufacturer shall be followed after verification of test reports and other details.

8 SITE OPERATIONS, PROCEDURAL CONTROLS AND PRECAUTIONS AND INSPECTIONS

8.1 Proper coordination and communication between the design, construction and supervision agencies is needed to be ensured in respect of all aspects of formwork, falsework or temporary structures at site. The preparation and erection of these activities requires the same skill and attention to details as that of the permanent structure. These shall always be regarded as a structure in their own right, the stability of which at all stages of construction is paramount for safety of the permanent structure as well as for the personnel working at site.

8.2 Work on site should be subject to the careful direction, supervision and checks to ensure that the Temporary structures are erected safely in accordance with the agreed design with materials of agreed quality, and the structure is first loaded only when all checks have proved satisfactory and then dismantled in accordance with an agreed sequence and procedure.

8.3 Multiplicity of actions normally is required when Temporary Works are being erected and put into service. Such activities may be widely separated in time and place and it is therefore essential that lines of communication and responsibility are explicit and clearly defined and known to all those involved in the activity. A methodical approach should be adopted and adequate records should be maintained.

8.4 Before starting any activity a comprehensive method statement should invariably be prepared and got approved. The entire team should be briefed about this statement.

8.5 Constant emphasis should be laid upon attention to details.

8.6 For proper planning, implementation, monitoring, coordination and supervision of this activity on major bridge projects a separate person should be identified/appointed as Temporary Work Coordinator. Wherever necessary, he should be supplemented by appointment of Temporary work Supervisors.

8.7 These designated individuals shall be competent and experienced appropriate to the complexity of the project and shall be responsible for establishing and implementing a procedure for the control of all the functions related to these structures to be performed by them for that project.

8.8 The Key Items are :

a) Responsibility for each of the actions set down in this code should be specifically allocated

b) The responsibilities should be clearly defined.

c) All instructions should be clear and complete.

d) Documented records of responsibilities allocated, instructions given and actions taken should be maintained.

8.9 The basic activities for which responsibility is to be allocated and which need to be coordinated and monitored are :

i) The preparation of an adequate design brief including wherever appropriate, establishing of the scheme/concept.

ii) The designs including calculations, sketches, drawings, specifications, risk assessment and where necessary, a designer's method statement for the temporary works scheme.

iii) The independent checking of the design. This should include the definition of the degree of check to be carried out on any design.

iv) The issue of a design/design-check certificate, where appropriate.

v) Preparation of Method statements and Check lists for different activities

vi) The procurement of materials in accordance with the designer's specifications.

vii) The checking of erection, safe use, sequence of loading, dismantling in stages, if required , maintenance and storage in stages where necessary, to ensure compliance with the design and any hold points.

viii) Where necessary, the issue of a formal "permit to load" and a "permit to dismantle" the temporary works.

ix) Management of coordination and monitoring of interfaces between different organizations involved in the related activities and retain an overview of the whole scheme to ensure each step of the procedure is completed and does

not adversely affect the scheme. Details of the interfaces should be included in the construction phase plan.

8.10 It is essential that the persons to whom these responsibilities are allocated to, are given adequate and defined authority to take and enforce decisions.

8.11 The site operations are broadly divided into the operations of erection, concreting/ applications of loads and dismantling.

8.12 All the works at site at different stages shall be done as per the method statement and the compliance check as per checklist.

8.13 The required standards of workmanship shall be explained to all involved and specifically to the less experienced workmen who should also be made to realize the importance of this activity.

8.14 Following points require particular attention during erection and before loading:

i) Whether the assumed design loads and sequences are compatible with the actual conditions at site.

ii) The field practice follows the working drawings/instructions from the designer. Any changes found necessary shall be effected in consultation with all concerned.

iii) Whether the formwork has not deteriorated and is still in accordance with the design.

iv) The foundations for the formwork are adequate in respect of scour conditions, bearing capacity and settlement characteristics.

v) Suitable precautions as necessary to guard against excessive storage of materials on a recently formed deck before it starts acting as self-supporting structure.

vi) Partially erected formwork is not left in place without proper support,

vii) Whether the wedges are of sufficient height to allow raising the forms to the required position. Wedges shall be used only at one end of a prop.

viii) For night construction, adequate, lighting facilities shall be provided. If electric wires are used these should be duly protected and insulated,

ix) All Construction equipments like cranes, hoists etc. shall only be operated by trained and experienced staff.

x) No distribution members (i.e. footing) shall be founded over ground (either partially or fully) which has previously been excavated locally and backfilled without proper precautions,

xi) Edges subject to erosion such as the edges of slopes and terraces shall be protected against eroding forces.

xii) Any rock outcrops, buried rocks or obstructions which are uncovered and not indicated on the drawings shall be reported to the designer as they can result in differential settlements,

xiii) All foundation members shall be set level,

xiv) Splicing of timber shall be done with the help of MS bolts and nuts.

xv) In respect of proprietary components, the manufacturer's recommendations shall be rigidly adhered to.

xvi) All the minor details, even of the smallest connections have been examined to be properly fastened. The thorough checking of work has been done and all precaution to achieve desired workmanship have been taken. It is possible that the omission of a bolt or ineffective fixing of securing devices or the failure to tighten up an item properly, may lead to local instability which might place the whole structure in jeopardy.

xvii) All bearing points and lifting points are identified.

xviii) Inserts, void formers and cast-in fixings are properly positioned and secured. Props supporting formwork having out of plumb alignment and runners located eccentrically in prop heads seriously reduce their load carrying capacity even in proprietary systems.

Props shall be checked for verticality.

xix) Proprietary formwork support system shall specify safe working loads and factors of safety at specified tolerances. They shall indicate whether the information given is based on the yield or on the collapse value of the unit and whether the values given are based on calculations or actual tests. The recommended safe working loads shall not apply to any prop in defective condition or to any prop erected outside the specified tolerances. Factor of safety for the first use shall not be less than 2 (with capacity calculated based on yield stress) and may be increased suitably for subsequent use.

xx) Normal tolerances shall be such that no runner shall be placed with its center-line more than 25 mm eccentric to the center of the prop head or no prop shall be erected more than (1 in 40) out of plumb. In case any of the following defects, prop may be set aside, discarded or returned to workshops or deport for attention or scrap.

xxi) The following or similar types of defective parts shall not be used.

a) Members with a bend, crease, dents or any noticeable lack of straightness.

b) Members with more than superficial corrosion.

c) A bent head or base plate.

d) An incorrect or damaged connecting pin.

xxii) Where a shutter vibrator is used, a step down transformer shall be provided to lower the voltage for the safety of the workers

8.15 The check list in general shall cater to the following functions and areas.

i) The structure is in accordance with detailed drawings;

ii) The structural dimensions are within agreed tolerances;

iii) The foundations are adequate and fully bedded;

iv) The verticals are true.

v) Bracings and ties are provided and properly connected;

vi) The component materials are free from defects;

vii) The planned sequence of concreting is fully understood and appreciated, including placement of concrete in layers.

viii) Facilities shall be provided to the safety supervisor in exercising his normal functions;

ix) The falsework shall be maintained in a serviceable state until rendered redundant by the maturity of the concrete;

x) In case the timber posts need to be spliced the ends made square to butt against each other.

xi) The splicing has been done with timber plates and using proper nuts and bolts?

xii) Suitable cleats have been provided at crossing or junctions of any two members?

xiii) Proper lateral supports of scantlings have been given to the vertical faces of the webs of beams?

xiv) Every individual beam supported independently right up to the ground level?

xv) Weep holes or vibrator holes, clean out holes and temporary openings for placing concrete upto height of opening and inspection windows are provided?

xvi) Safe scaffold platform is available for workmen to reach forms?

xvii) Fittings for form vibrators are provided?

xviii) Adequate lighting arrangements have been made, if required?

xix) Requirements of safety regulations have been met with at the work area?

8.16 Points to be seen before and during concreting operations and the application of loads are as follows :

i) Whether proper permission to commence the placement of concrete has been accorded?

ii) Whether the reinforcement and falsework have been checked?

iii) Whether the forms are clean and free from wood-shavings, grit etc.?

iv) Whether release agent to form surface has been applied? This should be avoided for concrete surfaces to be plastered. On such surfaces whitewash is desirable. If release agent is applied it should be checked that this is not applied or splashed carelessly on the reinforcement or pre stressing tendon and anchorages.

v) Where camber has been provided, the free (top) surface of the concrete should never be finished flat but should also be cambered to the same extent as the form i.e. the thickness for any element shall be maintained.

vi) Whether all forms are water/slurry tight?

vii) Whether the sequence and rate of concreting, that is of placement is as per the design brief?

viii) Whether all precautions have been taken to prevent accidental impact and scouring/flooding of foundations in case of river bridges?

ix) Whether adequate precautions have been taken to keep unnecessary materials away from the falsework?

x) Whether adequate access ramps etc. in the correct positions have been provided for the smooth flow of men, materials and machines?

xi) Whether the forms are in the correct position in space and adequately braced to remain there and the forms are dimensionally accurate to produce finished concrete of the required dimensions?

xii) The props and bracing shall be watched during the placement of concrete and the vibrations. Any members which may tend to get loose or wedges which get shifted should be attended to.

xiii) System of communication between the man in charge of formwork and the man in charge of concreting operations should be established so that concreting can be stopped instantly if at all it becomes necessary to do so.

xiv) Platforms for the movement of workers and mechanized concrete buggies (used in large works) shall be separated. It should not place load upon the reinforcing steel. If this is unavoidable, steel chairs shall be placed under the reinforcement at adequate spacing to prevent deformation of the reinforcement.

xv) Arrangements for field adjustments and constant inspections of forms, shores and foundations during placing of concrete both by supervising as well as construction agency to be ensured (to stop leaks, tightening wedges and clamps, to adjust shores and for timely action against disturbances, etc).

xvi) Adequate standby equipment should be available.

8.17 Removal/Dismantling of Formwork

i) The timing of formwork removal is a very important subject. For efficient use of formwork, it is important to have options that allow them to be removed as soon as possible without jeopardizing the structure's safety or damaging the edge of concrete surfaces. But not before the concrete has reached a strength at least twice the strength to which the concrete may be subjected at the time of removal of formwork or as decided from design considerations. The strength referred to shall be that of concrete using the same cement and aggregates with the same proportions and cured under conditions of temperature and moisture similar to those existing on the work where possible. Proper precautions shall be taken to allow for the decrease in the rate of hardening of concrete occurring during cold weather.

ii) The dismantling plan prepared at the time of design or before the start of construction should be strictly followed.

iii) The procedure for Formwork removal for concrete wall, sides of beams and columns will also be controlled by the possibility of damaging the concrete while removing the forms and not simply by the concrete's capacity to withstands its own weight.

iv) All the factors, like temperature, age and admixtures used, that can affect concrete strength shall be considered for calculation of stripping time.

For the formwork removal the stripping time can be determined by the use of any reasonable method.

The number of props to be left under, their sizes and disposition shall be such as to be able to safely carry the full dead load of the slab, beam or arch, as the case may be, together with any live load likely to occur during curing or further construction.

v) Falsework shall be gradually and uniformly lowered in such a manner so as to avoid any shock or vibration or injurious stresses in any part of the structure.

vi) Immediately after removal of the formwork, the concrete shall be carefully inspected. Defects if any, shall be made good as soon as practicable.

vii) Where the side shutter also support the flange of the T-Beam, such shutter shall be removed only after the flange concrete attains sufficient maturity.

viii) For pre-stressed units, the vertical side forms shall be released as early as possible and the soffit forms shall permit without restraint deformation/ shortening of the member when pre-stress is applied.

Form supports and soffit forms for cast-in-situ members shall not be removed until sufficient pre-stress has been applied to carry the dead load, any formwork supported by the member and anticipated construction loads.

ix) Records of checks carried out should be maintained.

Checking shall be done timely. Such checking shall be based on a system concept with check lists suitably standardized.

8.18 Common Fault and Causes

The following faults are generally noticed during construction. The possible reasons are indicated against each so that these points may be checked , investigated and corrective measures taken promptly-

Fault	Possible Design Deficiency	Possible construction deficiency
Dimensional Inaccuracy	Excessive deflection	Metal locking devices not tight enough in column or beam clamps

Joints opening and deflection of forms	Supports too far apart or section of support members too small	Forms filled too rapidly
	Incorrect or insufficient ties	Vibration from adjacent loads
	Bearing area of plate washers or prop heads/base plates too small	Insufficient allowance for live loads and shock loads
	Insufficient column or beam clamps. Failure to provide adequately for lateral pressures on formwork	Void formers and top forms floating due to insufficient fixing/anchoring
	Insufficient allowance for incidental loadings due to placing sequences	Plywood not spanning in the directions of its greater strength
	On cantilever soffits, rotational movement and elastic deformation of system	Use of lower strength class members than designed
		Change of concrete pressure by use of retarders etc;
Lifting of single faced forms	Forms not adequately tied down to foundations to resist uplift forces generated by raking props	Ties not tight enough. Ties omitted. Forms filled too rapidly. Vertical forms not bolted to bottom shuttering
	During Placement of Concrete	Wedging and strutting not adequately fixed
General	Props inadequate. Failure to provide adequately for lateral pressures on formwork	Failure to regulate the rate of sequence of placing concrete
	Lack of allowance in design for Various factors/eccentricities	Failure to inspect formwork during and after placing concrete
	Inadequate provision of support to prevent failure rotation of beam forms	Insufficient nalling, Screwing/Boltings
		Inadequately tightened forms or wedges
		Premature removal of supports, especially under cantilever sections
		Use of defective materials

8.19 Precaution to be taken

Precautions to be taken at various stages are given below for normal type of projects. Additional precautions shall be taken for complex projects as per requirements.

S. No.	Stage	Precautions
1)	Design of Permanent Structure	• Design assumption shall be realistic and commensurate with field conditions • Design assumptions, design constraints, sequences to be followed etc, shall be clearly spelt out in the notes on drawings • Effect of loads of the temporary structures as well as effect of sequence/stages of construction on the design of permanent structure shall be taken into account
2)	Design of Temporary Structure	• Design for all the components shall be done as per design brief • Mixture of different systems shall be avoided • Mixture of old and new parts shall be avoided • Constraints, assumptions etc. from the design of permanent structure shall be taken into account • Necessary field investigation to assess foundation conditions, ground profile etc. shall be carried out and data used in design • Likely eccentricities in loading provided for
3)	Fabrication	• Designs shall be prepared using commercially available sections • Detailing of the structural members must take into account fabrication sequence and practices • Thick rolled sections, generally more than 20 mm, may be avoided if possible to eliminate failures due to possibilities of lamination in the sections • Wherever falsework have been made into various pieces then these should be properly match numbered on both sides so as to facilitate their erection at the time of use

		• Date of the fabrication/manufacture be marked on each components
4)	Erection	• The scheme of erection of temporary structures must be made to suit the site conditions and availability of equipment
5)	Dismantling and Shifting	• Dismantling scheme shall be specified • Scheme of dismantling shall be taken care of in the design detailing • Dismantling sequence shall be specified whereever critical
6)	Storage for Reuse	• Various systems and their parts shall be suitably marked/numbered and stored in a proper manner for easy identification at later stage. Appropriate register shall be maintained for purpose of reference • Steel structures shall be stored above ground level • Protective coatings shall be applied to steel members to prevent corrosion All the parts and systems which have been stored shall be properly maintained. These shall be thoroughly inspected and checked before these are re-used

8.20 Inspections

8.20.1 All the activities related to the Formworks, Falsework or Temporary structures shall be properly inspected by the Temporary Works Coordinator or supervisory staff authorized by him, at different stages of work to insure that the work is being done properly and safely with all due precautions as enumerated above after checking the compliances with the help of Checklists. The formal inspections are required at following stages :

a) Before the start of work to check or confirm the site conditions, hydraulic and geotechnical conditions and other data related to erection of formwork.

b) Preparation of founding level for falsework.

c) When Falsework attains a height of 10 m or height equal to 1.5 times the minimum of plan dimensions.

d) When Falsework reaches its highest level.

e) At Intermediate stages, when the strength or stability of the falsework may have adverse effects by environmental or other loading conditions.

f) Immediately prior to loads being transferred

g) After the concreting is completed

h) During dismantling and immediately after removal of formworks

i) Before storing and before reuse

j) Immediately after any failure is reported

8.20.2 During concreting operation some skilled/trained worker or supervisor should watch and observe centering to notice if there is any warning or indication of likely failures. In the event of such signs of distress prompt action should be taken to bring to the notice of Temporary Works Coordinator or Supervisor to address and rectify the causes immediately to prevent collapse.

Table 8.1 Check List for Falseworks/Temporary Structures

Check list shall be prepared for different stages and operations as described above, in a tabular form and adopted for verification of erected/assembled temporary structures in the field. Typical format for one of the checklist is given below :

Job Name : _____

Portion to be Checked _____

Name of Engineer/Supervisor carrying out check _____

Drawing Ref. No. _____

Date and Time _____

Sr. No.	Item	Checked	Remark
1)	Ground below supporting system is having required S.B.C.		
2)	Vertical members used (a) Are as per drawing, (b) Are spaced as per drawings, (c) Are not bent/ deformed and are in plumb, (d) Bracings are provided as per drawings.		
3)	Horizontal members (a) Sizes are provided as per drawing, (b) Spacing is as per drawing, (c) Connection to vertical members is as per drawings, (d) Members are not distorted, (e) Horizontal members are seated uniformly on vertical members.		
4)	Load release mechanisms (like jacks/wedges) is provided		
5)	(a) Bottom forms provided are true to required line and level, (b) Pre-camber (if required) is provided, (c) Joints in forms are made leak tight (d) Adequate no. of Joint bolts are provided.		

9 CAUSES OF FORMWORK FAILURES AND POST FAILURE INVESTIGATIONS

Some of the causes for failures have been observed as follows

9.1 Inadequate Bracing Leading to Instability

a) The more frequent causes of formwork failure are the effects that induce lateral force components or displacement of supporting members. Inadequate cross bracing/diagonal bracing and horizontal bracing of shores is one of the factors most frequently involved in formwork accidents.

b) High shoring with heavy load at the top is vulnerable to eccentric or lateral loading. Diagonal bracing improves the stability of such a structure.

c) When a failure occurs at one part, inadequate bracing may permit the collapse to extend to a large portion of the structure and multiply the damage. Adequate bracing will prevent a minor accident or failure from becoming a disaster.

9.2 Vibrations

Forms sometimes collapse when their supporting shores, wedges or jacks are displaced by vibration caused by:

- Passing traffic
- Movement of workers and equipment on the formwork
- The effect of vibrating concrete to consolidate it
- Diagonal bracing can help prevent failure due to vibration

9.3 Vertical Members Not in Plumb

Vertical members must be set plumb to avoid eccentric loading which may lead to failure.

9.4 Unstable Soil Under Mudsills, Undermining or Scouring Under Supports

Formwork should be safe if it is adequately braced and constructed so that all loads are carried to solid ground through vertical members. The ground must be able to carry the load without permissible settlements.

Shores and mudsills must not rest on uncompacted ground; moisture and heat from the concreting operations, or changing air temperatures, may thaw the soil and allow settlement that overloads or shifts the formwork.

Site drainage must be adequate to prevent a washout of soil supporting the mudsills.

9.5 Inadequate Control of Concrete Placement

The temperature and rate of increase in height of concrete are factors influencing the development of lateral pressures that act on the forms.

If temperature drops during construction operations, rate of concreting often has to be slowed down to prevent a build up of lateral pressure overloading the forms. If this is not done, formwork failure may result.

Failure to regulate properly the rate and order of placing concrete on horizontal surfaces may produce unbalanced loadings and consequent failures of formwork.

9.6 Lack of Attention to Formwork Details

9.7 Improper Stripping and Shore Removal

Premature stripping of forms, premature removal of shores, and careless practices in re-shoring can cause failures.

9.8 There are some other Causes which can Cause Failure :

i) External causes like earthquake tremor, untimely floods and hailstorm etc.

ii) Defective centering structures and joints

iii) Unsuitable foundation support like earthen embankment

iv) Subsoil flow in sandy bed

v) Wrong sequence of construction or unbalanced horizontal forces as in arches

9.9 Post-Failure Investigations

The purpose of the false work failure investigation is to determine the reasons for failure and to collect data and carryout analysis to provide suggestions on preventing its recurrence. The following steps may be followed :

i) The failure site should be inspected immediately by the Temporary Works Coordinator or his authorized representative to ascertain by visual methods the probable cause of failure, such as, hydraulic, geotechnical, improper materials, design deficiency, erection or construction faults or supervision negligence etc.

ii) The area should be cordoned off and all safety precautions be taken immediately so that no further damage is done.

iii) An investigating team should be constituted to look into the matter which should preferably consist of a representative from design, supervision staff for the work and from the overall project management staff.

iv) The team should collect all the relevant data, consult records and drawings etc., take photographs, collect samples, test and investigate as may be necessary for the purpose and prepare the report giving detailed findings, lessons learnt, further precautions to be taken and preventive or remedial measures to be adopted.

10 SPECIAL FORMWORKS

10.1 Slipforms

10.1.1 *General*

Slipforms can be used for vertical structures, such as beams, piers and wells etc. These forms are usually moved by jacks riding on steel rods or pipes embedded in or attached to

the hardened concrete. The movement of forms may be continuous process until the structure is completed or in a phased sequence of finite placements.

Slipforms shall be designed, constructed and the sliding operations carried out under the supervision of persons experienced in slipform work.

Jacking rods or pipes may be left in place or withdrawn as conditions permit.

The design of the yokes must provide for adequate clearance to install horizontal reinforcing bars and embedments.

Forms shall be of about one meter height and may be of timber, plywood or steel. Special care must be taken in building the forms and arranging the jacks so that the forms will draw straight without twist.

Forms shall be constructed with a slight batter so that they will be self-clearing as they slide. A range of 6 mm to 8 mm in a height of 1 m of form is indicative of current practice.

10.1.2 *Sliding operations*

The sliding speed is determined by the rate of setting and hardening of the freshly placed concrete, the rate at which the concrete can be supplied, placed and compacted, and the rate at which reinforcement steel can be supplied and fixed. When using ordinary Portland cement, the average sliding speed is in the range of 150 mm - 300 mm per hour.

Alignment and plumbness of the structure shall be checked at the beginning and at least once in eight hours of operation.

10.2 Travelling Forms

10.2.1 Travelling forms consist of formwork mounted on moveable frames or scaffolding called travellers. After the purpose of the formwork is served at one section of the structure, the forms are released and moved along the structure to the next section to be concreted.

10.2.2 Travelling forms are suitable for many types of bridges particularly where a number of repetitions are involved. These forms can be used both for members of constant cross-section and variable cross-section.

10.2.3 Each set of forms and travellers shall be designed for the particular job. Forms are attached to the traveller mounted on wheels, skids, etc. Jacks are generally used for de-shuttering and for adjustment to profile at the next section.

10.2.4 Travelling cantilever formwork for cantilever bridges is a particular example of use of travelling forms for bridge deck construction. Such formworks, because of their importance and large loads involved, are designed with the same care as that for a permanent structure.

10.2.5 Cantilever formwork eliminates falsework all together. The deck is constructed as a series of segments progressively cantilevering out of the pier. The forms are suspended from a structural frame anchored to the already concreted segment of the deck and cantilevering out to sustain the forms for the next segment.

10.2.6 The cantilever forms shall be so arranged as to facilitate continuous concreting of the entire segment in one operation. Necessary provision shall be made to enable adjustments in profile to cater to the camber requirements of the bridge deck.

10.3 Caissons

General:

A hollow structure generally fabricated of structural steel having the dimension of the permanent foundation like well that forms part of permanent foundation. Though it generally forms part of the permanent structure it is not accounted for in the strength evaluations of the foundation. Caissons are generally circular but may be rectangular in some cases.

It generally is a floating steel structure, fabricated on the shore/bank/floating barge, and then lowered in water either by sliding or lifting. It is towed to the location and sunk with ballast added at its final location.

Height of Caisson:

While designing the caissons a detailed study for the various stages of construction shall be carried out. The height of caissons at any given time shall be such that the C.G of the completed stage shall always be below the top level by at least equal to diameter or smaller plan dimension of the structure. The first stage construction is very critical as the triangular shaped curb reduces the stability and hence this stage shall be planned for required height till the time the C.G. is lowered by concreting of the structure. The fabricated structure shall be checked against leakage at joint locations before floating. The structure shall be held in position against untoward movement by wire ropes/chains, etc. using winches mounted on stationary suitable platforms/ buoys or like anchoring systems. Anchoring in minimum three directions shall be provided to prevent unacceptable longitudinal and lateral movement. The system shall permit a small movement until the stage when the foundation is just getting grounded. Special care is necessary where variation in water level is frequent, e.g tidal zones.

Height of cassion shall be planned to ensure that at any given time, at least one meter of the shell shall be above water level of river. In case location has waves, the height shall be suitably increased to avoid water spilling in to caisson . In sandy/clayey soil, generally 3 to 5 meters of additional height shall be built as it may sink after grounding in bed even before the ballast is provided. Simultaneous sinking and concreting is required to prevent cassion from tilting. In sandy stratum especially with strong water current the bed is likely to scour locally when the caisson nears the bed and even after grounding has taken place. Appropriate additional height of caissons is necessary for this condition.

Design:

The shell shall be designed for water pressure from differential head, water current forces, wet concrete etc. it is likely to be subjected to. The minimum thickness of plate used shall be 4 mm for external face and 3.15 mm for internal face. Thickness of plate shall be increased for corrosion allowance if exposure conditions are severe, at alternate wetting and drying zone, subject to 1mm minimum. The plates shall be stiffened using suitable structural elements. Bracings both in transverse and vertical shall be provided . A minimum element of 50 x 50 x 6 angle or equivalent is recommended. Anchorage points and any other locations where concentrated loads are expected shall be locally strengthened suitably. All joints shall be continuously welded and shall be leak tight. The joints of shell shall preferably be located at the face of stiffeners so that proper welding is achieved. In critical locations where no stiffener support is available, use of 100 mm wide, 3.15 mm thick cover plate is recommended at such joint locations.

Precautions:

1) Stability of caissons during sliding into water, in floating condition, during transportation and during lowering in position shall be checked.

2) The anchorage of the caissons shall be designed for the maximum water current and wave effects expected with factor of safety of 3 minimum.

3) A dewatering pump of adequate capacity shall be provided at caisson location for emergency or routine leakage.

4) The anchorage ropes shall have adequate slackness to allow vertical movement of shell in tidal zones till grounding operations.

5) Very large size caissons may be provided with compartments so that in the event of any damage of shell, the quantity of gushing water is controlled.

Note: This Chapter is to be elaborated to include different types of special formworks and falseworks or temporary structures such as cofferdams, floating barges, access bridges, high rise platforms, launching girders, trolleys, casting yards etc, including the specific or additional design requirements, if any.

11 SAFETY, HEALTH AND ENVIRONMENT REGULATIONS AND LEGISLATION

11.1 A comprehensive Safety, Health and Environment Management Guide/Manual should be prepared at all construction sites and be a part of the Contract Documents.

This should define the principal requirements of the Safety, Health and Environment Management associated with the Employer , Contractor/Sub-Contractor and any other agency to be practiced at construction worksites at all time to ensure that adequate precautions are taken to avoid accidents, occupational illness and harmful effects on environment during construction.

11.2 The document should cover all the requirements and compliance of the Local and National Acts and Regulations on these aspects and ensure conformity to the guidelines given in OHSAS18001-Occupational Health and Safety Management System and ISO 14001-Environmental Management Systems.

11.3 Major part of safety concerns at any construction site is related to the preparation, erection, dismantling, launching, lifting, floating equipments etc. for formwork, false work and also the temporary structures. The Safety, Health and Environment Guide/Manual should adequately address all the issues related to them.

11.4 All and adequate measures should be taken for safe and sound construction. To ensure safety sufficient precautions should be taken, all investigations be done thoroughly, design and erection and dismantling should be as per design brief, all systems and procedures should be tested and calibrated, and all regulations should be strictly followed.

11.5 A system of conducting Safety, Health and Environment inspections and other risk management analysis on a periodical basis will be evolved and administered. All required Safety Inspection Check lists for all activities, operations and equipments conforming to Indian Standards, Rules and Regulations and Employer's requirements, shall be prepared and implemented.

11.6 In India Safety and Health aspects at work or during construction are not adequately regulated by any Rules or Acts as in some other Countries. There is need to identify the scope of such acts to cover all the Safety and Health aspects by regulatory Acts through legislation so that the careless and negligent attitude and approach of construction agencies towards this important issue is curbed and lots of accidents and failures occurring on almost all the construction sites could be avoided.

11.7 The Regulations and Acts need to cover the following aspects during construction:

1) Safety and Health in Construction

2) Work at Height

3) Lifting Operations and Lifting Equipments

4) Personal Protective Equipment at Work

   i) Head Protectlon (Safety Helmets)

   ii) Foot Protection (Safety footwear, Gumboot. etc.)

   iii) Body protectlon (High visibility clothing (waistcoat/jacket). Apron, etc.)

   iv) Personal fall protection (Full body harness. Rope-grap fall arrester, etc.)

   v) Eye Protection (Goggles, Welders glasses, etc.)

   vi) Hand Protection (Gloves. Finger coats, etc.)

   vii) Respiratory Protection. (Nose mask, SCBAs. etc.)

   viii) Hearing Protection (Ear plugs, Ear muffs, etc.)

5) Provision and use of Work Equipment

6) Construction (Design and Management)

7) Risk Assessment

8) Failures and Accidents Management

9) Environmental Management

10) Other controls for the specific requirements of the project

11.8 If the above aspects are not covered by the existing available Rules, Regulations and Acts, these shall be prepared and included in the Safety, Health and Environment Guide/ Manual.

11.9 Adequate number of trained and experienced personnel to be headed by a Safety, Health and Environment Supervisor/Manager/Coordinator, shall be identified and made responsible and accountable for ensuring compliances of all the Rules, Regulations, Acts and Manual and implementation of all the systems, procedures, inspections, checking and reporting etc.

11.10 The Safety, Health and Environment Supervisor will keep constant liaison with the Temporary Structures Coordinator and Supervisors to ensure that all activities related to Formwork, Falsework and Temporary Structures are carried properly and safely.

Appendix–1

(Clause 6.7)

Information to be Supplied by Manufacturers of Proprietary System

A-1 General

A-1.1 The information which the manufacturer is required to supply shall be in such detail as to obviate unsafe use of the equipment due to the intention of the manufacturer not having been made clear due to wrong assumptions on the part of the user.

A-1.2 The user shall refer unusual problems of erection/assembly not in keeping with the intended use of the equipment, to the manufacturer of the equipment.

A-2 Information Required

A-2.1 The manufacturers of proprietary systems shall supply the following information:

a) Description of basic functions of equipment.

b) List of items of equipment available, giving range of sizes, spans and such like, with manufacturer's identification numbers or other references.

c) The basis on which the safe working loads have been determined and whether the factor of safety given applies to collapse or yield.

d) Whether the supplier's data are based on calculations or tests. This shall be clearly stated as there may be wide variations between results obtained by either method.

e) Instructions for use and maintenance, including any points which require special attention during erection, especially where safety is concerned.

f) Detailed dimensional information, as follows:

   i) Overall dimensions and depths and widths of members.

   ii) Line drawings including perspectives and photographs showing normal uses,

   iii) Self weight.

   iv) Full dimensions of connections and any special positioning arrangements.

   v) Sizes of members, including tube diameters and- thicknesses of material.

vi) Any permanent camber built in to the equipment,

vii) Sizes of holes and dimensions giving their positions,

g) Data relating to strength of equipment as follows:

i) Average failure loads as determined by tests.

ii) Recommended maximum working loads for various conditions of use.

iii) Working resistance moments derived from design calculations and tests.

iv) Working shear capacities derived from design calculations and tests.

v) Recommended factors of safety used in assessing recommended loads and deflections based on design calculations and test results.

vi) Deflections under load together with recommended pre-camber and limiting deflections.

vii) If working loads depend on calculations, working stresses should be stated. If deflections depend on theoretical moments of inertia or equivalent moments of inertia rather than tests, this should be noted,

viii) Information on the design of sway bracing against wind and other horizontal loadings.

ix) Allowable loading relating to maximum extension of bases.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)