International Journal of Engineering, Management and Humanities (IJEMH)
Volume 1, Issue 1, pp: 91-109www.ijemh.com

Formwork Construction Techniques

Sarwar Nadeem(M.tech,CTM)
In the guidance of **Mr. Chittaranjan Singh**(Assistant professor,AFU)
Department of Civil Engineering , Al-Falah School of Engineering
Dhauj ,Faridabad (Haryana) India

Date of Submission: 26-01-2021 Date of Acceptance: 08-02-2021

ABSTRACT
Formwork is significantly important activity for concreting. Good quality of formwork can contribute a great to good quality of concrete. It not only holds the concrete during its wet stage but has many other important functions in this activity of concreting. Bad formwork has often yielded failures of minor as well as major magnitude. It is also fairly popular as shuttering. Its functional as well as financial share in the entire concreting activity can't be ignored. Many types of formwork exist across the globe. Many dimensions are attached to this activity. It is desired to touch upon some normal facts about formwork in this paper. An effort is made here to bring them before you in understandable manner. Let us begin this small trip of understanding about formwork which is like a preparation for big journey to concreting. Lot of people tend to think that formwork is a semi skilled occupation. To be fair there are a lot of guys who start off as labourers and finish up as formwork carpenters without any formal training. It is a fair bit of hard manual labour involved, but it is a very tricky job and it takes just as much know how to do it properly as any other jobs in the building trade. The best form carpenters are ones who plan to strip before they plan to build. Formwork, which holds and supports wet concrete till such time it cures, is a very vital element in concrete construction. With the globalization of Indian economy and introduction of multinationals in India for the construction and nations pride program of golden quadrilateral, it has become foremost to have speedy construction and timely completion of projects. Now days, low waste modern formwork systems for superstructure construction are commonly adopted. Formwork system affects on the cost, time, and quality of project delivery. But still these formwork systems are not much used in India and most of the contractors do not like to shift to the latest technology as they have the doubt of facing losses in the project and they are very much familiar with the existing formwork type, the conventional type. At the same time they believe that these formwork systems are bit expensive.
This paper aims to compare merits and demerits by using a conventional timber formwork system and modern formwork systems. The comparisons include costs, time, and quality of these systems. For better understanding of this topic, different construction sites are studied where most advance techniques in formwork are used and the data collected from these sites is presented in order to give comparison between modern formwork and traditional formwork system.
This study serves as a practical model for optimizing production planning, allocation of precast component storage, and transportation sites as well as for making timely adjustments for contracted projects. To ensure that the structure of the research model is reasonable and matches actual applications, the study uses a field survey to directly observe the largest precast concrete plants in Taiwan for a period of 6 months, followed by in-depth interviews with experts involved with the planning, design, installation, and manufacturing for precast projects. The mathematical model is then established and evaluated using the data containing over 90% of national production in Taiwan. The results show that the tested corporate profits increase by an impressive 38.4% and performance is significantly increased by 97.75%. The proposed model can not only make up for oversights in human decision-making but improve the decision-making process boosting corporate competitiveness.

I. INTRODUCTION

1.1 BACKGROUND

Formwork is the single largest cost component of a concrete building's structural frame. The cost of formwork exceeds the cost of the concrete or steel, and in some situation the formwork costs more than the concrete and steel combined.

For some structures, deciding the priority of the formwork design allow to reduce the total frame costs by as much as 25%. This reduction involved direct cost and indirect cost. Formwork is one of the main components in a project, it efficiencies in accelerate the construction schedule in order to reduce interest cost, labour cost, machinery cost and etc during construction and early complete for the project.

Formwork can be categorized into two types, which are conventional timber formwork and system formwork. Conventional timber formwork is the most common type of formwork, local contractors are already familiar and get used with this method. System formwork is a new technology which introduced by Industrialized Building Systems. Based on lack of knowledge on this technology, local contractor still refused to apply this method in project broadly. The main reason they refused to applied this technology is cost of conventional formwork is much lower than IBS or the technology of it.

1.2 AIM

The aim of this research is to compare and find out whether steel wall form system or conventional timber formwork is more suitable in high rise residential building construction.

The specific objectives were:

To analyze and cost and labor force required for both types of formwork system.

To define and study productivity of steel wall form and conventional timber formwork.

To study into different quality outcome from the both formwork system.

To compare of costing and productivity between steel wall form and conventional timber formwork.

1.3 SCOPE

This research will focus on the local projects that are using steel shear wall form and traditional formwork system. The study is limited to high-rise residential building construction. Site visit to the high rise residential building project will be carry out in this research. One project will be sampled for this research with two different of formwork system for wall only.

2.1 Research Methodology

This chapter will explain the process of the whole dissertation and the type of research Methodology. The method of collect data, information and analysis will be explained in this chapter.

a)All formwork activities will be carried out in accordance with the specification.

b) After studying the structural drawings, the Project Engineer will plan for sizes, numbers and type of formwork to be used in consultation with the Structural Engineer, if required. Depending upon the programme, the number of repetitions will be decided.

c)Availability of formwork will be checked with the Procurement Manager and decision will be taken to buy, hire or reuse formwork material.

d) During fabrication of formwork shutters, all dimensions shall be cross-checked with a view to avoiding corrective action during erection.

e) Paint reference numbers on all panels to ensure their use in correct positions.

f) Ensure that the props, shores, waling, bearers, clamps and tie rods are the right size and at the correct spacings. The Formwork designer shall check the falsework system with respect to load imposed on it and design parameters as laid down in the specification.

g) Checkthat the falsework is securely braced and is on a firm foundation.

h)Forms fastened to previously cast concrete must be tightly fixed to prevent grout loss. Cellular foam plastic strips can be used to make a seal.

i)Check qualityof shutter lining, tightness of bolts and wedges, built-in items, inserts and other embedments.

j)Tie – rod holes to be made in the formwork shall be neat so that they can be patched or plugged later on.

k)Particular attention will be paid to the rigidity and line of stop ends and joint formers.

l)Remove all tie-wire clippings and nails, which may stain both the formwork and the concrete.

m)Ensure that adequate access and working platforms are in place for the concreting gang and that toe boards and guardrails are provided.

n)A spreader or lifting beam shall be used to prevent distortion when placing formwork.

2.2 Data Collection

This chapter will be completed by carried out one case study in order to understand in more detail of the steel wall form system and conventional timber formwork. Besides, a structured interview is conducted for analysis. Data and photographs will be show as an evidence for case studies.

2.3 Data analysis

This chapter carries out analysis and discussion of the data collected from the interviewer and case study. The data analysis will included cost analysis, productivity analysis, quality analysis and manpower analysis.

II. RESULT AND RECOMMENDATION

This chapter includes the objectives review of this dissertation. All the studies on this dissertation will be concluded in this chapter too. There will be further recommendation of this "A Study on Cost, Productivity and Quality Comparison of Using Steel Wall Form System and Conventional Timber Formwork in Residential High Rise.

Indian construction industry has started using some of the world class technologies. Several formwork systems are in use at different places in the world; eventually the systems which are reasonably economical and easy for operation with skilled labour are more useful in India. Formwork system has significant role in the construction process, making the right decision by choosing the appropriate formwork system could lead to response to sustainable construction. Different systems have their own advantages but one needs to choose a formwork which best supports individual project requirement. Shortage/non availability skilled and semi-skilled workers results in problems of cost and time over-runs, inferior construction, poor finishes leakages, corrosion of structures etc. this can be avoided by adopting modern formwork systems. This also avoids repairs and rehabilitation of structures before its expected life span.

2.5 FORMWORK SCENARIO IN INDIA • Low technology • Labour intensive • Labour-unskilled, migratory, traditional and family oriented • Absence of monitoring body.

2.6 CONVENTIONAL FORMWORK This usually consists of standard framed panels tied together over their backs with horizontal members called waling. The waling is provided with the basic function of resisting the horizontal force of wet concrete. One side of the wall formwork is first assembled ensuring that it is correctly aligned, plumbed and strutted. The steel reinforcement cage is then placed and positioned before the other side of the formwork is erected and fixed. Plywood sheet in combination with timber is the most common material used for wall formwork. The usual method is to make up wall forms as framed panels with the plywood facing sheet screwed on to studs on a timber frame. This allows for the plywood to be easily removed and reversed and used on both sides so as to increase the number of reuses. The wall forms are susceptible to edge and corner damage and must be carefully handled. Special attention must be given to comers and attached piers since the increased pressures applied by wet concrete could cause the abutments to open up, giving rise to unacceptable grout escape and a poor finish to the cast wall.

2.7 NEED FOR MODERN FORMWORK SYSTEMS The earliest formwork systems made use of wooden scantlings and timber runners as it enabled easy forming and making at site. But these wooden scantlings and timber runners tend to lose their structural and dimensional properties over a period time and after repeated usage thus posing safety problems.

Many of the accidents take place in Reinforced Cement Concrete (RCC) construction because of inferior formwork and scaffolding.Now focus has to be shifted to other key factor “Formwork”, to face the challenges for the completion of fast track projects. By going in for system formwork, substantial savings are possible by faster return on investments.

2.8 MODERN FORMWORK SYSTEMS 1. MIVAN Technology 2. Tunnel Formwork 3. Climbing formwork 4. Flex formwork 5. Heavy duty tower system 6. Slab formwork 7. Column formwork system

For residential & commercial projects mostly MIVAN & Tunnel Form is used because of less cycle time as compare to all these form work systems. The scope of study of this paper is limited to only MIVAN Technology & Tunnel Formwork.

MIVAN TECHNOLOGY MIVAN is aaluminium formwork technology. MIVAN system is formwork construction, cast – in – situ concrete wall and floor slabs cast monolithic provides the structural system in one continuous pour. Large room sized forms for walls and floors slabs are erected at site. These forms are made strong and sturdy, fabricated with accuracy and easy to handle. They afford large number of repetitions (around 250). Theconcrete is produced in RMC batching plants under strict quality control and convey it to site with transit mixers.

Formwork systems for buildings are classified as either horizontal or vertical formwork. Horizontal formwork systems are those used to form the horizontal concrete work (slabs or roofs), while vertical formwork systems are those used to form the vertical supporting elements of the structure, e.g., columns, core walls, and shear walls.

Due to the fine tolerances achieved in the machined metal formwork components, consistent concrete shapes and finishes are obtained floor after floor, building after building, confirming to the most exacting standards of quality and accuracy. This allows plumbing and electrical fittings to be prefabricated with the certain knowledge that there will be an exact fit when assembled. The dimensional accuracy at the concreted work also results in consistent fittings of doors and windows.

The system of Aluminium forms has been used widely in the construction of residential units and mass housing projects. It is fast, simple, adaptable and cost – effective. It produces total quality work which requires minimum maintenance and when durability is the prime consideration. This system is most suitable for Indian condition as a tailor–made aluminium formwork for cast–in–situ fully concrete structure.

2.9TUNNEL FORM TECHNOLOGY It is a highly efficient Industrialized System of On-Site Construction, which enables putting-up stable structure on a 24-Hour cycle basis Tunnel form is a formwork system that allows the contractor to build monolithic walls and slabs in one operation on a daily cycle. It combines the speed, quality and accuracy of factory/offsite produced ready-mix concrete and formwork with the flexibility and economy of cast in-situ construction

This fast-track method of construction is suitable for repetitive cellular projects, such as hotels, apartment blocks and student accommodation. It offers economy, speed, quality and accuracy, as well as utilising the inherent benefits of concrete, such as fire and sound resistance.

Tunnel Formwork System: Tunnel formwork system is one type of construction techniques used for multi storied building construction to reduce cycle time and also the slab & the wall are cast monolithically. Its components are made of steel. Its usefulness also stems from the fact that no starter concrete is required for walls; it allows easy alignment and de-shuttering, hot air curing to enable early stripping and favours a standardized working sequence to improve labour productivity.

Half Tunnel Formwork. Tunnel form can accommodate room widths from 2.4 to 6.6m. When rooms are wider (up to 11m), a mid-span table is incorporated between the tunnels. The main component of the system is the half tunnel. Manufactured entirely from steel, including the face of the form, the half tunnel provides the rigidity and smooth face necessary to produce a consistently high quality finish to the concrete. When two half tunnels are put together this creates a tunnel. The tunnel sections come in two lengths, 1.25 and 2.5m. These are fixed together to produce a tunnel length that suits either the building dimensions. The tunnel is tailored to the room width and height by the inclusion of infill sections which are sacrificed at the end of the job. These are not loose fittings but are an integral part of the tunnel.

III. DISCUSSION

The data, information and reference materials will be collected through reference books, journals, magazines, newspaper and etc will be major tunnels for me to gather information for my research title. Initial study is carried out by comprehensive review on the literature on all the resources, to gain the basic understanding and ground theory on the relevant topics and area, which then be used in generating useful information and data.

3.1 Internet Research

Internet is a major tool to allow me finds out the information about steel shear wall form and traditional timber formwork. It also enables me to get the latest information which is related with my dissertation.

3.2 Site Visit

Throughout site visit, it allow me to understand the method of the construction in apply both different types of formwork in detail. Interview will be carrying out during the construction site visit. The people to be interview included contractors and other relevant party.

3.4 Case study

Case study about steel and timber formwork system used in high rise residential construction will be carried out. Interview will be carried out during the construction site visit. The people to be interview included contractor, project managers and other relevant party.

This chapter has been a general introduction to dissertation research and outlines the main aims and objectives of this dissertation. It also consists of clarity of problem statement and justification of the research before to start this research.

International Journal of Engineering, Management and Humanities (IJEMH)
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4. PRELIMINARY INVESTIGATION

6.3 Time of Removal of formwork

Sr. No	Structural Member	OPC (Ordinary Portland Cement)	Rapid Hardening Cement
1	Beam sides, walls & Columns	2-3 Days	2 Days
2	Slab (Vertical Supports remains intact)	4 Days	3 Days
3	Slab (Complete Formwork removal)	10 Days	5 Days
4	Beams (Removal of Sheeting, Props remains intact)	8 Days	5 Days
5	Beams & Arches (Complete formwork removal) (up to 6 m span)	14 Days	5-8 Days
6	Beams & Arches (Complete formwork removal) (more than 6 m span)	21 Days	8-10 Days

formwork methods and materials with risk in handling and installations. In this research, steel formwork is selected based on economy and volume of work with repeatability. From the Table 1, the selection of formwork panel thickness can be done by calculating the maximum formwork pressure exerted. 4.2 Equal Angles Panels are made rigid with the stiffening angles at the faces of the frame to support the concrete load and maintain verticality with help of alignment props if needed at the execution. Based on maximum concrete pressure, formwork panel thickness running throughout its length all along the height is restricted to 3mm. Stiffeners can be flattie or angle sections based on position and loading frame as in Fig. 5, Equal Angle Section 35*35*6 mm is selected as stiffeners all around the formwork panel. Properties of equal angles 35*35*6mm are, Sectional Area=386 mm2

. Weight/meter =35N
Iz=Iy=4.1*104mm 4
. Iu=6.5*104mm 4 .
Iv=1.7*104mm 4 .
Zez=Zey=1.7*103 mm 3
. Kl/rv=1000/6.7=149.25
Yield Stress, fy=250 MPa.
fcd=60MPa.
(Column Buckling Class _c‘) Total Load Capacity= Fcd*area=60*386=23.16KN>20KN.
OPC 53 grade (Class-F) Specific Gravity of Cement=3.15 Specific Gravity of CA=2.74 Specific Gravity of FA=2.68 W/c ratio=0.40

5 MIX DESIGN
Cement used: OPC 53 grade (Class-F)
Specific Gravity of Cement=3.15
Specific Gravity of CA=2.74
Specific Gravity of FA=2.68
W/c ratio=0.40
Water to be used (20mm coarse aggregate)=186 litres.
Superplasticiser, Conplast=3% weight of water.
VMA, Master Matrix =2% weight of water.
AEA, Micro air =.5% weight of water. Max.
Cement content=180/.43=420 Kg/m3 > 350Kg/m3.
Volume of Coarse Aggregate/Total Volume of agg=0.64.
Volume of Concrete=1 m3.
Volume of cement=350/(3.15*1000)=.11m3.
Volume of Water=180/1000=.18m3.
Volume of Coarse Aggregate=1-[.11+.18]=.71m3.
Mass of Coarse Aggregate=%CA*SGca*Vagg*1000 = .64*2.74*.71*1000= 1245Kg.
Mass of Fine Aggregate = %FA*SGfa*Vagg*1000 = .36*2.68*.71*1000= 685Kg.
Vcement: Vwater: Vfa: Vca=420:180:685:1245 =1: .43: 1.631: 2.96 VMA=2%Vwater=8.4 litres. AEA=.5%Vwater=2.1 litres.
6 DESIGN OF NORMAL AND CONGESTED COLUMN & WALL For normal reinforced section, minimum reinforcement of column= 0.8% BD.
Area of Reinforcement= 600mm2 .

Provide 6 nos. of 12mm Ø bars.
Lateral ties are 8mm Ø at 200 mm c/c.
For congested reinforced section, percentage of steel section= 1.5% BD.
Bar spacing should not be less than 75mm. Provide 12 nos. of 12mm Ø bars.
Lateral ties are 8mm Ø at 120 mm c/c. For normal reinforced wall,
Minimum transverse reinforcement, pt=0.2%BD.
Minimum vertical reinforcement, pv = 0.15% BD.
Area of Reinforcement = one layer of 300mm2 /m.
Provide 8mm Ø at 160 mm c/c.
For congested reinforcement, percentage of steel= 0.40% BD.
Provide 8mm Ø at 120 mm c/c.
7.1 Preliminary Tests
On preliminary tests of Self Compacting Concrete as in Table 2, slump flow is supervised with necessary satisfying conditions which are tabulated are as follows,
7.2 Sensor Observations
Voltage responses from the normal reinforced self compacting concrete column is recorded with one metre running length series connected sensors as V, sensors placed at 100mm, 300mm, 600mm, 850mm from bottom of formwork panel as taken as H1,H2,H3 and H4 respectively. From the Fig.7, maximum pressure on concrete can be observed at the H2 sensor pad.
Similarly, voltage responses for congested concrete column with similar sensor pads placed at V, H1, H2, H3 and H4 with same reference levels. From the Fig.8, maximum pressure is recorded. Pressure variation between normal reinforced concrete column against congested column is easily identified. For wall panels of 150mm thickness and single layer of reinforcement, normal reinforced wall sections are strapped with sensors at V, H1, H2, H3 and H4 with same reference levels from the bottom. From the Fig. 9, pressure responses are recorded with maximum pressure at the H3 sensor pad.

Various trials can be done by varying the aggregate proportions, superplasticiser products, sensor sensitivity and other major parameters may be introduced for exact precision for lateral pressure estimation and depending on site supervision, the expecting result shall be achieved at the best manner. By repetitive trials, the accuracy of lateral pressure shall be achieved. Proper care in handling the formwork panels and positioning the alignment props makes the concrete pouring reach great consistency irrespective of concrete volume and rate of pour. Surface finish at the completion looks more confined as self compacting concrete makes the concrete constituents fill the voids and easily flow at large heights and high level of pouring concrete.

the voltage values shall be termed into concrete pressure in terms of Pascal. Sensor sensitivity and mode of calibration are done through UTM helps to record by applying load and removed at instants to record accurate Force values versus voltage readings. Maximum lateral pressure is interpolated with respective voltage readings giving maximum pressure recorded as 6 KPa on 150 mm thickness wall panel. From Table 4, maximum pressure on Column with normal and congested reinforcement and wall with normal and congested reinforcement shall be observed. With maximum pressure recorded, following studies have been understood providing safe handling of formwork components at high level of concreting which are as follows,
1. Congested reinforcement exerts more pressure at fresh stage recommends alignment prop positioning at one-third height of formwork frame.
2. Normal reinforcement column sections have constant level of pressure while hardening resulting easy deshuttering at hardened time.
3. A wall with less width exerts more concrete pressure which makes risk of formwork verticality. So proper clamping and alignment props with more attention is required for wall panel concreting.
4. With proper positioning of formwork panels, repetitive use of frame is easy for handling and transporting at different locations provided skill on work with good supervision is recommended.
5. Pressure sensors at different fluid sensitivity and long term practices can be done with proper study for further research.

3. TERMINOLOGY

Arch Centering
Temporary framework or formwork, usually timber that masonry or concrete arches are built on top of.
Auger Underpinning
The underpinning of foundations by drilling a series of auger holes under the foundations. By part filling with concrete it is possible to lift the foundation with hydraulic jacks, before totally filling with concrete.
Back Propping
The technique of stripping the formwork in a suspended slab while still keeping it supported
.**Bamboo Scaffolding**
Scaffolding made out of natural bamboo
Beam Formwork
Formwork for beams. This particular page shows a low tech all timber method of forming a perimeter beam to a suspended slab.

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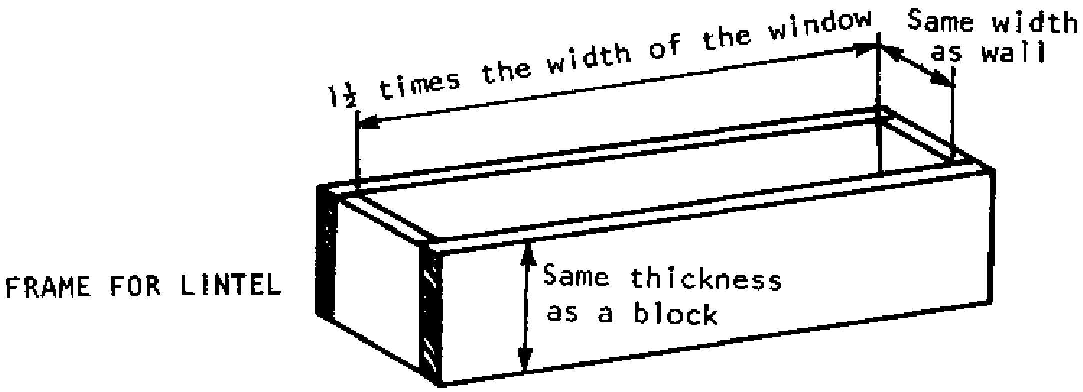
Volume 1, Issue 1, pp: 91-109www.ijemh.com

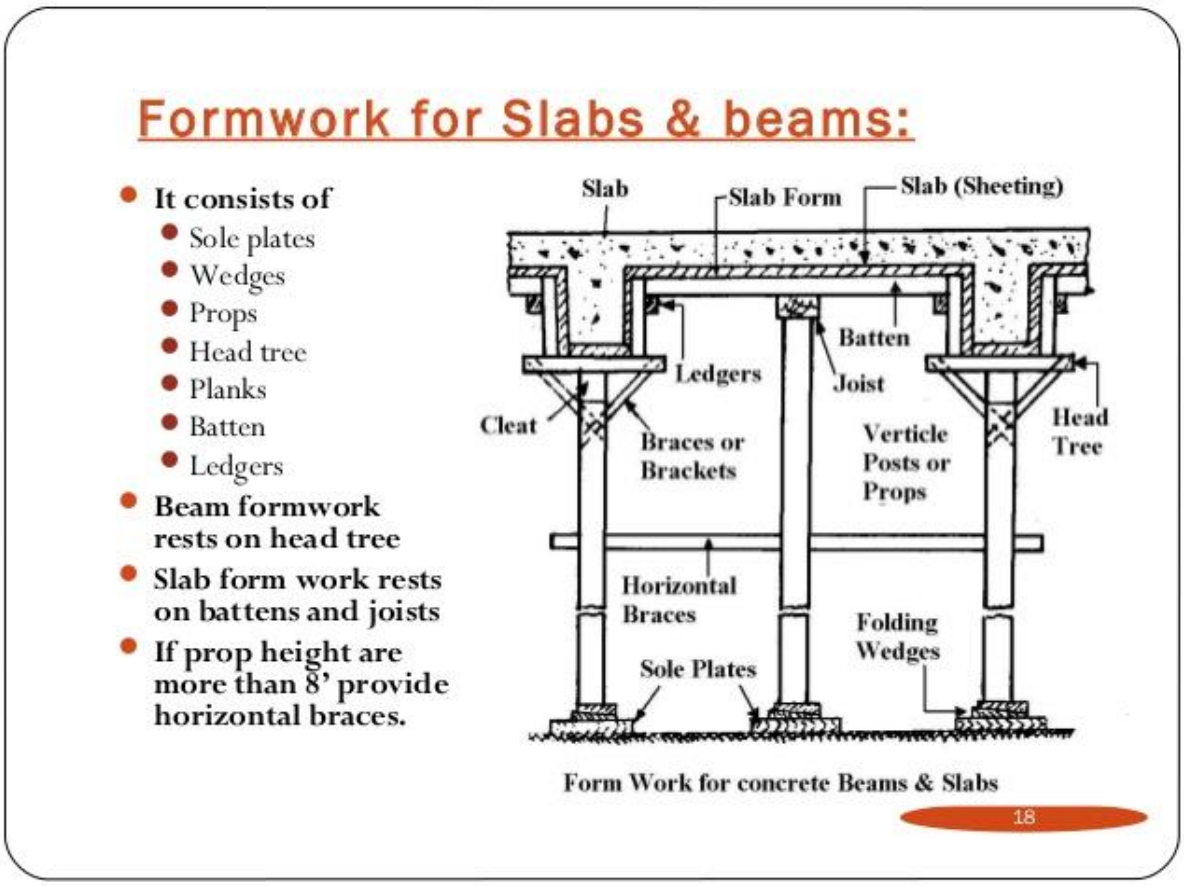


Boom Hoist
Access equipment. A mobile scaffold platform that is raised and moved by an articulated boom Also known as a Cherry Picker

.**Box Crib**
A layout of squared timbers or similar concrete beams used as the lining of a shaft in mining and excavation work.

Brace
An angled member working in compression only. Used to stiffen, straighten or support shutters etc.

Cantilever Needle Beam
In underpinning. A cast in situ concrete beam, usually sat on piles or concrete piers that passes through and supports a wall, or foundation from one side of the wall only.



Cat Ladder
In Scaffolding and while working on steep roofs. A ladder that lays on top of the roof surface as an aid to walking and working on a roof surfaces. Also known as a crawling board.

Chamfer
Usually a 45deg. bevel to a 90deg.(both internal and external) corner in concrete.

Column Clamps
Various methods of clamping and holding column formwork in position.

Column Formwork
Timber, steel or other materials used to form concrete columns.

Concrete Formwork
The materials that are used to keep wet concrete in the correct position until it has set. After a period of time it is usually removed.

Continuous Flight Augering
In basement excavation and shoring. Know also as CFA. A machine driven auger that drills holes and when withdrawn, grout or concrete is pumped into the hole through a hollow center. When withdrawn fully A rebar cage is inserted into the wet concrete. The process is repeated many times to form a continuous shield or secant pile wall.

Crane Loading Platform
In high rise work. A temporary platform, usually cantilevered out from an upper floor, to enable a crane to land and remove material to the floor.

Cribbing
Squared timbers or concrete members used to provide support or used in a retaining wall.

Double Raking Shore
A shore with two raking members, either steel or timber to support a larger and higher section of wall.

Earth Auger
An auger used for drilling circular holes in the ground. Usually machine mounted and hydraulically driven.

Fabric Formwork

Formwork that is formed out of various plastic and fabric materials. Not reusable, but cheap and quick to erect.

Fillets

Triangular lengths of timber or plastic used to form chamfers in concrete.

Flying Shore

A horizontal shore between two buildings to give temporary support to one or both of them

Form Oil

A generally low viscosity oil that is easily sprayed onto ply or steel form surfaces to stop the concrete sticking to the forms. Also called release oil or release agent.

Formply

Usually in 2400 x 1200 (8ft x 4ft) and either 12mm, 16mm or 18mm (1/2", 5/8", or 3/4") thick this plywood is made by various manufacturers with strength, water resistance and finish being the main criteria. Both sides are usually coated with a hard smooth resin finish.

Formwork Bearers

Heavier sections of steel or timber supported on props or shores, used to support the joists in suspended slab construction.

Formwork Cleats

Short lengths of timber used to join other timbers together.

Formwork Joists

Horizontal members sat on top of the bearers in suspended slab formwork.

Formwork Soldier

A vertical structural support member in formwork.

Formwork Waler

A horizontal structural support member in formwork. Also called Wales or Waling. The same term carries over into timbering for trenches.

Fox Wedges, Folding Wedges

Pairs of timber wedges used for adjusting timber props and many other wedging and tightening operations.

Hydrostatic Pressure

Wet concrete, especially under vibration acts like a liquid. In simple terms the pressure on the formwork is greater as the concrete gets deeper.

Kicker

A member parallel to the shutter being supported, hard up against the shutter and fixed to the support. A member parallel to the shutter being supported but offset from the shutter to allow for the fixing of braces.

Ladder Access

In Scaffolding. The provision of spaces and ladders to allow access to the different levels of the scaffold.

Ladder Hoist

A ladder frame used to hoist materials into upper floor windows and onto roofs.

Ledger

A horizontal member supported on standards, on which the transoms are laid in tube and coupler work. In modular systems they perform the function of stiffening the standards and maintaining the correct bay widths. Also they are used as hand rail and guard rail supports.

Modular Panel Formwork

Various steel, steel and ply panels to simplify erection and to save material costs. The many more cycles of use than simple timber systems.

Modular Scaffolding

A system that uses prefabricated sections to make up modules of standard sizes. Strong but compact for transport.

Needle

A short strong piece of timber which goes through a hole in a wall and which, via props or shores on either side of the wall supports the wall for further work. 2.) A short timber or steel member which passes through a hole in the wall to support a scaffold etc.

Needle Beam

In underpinning. A cast in situ concrete beam, usually sat on piles or concrete piers that passes through and supports a wall, or foundation.

Needled Raft Slab

In underpinning. An integrated raft slab and cantilever reinforced concrete needles sat on micro piles.

Permanent Formwork

Formwork that is left in place after the concrete is set. Examples are metal pan systems like "Bondek" that simply the forming of suspended slabs and because of their thickness and keying into the concrete also contribute to the strength of the slab, reducing rebar costs. Go to - Permanent Formwork page.

Poling Boards

In trench shoring. Vertical boards to the side walls of an excavation.

Preventive Shoring

The fixing of shoring and braces to building undamaged, but that could be put at risk by nearby excavation and other construction work.

Puncheons

In trench shoring. Short sturdy vertical lengths of timber that support the walers. Similar pieces in old timber framed buildings.

Putlog

In scaffolding. A horizontal member used for fixing a scaffold to a wall or other part of a buildings structure to brace the scaffolding.

Putlog Scaffold

A scaffold that is half supported by the building structure, saving on standards etc. The horizontal equivalents of the transoms are known as putlogs and the are attached or built into the structure as the work progresses. Rarely used in modern construction.

Raking Shore
A shore that is leaning at an angle (on the rake) to support the side of a building or other structure. The shore takes any thrust from the walls to the ground.

Raking Shore Details
Details of the setting out and construction of timber rakers.

Rebar Cage
.A made up cage of reinforcing steel main bars held in place by smaller bars.

Roof Edge Protection
In roofing the provision of temporary scaffolding edge guardrails to protect workers from accidentally stepping off the edge of a roof.

Safety Mesh
Various forms of mesh, steel or fabric that is designed to stop tools or materials falling off the platforms

Scaffold Brace
Sloping angled tubes that provides sideways and lengthways bracing.

Scaffolding
A temporary work platform inside or on the face of a building to allow worker and materials access to work areas above the ground.

Scaffolding Stairs
In modular scaffold systems, flights of stairs at normal ratios and wide enough to give access to different levels for a few workers at a time.

Scissor Lift
Access equipment. A mobile scaffold platform. Also known as a scissor hoist because of the method of raising the platform.

Screw Jacks
Steel course square threaded fittings that fit into shoring systems or scaffold pipes to adjust the height and to distribute the load of the frames or scaffolding through large steel flat plates.

Secant Pile Wall
Also known as Tangent, Soldier and Contiguous pile walls. A grout or reinforced concrete retaining wall made by the CFA system..

Semicircular-Arch Centering
Larger centering for a semicircular arch.

Settlement Bolts
Large diameter bolts,iron bars or straps that pass though a building in order to support it against settlement or to secure it due to damage.

Shore
A single prop or brace that is used to support temporary work or an unsafe part of a structure. They are often subdivided into the following categories:- Dead shores acting vertically, raking shores at an angle and flying shores bracing horizontally.

Shore Frames
Shoring systems for formwork to support suspended slabs etc.

Shoring
Using a number of shores to support a temporary construction element or to support an unsafe building or to temporarily support adjacent buildings when new construction is carried out.

Shutter
A made up reusable section of formwork or shuttering that could consist of timber and ply, or any number of steel, steel and ply, or other material. It is made once and used many times.

Single Raking Shore
A shore with only a single raking member, either timber or steel, aimed at a specific portion of a wall.

Sole Plates
Lengths of timber used as the base of rows of props and formwork shoring systems. Essential on the ground and the wider and heavier the better of soft ground. Used to fix the base of props etc. and also to spread the load.

Stair Formwork
The formwork for stairs is usually ply on timber, apart from jobs that have many repetitions or curves, in which case purpose made steel forms are used.

Standard
A long vertical tube or a shorter tube with welded fitments in modular systems. The main load bearing members.

Steel Props
First made by the "Acrow" company these items are used for supporting mainly formwork in a vertical position but can be used raked and even horizontally. They consist of one steel tube sliding into another with a course screw and collar for adjustment. The have square steel plate on each end to distribute the loads.

Stripping Formwork
The removal of the formwork.

Strongback
1.) In Stair Formwork. A timber or steel member sat on top of and bracing the riser forms in wide flights of concrete stairs.
2.) In Formwork. Any type of large stiffening member on the outside of formwork.
3.) In Tilt Slab Construction. Temporary steel or timber stiffeners as extra support to panels during erection. e.g. around openings or as legs to "L" shapes.

Temporary Fencing
Fencing around a construction site or work area.

Tie Bolts

High tensile steel threaded rod system for tying wall forms etc. together. Consisting of a course, rounded thread for speed of use and easy cleaning. Large wing nuts, plate washers, spacer tubes and polythene cones. allows the rods to be completely removed from the wall and re-used many times.

Tie Wire
A malleable black wire that is used mainly for tying rebar, but has many other uses in formwork. The basic principal of tie wire is that when it is twisted in a tournequet (tightening) fashion it does not untwist but remains tight even under load.

Tilt Edge Form
Purpose made extruded aluminium section suitable for tilt slab construction.

Tilt Props
Purpose made steel props or braces that temporarily hold tilt panels until they are secured.

Tilt Slabs
A form of concrete wall construction where flat slabs are made on site and lifted into position when the concrete has become strong enough to lift.

Timber Props
Vertical timber supports, posts or shores.

Timber Scaffolding
Scaffolding made out of sawn timber of lumber.

Toe Boards
Timber or steel boards fitted to a work platform to stop people slipping off the platform, or tools or materials being kicked off the platform. Also known as kicker boards

Transom
A horizontal member supported on standards, on which the scaffold planks are laid. Also used as safety rails to end bays.

Transom Beam
In scaffolding. A beam spanning a wider gap between standards than normal. Usually where wider access is required at ground level for vehicles and equipment.

Transom Truss
In scaffolding. A beam spanning a wider gap between standards than normal. Usually where wider access is required at ground level for vehicles and equipment. In modular systems they are deeper than transom beams and so have two attachment points at each end to the standards.

Trench Shoring
Usually steel or aluminium frames braced with adjustable struts to support the sides of excavations during pipe laying etc.

Trench Timbering
The provision of timber supports in excavations and trenches to prevent the collapse of the earth sides. A method of making trenches safe to work in.

Tube And Coupler
In Scaffolding. An assembly of heavy walled scaffold tubes used as verticals, horizontals and angled braces held together by purpose made bolted couplers.

Underpinning
Strengthening sub-standard or weak foundations.

Underpinning Pressure Grout
The stabilisation and adding new support to weakened foundations by pumping at high pressure a grout mixture under the footing to fill up voids in the subgrade.

Wall Formwork
Methods of formwork for walls can vary from proprietary steel/steel frame with ply, aluminium and all timber.

Wall Ties
There are various methods of tying wall forms together. Snap Ties, She Bolts, Tie Bars and even Tie wire

COST ANALYSIS

Sr. No.	Content	MIVAN building	Conventional building
1	Concrete grade	M15, M25, M40	M15, M25, M30, M40
2.	Thickness of wall	310mm, 300mm, 160mm, 140mm	230mm, 200mm, 160mm, 150mm, 100mm
3.	Steel	8mm, 12mm, 16mm, 25mm, 32mm	8mm, 12mm, 16mm, 25mm
4.	Slab	130mm, 110mm, 180mm, 200mm	110mm, 130mm, 150mm, 175mm
5.	No. of floors	12	12
6	Area	2BHK:-100.68sqm, 3BHK:-137.75sqm	2BHK:-100.68sqm, 3BHK:-137.75sqm

Content	MIVAN building	Conventional building
Duration of Construction	438 days	880 days
Total Cost	Rs.42750000	Rs.48750000
Wastage of formwork	Very less	More
Resistance to earthquake	More	Less than MIVAN system

Graph 1.Cost comparison

Graph 2.Duration comparison

IV. CONCLUSION

Different formwork systems provide a wide range of concrete construction solutions that can be chosen to suit the needs of a particular development. Traditional formwork for concrete construction normally consisted of bespoke solutions requiring skilled craftsmen. This type of formwork often had poor safety features and gave slow rates of construction on-site and huge levels of waste – inefficient and unsustainable. Modern formwork systems, which are mostly modular, are designed for speed and efficiency. They are engineered to provide increased accuracy and minimize waste in construction and most have enhanced health and safety features built-in. The main systems in use are Mivan technology and tunnel form. This guide sets out their key features – process efficiency, safety, sustainability and other considerations – in order to help construction professionals to take advantage of them to achieve modern, efficient concrete construction.

By using MIVAN system & Tunnel Form system we can achieve cost reduction in less time. By reducing cycle time than conventional method overall financial cost saving can be achieved.

MATERIALS FOR FORMWORK. Formwork can be made out of timber, plywood, steel, precast concrete or fibre glass used separately or in combination. Steel forms are used in situation where large numbers of re-use of the same forms are anticipated. For small works, timber formwork proves useful. Fibre glass made of precast concrete and aluminum are used in cast-in-situ construction such as slabs or members involving curved surfaces. (A) Timber Formwork: Timber for formwork should satisfy the following requirement: It should be 1. well seasoned 2. light in weight 3. easily workable with nails without splitting 4. free from loose knots Timber used for shuttering for exposed concrete work should have smooth and even surface on all faces which come in contact with concrete. Normal sizes of members for timber formwork: Sheeting for slabs, beam, column side and beam bottom 25 mm to 40mm thick Joints, ledges 50 x 70 mm to 50 x 150 mm Posts 75 x 100mm to 100 x 100 mm Wooden formwork – a pictorial view (B) Plywood Formwork Resin bonded plywood sheets are attached to timber frames to make up panels of required sizes. The cost of plywood formwork compares favorably with that of timber shuttering and it may even prove cheaper in certain cases in view of the following considerations: Chirag K. Baxi 1. It is possible to have smooth finish where cost in surface finishing is involved. 2. By use of large size panels it is possible to effect saving in the labour cost of fixing and removal. 3. Number of reuses is more as compared with timber shuttering. For estimation purpose, number of reuses can be taken as 20 to 25. 4. If you have holes in your ply, plug them up, or else accept ugly lumps and loss of fines on your finished concrete surface. 5. Apart from the nails fixing ply to make up forms, the rest of the nails on a formwork job are never driven home fully. They are left, or bent over so that they can be pulled out easily with a claw hammer or pinch bar when it comes time to strip the forms. (C) Steel Formwork This consists of panels fabricated out of thin steel plates stiffened along the edges by small steel angles. The panel units can be held together through the use of suitable clamps or bolts and nuts. The panels can be fabricated in large number in any desired modular shape or size. Steel forms are largely used in large projects or in situation where large number reuses of the shuttering is possible. This type of shuttering is considered most suitable for circular or curved structures. If the form is rusty, you might get rust on the surface of your concrete. Steel forms compared with timber formwork: 1. Steel forms are stronger, durable and have longer life than timber formwork and their reuses are more in number. 2. Steel forms can be installed and dismantled with better ease and speed as compared to timber formwork. 3. Steel formwork does not absorb moisture from concrete. 4. Steel formwork does not shrink or warp. Steel Formwork – a pictorial view (D) Plastic Formwork · Re-usable plastic formwork: These interlocking and modular systems are used to build widely variable, but relatively simple, concrete structures. The panels are lightweight and very robust. They are especially suited for low-cost, mass housing schemes. · (i) Permanent Insulated Formwork: This formwork is assembled on site, usually out of insulating concrete forms (ICF). The formwork stays in place after the concrete has cured, and provides advantages in terms of speed, strength, superior thermal and acoustic insulation, space to run utilities within the EPS layer, and integrated furring strip for cladding finishes. · (ii) Stay-In-Place structural formwork systems: This formwork is assembled on site, usually out of prefabricated fiber-reinforced plastic forms. These are in the shape of hollow tubes, and are usually used for columns and piers. The

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 1, Issue 1, pp: 91-109www.ijemh.com

formwork stays in place after the concrete has cured and Chirag K. Baxi acts as axial and shear reinforcement, as well as serving to confine the concrete and prevent against environmental effects, such as corrosion and freeze-thaw cycles. (E) Corrugated & Flat Permanent Formwork Glassfibre Reinforced Concrete (GRC) has been extensively used as permanent formwork for the past twenty years, corrugated or flat to suit all supporting beam design. The extent of its success and its practical application can be illustrated by the fact that more than 45 000 square metres were used on various bridge and tunnel works. GRC permanent soffit formwork, produced specifically to suit all forms of structures, provides both a practical and economical way of supporting freshly poured in-situ concrete in composite bridge decks. Dependent upon the depth of the concrete deck formwork, spans up to 1200mm do not require temporary support. However, in the case of steel beam designs requiring greater spans, a specialized system for supporting the GRC formwork can be used. In either event, GRC panels - whether flat or corrugated - are designed to meet the stringent conditions laid down in codes. Formwork manufactured from GRC is capable of supporting various slab thicknesses over a variety of spans between main bridge beams. In addition, it's characteristics allow it to behave as a composite part of the in-situ concrete under normal in-service dynamic loading. Available in thin panels, in either flat sheet or corrugated form, GRC formwork remains in contact with and becomes bonded to the in-situ concrete over the full surface area of the panel. Available in a standard range of panel sizes or produced specifically to suit individual projects, GRC formwork is delivered to site ready to use. Features GRC formwork has excellent performance characteristics and its inherent material properties provide the specifier and contractor with a permanent surface skin to the bridge deck concrete which: • has a thin cross section, yet provides durability and steel protection equal to much thicker concrete cover • has a high resistance to fire and will not emit toxic fumes • eliminates spalling of exposed faces • provides flexibility for pouring sequences and concreting schedules, which can reduce construction time • enables the final appearance of the deck structure to be assessed on-site before concrete is poured 3.0. TYPES OF FORMWORK 3.1. Foundation Formwork Foundation formworks can be designed in various ways. Basically there is a difference between formwork for individual foundations, normally designed as socket foundations, and formwork for strip foundations. The type of design is dictated by the size, mainly by the height of the foundation formwork. The formwork for individual foundations is similar to column formwork and the formwork for strip foundations is similar to the formwork. Normally sheeting panels with formwork bearers in the form of wall clamps are used for foundation formwork. Individual foundations are also secured by means of wall clamps but of rim type. Bracing is by squared and round timbers as well as boards diagonally arranged. Tie wires as well as metal screws are used as formwork ties. 3.2. Wall Formwork Wall formwork consists of vertically arranged upright timbers (formwork bearers) to which sheeting boards are nailed at the concrete side. The upright timbers are diagonally braced by means of boards at both sides. On cleats situated at every third upright timber, there are horizontally arranged wall clamps. The opposite wall clamps are tied at specified distances. Prefabricated sheeting panels may also be used instead of sheeting boards. Cleaning holes are to be provided at the foot of the formwork. 3.3. Ceiling Formwork Ceiling formwork is the type of formwork mostly found in structures/buildings. The formwork sheeting may consist of sheeting boards or prefabricated sheeting panels. The formwork sheeting may consist of sheeting boards or prefabricated sheeting panels. The formwork sheeting lies on squared timber formwork bearers which are arranged on main bearers carrying off the forces to round Chirag K. Baxi timber columns. With smaller rooms, the main bearer together with two columns, form a trestle. Diagonal board bracings are provided to take up horizontally acting forces. The round timber columns are placed on double wedges which serve as stripping aid and correction device. 3.4. Beam Formwork Beam formwork has prefabricated formwork sheeting parts (sheeting bottom and side sheeting panels). Such individual parts are manufactured based on the beam dimensions specified in the project. For prefabrication of the formwork sheeting parts, a special preparation table must be manufactured on site. The sheeting bottom and the side panels consist of sheeting boards nailed together by means of cover straps. Depending on the size of beam, the width of sheeting bottom is dimensioned so as to accept, at both sides of the width of the reinforced concrete column, the thickness of the sheeting and cover straps and the width of a thrust-board (approximately 100 mm). The sheeting bottom can be placed on a pedestal support (a trestle formed by a wall clamps connected with two columns by means of cleats) or on a round timber column also supporting a wall clamps with cleat connection. In the latter case, the

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round timber column is located under the centre of the beam. By diagonal board bracing the round timber column and the wall clamps above it, a composite triangle is formed. The side sheeting is erected on the sheeting bottom and held by a thrust-board. At the upper edge of the side sheeting a wall clamps is mounted at both sides holding together the formwork by wire or spindle ties. A stull-batten is to be nailed on the formwork immediately above the ties to ensure that the projected beam width is kept when tying the formwork. The wall clamps and the columns are additionally braced by diagonal boards. 3.5. Column Formwork Similar to beam formworks, the sheeting of column formworks are prefabricated according to the column dimensions from sheeting boards connected by cover straps. The sheeting panels are placed in a foot rim which is anchored in the soil by steel bolts. The foot rim consists of double-nailed boards. The foot rim must be exactly measured-in because it is decisive for the exact location of the column. It has the same functions as the thrust-board for foundation or beam formwork. When the sheeting panels have been inserted in the foot rim, vertical arch timbers are placed to take up the forces from the cover straps of the formwork sheeting. Around the arch timbers, which have the function of walers, column clamps of flat steel are clamped with wedges or a rim of boards is arranged similar to the foot rim. Additional formwork tieing by tie wires or steel screws is not necessary. The distances of the clamps are specified in the formwork project. Normally they are approximately 700 mm. The column in the formwork is laterally tied by diagonal board braces. Column formwork (horizontal section) Chirag K. Baxi A lateral cleaning hole is to be provided at the foot of the formwork for removal of any impurities in the form-work before the concrete is placed. If a steel reinforcement is to be erected in the column formwork, two sides of the column only are to be provided with formwork first to permit easy erection of the reinforcement. After erection of the reinforcement, the remaining two sides of the column formwork can be mounted. The two sides mounted first are to be arranged cornerwise to ensure provisional stability. Scaffolding prop arrangement supporting formwork – a pictorial view. Scaffolding prop arrangement supporting formwork – a pictorial view. Chirag K. Baxi 4.0. HYDROSTATIC PRESSURE Column formwork closer spacing of the column clamps at the bottom. Wet concrete delivers hydrostatic pressure. Simply put, when concrete is wet, or as the engineer's say in a fluid state, it acts like any other liquid in spite of all the extra stuff in it. So that the deeper the concrete pour, the greater the pressure at the bottom of the forms. Forms which are holding the edge of a 100mm thick pavement slab have hardly any sideways protection for them. If that same slab was 1M thick it would be a different story. So particular attention is to be paid to holding the bottom of the formwork. As a general rule, if the bottom holds, so will the rest. Blowouts invariably happen at the bottom of a deep pour. The picture on top shows a column form that will be poured about 3m deep. Notice that the column clamps are close spaced at the bottom and wider at the top. Also because the column is wide, precaution is taken of putting in through bolts to stop the bottom column clamps bending. A collapse could bring down a few tones of material with disastrous results. Nail everything. Don't just wedge it in tight and say it's OK. When the concrete is being poured there is a heck of a lot of vibration going on and things that are not fixed in position can and do shake loose. Say you get a large load of concrete dropped on a suspended slab. The formwork in the immediate area bows downwards and the bit in the next section can lift up a touch. If the props are not fixed at the top or otherwise braced, they can fall out and leave a section of the slab unsupported. For this reason the formwork must be closely watched during the pour to check props, braces etc. Just to catch any possible movement before it gets too bad. It is good to have someone not physically involved in the concreting work, just watching out for the odd little things that happen. It is always good practice to have a removable panel in lowest part of the formwork. This is to facilitate the removal of rubbish. This panel gets lifted out just before the pour and the formwork can be blown out, shifting all the bits of sawdust, nails and tie wire without any trouble. Don't forget to Chirag K. Baxi replace the panel before pouring. Keep the formwork neat and with tight joints. Gaps as small as 3mm will let out the fines and cement juice leaving ugly and weak patches in the concrete finish. When formwork under the pressure of wet concrete moves, it is most times impossible to push it back. An extra small timber brace might stop the form from moving in the first place, but once the form has pushed out of line, no amount of pushing with steel props will get it back which is usually not possible because of steel. So, make sure it doesn't move in the first place. Make it stronger than you need. As soon as the formwork is stripped, clean It and oil the ply with proper recommended form oil. There are many different standards, or codes of practice governing the construction of concrete formwork. o Check out your local conditions, at the least think about the following points:- o The need for edge protection. o Access, and platforms for workers. o Protection from falling objects. o Wind bracing for walls. The final bracing of walls, due to be poured, is (or should be) well inside the requirements for wind loadings, but think about keeping temporary braces on anything high enough to cause hurt to a worker if it falls down due to a gust of wind. Don't cut timber to exact size unless it is necessary. Formwork by it's nature is temporary. The finished job is the concrete. That has to look straight and true. The look of the formwork is not critical. If you can let timbers lap, or fly over at the ends and not cut them to length, do it. Hence, don't cut timber unless it is necessary. You might need that extra length next time. 5.0. ORDER AND METHOD OF REMOVING FORMWORK: The sequence of orders and method of removal of formwork are as follows: 1. Shuttering forming the vertical faces of walls, beams and column sides should be removed first as they bear no load but only retain the concrete. 2. Shuttering forming soffit of slabs should be removed next. 3. Shuttering forming soffit of beams, girders or other heavily loaded shuttering should be removed in the end. Table: Period of removal of formwork S. No. Description of structural member Period of time 1 Walls, columns and vertical sides of beams 1 to 2 days 2 Slabs (props left under) 3 days 3 Beam soffits (props left under) 7 days 4 Removal of props to slabs (a) For slabs spanning upto 4.5 m 7 days (b) For slabs spanning over 4.5 m 14 days 5 Removal of props to beams and arches (a) Spanning upto 6 m 14 days (b) spanning over 6 m 21 days 6.0. THINK FORMWORK - REDUCE COSTS Every project has unique features, requirements and challenges. As the design of structural concrete projects becomes more and more complex, a simple method for reducing the cost of construction is frequently overlooked. The most common approach to reduce the cost of a structure was solely to search for ways to reduce the amount of permanent material - "lesser the better". However, this approach overlooks the most important component in concrete structure cost which is the concrete formwork. Concrete formwork consists not only of formwork materials, but also the cost of the labor required to use this material. Chirag K. Baxi Cost of concreting activity Concrete formwork cost is significant. The cost of formwork ranges from 40 to 60% of the cost of a concrete structure. The cost of concrete formwork and labor can exceed the combined total cost of concrete and reinforcement materials and labor. Formwork materials are only a small percentage of the total concrete formwork cost. The major cost is the formwork labor - the costs associated with the installation and removal of the formwork. Therefore, any effort to reduce the costs of a concrete structure must include the construction process. The concrete structural design engineer must be aware of the cost of construction and design the structure accordingly. A well designed structure utilizes optimum concrete formwork, which obtains fast paced construction while keeping costs at a minimum. A structure that is easy to build reduces the required labor and leads to potential cost savings. 6.1. Designing For Cost Savings Due to amount of concrete form-work required for the floor system, it is the potential source for cost saving. From a concrete formwork point of view, the most economical system is the flat slab or constant soffit. In this system, the formwork has limited interruptions, and is easily assembled and removed. Any drop below the soffit elevation, causes a break in the formwork operation. The formwork must stop at this point, possibly change direction and cut to fit. Any change in operation leads to a decrease in formwork productivity and an increase in cost. Deep beams also require additional beam side formwork not needed in the level soffit design. A variable height structure may require different vertical formwork in the floor support, and also different column and wall forms. An optimum design eliminates these vertical drops completely by increasing the reinforcement spearheads in the floor slab. If the drop-heads can’t be avoided, size the vertical drop such that standard dimensions may be utilized. Drainage slopes also have different costs on concrete formwork. A drainage slope which is only on the top surface, maintains the constant soffit elevation is the most cost effective. The added concrete required for a top surface slope is far less costly than constructing a one way or two way sloped formwork system. If it is necessary to use a one way slope, also slope the beams to maintain a constant beam side dimension. A two way slope, where both the top and bottom of the slab slopes with valleys and ridges in two directions, has to be carefully reviewed for formwork costs. Columns are another area in the structural design where potential cost savings can be obtained by limiting the different size columns in the structure. Review the possibility of increasing the concrete strength and reinforcement instead of increasing the column size to carry the higher loads at the lower levels. Alternately, limit the reduction in size of the columns at the upper levels, even if additional concrete is required. This additional concrete is usually minor in cost as compared to changing the column formwork. By limiting the different column sizes in the structure, the same formwork may be used for every column and reduces the corresponding material cost. Column layout can also influence concrete formwork costs. Columns which are aligned as to provide an open area for gang formwork Chirag K. Baxi systems is another way where the structural design can reduce construction costs. Even maintaining consistent column orientation to the building grid will reduce the formwork cost. 6.2. Minimal Considerations In order to obtain economy in concrete formwork, four basic considerations must be contemplated. The concrete formwork must be simple. This concept is based on the formwork being simple to erect, use, and dismantle. An overly complex formwork system leads to reduced production and higher costs. Use the simplest formwork that will do the job. The concrete formwork must be easy to handle. The concrete formwork must be of a size and weight that can be easily handled. If the formwork is to be man handled, a light weight, ergonomic system will lead to increased productivity and cost saving. Furthermore, if the formwork is to be crane handled, a structure designed for easy formwork movement reduces costs by increasing the reuse potential. The concrete formwork must be standardized. If the concrete formwork utilizes industry standard sizes, assembly costs are minimized. If custom or special sized formwork is avoided, material cost is held to a minimum. The concrete formwork must be reusable. If the design permits concrete formwork to be easily removed and repositioned, costs are again minimized. A designed structure that requires little formwork modification and limits potential formwork damage saves construction time and costs. Another option to provide an economical design is to base the design around a concrete formwork system.

ACKNOWLEDGEMENT

There are people without whom this dissertation might not have been possible and to whom I am greatly thankful. Therefore, I would like to acknowledge:

My supervisor **Mr. Chitranjan Kumar,** Assistant Professor and Project Guide, Department of Civil Engineering, Al-Falah University who was not simply supervisors, but also friends and mentors. Without him and his wealth of knowledge, patience and reliability; I could not reach this far.

I express my heartfelt gratitude to Dr Syed Khursheed Ahmad**,** Professor and Head of Department of Civil Engineering, Al-Falah University for his consistent encouragement in completing the project.

The administrative, technical and academic staff of the Departments of Civil Engineering, Al-Falah University for their valuable support.

I express my deep love and warm regards to my parents and my friends for their support, constant encouragement and timely help.

To God be all the glory for the great things He has done.

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