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Review of Prefabricated Prefinished Volumetric Construction and Its Application in India

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A B S T R A C T

Indian construction industry is changing day by day particularly due pandemic period in which the industry is facing lot of challenges from delay in material supply to unavailability of labour force which leads to finding or adaptability of advance construction methodology and one of them is modular construction also known as a 'Prefabricated Prefinished Volumetric Construction'. In Western countries, this system has been widely used in the construction of office buildings and residential buildings. This construction system provides the advantages of construction effectiveness, high levels of quality control, saving of construction time, minimization of skilled labour, reduced manpower requirements on site, and saving in formwork requirements when compared with the traditional construction method (cast-in-situ concrete). In India, cast-in-situ is the traditional construction system that has been mostly used generally and Only a few parties in the Indian construction market have adopted prefabricated volumetric concrete systems. However, many factors have an impact on the adoption of this system completely. This review paper presents the overall technology and its various methods of application and limitations in sites in India. The study concludes the significant adoption of prefabricated volumetric concrete systems is the need for developing countries like India and fulfil the need of housing for all.

Keywords: Prefabricated Volumetric Concrete, Modular Construction, Construction Industry, Project

1. Introduction

The concept of Prefabricated Volumetric Concrete (also known as "Modular") construction includes those buildings, where the majority of building components are standardized and produced in a controlled environment in plants away from the project site, and then transported to the site for assembly. The components are assembled in units as per the site requirement and needs. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost. Prefabricated Volumetric Concrete construction plays a major role in the era of modernism architecture. [1,2] The application of this method can lead to the efficient utilization of resources and cost of construction as well as no doubt can save time as compared to conventional methods of construction because of the parallel and rapid construction of building components or units in manufacturing plants as shown in fig 1.

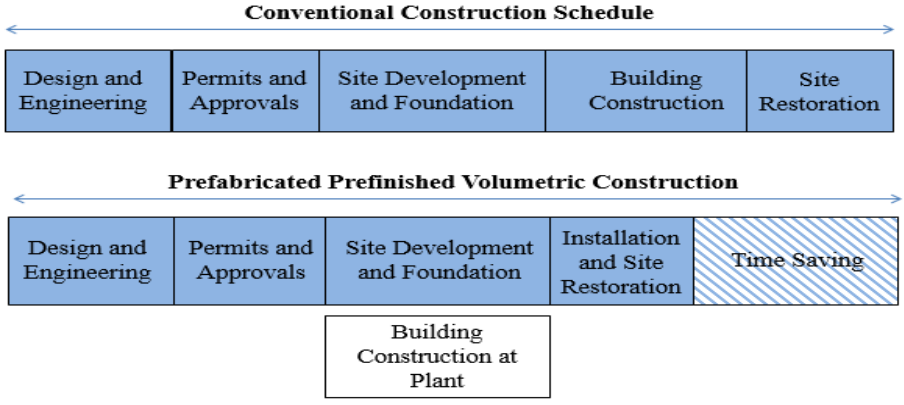

Fig 1: Comparison of Conventional and modular construction methods

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The other main features of this construction process are as follows which make it distinct from conventional method:
1 The division and specialization of the human workforce
2 The use of tools, machinery, and other equipment, usually automated, in the production of standard, interchangeable parts and products
3 Compared to site-cast concrete, Prefabricated Volumetric Concrete erection is faster and less affected by adverse weather conditions.
4 Plant casting allows increased efficiency, high quality control and greater control on finishes.
This type of construction requires a restructuring of the entire conventional construction process to enable interaction between design phase and production planning in order to improve and speed up construction.
The chart below in Fig. 2 summarizes the decades long path from material-based construction to the current manufacturing of buildings as modules, assembling them into pre-finished transportable Volumetric Modules for installation as Built Environment.

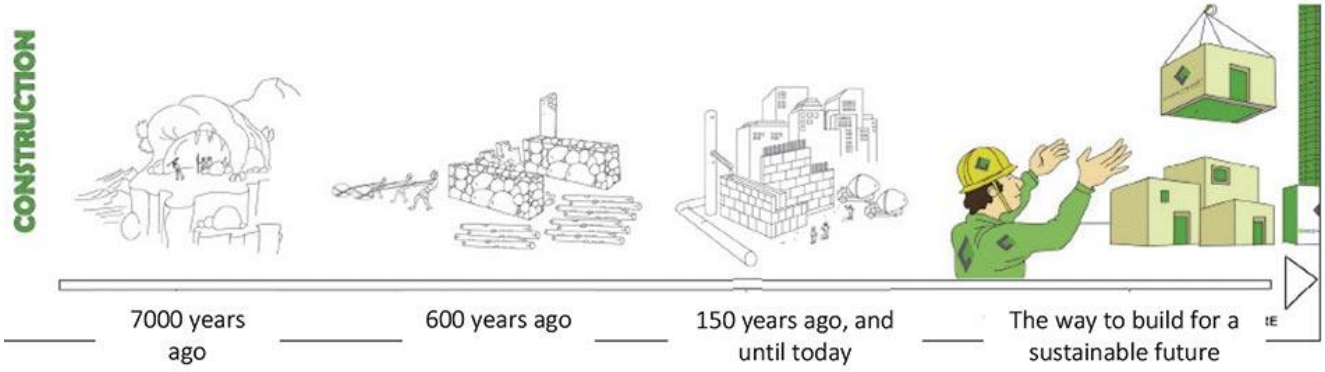

Fig 2. Summarizing the Construction Method (Reference: nbmcw)

2.Methods of Prefabrication Construction

The modular construction is very new to India but thousands of modules are manufactured annually in the UK and Singapore. The following types of modules may be used in the design of buildings using either fully modular construction or mixed forms of steel construction: **[4]**

2.1 Four sided modules

Modules are constructed with four closed sides in this style of construction to generate cellular type spaces that carry the aggregate vertical weight of the modules above as well as in-plane loads (due to wind action) through their longitudinal walls. The amount of cellular space available is constrained by transportation and installation constraints. Buildings with entirely modular construction range in height from 6 to 10 stories, depending on location and exposure to wind. Modules are made up of a sequence of 2D panels, starting with the floor cassette, to which the four wall panels and the ceiling panel are screwed. The longitudinal walls of the higher module are designed to sit on the longitudinal walls of the lower module to transfer vertical loads. In the recessed corners of the modules, additional steel angles may be inserted for lifting and enhanced stability. Connections between modules are normally made with plates that are bolted on site. The modules are unhooked safely from a height using special lifting frames.

2.2 Partially open-sided modules

By introducing corner and intermediate posts and using a rigid continuous edge beam in the floor cassette, four-sided modules can be built with partially open sides. The bending resistance and rigidity of the edge element in the floor cassette limit the maximum opening width. In order to fit within the wall width, additional intermediate posts are commonly square hollow sections (SHS). To build larger rooms, two modules can be stacked on top of each other. The maximum height of the building is limited by the compression resistance of the corner or interior supports, however as with totally modular construction, 6 to 10 stories can be reached. This method can also be used to create long modules with an incorporated corridor. Transport and site access may limit the module's length, however a length of up to 12m is usually feasible. By reducing weather tightness issues during installation and finishing work, using modules with incorporated corridors helps speed up construction.

2.3 Open sided (corner-supported) modules

By transferring weights from the longitudinal edge beams to the corner posts, modules can be built to have completely open sides. The module's framework is often made up of bolted together hot rolled steel elements such as Square Hollow Section (SHS) columns and Parallel Flange Channel (PFC) edge beams. The ceiling may be supported by a shallower parallel flange channel (PFC) section, although the overall depth of the edge beams is always greater than for four-sided modules. Modules can be stacked to create bigger open plan rooms, such as those seen in hospitals and schools.
The building's stability is usually ensured by a separate bracing system consisting of X bracing in the separating walls. As a result, totally open ended modules are rarely employed for structures taller than three stories. Except where walls attached to the columns offer in-plane bracing, infill walls and partitions within the modules are non-load bearing. The corner posts, which are normally 100 x 100 SHS members, provide compression resistance. Fin plates, which provide minimal bending resistance, can be used to link the edge beams to these posts. SHS members can also be secured with end plates and Hollo-bolts. The corner posts have enough compression resistance to be used in structures with at least 10 stories.

Because open-sided modules are only stable for one or two storeys on their own, additional vertical and horizontal bracing is frequently used. Suitable connections at the corners of the modules can transfer in-plane forces. A rigid end frame, usually made of welded or rigidly attached Rectangular Hollow Sections, is supplied in an open ended module, which is a version of a four-sided module (RHS). The stiff end frames are made as part of the module or as separate components that can be combined.

2.4 Mixed modules and floor cassettes

Long modules may be stacked to form a load-bearing serviced core, and floor cassettes span between the modules and load-bearing walls in this 'hybrid' or mixed style of construction. The modules are built in the same way that open-sided modules are, but the load put to the side of the modules is substantially larger. As a result, hybrid modular and panel construction is confined to structures with a height of 4 to 6 stories. It is commonly utilized in residential buildings, particularly terraced buildings, and consists of modular stair 'cores' and heavily serviced regions. The modules form a'spine' that runs the length of the building, with the floors attached to it.

3.Literature Review

Mohak Patel, Jayeshkumar Pitroda et. Al

Erection of Building Construction Easy To Made - In this research paper author has studied various phases of precast element implementation and in that erecting of precast element has been studied in detail. The process effectiveness of a structure is a degree of feasibility of its manufacture, transportation and erection with minimum consumption of materials, labor and other resources. The erection effectiveness is ease of erection with minimum consumption of Labor, time and other means. Characteristics of erection effectiveness are an efficient pre-assembly of structures, relatively equal weights of erection units, high degree of prefabrication and accuracy of manufacture, and last but not the simplicity of butt joints and provision of fastening devices. An erection cycle is a series of operations for placing a component in its design position. The operations requiring an erecting crane and, therefore, consumption of machine time are as follows: slinging, lifting and delivering the component to a point of erection, guiding, positioning and placing it in design position, temporary fastening of components, unslinging and returning load-lifting hook to the initial position. [5]

The operations which require no cranes and are performed with the use of fastening-and-truing and other devices comprise trueing of components and their final fastening in design position. The duration of operations involving guidance, spatial orientation, placement and unslinging the component may vary greatly depending on the efficiency of slinging arrangements. These operations account for 50 to 60% of the total erection cycle time, and for up to 70% of labor requirements. As per Author erection of building is a very important modern construction technique in the context of economy, facility, modern technology and comfort. It is very useful for special purpose projects like for the use of residential building, parking area, industrial flooring like flooring of large area, it has minimum consumption of materials, labor and time, decrease project cost and nowadays Erection multi story building process are very easily used in the construction residential using any modern techniques and machineries. [5]

Ram Kumar, Manoj Patterson et. Al

A Case Study On Use Of Precast Technology For Construction Of High-Rise Buildings - Author has studied a case study of precast operation in building and presented his interpretation on the same. Precast holds the key to success in achievement of "Housing for all" by the year 2022. This paper highlights the case study for adoption of Precast Technology to achieve fast-track, sustainable, and cost-effective construction of high-rise buildings in Indian Scenario. The case study of Dream Valley project is located in Greater Noida (West), Delhi NCR, India. It's a residential township with 47 high-rise residential towers, 379 villas, commercial & institutional buildings, and other developments. The total built-up area of the project is more than 10 million sq.ft has been examined. [6]

Following educations could be the key takeaways though this case study:

- Adopting mix of CIS & factory made precast units wherever required, instead of usually considered 'all precast or no precast' approach offers more benefits in terms of time, cost, and quality.
- Repetition of precast components is essential in order to meet quantity for cost effectiveness.
- The adoption of precast compared with traditional constriction demonstrated significant advantages, such as improved quality control, reduction of construction time, construction waste, dust & noise on site, and labor requirement on site. In addition, it results in higher useful gross floor area which contributes to significant cost benefits.
- A considerable reduction in steel factor can be achieved even for seismic zones IV& V.
- It becomes easy to perform non-destructive testing (NDT) if the need arises and becomes easy to mitigate.
- Precast has evolved towards the use of a non-standard design approach with modular elements optimizing site opportunities & constraints.
- Precast technology allowed for flexible design and longer clear spans in the non-tower areas like parking.

N. Dineshkumar and P. Kathirvel

Comparative Study on Prefabrication Construction with Cast In-Situ Construction of Residential Buildings - The main objective of the research paper is to study the present situation of the precast construction industry in India. Author has Proposals for improvement of the industry and study on cost effectiveness of precast concrete construction for single and multi-story residential buildings. The prefab construction for individual double story residential building cost is 13% more than the conventional construction. Prefab construction is easy to work and reduces the project duration of similar magnitude of project, reduced by 63 days when compared to the conventional. It's the main advantage for prefab construction and also it helps when there is labor shortage. As per the survey carried out by the author, the prefab constructions have more advantages and procurement in industrialized, heavy infrastructures. But in individual houses there are a lot of constraints and lack of knowledge that are struggling to be implemented in India. At this stage conventional construction is economical and comfortable when compared to the prefabrication construction. [7]

Vaishali Turai and Ashish Waghmare

A Study of Cost comparison of precast concrete vs. Cast-in-Place - Author has analyzed the precast practice followed in India with case study. The paper is based on a cost comparison of precast concrete vs. cast-in-place concrete. Cost of any construction is directly varied with time of construction. Precast is manufactured in a factory (i.e. in a controlled environment) with required quality, can easily mix, and cure with good quantity. Precast concrete is manufactured in factories and transported to site. The precast construction requires less manpower; laborers are required only to join precast members. That means indirectly saving cost on labours. [8]

In precast concrete construction wastage of materials is negligible as compared with cast-in-place concrete. There is no need of curing on site after erection of members because members are cured in the factory for desired days. Therefore the time (in days) is saved in construction which will reduce the cost of construction. Precast construction reduced the cost of construction required for maintenance of work. The cost on shuttering and deshuttering is eliminated by using precast and will result in saving total cost of construction. The cost of rework due to improper work, faulty construction method, unskilled labor, material quality, and onsite environmental problem can be eliminated by using precast members. [8]

B. Raghavendra K. Holla, Siddhant Anant et. Al

Time, Cost, Productivity and Quality analysis of Precast Concrete System - This paper reviews and summarizes the role of time, cost, quality and productivity of the precast system in order to compare with the conventional. The productivity of the construction is high and wastes are minimal. Being a county with a large number of unskilled laborers, 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.

At present India has only 2% of skilled Labour. To implement precast on a larger scale in India this percentage should be increased which can help in meeting the huge housing demand using precast. Author expressed his view on the site. [9]

Akash Lanke and Dr. D. Venkateswarlu

Design, Cost & Time analysis of Precast & RCC building - In this research paper the author has taken one building as a case & designs the same building as a precast building & Traditional Cast in-situ building. Author has made a cost analysis as well as feasibility check on the basis of costing & duration. Author analysis resembles the cost of precast building is significantly reduced & duration of construction is also much lesser than traditional methods. From all this study it has been concluded that the precast concrete system is more economical than conventional cast in place method but still there are some conditions which we have to take care of while using precast, those are quantity of construction, distance of site from manufacturing unit, type of building etc. [10]

VPS Nihar Nanyama, Riddha Basua et. Al

Implementation of Precast Technology in India Opportunities and Challenges - Author studied and presented a cost analysis model for precast technology versus traditional construction to address some of the challenges in this research paper. Presented cost model is applied to two projects wherein precast technology and conventional technology are utilized to construct the project and an inference is drawn comparing the time and cost aspects of precast technology. [11]

The main aim of the research has been accomplished by proposing a cost analysis model for precast technology and comparing the time and cost aspects of precast buildings vs. conventional construction in two live projects. Time savings of 20-35% have been demonstrated using precast technology in comparison to the conventional method of construction. In contrast, cost comparison showed us that there is enormous cost variation when compared to the traditional/conventional method of construction. [11]

The cost incurred in adopting precast technology is 15-30% more than the cost of traditional/conventional technologies for the projects considered in the research. This analysis and comparison have paved the way to identify that there are constraints associated with adoption of precast technology. Author has carried out a questionnaire survey to collect responses about constraints from all the stakeholders involved with the adoption of precast technology. Respondents have ranked economies of scale, high initial cost, lack of skilled workforce, and leakage issues as the top four constraints. [11]

Krish R. Villaitramani and Dhruv P. Hirani

Prefabricated Construction for Mass Housing in Mumbai - In this paper the author has studied the feasibility of Prefabricated Construction for Mass Housing in Mumbai. Prefabrication of houses, an innovation that has potential to address environmental and sustainability concerns at a rapid pace, mechanizes the construction process, enabling mass manufacture of affordable houses. This paper discusses the case of Mumbai, the city of maximum slum population density in the world, where prefabrication can be a promising solution to housing scarcity. [12] Author has review in this paper to plan, analyze and design residential building using prefabricated techniques in Mumbai, bearing in mind, the cost of total construction and planning of the building are done in such a way that the maximum area utilization is achieved for minimum space and cost. Prefabrication has the capability to make a difference within the Indian construction industry in economic, social and environmental terms. It is essential that the potential benefits of this innovation are yielded so that required development can take place. [12]

4.Consideration of Prefabricated Volumetric Construction Technology in India

The surging construction industry in India is marred by problems such as shortage of skilled workers, reduced productivity and uncertainties in the delivery cycle. This trend has pushed the large players to adopt mechanized and prefabricated methods of construction. Be it for flyovers, railway over bridges or the ever-expanding metro network, builders have increasingly taken over the prefabricated mechanized modules for faster construction. Despite adopting the new-age construction techniques, India is still stuck with the two-dimensional approach of construction. In this, only elements of a building are made offsite. Transporting the components, plumbing, assembling them at the site and sealing numerous joints poses critical challenges for the

construction workers. A transition from the elementary approach to delivering a preassembled room or unit is the way to go, that is the prefabricated prefinished volumetric construction and unlike the 2D methodology, this technology involves modules fitted with windows, doors, and electrical and plumbing conduits. All five sides are cast in a single pour creating a single room or multiple rooms in one go. The three-dimensional design process allows for customizing molds at the design stage. All the openings like doors, windows, and conduits are designed into the mold. The openings are so precise that they can be ordered right from the drawings. Incorporating all the features at the design stage reduces cost and project turnaround time.

For the success of the prefabricated construction system in India, the govt. should come forward in establishing building factories and they should be located in various places in the whole country. For continuous flow of production a stable market must be created and govt. should fix the annual quota for the construction of prefabricated houses for mass housing. In this step the government of India shortlisted six alternate technologies suitable to the geo-climatic and hazard conditions of the region. This technology will demonstrate and deliver ready to live houses with speed, economy and with better quality of construction in a sustainable manner and one the technology is prefabricated prefinished volumetric construction.
Since the govt policy affects the building history as it provides a large scale market both positive and attractive. Another factor to keep in mind is there must be a proper understanding among manufacturers, architects ,designers and builders. The architect and designers should go for standardization in planning and design. Also builders must be conscious about quality, strength and economy of prefabricated components. So they must be educated by seminars, workshops,exhibitions, demonstration of prefabricated systems etc. We have to also raise the standards of teaching by enforcing this as compulsory in the subject curriculum so that it can be implemented practically as well. Prefabrication has the capability to make a difference within the Indian construction industry in economic, social and environmental terms. The possibilities and opportunities are immense and what all needed is a courageous step by entrepreneurs to make a change.

5.Challenges using In India

As India started using the Prefabricated Volumetric Construction technology in countable projects but still the technology and the favorable system for it has a long path to go in India. Following are some of the challenges facing in India for adopting this technology:

a) Limited Design Options

Prefab construction has limited amount of material options and home layout possibilities depending upon the prefab construction company. This point toward that the building has less flexibility in the design.

b) High Initial Cost

As prefabrication technique is in its nascent stage the initial cost will be higher and it require large investment to get establish in a market which will reduce the investment required through economies of scale.

c) High Upfront Costs

The end users should have cash in hand prior to the construction of building as this technique complete the construction within months unlike conventional methods. Thus, prefab buildings should be built with a corresponding finance plan. As it's a modern technology the financial institutions like banks are denying the funding which also affect the acceptance of prefab technology.

d) Transportation Issues

Prefab components are transported from the factory to the building site, which can have possibilities of damage during transit. And the transit cost is high as it requires large module to be carried and the cost will be relatively high depending on the distance to transit.

e) Assembly Issues

Precision is another important factor to be considered while engaged in prefabricated construction. The beams, columns, and floor required to be flawlessly aligned and joined together to stand up. An improper assembly can end up in joint failure and leaks which results in danger to an entire building.

f) psychology Problems

Although prefab building possesses all its advantages, speedy construction, eco-friendly materials and cost compared to traditional methods, many people still perceive it as substandard and low-income buildings especially in individual housing sector which give less resale value to such buildings in turn result in builders to use this technology

These challenges can be overcomed by the initiatives and awareness to the construction industry aspirants and professionals.

6. Conclusion

The rapid increase in the urban population has resulted in huge demand for majorly housing, infrastructure developments, and commercial zones. As per the report of Ernst & Young and FICCI shows 65% of labor shortage by 2021. The GOI planned the proposal of Housing for All under the scheme of Pradhan Mantri Awas Yojana (PMAY). To achieve the target of PMAY-2022, the application of modular technology is not only improvising the construction quality but also reducing the execution time of the project.

Its been observed that the use of prefabricated prefinished volumetric construction is limited to government sectors mainly due to factors like high amount of initial investments, a smaller number of trained persons, space requirements, vertical and horizontal hindrance in transportation of modules, lack of standardization of joining details in IS codes and certification of precast modules by BIS etc.

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