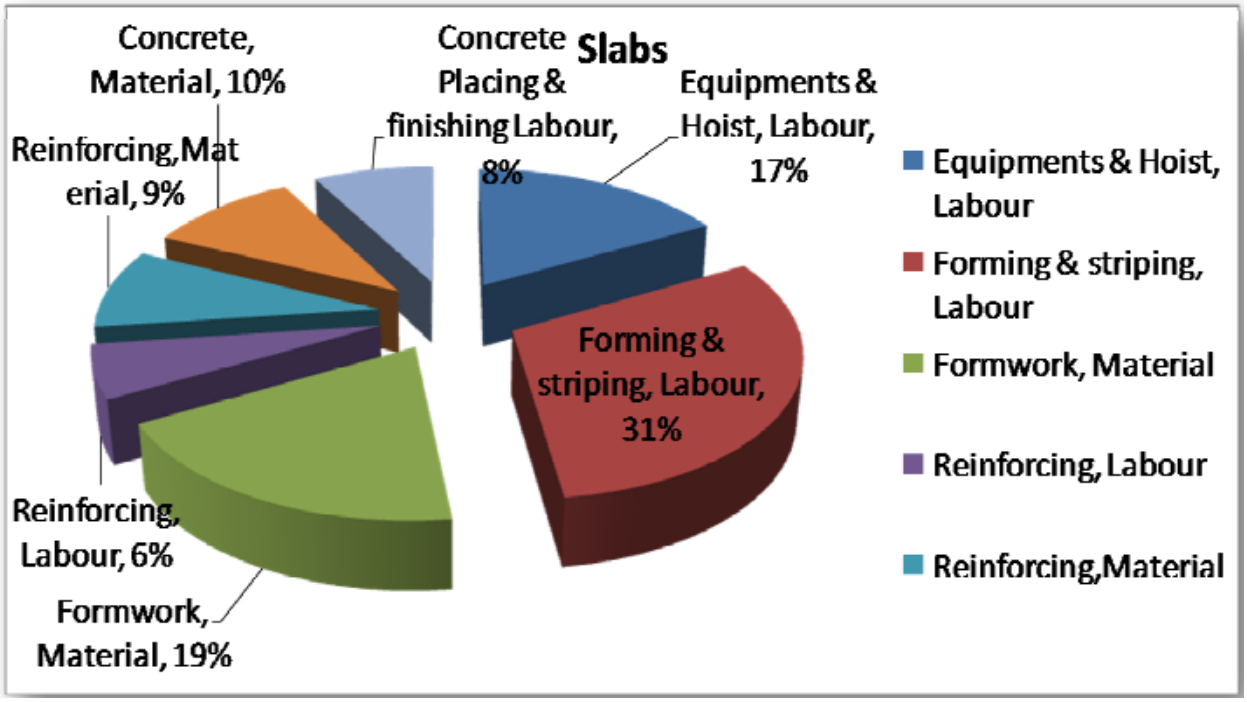
CONTENTS

1. INTRODUCTION

- **Formwork**, sometimes known as **shuttering** or **casing**, is the boarding or sheeting which is erected to contain and mould the wet concrete during placing and the initial hardening period.
  - **Formwork** is a temporary structure that is required to support and form concrete members.
  - **False work** is the complete structure erected to support the wet concrete.
- In most of the project formwork activity accounts for 30% to 60% of the cost of the concrete skeleton and extends 40% to 60% of the total project duration.
- Proper selection of formwork has greater influence:
  - On reducing materials and labor cost,
  - Improving the quality of the produced concrete and
  - Saving time leading to smooth running of the projects.

- **TYPICAL COST BREAKDOWN OF CONCRETE SLABS**



2. REQUIREMENTS OF A GOOD FORMWORK

BASIC OBJECTIVES

i. **Quality**
- Desired size, shape and finish of the concrete is achieved.

ii. **Safety**
- Capable of supporting all dead and live loads without collapsing or danger to workmen and to the concrete structure.

iii. **Economy**
- Efficient, saving time and money for contractor and owner

- A good formwork should satisfy the following:
  - i. it should be strong enough to withstand all types of dead and live loads such as:
    - Self weight,
    - Weight of reinforcement,
    - Weight of wet concrete,
    - Loads due to workmen,
    - Construction equipment,
    - Other incidental loads and forces caused by placement and consolidation of concrete imposed upon it during and after casting of concrete.
  - ii. It should be rigidly constructed and efficiently propped and braced both horizontally and vertically so as to retain its shape without undue deflection.
  - iii. The joints in the formwork should be tight against leakage of cement grout.
  - iv. It should be constructed in such a manner that it may permit the removal of various parts in desired sequence without damaging the concrete.
  - v. The material of the formwork should be cheap, easily available and should be suitable for reuse several times.
  - vi. It should be set accurately to the desired line and levels and should have plain surfaces.
  - vii. It should be as light as possible.
  - viii. The material of formwork should not warp or get distorted when exposed to sun, rain or water during concreting.
  - ix. All joints of the formwork should be stiff so that lateral deformation under loads is minimum. Also the joints should be leak proof.

- A good formwork should satisfy the following:
  - Containment;
  - Strength ;
  - Rigidity;
  - Tightness;
  - Good alignment;
  - Surface finish;
  - Durability;
  - Resistance to leakage;
  - Accuracy;
  - Ease of handling;
  - Finish and re-use potential;
  - Access for concrete;
  - Economy, and
  - Ease of stripping and economy.

3. MATERIALS FOR FORMWORK

- Formwork can be mainly made up of
  - ***Timber,***
  - ***Plywood,***
  - ***Steel***
  - ***Aluminium***
  - ***Precast concrete or fibreglass***, used separately or in combination.

TIMBER FORMWORK

- The timber used for the formwork should satisfy the following requirements:
  - It should be well seasoned,
  - It should be light in weight,
  - It should be easily workable with nails without splitting, and
  - It should be free from knots.

TIMBER FORMWORK

- Timber used for shuttering exposed concrete work should have smooth and even surface on all faces, which are to come in contact with concrete.
- In situations where concrete surfaces are not exposed, as in the case of foundations, undressed timber can be used to reduce cost.

PLYWOOD FORMWORK

- Use of plywood instead of timber planks is getting popular these days.
- Resin bonded plywood sheets are attached to timber frames to make up panels of required sizes.
- Ensures quality surface finish and is especially recommended in works where large exposed areas of the concrete are to be constructed such as floor slab, faces of retaining walls, etc.
- Generally, the number of reuses of plywood formwork is more as compared with timber shuttering.

STEEL FORMWORK

- This consists of panels fabricated out thin steel angles.
- The panels can be fabricated in large numbers in any desired modular shape or size.
- Although steel shuttering costs more initially, it may work out to be economical in the long run due to its large number of reuses of the same shuttering.
- The advantage of steel formwork over timber formwork include:
  i. It is stronger, more durable and have longer life as compared with timber forms
  ii. It can be put to sufficient large number of reuses, as high as 100 cycles.
  iii. It can be installed and dismantled with greater ease and speed.
  iv. The quality of exposed concrete surface obtained by use of steel form is excellent and most of the time it need no further treatment.

STEEL FORMWORK

  v. There is no danger of the formwork absorbing water from the concrete and hence the chances honey combing are minimised.
  vi. They are not liable to shrink or distort an hence it is possible to achieve better workmanship and higher accuracy by use of steel forms.

ALUMINIUM FORMWORK

- Enables the walls and slab to be placed monolithically in the same operation
- Consistent concrete shapes and finishes are obtained
- The smooth finish of the concrete greatly reduces or eliminates the need for costly plastering.

4. FACTORS AFFECTING SELECTION OF FORMWORK

- Formwork for building nearly account for 25% of RCC work.
- Selection of formwork material to be used should be based on maximum economy to the contractor consistent with safety and quality required in the finished work.
- Proper selection of formwork has greater influence:
  - On reducing materials and labor cost,
  - Improving the quality of the produced concrete and
  - Saving time leading to smooth running of the projects.
- Factors to be considered at the time of selection :
  - Strength
  - Economic use
  - Ease of handling, erection and dismantling
  - Ability to form the desired shape
  - Concrete quality and finish required
- For a given set of circumstances and as a result of certain specific requirements each material may have some particular attribute that will resolve a particular constructional problem on a work

DECISION MAKING PRINCIPLES

i. Knowledge base evaluation

- Factors considered
  - Type of finish
  - Re-use for good finish
  - Re-use for rough finish
  - Formwork component applied
  - Shuttering shapes
  - Likely concrete defects
  - Area practice
  - Where fabricatable

- Noise produced
- Fire resistance
- Liability of shuttering damage
- Formwork repairs
- Ease of making openings
- Insulation properties

ii. ***Project data***

- Contract Specialty
  - Contract type
  - Contract conditions
  - Project duration
  - Type of concrete finish
- Building Specialty
  - Building type (commercial, residential, industrial)
  - Structural systems and details
  - Building scale (shape, length, width, height and no. of floors)
  - Building area(total, floor-wise and phase-wise)
- Site Specialty
  - Access to site
  - Site size
  - Site surroundings and its relationships
  - Space for formwork fabrications
- Contractor Specialty
  - Contractor's experience with different formwork systems
  - Formwork available with contractor

- Construction Specialty
  - Labor available and productivity
  - Construction equipments used and frequency of use
  - Construction sequence/ program
- Site Specialty

s. No.	Formwork material	Surface finish	Re-use for good finish	Re-use for rough finish	Formwork component applied	Shuttering shapes	Likely concrete defects	Area Practice	Where Fabricatable
1	**Timber**	Normal/ plain finish	1 to 2	10 to 12	Sheeting, shutter frame props	Flat	Uneven surfaces	yes	site/offsite
2	**Plywood**	High class/fine finish	2 to 4	20 to 25	Sheeting	Flat/ reasonably curved	Ply pieces sticking to concrete	yes	site/offsite
3	**Steel**	High class/fine finish	45 to 50	100 to 200	Sheeting, shutter frame props, accessories	Any	Blowholes	yes	offsite
4	**Fibre glass**	High class/fine finish	85 to 100	120 to 150	sheeting	Any	Blowholes	yes	Offsite
5	**Concrete**	High class/fine finish	1	-	sheeting	Any	Edges chip off	yes	site/offsite

s. No.	Formwork material	Surface finish	Re-use for good finish	Re-use for rough finish	Formwork component applied	Shuttering shapes	Likely concrete defects	Area Practice	Where Fabricatable
6	**Polypropylene**	High class/fine finish	100 - 120	150 to 180	sheeting	Any	Blowholes	No	Offsite
7	**Hardboard**	Rough/basic finish	1 to 2	2 To 10	sheeting	Flat to slightly curved	Hardboard pieces sticking to concrete	Rarely	site/offsite
8	**Polystyrene**	High class/fine finish	1	-	sheeting	Generally flat/ curve possible	Sticking to concrete	Occasionally	site/offsite
9	**Rubber**	High class/superfine finish	10 to 12	15 to 20	sheeting	Any	Poor rubber may differ shape of concrete	No	Offsite
10	**Plaster of Paris**	High class/superfine finish	1	-	sheeting	Any	Give uneven concrete surface finish if it cracks	Rarely	Offsite
11	**Aluminum**	High class/fine finish	20 to 40	80 to 100	Sheeting, shutter frame props	Any	Alkali in conc. can react to Al, if moisture present	Occasionally	Offsite

5. CONSTRUCTION OF FORMWORK

- The construction of formwork normally involves the following operations

i. *Propping and centring*

- The props used for centring may be of steel or timber plates.
- In case of wooden posts are used as props, they should rest squarely on wooden sole plates.
- The wooden plates should have an area of at least 0.1m2 and 40mm thickness.

ii. *Shuttering*

- The shuttering can be made up of timber planks, or it may be in the form of panel unit made by either by fixing plywood to timber frames or by welding steel plates to angle framing.
- The shuttering joints should be tight against leakage of cement grout.

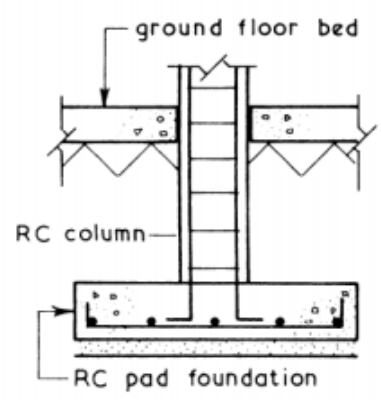
iii. Provision of camber and cleaning

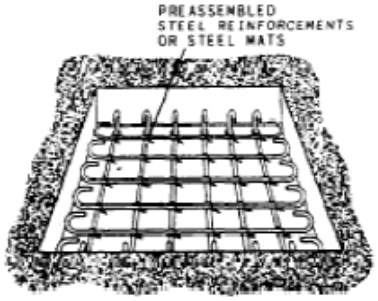
- it is desirable to give an upward camber in the horizontal member of the concrete structure, especially in members having long span, to counteract the effect of deflection.
- The provision of desired camber should be in the formwork itself during its erection.

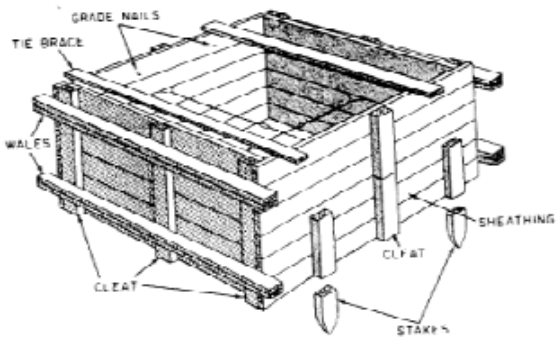
iv. Surface treatment

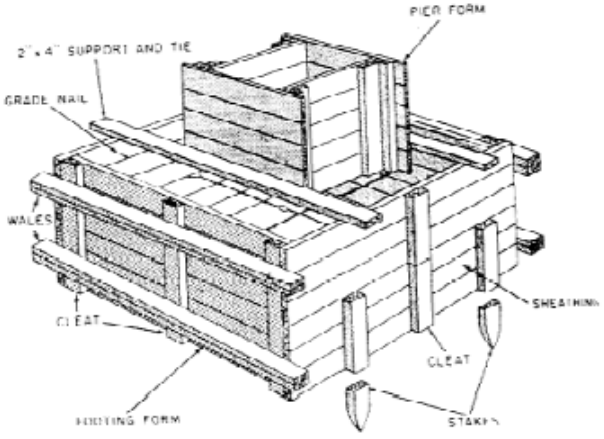
- The shuttering can be made up of timber planks, or it may be in the form of panel unit made by either by fixing plywood to timber frames or by welding steel plates to angle framing.
- Before laying concrete the formwork should be cleaned of all rubbish particles.
- All surface of timber shuttering that are to come in contact with concrete should be well wetted with water.
- All surface of shuttering should be given a good coating of a releasing agent.

FORMWORK FOR FOUNDATION









FORMWORK FOR COLUMNS

- Columns are usually square or circular in section.
- The shuttering must be able to withstand the hydraulic pressure exerted on it by the poured concrete.
  - For this reason, the column shutter supports near the base of the form should be closer.
- To prevent segregation of the concrete when pouring high columns, it may be necessary to incorporate a ***trap door*** in the shuttering at approximately the midpoint in height of the column, thereby allowing concrete to be placed without it dropping full height.
  - The alternative is pour the concrete from the top of the form using a ***termite pipe***.

FORMWORK FOR BEAMS

- this is basically a three sided box supported and propped in the correct position and to the desired level.
- The beam formwork sides have to retain the wet concrete in the required shape and be able to withstand the initial hydrostatic pressure of the wet concrete,
- Whereas the formwork soffit apart from retaining the concrete has to support the initial load of the wet concrete and finally the set concrete until it has gained sufficient strength to be self supporting.
- It is essential that all joints in the formwork are constructed to prevent the escape of grout which could result in honeycombing and/or feather edging in the cast beam.
- The design of the shuttering should allow the slab and beam side forms to be removed while the beam soffit remains supported.

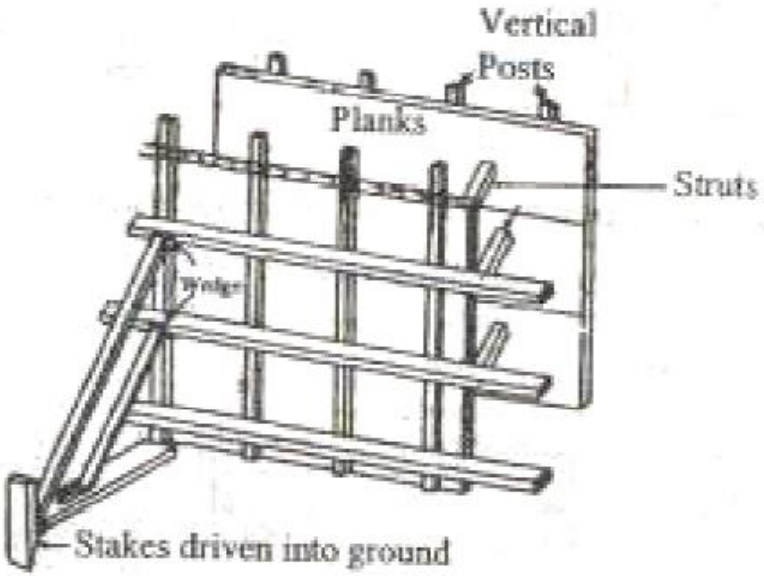
Beam and slab formwork

FORMWORK FOR SLABS

- Formwork to suspended slabs is similar to that for beams, except that the soffit shuttering is far wider.

FORMWORK FOR WALLS

- This type of form work consists of timber sheeting supported by vertical studs or posts and horizontal struts or walls.



FORMWORK FOR STAIRS

- The landing is first set in position. The process for constructing the landing is the same as that of floors.
- After the landing has been set, the flight will be constructed.

6. FORMWORK STRIKING

- Removal of formwork is also important as erecting it.
- Before formwork can be removed the concrete must have sufficient:
  - Strength to support itself
  - Surface hardness to resist damage
  - Curing.

FACTORS AFFECTING FORMWORK STRIKING

- Ambient Temperature
- Layout of concrete viz. horizontal, vertical or inclined
- Type of cement used
- Grade of concrete
- Use of retarders, plasticizers, etc.
- Feasibility of removal with props left under
- Feasibility with re-propping
- Standards of finish required
- Structural configuration e.g. simply supported or cantilever
- Curing procedures adopted

- Factors to be considered in producing required concrete finishes of uniform color and texture
  - The right concrete mix
  - Consistency of the concrete
  - Use of a constant rate of placing
  - Uniformity of compaction
  - Uniformity of face contact material
  - Correct choice of formwork pre-treatment and release agents
  - Correct curing procedures

FORMWORK STRIPPING PERIODS

OPC CONCRETE (FROM BS 8110)		
	Surface temperature of concrete	
	7^0 C	**16^0 C and above**
Formwork for columns, walls	18 hours	12 hours
Soffit formwork to slabs	6 days	4 days
Soffit formwork to beams and props to slabs	15 days	10 days
Props to beams	21 days	14 days

OPC CONCRETE (FROM EBCS 1995)	
	Stripping time
Formwork for columns, walls	18 hours
Soffit formwork to slabs	7days
Props to slabs	14days
Soffit formwork for beams	14days
Props to beams	21days

METHOD OF REMOVING FORMWORK

- Formwork should be planned and constructed in such a manner that it is possible to remove the different components in the following order of sequence:
  i. Shuttering forming vertical faces of walls, of beams and columns sides, which bear no load but are used only to retain the concrete, should be removed first.
  ii. Shuttering forming soffit of slabs should be removed next, and
  iii. Shuttering forming soffit of beams, girders or other heavily loaded shuttering should be removed in the end.

7. FORMWORK ECONOMY

- Formwork is the single largest component of concrete building.
- Considering the impact of formwork on the total cost, the engineer should design the formwork so that the maximum economy can be obtained.
- Economy of formwork begins with the design development of the structure itself.
- The following point should be considered while designing formwork for a building structure.
  i. While designing the structure, consider the material and tools that will be required to make, erect, and remove the formwork.
  ii. Design the structure with standard dimensions that will be unit multiple of forms and centering sheets.
  iii. Use the same size of columns from the foundation to the roof, this will permit the use of column forms with out alteration.
  iv. Use beams of the same depth and spacing in every floor; this will permit the reuse of beam forms without alteration.
  v. Specify the same for columns and column-support girders in order to reduce or eliminate the cutting and fitting of girder forms into column forms.
- Some of the important points to achieve economy in formwork expenditure are as follows:
  i. While designing formwork, maximum usage of material should be achieved.
  ii. High quality finish on concrete surface is not required for sides that will not be exposed.
  iii. When planning forms, consider the sequence and methods of striping.
  iv. Use prefabricated panels wherever possible.

v. Strip forms as soon as it is safe in order to facilitate maximum reuse of forms.
vi. Create cost awareness among carpenters and other workers involved in formwork construction.
vii. Use long length timber or plywood with out cutting, where their extending beyond the working area is not objectionable.
viii. After removal clean panels and store them at a safe place so that they can be reused.

8. RELEASING AGENT

- Facilitate the striking or removal of the formwork.
- Prevent the concrete adhering to the form face.
- Most oils will fulfill the function of a release agent, but different oils can produce ***blow holes*** or ***variations in the color*** of concrete, affect ***efflorescence***, or ***retard the hardening*** of the surface.



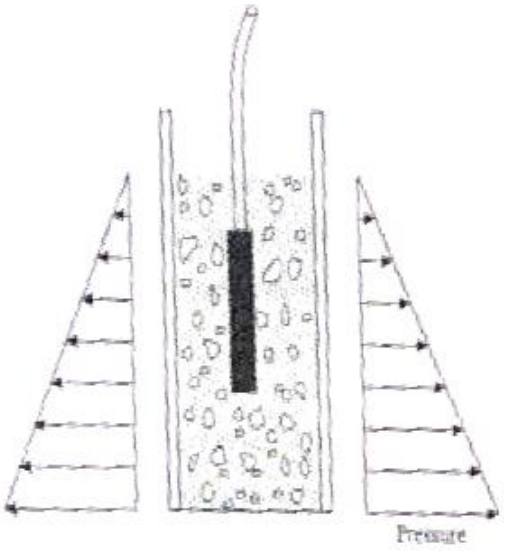
9. FORMWORK DESIGN PRINCIPLES

- The person designing the formwork for a project is doing much more than planning the containers with in which the in situ concrete will be cast.
- Formwork design includes
  - design of the formwork support structure,
  - the formwork deck and connection details.
- The design of formwork will involve decisions on the location of construction joints, which may impinge on reinforcement detailing, and will certainly relate to the volume of concrete to be placed in one pour.
- It will also be necessary for the designer to take into account the skills available, both quantitatively and qualitatively, for fabricating and handling the formwork.

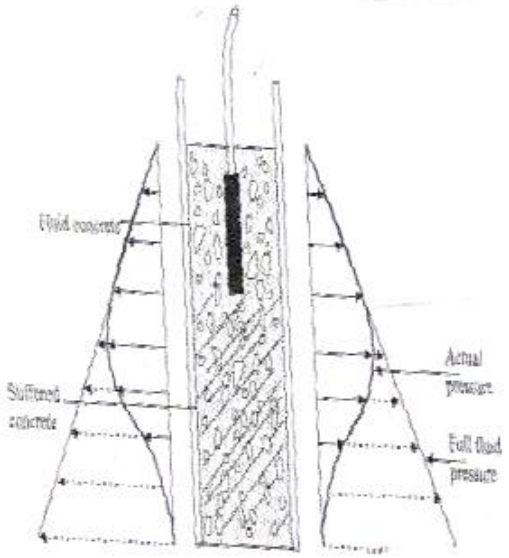
LOADS ON FORMWORK

- Wind loading
  - Vertical elements must be fully braced
  - Wind loading will vary depending on:
    - size of form;
    - nature of the form;
    - wind speed;
    - wind direction.
- Concrete Loading
  - The force exerted by concrete is complex, because concrete starts off acting as though it were a fluid

Fluid pressures on forms

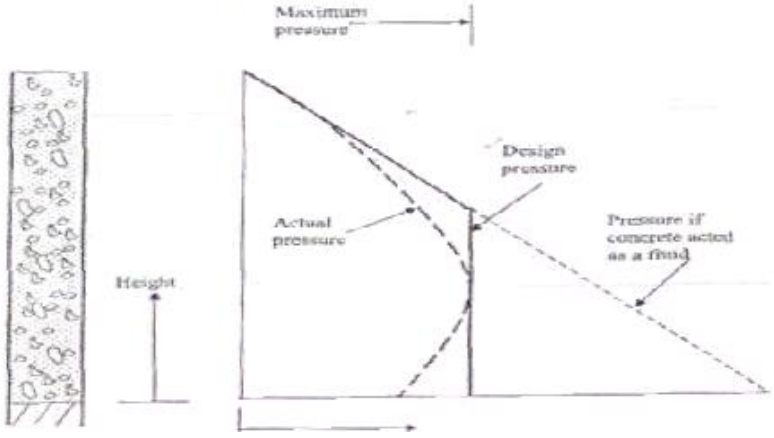


Pressures reduced by stiffening



FACTORS AFFECTING PRESSURE

- Concrete density,
- Rate of rise,
- Height of section cast,
- Concrete temperature,
- Cement type, admixtures, latent hydraulic binders and shape and plan area of the section.



10. Failure of formwork

- The failure of formwork is always embarrassing and expensive for everyone involved in the project.
- Failure may be collapse of entire formwork or part of it.
- Some of the reasons for the failure of formwork are given below:
  a) Improper or inadequate shoring
  b) Inadequate bracing of members
  c) Lack of control of placement of concrete
  d) Improper connection
  e) Premature striping of formwork
  f) Improper design
  g) Failure to follow codes and standards
  h) Negligence of workers or supervisors
- In order to prevent failure of formwork the following precautions should be taken:
  i. The formwork should be designed properly
  ii. Erection and stripping should be done only under engineering supervision
  iii. The sequence of removal should be pre-designed and correctly executed.

11. SCAFFOLDS AND FALSE WORKS

- Where work cannot safely be done on or from the ground or from part of a building or other permanent structure, a safe and suitable scaffold shall be provided and maintained or other equally safe and suitable provisions should be made.
- It is essential that scaffolds should be provided with safe means of access, such as stairs, ladders or ramps.

MATERIAL

- In the construction of scaffolds, sufficient, suitable and sound materials should be used.
- Where timber is used in the construction of scaffolds, it should be straight grained, sound, and free from large knots, worm holes and other defects likely to affect its strength.
- The mechanical properties of fastening on wooden scaffolds should conform to the national regulations and code of practices or be approved by the concerned authority.

INSPECTION AND MAINTENANCE

- Scaffolds should be inspected at periodic intervals as prescribed by national standards or code of practices, and the results recorded y a competent person.
- Inspection by the competent person should more particularly ascertain that:
    i. The scaffold is of suitable type and adequate for the job,
    ii. Materials used in its construction are sound and of sufficient strength,
    iii. It is of sound construction and stable, and
    iv. That the required safeguards are in position.