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Constructability assessment of conventional formwork and automated formworks in commercial building

K Anitha[1], P Deepan[2], V Shanmugavadivu[3], P Kathirvel[4]
[1] P.G Student, Department of Civil Engineering, Mahendra Institute of Engineering and Technology, Namakkal, Tamil Nadu, India
[2, 3] Assistant Professor, Department of Civil Engineering, Mahendra in Engineering College, Namakkal, Tamil Nadu, India
[4] Assistant Professor, Department of Civil Engineering, Mahendra Institute of Engineering and Technology, Namakkal, Tamil Nadu, India

Abstract
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 effects 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.

Keywords: economy, construction, commercial building

Introduction
India measures 3,214 km from North to South and 2,933 km from East to West. It has a land frontier of 15,200km and a coastline of 7,516.5 km. It has a population of approximately 1.21 billion people (2011 Census), which is the second most populous country in the world. Although India occupies only 2.4% of the world s land area, it supports more than 17.5% (2011 Census) of the world's population. 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.

Formwork practice in India
For many years reinforced concrete construction is predominantly followed in India, thus the formwork plays a vital role in the Indian construction. The most commonly used type of formwork systems are the traditional or conventional systems made of dressed lumber and fabricated at site during construction as shown. They are also known as as-built formwork. Currently even for construction of wide variety of structures from small to medium sized projects, the conventional formwork systems are used. Quality, safety and economy are the three objectives of formwork construction. The conventional formwork systems could account only for the economy aspects of form construction, thus the modern Formwork systems known as Engineered or System Formwork Systems were developed later.
System Formworks are built of prefabricated modules (standard timber beams) with the metal frames and patented plywood sheathings. Since 1980, the concept of system formwork is improving tremendously due to the advancement. In forming technology and fabrication process. New and innovative materials such as Plastic, FRP (Fibre Reinforced Polymer), Aluminium, etc., are used as an alternatives for the timber components as shown Figure 1.

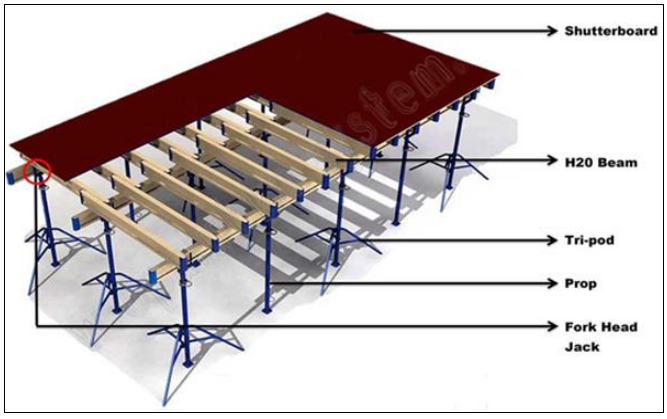

Fig 1: Horizontal formwork

Formwork scenario in India

Though the system formwork has many advantages over traditional or conventional formwork, their usage in the Indian construction is very minimal

- Low technology
- Labour intensive
- Labour-unskilled, migratory, traditional and family oriented
- Absence of monitoring body.

The two major advantages of system formwork over conventional timber formwork systems are as follows:-

1. Speed of construction (reduced time in assembly and stripping)
2. Lower life-cycle costs (maximum number of re-use).

The reason being, lack of awareness, misconception among the Indian construction personnel, that these formworks are costlier and heavier, requirement of highly skilled labours and supervisors, requirement of specialised equipments for erection and assembly but in reality it is the most effective system. Formwork the surface, support and framing used to define the shape of concrete until it is self-supporting. In the modern construction world safety is become more prominent so according to it we should assess the risk in the formwork based on the types of formwork, materials used in the formwork, design accordingly the loading in the formwork. Stripping formwork is the most used type of formwork. It can be one of the most hazardous phases of in-situ concrete construction. Formwork includes the forms on or within which the concrete is poured, the supports which carry the forms and the concrete. The formwork supports, bracing, foundations and footings are sometimes known as false work. 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.

Steel forms are stronger, durable and have longer life than timber formwork and their reuses are more in number Steel forms can be installed and dismantled with greater ease and speed. The quality of exposed concrete surface by using steel forms is good and such surfaces need no further treatment. Steel formwork does not absorb moisture from concrete. Steel formwork does not shrink or warp the steel form work.

This is by far the most common material used for the facing panel. It is easily cut to shape on site, and if handled and stored carefully, it can be used many times. A standard plywood thickness on site is 18mm. This is usually sufficient for most pours. However, if the formwork is curved, thinner plywood is used to facilitate bending. Thicker plywood may be used when the weight of concrete causes standard thickness plywood to bow out, distorting the concrete face.

Objective of the study

- To find efficacy of automated formwork over conventional formwork among the metrics Cost, Quality, Durability, Manpower efficiency, Accuracy, Safety mostly in Commercial building.
- To analyze the total cost for formwork with mathematical tool MAT LAB
- To analyze the constructability constraints for conventional formwork and automated formwork with SPSS**.**

Scope of study

- Automated formwork plays a vital role in current and future construction industry.
- It is important to note that, Automated formwork will be one the most valuable in the future industry as it improves the Quality of concrete and the Structure.
- In that aspect it has been proposed and decided to work on automated formwork.
- The Detailed Analysis of Automated formwork is carried out and the Physical Problems are analyzed and Solution is carried out. Also we compared the results with Conventional formwork

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.

Automated formwork

The System formwork t has the standard prefabricated modular components along with casting panel. The system formwork can suit the required shape of concrete structures. The System form-work has good casting quality, speedier erection and more recycle times compared to the traditional formwork. The initial investment of system formwork is higher than the conventional one. The main components of the system formwork include plywood, beam, waller, false work, joint parts, bracing and operation platform. System formwork is applied in a specialized kind of job. It supports the in-situ RC contractors by providing services of design, delivery, site support and buy-back after job completion.

Specialised formwork technology

Project Formwork

Apart from the already available technologies in this age of

innovation the companies are going a step further and creating their specified formwork technology to suit the requirements of a specified project. Individual Formwork stands for solutions are the recent trend. Now there are firm that individually plans and pre-assembles formwork systems for project-specific solutions, what is meant here is formwork which undergoes stationary prefabrication before use.

Conventional Formwork

Cuplock easy to erect

No wedges – just a simple locking cup at each node point on the Standards enables connection of the ends of up to four members in one locking action. With all four members attaching at the same level the system is ideal for birdcage construction as well as conventional face scaffolding. This is shown in Figure 3.1.

It is suitable for access or formwork support with an extensive range of special applications. Versatile and durable, Cup Lock Scaffolding Systems are built to efficiently assist with construction and various support structures the horizontal members can be angled to suit many different applications. The system has been used in triangular, trapezium and is ideal for curved surfaces are shown in Figure 3.2.

Before commencing the erection of any CUPLOK scaffold, care should be taken to check that the ground is suitable and clear of loose rubble to provide a stable base and clear access for erection. The scaffold must be erected on adequate soleplates and the foundation on which the soleplates are placed must have sufficient bearing capacity to support the imposed loads transferred from the scaffold. As a general rule, each soleplate should be long enough so that it supports at least two Standards. Bricks or masonry blocks are not suitable and must not be used. Not only project based but now formworks are being created for specified heavy structures across the globe. These are those forms that are specially designed and manufactured for heavy structures. This demand needs for a special formwork dimensional tolerance.

H-Frame Formwork

H Frame Scaffolding System is the one of the most consuming allied product of steel scaffolding system in building construction line. Which is shown in Figure 3.4, the uses are multiple to support Beams, Slab, Staging of Bridges, storage of building material and easy movement on the top of the work place by labour and engineers H Frame System is Light weighted and easy in transportation with longer lasting in uses.

Consists of welded frames, with 48.3mm OD verticals, braced together with scissor type cross braces secured by spring clips, Bracing is provided in alternative bays for scaffold heights up to 20mm and in all bays for greater heights. H-Frame with 60.3mm OD.

Cross Braces: Suitable for H-Framer at spacing of 2.5, 2.0, 1.5 & 1.0m which is shows in Table 1.

Table 1: H frame scaffolding system

Prop Size	Extension (mtr)
Verticals	40 MM NB B Class Tube
Horizontals	40 MM NB B Class Tube
Size	1500 x 1200 MM
Size	2000x 1200 MM
Size	2400 x 1200 MM

Automated Formwork

Doka formwork Doka system components

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 water proof ply wood 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 of time 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 size namely in H-16 - 16 cm depth & H-20 - 20 cm depth, length varying between 1m to 6m.

Table 2: Bending moment for Doka

Max. Shear Force	Max. Bending Moment	EI
11 KN	4 KN/M	170 x 106 KG.CM^2

RMD Framework

RMD Kwik form's commitment to providing practical and effective onsite support to customers, through the provision of onsite assistance technicians, has made it the first choice for many contractors requiring formwork and shoring solutions throughout India. It starts with an in-depth knowledge and understanding of a project to produce technical drawings to site construction teams. These innovative formwork and shoring designs then translate into safe and efficient solutions that save the customer time and money. Throughout the project, qualified engineers will be on hand to ensure safe equipment erection through inspections and for pre pour checks to give customers peace of mind throughout the construction. This approach underpins RMD Kwikform's commitment to deliver added value to its customers.

Perri Formwork

SKYDECK (peri) range of applications extends from residential construction through to industrial construction projects with thicker slabs. With extensive range of accessories, the slab formwork is ideally suited for markets with very high safety standards. The systematic assembly sequence and lightweight system components accelerate working operations. In addition, early striking with the drop head system reduces on-site material requirements. The small

prop requirements ensure more freedom of movement under the slab formwork and simplify the horizontal transportation of materials

Sample Collection

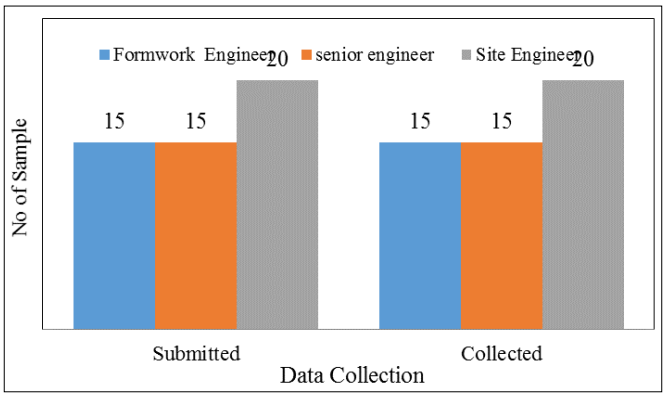

Fig 2: Percentages of responses

Total 51 questions are framed and the samples are collected from various types of experienced persons in different firms Total 50 samples are collected and it is shown in Figure 2 analysed with SPSS the test which are more reliable for the project the test's are Reliability test, chi-square test, one way annova, correlation tests are analysed and the major questions which mostly affect the construction Each questions are categorised with a selection of strongly disagree, disagree, neutral, agree, strongly agree.

Major Factors

These are the main factors which mostly affect the formwork system in construction industry. In which the Questioner is framed which is shown in Appendix 1.

- Initial cost: Initial cost is Most considered in form work system
- Repetition cycle: Repetition cycle is most Important in formworks for cost saving
- Time frame - Time frame is most considering factor for faster construction which take more time.
- Labor efficiency: labor Enables the Quality of work in formwork
- Durability: All the form works Materials Durability are most important for Construction Industry
- Risk Factor: In construction Industry Near miss and Faulty is main Disaster in Construction. Proper Form works with safety System to used
- Safety: Safety is most Concern in Construction Industry and important Factor for safety

Statistical Package of the Social Sciences (SPSS)

SPSS Statistics places constraints on internal file structure, data types, data processing, and matching files, which together considerably simplify programming. SPSS datasets have a two-dimensional table structure, where the rows typically represent cases (such as individuals or households) and the columns represent measurements (such as age, sex, or household income). Only two data types are defined: numeric and text (or "string"). All data processing occurs sequentially case-by-case through the file (dataset). Files can be matched one-to-one and one-to-many, but not many-to-many. In addition to that cases-by-variables structure and processing, there is a separate Matrix session where one can process data as matrices using matrix and linear algebra operations. The graphical user interface has two views which can be toggled by clicking on one of the two tabs in the bottom left of the SPSS Statistics window. The 'Data View' shows a spreadsheet view of the cases (rows) and variables (columns). Unlike spreadsheets, the data cells can only contain numbers or text, and formulas cannot be stored in these cells. The 'Variable View' displays the metadata dictionary where each row represents a variable and shows the variable name, variable label, value label(s), print width, measurement type, and a variety of other characteristics.
Statistics included in the base software:
Descriptive statistics: Cross tabulation, Frequencies, Descriptive, Explore, Descriptive Ratio Statistics Bivariate statistics: Means, t-test, ANOVA, Correlation (bivariate, partial, distances), Nonparametric tests Prediction for numerical outcomes: Linear regression Prediction for identifying groups: Factor analysis, cluster analysis (two-step, K-means, hierarchical), Discriminate.

Cost analysis using mat lab

MATLAB is a computer program that provides the user with a convenient environment for performing many types of calculations. Besides it is usually used to solve differential equations and it is an effective way and can be considered as quick and easy. Moreover, it may also provide the student with the symbolic solution and a visual plot of the result. One of the most popular codes used to solve differential equation which is mainly used for solving engineering applications of the MATH 2210. Dealing with diverse engineering applications can result different order of differential equations, besides the engineering system it may result a system of differential equation whether the system has the same style of DE or mixed order. This can cause a sort of complication toward writing the MATLAB program which is dedicate to predict the behaviour of the engineering case studied.

Reliability test – cronbach alpha test

Reliability analysis is performed to determine the internal consistency level of the obtained responses which is in liker scales type. This test is done to find the information collected is fit for analysis. The most commonly used method to check the consistency level is the Cronbach alpha test. The Cronbach alpha test was done on the received data to determine its consistency level thereby to prove its fitness for further analysis.
The reliability of information is accepted only when the value of the Cronbach alpha is greater than 0.3 and if the value is less than 0.3 the collected information is rejected and the analyses are not performed. The data with Cronbach alpha value greater than 0.7 are said to be more reliable. This is shown in Table 3.

- Internal consistency of data
- Values should be between 0.7 and 0.9

Table 3: Cronbach alpha test

Cronbach Alpha Value	No. of Items
0.909	51

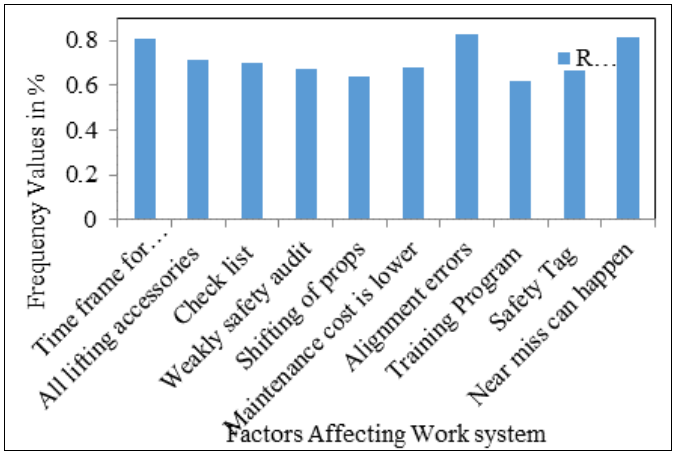

Fig 3: Values of R II

5.4 Chi-square test using SPSS

The Chi-Square Test of Independence determines whether there is an association between categorical variables (i.e., whether the variables are independent or related). It is a nonparametric test. This test is also known as Chi square test of association.

The chi-square test for independence, also called Pearson's chi-square test or the chi-square test of association, is used to discover if there is a relationship between two categorical variables This test utilizes a contingency table to analyze the data. A contingency table (also known as a cross-tabulation, crosstab, or two-way table) is an arrangement in which data is classified according to two categorical variables as shown in Table 4. The categories for one variable appear in the rows, and the categories for the other variable appear in columns.

Table 4: Chi square test for project value

Case Processing Summary						
Description	Cases					
	Valid		Missing		Total	
	N	Percent		Percent	N	Percent
Project value * Toe guard is important in formworks	50	76	41	13.2	91	100
Project value * Near miss can happen in conventional	50	58	41	10.4	91	100
Project value * Collapsing of Stagging in Conventional is higher	50	62	41	7.3	91	100
Project value * All lifting accessories to be inspected monthly	50	74	41	12.2	91	100
Project value * Safety Tag is necessary in formworks	50	53	41	10.4	91	100

One-way ANOVA test with SPSS

The one-way analysis of variance (ANOVA) is used to determine whether there are any statistically significant differences between the means of two or more independent (unrelated) groups (although you tend to only see it used when there are a minimum of three, rather than two groups) ANOVA is an omnibus test statistic and cannot tell you which specific groups were statistically. The One-Way ANOVA ("analysis of variance") compares the means of two or more independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different.

This test is also known as:

- One-Factor ANOVA
- One-Way Analysis of Variance
- Between Subjects ANOVA
- The variables used in this test are known as:
- Dependent variable

Correlation test with SPSS

The inferences from the correlation test have been according to the determined values. The factors which have been numbered as 2 and 12 were said to be highly correlated with the value of 0.98. This signifies that the changes in material types & specification and the modifications in plan & design were said to be associated closely with each other. The factor named modifications in plan & design was associated with another factor named inaccurate cost estimate at tender stage and also with planning and scheduling deficiencies. The two equipment related factor namely poor quality of equipment and the frequent equipment breakdown were the factors found to be highly correlated with the value of 0.916 which states that both the factors were connected to each other and have high degree of association. This states that much importance has to be given to equipment management & maintenance.

Conclusion

All the assessments had been done to identify the most influencing factors which results in Formwork problems in construction projects**.** The major part of construction projects is formwork system to improve the quality of the structure**.** Complete formwork problems and in future weather conventional system or automated system will be effective for better construction. The results are analysed by SPSS.

- In long run the cost will be optimized in automated formwork compared to Conventional formwork. By 20%
- In Short Duration projects, automated formwork will be most suitable. Removal of formwork time will be reduced by 40%.
- Near miss or collapsing of formwork can be highly protected in automated formwork Accidents can be reduced by 90%.
- Material wastage is extremely good in automated formwork compared to conventional. Wastage can be Reduced by 30%
- Maintenance Cost is controllable in automated formwork. Compared to conventional by 30%.
- Manpower requirement is tremendously reduced. Compared to conventional by 40%.

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