Design and Cost Analysis of Advanced Shuttering

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Abstract—Man from the start of time is known to have construction etiquettes. In the high-rise buildings, the core is one of the most important elements in such enormous structures. Fast and efficient construction of the concrete core of a high-rise building is essential to maintain phased progress on other parts of the building. Formwork is one of the most important factors in determining the success of a construction project in terms of speed, quality, cost and safety of work as it accounts about forty percent of the total project cost of the structure. In high rise building construction, the most efficient way to speed up the work is by achieving a very short floor cycle. That directly depends on the selected formwork for the construction.The formwork development is equally important to the development of concrete in the construction industry. Nowadays extra effort has been put to improve the design of shuttering which ultimately leads to the reduction in weight. Apart from the primary materials of conventional techniques, the materials are now extended to aluminum, plastic, fibre glass, etc. Significant use of advanced formwork is suitable for complex construction processes and provides best results in cost effectiveness. This project describes the comparative analysis of conventional formwork and modern formwork techniques based on different parameters.

IndexTerms—Mivan, yokes, batten, shuttering.

I. INTRODUCTION

Formwork is artificial support provided below and around the precast and cast in situ concrete work. They are basically moulds to receive concrete in its plastic form. It is a temporary structure which is removed after the concrete stiffens also known as false work or shuttering. Formwork should be capable of carrying all imposed dead and live loads apart from its own weight. Since years conventional methods of shuttering have been used but the modification of these techniques has been proving to be a boon in the world of modern structures.

1. Conventional (Plywood) Shuttering

The most common material used for formwork of the wall is the Plywood sheet in which it is used in combination with timber. If the special attention is not given to the corners and joints of the panels, grout may come out in the form of slurry which will lead to poor quality construction.

The cycle time for one floor with the use of conventional formwork is minimum 3-4 weeks. Also, the block or Brick work and plastering is needed in order to get the finished surface. This takes more time and skilled labours too. This ultimately increases the time required for the completion of the project.

Types:

Plywood for concrete shuttering work shall be treated and it shall be of BWP grade and classified as given below:

a) Plywood for concrete shuttering work
b) Plywood of plastic coating for concrete shuttering work
c) Plywood of suitable overlay for concrete shuttering work

Advantages of Conventional Formwork:

a) Easy to handle because of its light weight.
b) Easy to remove.
c) Damaged parts can be replaced with a new one.
d) It is very flexible.
e) Easily available.

2. Aluminium (Mivan) Formwork

This type of formwork was first developed by a European construction company. In 1990, Mivan Company Ltd. From Malaysia started manufacturing these formwork systems. Today, more than 30,000 m^2 of formwork is used across the world. The MIVAN formwork has proven economical and satisfactory as well as efficient for the overall construction environment. The rapid advancement in the field of formwork along with the innovation in concrete as a material has led to a revolutionary change where safer, quicker, sustainable and more efficient construction is possible these days.

Mivan technology is most suitable for constructing a large number of houses in a short span of time using room size forms to construct walls and slabs in one continuous pour on concrete. Certain aluminium alloys, which are resistant to wet concrete as well as atmospheric corrosion, are used for making aluminium forms. These forms are very similar to steel forms. Aluminium panels are generally made with aluminium frames. Lightweight props are made from aluminium alloy tubes. The aluminium forms are the recent scenario of the Indian construction industry.

This system is identified to be very much suitable for mass construction, where quality and speed can be achieved at a high level. This method is very much effectiveto speed up the construction, to assure quality control and durability. Aluminium formwork has been used vastly in recent years due to their lightweight and corrosion resistance.
This method is very cost effective for repetitive Building layouts and for above the plinth work. In this system, all the components in a building including slabs, columns, beams, walls, balconies and special window hood are of concrete and there is no need for block work or brick works. Aluminium formwork is successfully used worldwide for the construction of apartments and buildings.

Advantages of Aluminum Shuttering:

a) Speed-Due to its simplicity of assembly, 4 days required tocomplete 7 to 9 days work for conventional formwork system.
b) Quality- Due to the smooth surfaces and accurate dimension of panels, plastering or remedial work after concrete casting can be ignored.
c) Safety- props and prop heads need not be removed during the dismantling of slab panels.
d) Easy assembly-Due to its easiness of assembly, no need for skilled workers or carpenters. There is only panel fixing is done which eases the work to a great extent.
e) Mobility-The formwork can be taken to the next level through material transfer box on the slab thus use of the crane can be avoided.
f) Freedom of design & jobsite planning-Aluminum Formwork System is a "modular" formwork. It can be used where any architectural and structural layout is to be provided.
g) Durability- The material yields its repetitive use up to 250 times which results in decreasing construction cost compared to conventional formwork.
h) Cost reduction -As form designed for maximum reuse is stronger and more expensive than one designed for single use, but it reduces the total form ofinvestment.

3. Doka Formwork

Doka is an international company which produces, and supplies formwork used in all fields of the construction sector. Doka offers formwork solutions for all areas of construction activity – for anything from housing developments to transportation infrastructure and power-generation facilities, or for building the world's tallest structures. You can choose from formwork systems and components for a Panel floor formwork Dokadek 30

Dokadek 30 is a beam-less, hand-set formwork system designed as a lightweight steel construction with yellow coated frames faced with a wood/plastic-composite sheet. Dokadek 30 provides the good properties of a panel floor formwork system and Dokaflex floor-slab formwork that means its 3 m² large panels makes it fast in typical zones. Dokadek 30 - with or without drop-head: Slab formwork at its most evolved.

II. OBJECTIVE

In this project, we will be discussing the modern techniques used in shuttering and formwork for the ease of construction of structures. Furthermore, adding to the points already stated above our topic relies on some of the most widely used modern techniques implemented to make construction efficient. The main objectives of the study are:

a) To design the traditional formwork, mivan formwork and doka formwork as well.
b) To compare different shuttering techniques viz. conventional, aluminum, and doka formwork along with formwork sustainability and study on self-climbing formwork.

III. LITERATURE REVIEW

Today the speed of construction needs to be given greater importance for small as well as large housing projects. This is important for the effective use of the equipment and the reduction in the housing cost for achieving the national objective. Fortunately, some of the advanced technologies providing the faster speed of construction which are already available in the country.

Miss. Patil Dhanashri Suryakant et.al. have coved every aspect related to conventional and aluminium form of construction. Thus, they infer that aluminium form construction can provide high quality construction at unbelievable speed and at a reasonable cost. Thus, it can be concluded that quality and speed must be considered with regards to the economy. Good quality construction will never deterprojects speed and won't be uneconomical. In fact, time consuming repairs and modification due to poor quality work delay the job and cause additional capital on the project. Some experts feel that housing alternatives with low maintenance requirements may be preferred even at the higher inceptive cost.

Himanshu Rivankar et.al. have found out that it is the need of time to analyse the depth of the problem and find effective solutions. Formwork technology emerges as a cost effective and efficient tool to overcome the problems of the mega housing project. It aims to maximize the use of modern construction techniques and equipment's on its entire project. To overcome the problem of population explosion, this technology has great potential for application in India to provide affordable housing. Thus, it can be concluded that quality and speed must be considered as far as the economy is considered. Good construction will never put off to projects speed nor will it be uneconomical. Thus, we can conclude that the overall cost of the project using Aluminium formwork technology is lesser when compared to the project using traditional methods.

Rokade Mitul R et.al concluded that the conventional methods of formwork system are economical for small scale projects. While the modern-day methods are economical for high growth mass constructions, the modern techniques save cost for construction work and period of construction work. The use of current construction techniques and equipment's on its entire

project is maximizing our goal. Aluminium formwork construction technique is cost actual for the mass construction tedious projects. It is a rapid construction technique in which construction takes place at high speed. The understanding of formwork behaviour during the construction of concrete structures and the developing of useful computer-based models to determine the construction load distribution between shoring system and interconnected slabs of multi-storey concrete buildings, the lateral pressures exerted by fresh concrete on wall formwork. Thus, it can be decided that quality and speed must be given due consideration with regards to the economy. The construction work should be of good quality as it will never deter to project speed. Also, it will be economical.

Mohammed Taher Ahmedet.al. studied that the formwork system has a significant role in the construction process, making the right decision by selecting the appropriate formwork system could lead to a response to sustainable construction. Sustainable formwork could be achieved by enabling and following the property benchmarks. A sustainable formwork system could be benchmarks in the balance of three main categories; environmental, economic, and social thus it will cover all activities and processes related to formwork system. The research outcomes can develop new guidelines and tools to evaluate project sustainability performance. The identification of property measures for formwork system will help the decision makers to evaluate the system and determine the technology to use.

IV. METHODOLOGY

For endeavour mass housing works, it's necessary to possess innovative technologies that square measure capable of quick rate construction and square measure ready to deliver sensible quality and sturdy structure in cost effective manner.

Building Specification:

A random plan of a structure was considered to calculate the quantity of formwork materials and to estimate the cost of each type of shuttering technique.

Specifications of structural components:

- A Flat Slab of 200mm depth was considered
- Total surface area of slab (excluding column portion) is 228.32 m^2
- Column (type 1) dimension = 600mm x 600mm (48 nos.)
- Column (type 2) dimension = 600mm x 1000mm (4 nos.)
- Floor to Floor height is 3.5m
- Overall height of the structure = 7.6m
- Staircase dimensions:
- Riser = 130mm
- Tread = 300mm
- Total steps = 13 + 13 = 26 nos.

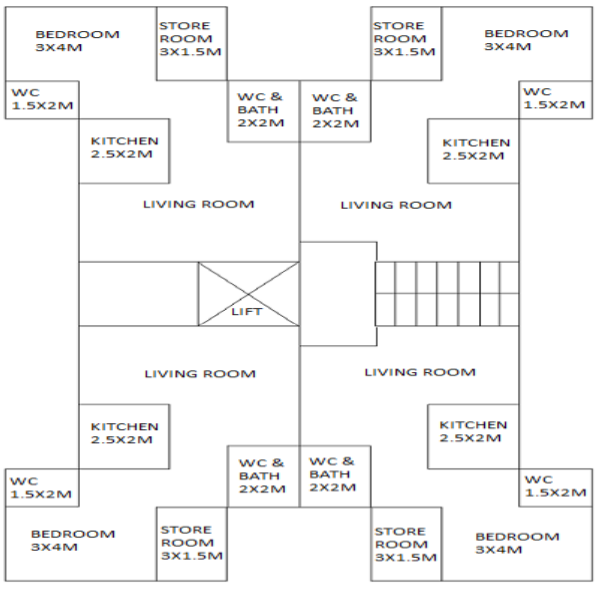


Fig 4.1: Typical Floor Plan

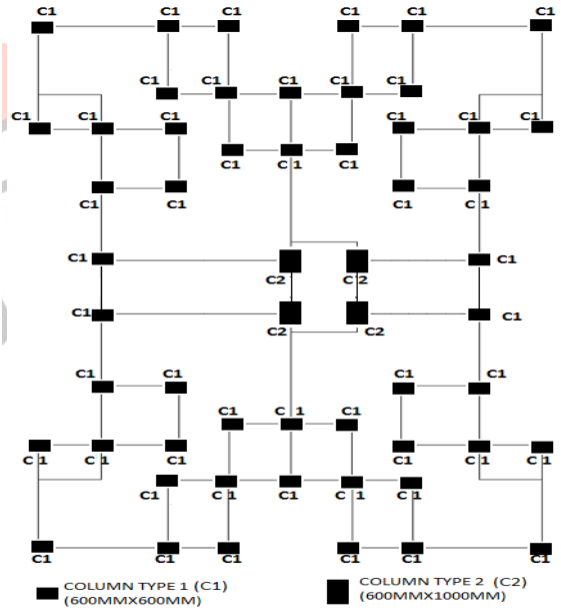


Fig 4.2: Column Plan

1. Conventional (Plywood) Shuttering

Column Formwork: The dimensions of column formwork are achieved after designing for the concrete pressure coming on the formwork. The size and thickness of the sheathing and yokes are calculated by checking for the deflection criteria.

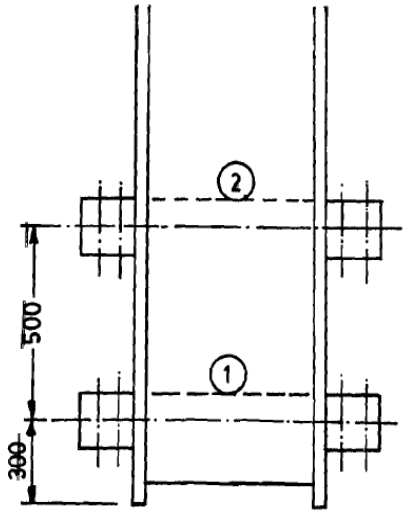


Fig 4.3: Sectional Elevation

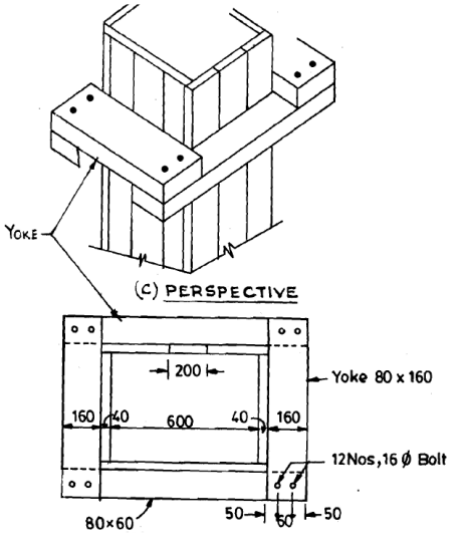
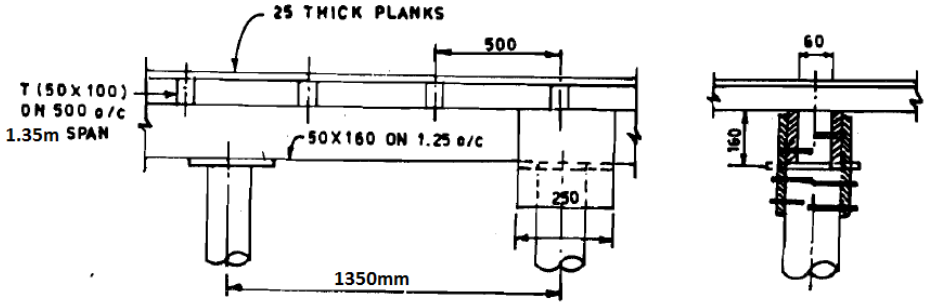


Fig 4.4: Plan

Slab formwork: The size and thickness of the sheathing are calculated by checking for the deflection criteria and the spacing of the batten is kept 1350mm.



(a) Elevation (b) Section

Fig 4.5: Formwork for R.C. Flat Slab

2. Aluminium (Mivan) Formwork

Beam components:

a) Beam side panel –the cutting is done in rectangular shape according to the size of the beam.
b) Prop head for soffit beam –Formwork with a V shaped head is used for easy displacement or removal.
c) Beam soffit panel –It is a plain rectangular aluminium structure which supports the soffit beam.
d) Beam soffit bulk head – It is used to carry the bulk loads.

Wall components:

a) Wall panel- An aluminium sheet which forms the face of the wall is carefully and properly cut to fit the size of the wall.
b) Rocker -It is of L-shape and additionally a supporting part of the wall.
c) Kicker- It acts as a ledge to support and at the top of the panel it forms the wall face.
d) Stub pin- It helps to join two wall panels together.

Deck components:

a) Deck panel -It forms a horizontal surface for the safety of workers and for the casting of slab.
b) Deck prop-It is a supporting component of the deck and it also bears all the loads coming on the deck. It has a prop head with V-shaped form.
c) Prop length- It is the length of the prop and it depends on the slab length.
d) Deck mid- It helps in supporting and to hold the concrete in the middle portion of the beam.
e) Soffit length- It supports the edges of the deck panel.

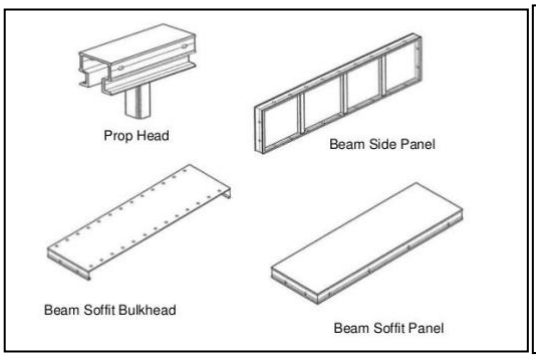


Fig 4.6: Beam Components

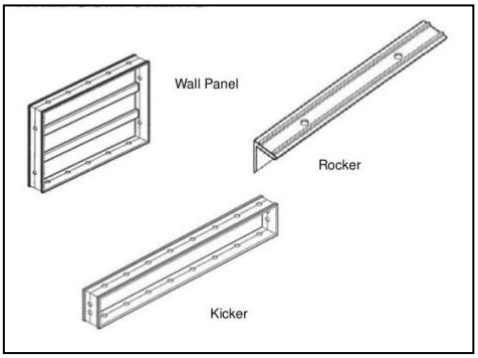


Fig 4.7: Wall Components

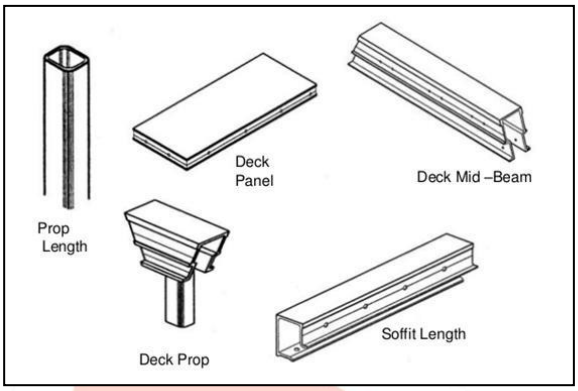


Fig 4.8: Deck Components

3. DOKA Formwork

Doka formwork beams:

The core of the system lies in the usage of an engineered timber component, the H-Beam. The H-beams are manufactured in a modern automated plant at Pondicherry under strict quality control the flanges are made of seasoned chemically treated timber. The web is made of boiling waterproofplywood and joined with the flange by the unique finger jointing method. The H-beams thus manufactured are light, dimensionally stable and retains its structural properties over a period even after repeated usage. It is more predictable, easy to design and use, the number of reuses of H-Beams is more than 100 times (8 times that of conventional timber) and it consumes only 40% of timber volume required. The H-beams are available in two sizes namely in H-16 - 16 cm depth & H-20 - 20 cm depth, length varying between 1m to 6m

Doka formwork sheets:

Doka has an extensive range of formwork sheets for the most varied areas of application. All sheets are made of layers of wood bounded by glue and are extremely strong and stable. Three-ply concrete-formwork sheet, made of European spruce (piceaabies), designed especially for building to produces a uniform concrete surface.

High-grade multi-ply sheet made of Finnish birch hardwood for use again and again to produces a high-quality, smooth concrete surface.

Doka-dur panels

Dokadur panels are the state of the art for floor-slab panels. All-round edge and surface sealing dependably protect the panel against the wear and tear of everyday construction work.

Doka Floor Props

Doka floor props are the right choice for every application. High load-bearing strength plus many practical details that help to make handling easier

Form ties and suspension cones

Doka has a complete range of tried-and-tested form tie solutions and dependable suspension points for wall formwork, single-sided formwork and climbing formwork in uncompromising quality for maximum safety.Doka tie rods and anchor accessories provide safety through superb manufacturing quality Reduce labour costs for installing ties, because of a hammer is all that is needed for easy installation are durable, robust and unaffected by dirt robustly dimensioned universal climbing cones ensure a firm connections between structure and formwork for safety on high structures for all kinds of climbing formwork safe suspension solutions for working and protection platforms with different attachments to suit the application.

V. ESTIMATION

Cost comparison of various formwork systems:

1. Conventional (Plywood) Shuttering:

Quantityof plywood shuttering materials required:

Quantity of Plywood sheathing (40mm thickness) required for columns of size 600mm x 600mm is given below:

Height = 3.5m; Number of columns = 48

Therefore, the total area of plywood sheathing required for 1 = 48 x (0.6 x 0.6 x 3.5) x 4

Floor height = 3.5m.

For 2 floor's height = 241.92 x 2 = 483.84 m^2 = 483.84 x 10.764 = 5208.05 ft^2
Quantity of plywood sheathing (40mm thickness) required for columns of size (1000 x 600 mm) is given below:
Number of columns = 4
Therefore, total area of plywood = 4 x 0.6 x 1 x 3.5 x 4 = 33.6 x 2 = 67.2 m^2 = 723.34 ft^2
Quantity of plywood sheathing 20mm thick required for flat slab:
(23 x 14) – (2 x 14 x 2) – (2 x 3 x 3) = 248m^2 = 2669.47 ft^2
However, this value is to be deducted of the column area.
= 248 – 17.28 – 2.4 = 228.32 x 2 = 456.64 m^2 of sheathing is required or 4915.27 m^2

Total number of yokes required for column:
Size of yoke = 60 x 160 mm
Spacing between two yokes = 500 mm c/c
Taking 5 yokes for each face of column
Therefore, total number of yokes required for one column = 20 yokes
Total number of yokes = 52 x 20 = 1040 nos.
Number of bolts required to join one yoke perimeter = 12 nos.
Total number of 16 mm diameter bolts required for one column = 12 x 5 = 60 nos.
Total number of bolts = 60 x 52 = 3120 nos.
Total number of joists required for slab:

Size of joist = 50 x 100 mm and 1.35 m span
Number of joists = 1000 (lumpsum) for each floor
Therefore total 2000 nos. of joists required.
Number of beams (50 x 160 mm and span 1.25m) required:
Assuming lump sum quantity for beams as 1000 nos.
Number of props required:
Assuming 10 props per column
Therefore, total props for columns = 10 x 5 = 520 props
Props for slab, assuming props at 1m apart from each other
Total props = (23 – 1) x (14 – 1) = 286 x 2 (two floors) = 572 props

Total cost of plywood shuttering materials:
Cost of 40mm thick plywood sheet = Rs. 50/ft^2 = 50 x (5208.05 + 723.34) = Rs. 2,96,592/-
Cost of 20mm thick plywood sheet = Rs. 30/ft^2= 30 x 4915.27 = Rs. 1,47,470/-
Cost of yokes = Rs 45/metre length = 45 x (1040 x 1) = Rs. 46,800/-
Cost of bolts = Rs. 4/piece = 4 x 3120 = Rs. 12,480/-
Cost of Joists = Rs. 60/metre length = 1.35 x 1000x 60 = Rs. 81,000/-
Cost of Beam (50 x 160mm) = Rs. 340/ piece = 340 x 1000 = Rs. 3,40,000/-
Cost of props = Rs. 55/piece = 55 x 72 = Rs. 31,460/-
Total cost of all materials = Rs. 9,55,797/-
Cost of shuttering for staircase = Rs. 300 /ft^2= 300 x 149.62 = Rs. 44886 /-
Total shuttering cost = 955797 + 44886 = Rs. 10,00,683 /-

2. Aluminium (Mivan) Formwork

Quantity of Aluminium shuttering required
Total column shuttering area = 483.84 m^2 + 67.2 m^2 = 551.04 m^2
Total slab shuttering area = 456.64 m^2
Total staircase shuttering area = 13.9 m^2

Total cost of Aluminium shuttering
Column shuttering cost = Rs. 2000/m^2
Slab shuttering cost = Rs. 2500/m^2
Staircase shuttering cost = Rs. 1200/m^2
Total cost for aluminium shuttering = (2000 x 551.04) + (2500 x 228.32) +(1200x13.9) = Rs. 16,89,560/-

3. DOKA Formwork

Quantity of Doka shuttering required:
Total column shuttering area = 483.84 m^2 + 67.2 m^2 = 551.04 m^2
Total slab shuttering area = 456.64 m^2
Total staircase shuttering area = 13.9 m^2

Total cost of Doka shuttering:
Column shuttering cost = Rs. 1800/m^2
Slab shuttering cost = Rs. 2000/m^2

Staircase shuttering cost = Rs. 1000/m^2
Total cost for aluminium shuttering = (1800 x 551.04) + (2000 x 228.32) +(1000x13.9) = Rs. 14,62,412/-

Labour cost
Following are the daily wages of Mason and helper:
Labour required for shuttering of column: 1 mason & 3 helpers
Labour required for shuttering of slab: 2 masons& 6 helpers
Daily wages of mason = Rs. 1000
Daily wages of helper = Rs. 500

1. Labour cost for Plywood Shuttering:

Number of columns formwork prepared by 1mason &3helper per day = 4 columns
Number of days by 1mason &3helper to setup 104 column formwork = 26 days
Slab area covered by 2masons & 3helper per day = 40 m^2
Number of days for slab formwork setup = 12 days
Per day labour cost = (3 x 1000) + (9 x 500) = Rs. 7500
Total labour cost for plywood shuttering = 7500 x 38 = Rs. 2,85,000/-

2. Labour cost for Aluminium Shuttering:

Number of columns formwork prepared by 1mason & 3helper per day = 8 columns
Number of days by 1mason &3helper to setup 104 column formwork = 14 days
Slab area covered by 2masons & 3helper per day = 75 m^2
Number of days for slab formwork setup = 6 days
Per day labour cost = (3 x 1000) + (9 x 500) = Rs. 7500
Total labour cost for aluminiumshuttering= 7500 x 20 = Rs. 1,50,000/-

3. Labour cost for Doka Shuttering:

Number of columns formwork prepared by 1mason & 3helper per day = 6 columns
Number of days by 1mason &3helper to setup 104 column formwork = 18 days
Slab area covered by 2masons & 3helper per day = 60 m^2
Number of days for slab formwork setup = 8 days
Per day labour cost = (3 x 1000) + (9 x 500) = Rs. 7500
Total labour cost for Doka shuttering= 7500 x 26 = Rs. 1,95,000/-

VI. CONCLUSION

Shuttering type	Material cost	Labour cost	Total cost
Plywood	Rs. 10,00,683	Rs. 2,85,000	Rs. 12,85,683/-
Aluminium	Rs. 16,89,560	Rs. 1,50,000	Rs. 18,39,560/-
Doka	Rs. 14,62,412	Rs. 1,95,000	Rs. 16,57,412/-

Formwork technology is a value effective and economical tool to resolve the issues of the mega housing project everywhere the globe. It aims to maximize the use of modern construction techniques and equipment's on its entire project. Traditionally, construction firms all over the world have been slow to adopt the innovation and changes. Contractors are a conservative lot. It is the necessity of your time to investigate the depth of the matter and realize effective solutions. Our aim is to serves as a cost effective and efficient tool to solve the problems of the mega housing project all over the world. Our aim is to maximize the utilization of recent construction techniques and equipment's on its entire project. We have tried to cover each aspect related to conventional, aluminum and doka form construction. We thus infer that aluminum and doka form construction can provide high quality construction at unbelievable speed and at reasonable cost. This technology has great potential for application in India to produce cheap housing to its rising population.

Cost of material with aluminum formwork increases by almost 60 % as compared to the conventional method. Cost of material with doka formwork increases by almost 40%. Duration of Construction in aluminum is less than Conventional Method by almost 50 % and that of doka by almost 35% Thus from the above points it is quite clear that construction by aluminum and doka formwork is quite expensive than the Conventional Method. However, it can save considerable amount of time in construction of high-rise building. Also, many of the finishing works is saved in aluminum and doka which includes plastering (both internal and external), brickwork.

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