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Time, Cost, Productivity and Quality analysis of Precast Concrete System

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Abstract

Out of the various determinants that lead to the success of a project, construction management plays a vital role among them. Delay in a construction project would cause wastage of resources and money that needs to be analysed. The construction methodology adopted has a direct impact on the strength and the quality of the structure. In this aspect, precast concrete construction is considered to produce better productivity and reduce completion time, cost and dependency on work force. This paper reviews and summarizes the role of time, cost, quality and productivity of the precast system in order to compare with the conventional.

Keywords: *Precast construction, construction management, time and cost analysis, quality and productivity*

1. Introduction

The development of the construction industry has been increased rapidly with the introduction of new system of construction and new technologies. Pre-cast concrete technology is being used widely by many countries around the world, which is one of the most cost effective and quality monitored system. Due to the protective environment, the quality and efficiency can be monitored and safety can be assured [10]. In order to improve and speed up the construction, division and specialization of the human workforce and interaction between the design and planning phase has to be carried [19].

Prefabrication has been used since ancient times. The Sweet Track constructed in England around 3800 BC, employed prefabricated timber sections. Sinhalese kings of ancient Sri Lanka have used prefabricated buildings technology to erect giant structures. In 19th century in Australia, a large number of prefabricated houses were imported from the United Kingdom. The method was widely used in the construction of prefabricated housing in the 20th century, like in the United Kingdom to replace houses bombed during World War II. Assembling sections in factories saved time on-site and reduced cost. The Crystal Palace, erected in London in 1851, was made of iron and glass prefabricated construction [20].

India is an infrastructure starved country [6]. With the rise in technology, the construction boom in India is developing at a fast growth rate. It provides a wide spectrum for the introduction of precast concrete building systems to our construction methodology. Though with the second largest population in the world and majority of people earning below poverty line it deals with a shortage of skilled construction workers. Presently, fast track construction is a rapidly growing technique, and the time save in construction would compensate the overall construction cost, making prefab technology widely accepted all over India.

2. Barriers to Entry

The use of prefabrication in the private sector has been encouraged by the government with the sweetener of an increase in saleable area, given the benefits of higher quality and environmental standards. The adoption of prefabrication by manufacturers suggests that any increase in building cost has been absorbed by an increase in revenues. Prefabrication is a portion of the structural element only; the cost increases would in any case be more marginal than substantial. Although if capital costs of plant establishment are amortized, mass production of repetitive prefabricated units will eventually bring down the costs to a level comparable with in-situ construction. In the long run, quality assurance and waste reduction is guaranteed. Another factor governing is the shortage of manpower in different parts of the country mainly because many of them work in their agriculture fields for 3-4 months and are unavailable at that time. Even if the demand is met, say several thousand workers for a big project, there is likely to be shortage of logistics and professional management staff. There is also a dearth of skilled manpower at the production and the on-site erection stage [1]. The taxes implied by the government on finished products of the prefabricated components are 25% of the cost of the construction. Thus, the government needs to come up with smart incentives for the use of prefabrication in order to meet the growing demand of affordable housing [2], proposed by Yat-Hung Chiang et.al in Hong Kong.

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According to Vidya Devi T et.al from India [4], the technology to be adopted for housing components in India should be such that the production and erection technology be adjusted to suite the level of service available under the urban and rural conditions. An insight into the 'Prefabricated Building in India to 2016: Market Data Book' revealed that there is a demand for 26.5 million affordable housing units in India and it will be a challenging task to cater to such needs with the help of the conventional Cast-in-Situ Building Technology. In a building the foundation, walls, doors and windows, floors and roofs are the most important components. These components have to be worked upon to minimize the cost, time and quality of construction [4], proposed by RinkuTaur et.al in India. Case studies done by the Building Materials & Technology Promotion Council, Govt. of India have been focusing on cost effective and environment friendly building materials all over the country for the past few years. The need for the adoption of such a methodology also needs a guaranteed market to function and this cannot be done unless the product is effective and economical. All such efforts have helped professionals, contractors, private and public agencies towards a wider acceptance and knowledge of the precast technology. The aim is to replace the conventional labour intensive method with use of the precast technology by creating a management system that functions on the special and individual needs based on surveys, population needs and rational use of materials and resources [3],proposed by Yat-hung-chiang et.al in Hong Kong.

3. Comparative Study of Precast and Conventional Methods

The most important aspect of any building is concrete and its strength. There are different methods of concreting like a conventional method called cast-in-situ method and the other is called pre - cast concrete method. In cast-in-situ method, concrete is prepared on the site and in pre-cast method, it is casted in a factory away from the site and is transported to the site for installation [5], Clyde Zhengao li et.al in Hong Kong.

Cast-in-situ is the oldest method of construction, but it has its drawback s in quality and efficiency. Quality of the concrete for a building is one of the most important aspects, so the modern era of construction has taken it a set further that is called 'pre-cast' method where the quality can be improved to provide maximum efficiency. The pre-cast method is used mostly now all over the world, because of rate of construction is rather faster than that of cast-in-situ construction [10] and all the information provided by Mr Virendravyas gives a detailed comparison of precast and other conventional methods with relevant data from India.

3.1 Time Comparison

Compared to cast-in-situ method, the precast method consumes less time because the prepared materials and elements are delivered just in time and placed on site which reduces unnecessary handling and equipment use. This allows other trades to begin work more quickly which speeds up the construction time and is more economical with fewer disturbances for the surrounding. Cast-in-situ method of concreting requires lots of time because concrete requires minimum 28 days to achieve 99% strength of its total strength [11] and this data was noted by N.Dineshkumar et.al. This requires a lot of time and labor making it much more uneconomical than pre-cast method.

In most building projects, speed of construction and tight construction programs are primary considerations and this is where precast concrete excels. To escalate the advantages of precast these two factors should be taken into considerations:

a. Design the building layout to maximize repetition of precast units.
b. Design construction details to maximize the number of standardized components.

The duration of a pre-casted building was calculated through the data collected from the pre-cast manufacturers. The duration period for the completion of the project was categorized into three stages- sub-structure, super structure and finishing works. Where sub structure took the same time for cast in situ and pre cast but the super structure was finished quickly with pre cast, as the walls and slabs are manufactured off site and installed on site during the time of the project.

Table 1: Total Duration of Prefabrication Construction

Sl. No.	***Description***	***Duration***
1	Sub Structure- (Site Cleaning, Earthwork, Foundation, Basement, Soil Filing)	22days
2	Super Structure-(Wall Panel Framing and roofing slabs)	12 days
3	Finishing Work- (Electrical, Plumbing, Painting, Tiling and Windows)	31 days

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Pre-cast construction takes less time duration in finishing works when compared to cast-in-situ, because of the electrical piping work is fitted already in precast walls and slabs. The plastering work is no need for pre-cast elements, which is good in appearance and finishing [10], proposed by N. Dineshkumar in India. Thus the total duration for a double storey residential building with prefab technology was 65 days while with the conventional method was 128 days (Table 1 & 2)

Table 2 –Total duration for Conventional Construction

Sl. No.	*Description*	*Duration*
1	Sub Structure- (Site Cleaning, Earthwork, Foundation, Basement, Soil Filing	22 days
2	Super Structure-(Column Lintels & Sunshade, Beams, Roof Slabs)	52 days
3	Finishing Work- (Electrical, Plumbing, Painting, Tiling and Windows)	54 days

3.2 Cost Comparison

Pre-cast is an ideal solution for constructing a residential building due to the production of similar types of elements repeatedly in bulk, thus reducing cost. Pre-cast concrete provides durability, flexibility and sound durability with cost efficiency. Maintenance cost is also less in pre-cast system [8], proposed by Toong Khuan Chan, Faculty of Architecture Building and Planning, University of Melbourne, Australia.

Cost of pre-cast may vary with the type and the size of construction. For a small project the cost of pre-cast increases due to no production of elements in bulk. However, for bigger projects the cost may decrease significantly [9]. In a housing project, activities can be divided such as, foundation, column, beam, and slab construction. Same aspect is presented as % of total cost of project of a multilevel car parking in the table below [6].

In the below shown graph the construction cost of the footing, columns beams and slab, which are made by using steel frame, precast frame and combination of both, are compared. Results showed that precast frame with precast concrete floor are more economical

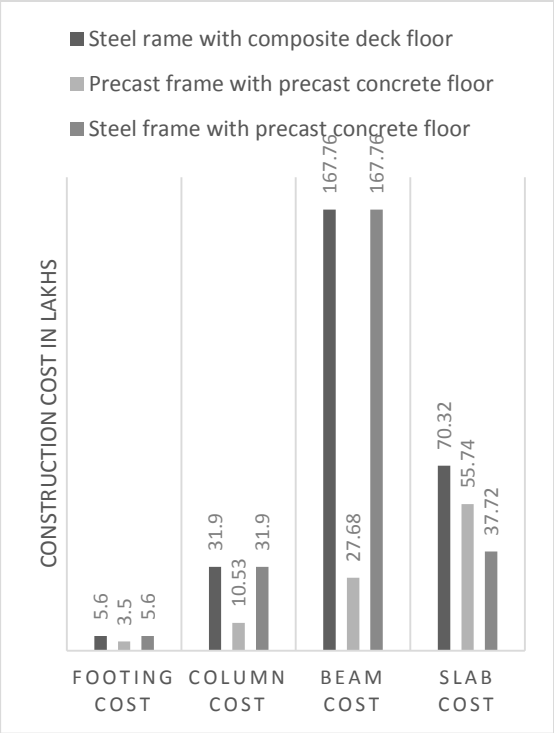

Fig. 1 Construction cost of building

The direct cost of the precast frame with precast concrete floor comes out to be 23.10% lesser than the steel frame with composite deck floor [6]. But, in one of the case studies of a double storey residential building it was found that the cost of the construction using precast elements came out to be 13% more than the cost of the cast-in-situ method [11] Virendra Vyas International Journal of Engineering and Technical Research(IJETR) Mumbai, India. This is due to the fact that the prefab construction has an upper hand in the construction of heavy, industrialized infrastructure but its implementation in the construction of individual houses has had a lot of constraints in India. Construction companies in developed countries have comparatively high labour wages and thus they increase the capital investment in order to decrease the labour input. Since Prefab construction is basically more of machine made products and less of labour intensive works, it proves to be economical such as in countries like Australia [7]. On the other hand, construction companies in developing countries like India rely heavily on cast-in-situ by exploiting the cheap and large number of labour inputs getting better cost savings than the prefab construction. The construction sector in India accounts for about 11 % of India's GDP and feeds as the main source of employment for 33 million people overall. According to an article by the 'Economic Times' a survey revealed that there are only 2% skilled work force in the country. The financial incentives offered by the government are also not up to the mark making it even more difficult to compensate the higher initial investment cost in prefab construction

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3.3 Productivity

The labour productivity of a structure through pre-cast system is more than that of Cast-in-situ system. The time required to install structural components using pre-cast is less compared to CIS method. The variability of the productivity in pre-cast method is also small, which means that it has more consistent productivity values over a period. Loss of efficiency during the construction process is also analyzed. The loss of efficiency in pre-cast method is less as a result of smaller work force at the pre-cast construction sites is demonstrated. The cost incurred in the project is affected by the labour efficiency. The baseline productivity for both the methods, the pre-cast component unit rates and the correlation of the productivity factors to construction productivity were found out. This research by Indra Gunawan in Malaysia was based on questionnaires interviews, video camera, and secondary data collection such as project schedules, monthly progress reports, and other relevant materials subjected to construction labour productivity [17] proposed by Mura S.Samhouri. These findings can be used to compare with similar pre-cast and CIS construction projects' performance in the future. However, a study by onsite productivity can be tackled by the use of Method Productivity Delay Model (MPDM) and the ANOVA Analysis on various installation cycles of a proposed project. Use of these methodologies of one such project in Jordan [16] yielded that the material unavailability, equipment unavailability and management errors were among the top 3 in terms of severity to system productivity. Souma M. Alhaj Ali et.al, on the productivity improvement of precast in Jordan, Firstly did a study on the severity and comparative impact for five delay causes namely: labour, management, environmental, equipment and material on overall system productivity of forty installation cycle times. Secondly, three components of precast were used and a statistical analysis was done on their installation cycle time so as to check whether the delay caused in the previous method was due to the variation of precast segments. While the Government needs to take incentive to the establishment of concrete production plants, at the same time onsite production can be improved by developing a decision model that can be used by suppliers ,contractors and managers in a way that helps cater to the growing demand. A questionnaire survey study by Mr. B Prakash Rao et.al, revealed that precast construction technology was perceived to be a better solution for the huge housing demand for the Economically weaker sections and Lower income groups of the society because of its low cost in construction and high efficiency in productivity but there is need for a proper collaboration from the Government, Precast designers and the Private firms [18] proposed by Indra Gunawan, Malaysia.

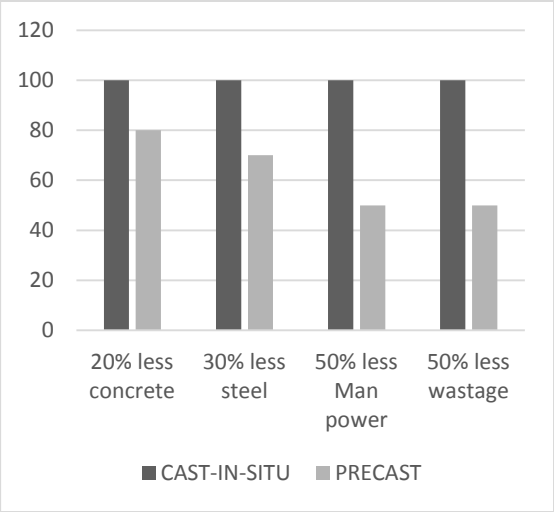

Fig. 2 Benefits of Precast

In the above figure the two different construction methods i.e. cast–in-situ and precast are compared and the benefits of precast are shown. It clearly depicts that precast uses 20% less concrete, 30% less steel, 50% less manpower, and 50% less wastage during construction.

3.4 Quality

Technological advances changes the way of doing business in areas of the construction industry. Companies that still practice traditional methods in construction process don't have the chance to get success in today's competitive business environment. Adoption to the new trends and methods in technology is a necessity for the success of companies and the development of the industry. Precast concrete solutions can help to reduce the waste generated on site by up to 50% of a construction building compared to Cast-in-situ method. The design system which can be implemented by the manufacturing company is tri-dimensional modelling software that helps maintain the interface between the different construction elements. A further study on the software will help designers to better understand the design and specification of elements that cannot be manufactured or transported. Hence the waste reduction technique needs to be implied as prior to manufacturing and construction on site as possible [12] G.Arsnal, Turkey. Web-based quality management system can offer many advantages in the quality control process of precast concrete. The program's aim is to obtain the information during production, transportation and erection stages and checking the quality standards and specifications of precast concrete which can control the properties, dimensions of the products and irregularities at the production stage. The transportation and erection stages are also preceded by this program. This helps in understanding the precast stages from production, transportation to erection. It

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considerably reduces mistakes and increases construction speed. Saving time and money are the other important advantages. Obviously a better quality control mechanism is obtained by using this system. [12] N.Dineshkumar, P.Kathirvel in India.

4. Conclusion

Precast is economical when compared to other conventional methods which are being used since 700 B.C, precast is a cost and time saving construction method which assures quality of concrete to its maximum extent. The productivity of the construction is high and wastes are minimum. Even after being very economical, it has its own drawback as the precast system has not been fully implemented in India and there is less knowledge about this method in the construction sector of India. Being a county with a large number of unskilled labours, it gets difficult to work with heavy machinery without experience and the cost of transportation of structural elements from the factory to various sites is variable. Cost of precast varies with the size of the structural building, for small one storey or two storeys, there are very few similar elements and the cost of construction increases due to its unique nature.

At present India has only 2% of skilled labour [3]. To introduce precast in India this percentage should be increased which can help in meeting the huge housing demand using precast. The government needs to come up with smart incentives to facilitate the establishment of concrete production plants to avoid any kind of productivity delay. Even on-site management is crucial for enhanced construction speed and ensuring quality and exact specification. The need for adoption of such a methodology also needs a guaranteed market to function and thus contractors, suppliers and managers also need to be made aware of the potential of such a technology in India. A study conducted on the perception of clients, contractors and consultants towards pre cast construction technology" [18], reveals the acceptability and knowledge of this technology in India. However, future studies are called for the establishment of precast concrete construction methodology as the primary mode of construction technique in India.

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