# Comparative Study of Existing Column Formwork

[1]Jayanth Rama Naik, [2]N. Bhavani Shankar Rao, [3]Ravi Shankar M. Suresh.

[1]PG Student, [2]Professor, [3]Stuctural Engineer
Department of Civil Engineering,
NMAM Institute of Technology, Nitte, Karnataka, India

***Abstract*—Formwork is a major component of any Civil engineering construction. It constitutes about 35 to 45% of the total cost of the structure. The use of conventional formwork will lead to wastage of materials, time and money. In some cases conventional formwork will not meet the structural requirement. The aim of the study is to review existing column formwork and to arrive at cost effective and easy to handle formwork by making comparative study. It is envisaged that such a formwork will be more productive and possible to use for more number of cycles.**

***Index Terms*— Formwork, Column, Conventional Formwork, System Formwork, Cost Effective Formwork.**

---

## I. INTRODUCTION

Formwork serves as a mould to produce concrete elements having a desired size and configuration. It is a temporary structure (in some case part of the permanent structure) whose purpose is to provide support and containment to fresh concrete until it can support itself. Since 20th century the formwork is developing parallel to the growth of concrete construction. To perform satisfactorily, formwork must be sufficiently strong and stiff to withstand the force produced by the concrete, the workers working on same stage and finishing the concrete, and any equipment or materials placed on the formwork. The term 'formwork' includes the actual material contact with the concrete, known as form face, and all the necessary associated supporting structure. [1]

Vertical formwork must primarily resist the lateral pressure of concrete due to particular height of plastic concrete. It must also resist the other forces due to wind and power equipment during construction. [1],[2]

### *A. Types of Formwork*

There are different types of formwork available in construction industry and they manufacture or modify the formwork based on the structural requirement. Generally, the formworks used for vertical concreting are called column formwork and those for horizontal concreting are called floor or slab formwork. [2]

#### *1) Conventional Formwork:*

This generally consists of standard size of framed panels tied together over their backs with waling, which is a horizontal supporting member for the panel to resist horizontal force exerted by concrete. Initially for wall or column steel reinforcement cage is placed and positioned. Then one side of the formwork panel is first assembled confirming its plumb, alignment and strut are accurate. Then other side is erected and fixed. Plywood sheet with timber frame is the common materials used for column and wall formwork. With the plywood facing sheet screwed on studs to form a timber frame. These methods allow for remove and replace the plywood. To increase the repetition it can be reversed to use both side. The column and wall forms are subjected to edge damage because of open plywood face. Special attention must be given to lumbers and attached piers since the pressures exerted by fluid concrete could cause the supports to slide and edges are open up, which will give rise to unacceptable slurry escape and a poor surface finish of column or wall structure. [2]

#### *2) System Formwork:*

System formwork has the modular components with standard prefabricated large casting panels. After "Legoing", with the aid of CAD design, the modular components through different combination are assembled on site. Thus the system formwork can suit the required shape and size of concrete structures. Minor conventional formwork is used to complement the fault of the system formwork on site. System formwork has good molding quality, faster erection and more cycle times compared to the conventional formwork. The initial investment of conventional formwork is lower than system formwork. Since the system formwork is used for number of repetitions it will be more economical in the long run. The difference parameters in conventional and system formwork are shown in Table1.

Table 1 Conventional Vs. System Formwork

| Parameters | Conventional | System Formwork |
|---|---|---|
| Load Carrying Capacity | Less | More |
| Overall Cost | High | Economical |
| Initial Cost | Low | High |
| Maintenance Cost | Low | Medium |

| | | |
|---|---|---|
| Productivity & Reusability | Low | High |
| Alignment & Surface Finish | Poor | Very Good |
| Time Required | More | Less |
| Labour Required | More | Less |
| Safety | Low | High |

## II. LITERATURE REVIEW

- James (1992), studied that, concrete formwork labour costs constitute over 1/3 of total cost of concrete construction. The factors which majorly influence formwork productivity must be identified and their impacts quantified to improve productivity and to get accurate prediction. The scope was limited to wall and column formwork. From the literature survey factors which significantly impact productivity are repetition, sequencing, weather events and material management.

  His study identified the factors which can reduce the number of labour hours required to erect, align and strip concrete formwork will help to improve the cost effectiveness of construction operations. Formwork labour expenses constitute nearly 35% of the total cost of vertical concrete work. Proper system selection, repetitive design dimensions, efficient scheduling, and careful activity coordination can yield significant productivity savings. Productivity depends on form type, panel size, formed surface shape, form height, method of assembly and placement. [3]

- Belden (1998), examined some issues involved in formwork at the construction site. His study identified the factors that control the quality, performance and safety of formwork and the methods used to optimize them to reach the economy. Finally his works identified some of the new formwork innovations that aim at improving the cost and performance of formwork.

  Improved formwork method initially increases 5% of cost but will result in savings of 15% of total cost from improved labour productivity. Cost of project can be reduced by designing the structure as uniform size, choosing the innovative formwork systems, safety, using lightweight materials as formwork. [4]

- Shen et al. (2002), investigated the profile of waste generation from applying different types of building materials to different types of projects in construction. It is considered that the application of various building materials to different types of projects has different impacts to the size of waste generation.

  Private housing projects are found generating the highest wastage levels (15%), when compared with other types of projects (Public housing 5%). The reason may be resulted from the fact that the private housing projects normally are of non- uniform building structures. [5]

- Elbeltagi et al. (2012), present a fuzzy logic-based model that supports vertical formwork system selection, which makes easy to take a decision. Ten commercial vertical formwork systems commonly used in Egypt are identified with the most important factors affecting their selection. The data collected were tabulated to serve as a knowledge-based system (KBS) with respect to five factors which are defined by the experts as the most governing factors. These factors are Structural system, Building shape, Floor height, Initial allocated budget, and Construction progress rate to guide site engineers in selection proses. On the basis of the KBS, a fuzzy logic model developed with five input variables, representing the governing factors. The model is tested by applying it on a real-life case study. Results are acceptable and shows that developed system by a group of formwork experts revealed an average satisfaction level of 77% and a promising role for fuzzy logic in formwork selection.[6]

## III. SCOPE AND OVER VIEW

According to study from the literature, in small scale projects use of more innovative formwork system is less feasible and using conventional formwork is uneconomical. The formwork takes a major role in the construction industry. It is very important to study the available formwork which is feasible and economical. If the available formwork is not meeting the requirements, it is very important to improve the things available. Aim of the present work is to study the existing formworks used in the small scale projects, comparing and designing the column formwork to meet the requirement.

### *A. Objectives:*

- To study the existing column formwork
- Identification of Critical parameters from literature review.
- Comparing existing column formworks.
- Identifying the suitable formwork for a particular project.

### *B. Steps Involved In Present Work:*

- Preparing the questionnaire on different parameters of formwork.
- Surveying the construction industry based on prepared questions.
- Comparative study on different parameters from collected data.

- Finding the drawbacks of the existing formwork (By applying it to on-going project – Golden Lotus apartment).
- Suggesting the suitable formwork for the on-going project.

Table 2 Questionnaire Survey

| Sl. No. | Parameter \ Company | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | Panel material | Plywood, H-Beams | Plywood, H-Beams | Plywood, Wood frame | Mild steel | Aluminium |
| 2 | Cost of product (Rs/m$^2$) | 3500 | 3500 | 1725 | 4500 | 7500 |
| 3 | Additional items | Tie rod , Staging | Tie rod, Wing nut | Tie rod, Nut | Nut-bolts, Prop supports | Tie rod, Wing nut |
| 4 | Size of panel | 1.15X3.2 | 1.22X2.44 | 0.45X2.44 0.23X2.44 | 0.45X1.2 0.20X1.2 | 0.6X1.8 |
| 5 | Rate of productivity | 2.5 sqm/manday | 2.5 sqm/manday | 2.5 sqm/manday | 3.0 sqm/manday | 6.0 sqm/manday |
| 6 | Weight of panel | 20.38 kg/m$^2$ | 10.08 kg/m$^2$ | 10.00 kg/m$^2$ | 30.00 kg/m$^2$ | 18 kg/m$^2$ |
| 7 | Ease of work | Needs tower crane | Requires 2-4 Labours | Requires 2 Labours | Requires 2 Labours | Requires 2 Labours |
| 8 | Maintenance | Requires | Requires | Requires | Only oiling | Only oiling |
| 9 | Surface finishing | Smooth | Smooth | Smooth | Smooth | Smooth |
| 10 | Number of repetition | 15-20 | 10-20 | 10-12 | 40-50 | 120-150 |
| 11 | Allowable bending moment | 0.20 kN-m | 0.20 kN-m | 0.20 kN-m | 0.75 kN-m | 2.50 kN-m |
| 12 | Customised | - | - | - | - | 200-600mm |

Analysis of data from questionnaire survey:

- Plywood with H-Beams: Initial cost is reasonable, productivity is average, but number of repetition is less compared to steel and aluminium form work, edges are not closed in this system and customize is nil. This system is also one of the factors causing deforestation.
- Plywood with wood frame: Initial cost is less compared to other materials. Number of repetition is less compared to other materials and customize is nil.
- Mild steel: Initial cost is in average. Mobility is difficulty and costly because of its self-weight (30 kg/m$^2$). Number of repetition is more compared to plywood with H-beam, plywood with wood frame and less compared to aluminium formwork.
- Aluminium: initial cost is high, but considering productivity and repetition it will be economical and more feasible. Allowable bending moment depends on the particular type of section.

## IV. Case Study On Golden Lotus Apartment

Considering the data from Table 2 applying it on an ongoing project to compare the cost and other parameters will give an idea of which type of formwork will be suitable. A detail of the project under consideration is shown in Table 3.

Table 3 Project details

| Project name | Golden Lotus apartment |
|---|---|
| Place | Bengaluru |
| Storey | B+G+11 |
| Built-up Area | 1400 m2 per floor |
| Number of columns | 87 per storey |
| Total shuttering area of column | 7491.90 m2 |
| Duration (Structural Work) | 254 Days |

Calculating the labour unit rate on formwork is a necessary thing, because it is the part of total cost of the formwork in construction activity. It mainly depends on the daily wages of the labour, labour productivity and labour crew size. Labour unit rate details are mentioned in Table 4 and Table 5.

Table 4 Labour unit rate calculation inputs

| Description | Quantity |
|---|---|
| Total labour in gang | 8no. |
| Carpenter or skilled (Rs.470/day) | 3no. |
| Unskilled (Rs.375/day) | 5no. |
| Productivity decreases at rate of | 3% for each floor |
| Total work to be completed in | 65 days |
| Shuttering area of column at each floor | 576.30 $m^2$ |

Table 5 Labour unit rate for each material

| Sl. No. | Description | UOM | Plywood with H-Beams | Mild Steel | Aluminum |
|---|---|---|---|---|---|
| 1 | Productivity | sqm/manday | 2.50 | 3.00 | 6.00 |
| 2 | Total team hour required | hour | 45751.74 | 38126.45 | 19063.23 |
| 3 | Total no. of labour gang required | no. | 88 | 73 | 37 |
| 4 | Total work force required | no. | 704 | 584 | 296 |
| 5 | Man days required | days | 45760 | 37960 | 19420 |
| 6 | Unit labour cost for the activity | Rs/sqm | 192.93 | 160.04 | 81.12 |

The above table shows that the labour unit rate for the aluminum formwork is 57.95% lesser than plywood with H-Beams and 49.31% lesser than Mild steel. It is because of its high productivity. So that total work force required on the site is 296.

*Cost comparison of column formwork:*

Total cost of formwork calculated based on different factors are tabulated in Table 6. The product cost and other parameters are taken from the questionnaire survey i.e., Table 2 and salvage value is taken from present market rate.

For calculating unit cost of formwork total repetition required for project is taken as 52 by considering set of formwork used in the site is ¼$^{th}$ of one floor column formwork area requirement.

$\therefore$ Formwork quantity on site = $\frac{576.3}{4}$ = 144.1 sqm

Number of repetition required = $13 \times 4 = 52$ number.

Table 6: Unit rate calculation details

| SL. No. | DESCRIPTION | UOM | Ply wood with H-Beams | Ply wood with wood frame | Mild Steel | Aluminum |
|---|---|---|---|---|---|---|
| 1 | Cost of Product | Rs/sqm | 3500.00 | 1725.00 | 4500.00 | 7500.00 |
| 2 | Number of repetition | No. | 15.00 | 12.00 | 40.00 | 120.00 |
| 3 | Salvage value | Rs/kg | 0.00 | 0.00 | 25.00 | 110.00 |
| 4 | Weight of penal | kg/sqm | 20.00 | 20.00 | 30.00 | 18.00 |
| 5 | Salvage value per sqm | Rs/sqm | 0.00 | 0.00 | 750.00 | 1980.00 |
| 6 | Value to be depreciated | Rs | 3500.00 | 1725.00 | 3750.00 | 5520.00 |
| 7 | Depreciation per sqm | Rs/sqm | 233.33 | 143.75 | 93.75 | 46.00 |
| 8 | Maintenance cost | Rs/sqm | 15.00 | 15.00 | 10.00 | 10.00 |
| | **Unit cost of the product:** | | | | | |
| 9 | Unit cost considering 52 repetition | Rs/sqm | 127.31 | 176.92 | 101.54 | 46.00 |
| 10 | Unit cost including maintenance | Rs/sqm | 142.31 | 191.92 | 111.54 | 56.00 |
| 11 | Labour unit rate | Rs/sqm | 192.93 | 192.93 | 160.04 | 81.12 |
| 12 | Total unit rate of the product: | Rs/sqm | 335.00 | 385.00 | 272.00 | 137.00 |
| 13 | Overall cost of formwork for Golden Lotus apartment | Rs | 2509786.5 | 2884381.5 | 2037796.8 | 1026390.3 |

The result shows that the cost of aluminum formwork in this project is 59.1% less than plywood with H–beams, 64.41% less than plywood with wood frame and 49.63% less than mild steel formwork.

## V. SUMMARY AND CONCLUSION

There are several types of formwork available in the industry. By preparing questionnaire data have been collected from different companies, which have given valuable information to compare the different types of formwork. To compare those data collected from the questionnaire the Golden Lotus apartment taken as a case study.

From the above study these are the conclusions drawn:

- It is very important to gain the knowledge of formwork in construction industry to make a structural work economical.
- All parameters noted in table 4.2, 5.4, 5.5 and 5.7 are important to find the unit cost of the formwork to a particular project.
- For aluminum formwork labour cost comes around 57.95% lesser than plywood with H-Beams and plywood with wood frame and 49.31% lesser than Mild steel, because of its high productivity.
- Total cost of aluminum formwork used in the Golden lotus apartment project is less than 50% of mild steel, plywood with H-beams and plywood with wooden frames.
- Total cost of aluminum formwork lesser compared to other because of its increased number of repetitions, more productivity, low maintenance cost and its good salvage value.
- Aluminum formwork is better one compared to other three types of formwork.
- For designing the formwork the important factor are maximum allowable pressure which depends on height of formwork, height of pour of concrete, rate of rise of concrete and temperature.
- For using the system formwork manufacturer will provide the user manual to know the design consideration.

## VI. ACKNOWLEDGEMENT

Authors are thankful to our beloved HOD of Civil Department N.M.A.M.I.T. Nitte, Dr. Srinath Shetty. We sincerely thank our principal Dr. N. Chiplunkar. We extend our gratitude to LEAP Constructions Mr. Ajay Inamdar (MD. LEAP Constructions) for supporting this research work.

## REFERENCES


[1] Arch Alexander, "Design and Construction of Concrete Formwork", Purdue University, 2003, CRC Press LLC.
[2] (2010) Civil-resources.blogspot.inhttp://civilresources.blogspot.in/2010/06/formwork.html.
[3] James D. Shumway IV, "A Comparative Analysis of Concrete Formwork Productivity Influence Factors" MS. Thesis, The Pennsylvania State University, May. 1992.
[4] Belden Nago, "Optimizing the Perfuormance and Cost of Formwork" M.E. Thesis, Massachusetts Institute of Technology, U.S., June. 1998.
[5] LY Shen, VWY Tam, CM Tam, S Ho, "Material Wastage in Construction Activities - A Hong Kong Survey" 1.Department of Building & Real Estate, The Hong Kong Polytechnic University, Hong Kong, 2.Department of Building & Construction City University of Hong Kong 83, Tat Chee Avenue, Kowloon, Hong Kong,tam.vivian@student.cityu.edu.hk. 2002.
[6] Emad E. Elbeltagi, M.ASCE, Ossama A. Hosny, Ahmed Elhakeem, Mohamed E. Abdelrazek, and Mohammed El-Abbasy, "Fuzzy Logic Model for Selection of Vertical Formwork System" Journal of Construction Engineering and Management ASCE, pp.832-840, July 2012.
[7] Concrete Society's Construction Group "Formwork A Guide to Good Practice" Second Edition 1995. pp 1-281.
[8] Bureau of Indian Standards, 4990:2011 Plywood for Concrete Shuttering Work – Specification, New Delhi.
[9] Bureau of Indian Standards, 14687:1999, Guidelines for Falsework for Concrete Structures, New Delhi. Questionnaire