

## **Study of the Efficiency of Insulated Concrete Formwork and Similar Fast-Paced Construction Systems in the Indian Context**

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### **ABSTRACT**

*Insulated concrete formwork has been used around the world to reduce time taken during construction and to cut down costs. Recently adopted in the Indian context for the low-cost housing systems in different regions along with other fast paced methods identified by BMTPC, it is important to switch to these alternatives. How has this been done and what are the implications are the major questions to be explored. The method used was to study the manuals provided by BMTPC along with literature review of the systems in India and abroad to understand the feasibility under various layers including technical, economic, climatic, embodied energy etc.*

**Keywords:-***Insulated formwork, stay-in place system efficacy, monolithic construction systems*

### **INTRODUCTION**

The rapid growth in population and urbanisation has led to increase in the demand for buildings, and hence, the necessary materials, processes and construction methods. Further, a significant gap has been recognised in the supply and demand of various materials [11]. Fast-paced construction systems are project delivery strategies to shorten the execution time of structures. These involve use of a combination of precast or manufactured elements along with those constructed at site. Such systems reduce the time of execution, thereby saving cost.

In India, focusing on the “Housing for All” scheme under the PMAY, around 20 million houses will be constructed in urban areas by 2022 and 10 million houses in rural areas in the next 3 years [10]. Fast-paced newer technologies have become more important in this context, since the conventional materials have a finite resource base with a generally high demand and this directly leads to cost

escalation, thereby increasing the cost of the proposed shelters. Additionally, inefficient supervision and handling of processes and resources has been found to cause delays in construction of such projects. The project performance and cost gets affected, causing litigation and disputes.[6]

BMTPC (Building Materials and Technology Promotion Council), under the Central Government Ministry of Housing and Urban Affairs (MOHUA), identifies emerging construction systems and advocates for them after conducting studies on the materials over various aspects, technical and economic features being the foremost.

Even as standardised materials and processes can maximise value and benefit in a project, newer materials and construction systems and their usage on site can help project managers and building professionals to improvise and enhance the projects as per necessity [9].

These systems can also prove to add value by the way of speeding up construction processes, which can further lead to increased economic growth [6].

BMTPC approved the construction material, ICF, in 2017. In 2020, ICF was approved as a “New Technology” for constructing all government buildings in the future. PMAY Housing constructions have already begun in states like Tamil Nadu where ICF walls are being used. Though used widely abroad, the material has not seen rapid use in the country.

It needs to be evaluated if the system is suitable in a tropical climate and if that has been a hindrance in employing the mechanism here. Usage of such materials and technologies can prove to be useful for building professionals and project managers and help them prioritise maintenance and management processes [13].

Further, inadequacies in current processes of construction, and the need to enhance the quality provide a platform for development of new and improved construction processes [8].

Insulated Concrete Forms or Formwork or ICF or Permanent Insulated Formwork is a building system that uses lightweight formwork (made from an insulated material like Expanded Polystyrene) to support concrete walls whilst they are being cast in-situ and which is then left in place as insulation.

These systems are strong and energy efficient. Common applications for this method of construction are low-rise buildings, with property uses ranging from residential to commercial to industrial. Traditional finishes are applied to interior and exterior faces, so the buildings look similar to typical construction, although the walls are usually thicker.

Buildings are expected to be designed and developed to fulfil the needs as well as expectations of the users, community, and professionals involved. The quality of materials and systems used plays an important role in the quality of built environment and user experience [12].

## **BACKGROUND AND RESEARCH QUESTIONS**

Broadly, the questions that could be explored on the topic of emerging construction systems are listed as below.

- How will fast-paced construction techniques help in low-cost housing solutions proposed in the Indian context?
- Insulated Concrete Forms and other alternatives have been used widely abroad for a long time. Why is it that the usage has just been introduced in the country in the last few years? How does that imply feasibility in the country with respect to manufacturing and transport?
- How does the tropical climate affect the innovative systems, especially the EPS formwork systems? Drawbacks associated with the use, if any.
- How beneficial is it to switch to the modular techniques when building low-cost housing under PMAY and other schemes?
- How will industrialisation of the housing sector benefit in terms of sustainability and affordability?

## **OBJECTIVES**

1. To study and analyse the functioning of approved alternate and innovative construction systems for housing in different aspects - technical details, climatic & environmental impact, durability, resilience, capital and operating costs, etc.
2. To analyse the occupants' comfort in these systems through data available from the executed housing projects in India.

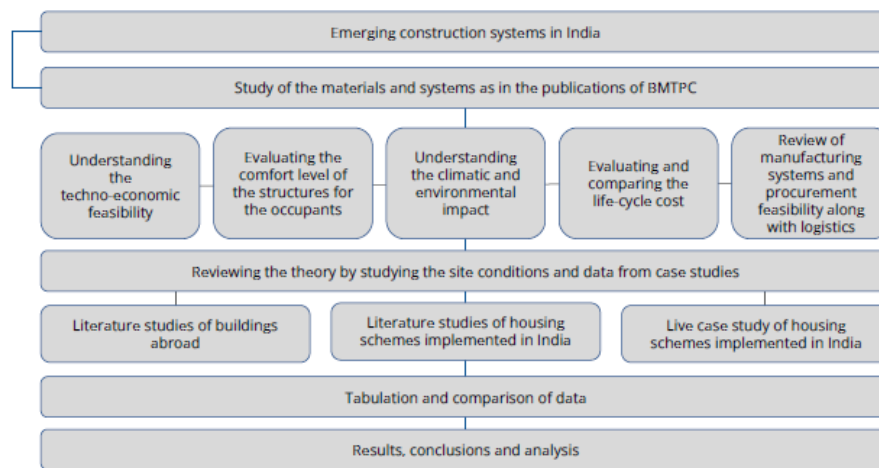
## METHODOLOGY

For a logical exploration of the questions and to achieve the targeted objectives, the first step would be to study the various emerging construction trends listed and defined as part of the review published by the BMTPC.

The layers under which each of the system has to be understood and analysed are the technical details, comfort levels, climatic impact, life-cycle costing, procurement and logistical feasibility in India. This can

be supplemented by an understanding of the use of the system and the conditions of use abroad. The data reviewed can be compared with the available case examples in India and understanding the gaps here would be vital. Comparison and analysis of the features will help in guiding towards a conclusion.

The following is a flow of how the questions can be explored and the hypothesis can be developed and refined further.



**Fig.1:-Flowchart of Methodology**

## LITERATURE REVIEW

### *Emerging construction systems in India (as studied by BMTPC)*

When we say conventional construction, we mean load-bearing structures, RCC framed structures and steel-framed structures. The conventional systems are mostly cast at the site, and are slow paced, hence are not efficiently able to meet the current requirement of housing shortage in the country.

The emerging systems focus on precast methods, hot and cold form steel construction, formwork systems, sandwich panel systems, and factory produced prefab systems, etc. There are examples of use of these systems to counter housing shortages in countries abroad.

Engineered formwork systems are those which enable monolithic casting of all walls, floors/slabs, stairs, and door and window openings using specially designed modular formwork made of aluminium, composite, plastic or steel.

Modular tunnel formwork is used for cellular structures where two half shells are placed together to form a room. It is a mechanised system. In these, walls and slabs are cast together.

The formwork is set up, reinforcement is placed and services are positioned and concrete is then poured in a single step. The formwork can be stripped the next day (Pocket book of emerging construction trends, 2020).

Stay-in place formwork systems are of various types. The Sismo building technology is an insulated shuttering formwork for a building unit based on a lattice made of galvanised steel and EPS panels. The lattice is filled with materials to serve as formwork. The steel wire helps anchor the finished material and holds the reinforcement in place during pouring of concrete.

Coffor is another example, used to build load-bearing monolithic concrete wall structures based on shear wall concept/ there are two filtering grids comprising of rib meshes which are made of galvanised plain steel sheets with a herringbone mesh pattern and vertical GP sheet stiffeners. After the erection of formwork panels in alignment, corners, edges of door and window frames are closed with rebar positioning & concrete of required Grade is poured in the panels. The concreting may be done with a pump, bucket or with a

shovel loader. The ICF system is patented by system of M/S Reliable Insupacks (P) Ltd in India and comprises of a panel of two walls of EPS separated by a distance of 150 mm held together by plastic ties. These are assembled on site and concrete is poured. Monolithic Insulated Concrete System (MICS) is a formwork system for RCC made with a rigid thermal insulation.

Lost in place formwork systems are plaswall panel system and plasmolite panel systems where fibre cement boards of 6 mm thickness are bonded through HIMI - High Impact Molded Inserts spacers. GFRG panel systems are load-bearing prefabricated cage panels and monolithic cast in-situ concrete is used to infill them, these are used for walls and floor or roof slabs. The panels are made of calcinated gypsum plaster reinforced with glass fibres and panels. The other examples that work on similar mechanisms are PVC wall forms[4].



Formwork for monolithic construction



Structural stay-in-place formwork

**Fig.2:-Types of alternative systems**

Precast sandwich panel systems based on EP have an EP core sandwiched between welded wire fabric mesh made of high strength galvanised wire. Cement shotcrete mix is applied on the panel on both sides at site while using. Other precast panel systems include aerocon panels, where lightweight concrete core is sandwiched

between cement facing panels. EPS Beads cement panels have EPS granule balls, adhesive, cement, sand and fly ash in the centre. Nano living system technology comprises of an inner and outer skin of Magnesium Oxide board, with injected core of closed cell PU foam, free of CFCs. This is used in residences of upto G+3.



Light gauge steel framed structures are factory made and are suitable for 3-4 storey structures. Infill walls of precast boards, blocks, EPS panels or an external layer of insulation material and outer leaf of cement particle board or dry mix shotcrete. Speed floor is a suspended

concrete flooring system using a hot rolled steel joist as a part of the final concrete and steel composite floor. Waffle-crete, precast large concrete panel system, hollowcore concrete panels, are precast forms of concrete that can be used for modular construction [2].



*Fig.3:-Types of alternative systems*

### **Basis of selection of the various systems in various contexts**

#### ***Techno-economic consideration***

Technical aspects: The structural design efficiency of these systems is optimised based on performance in the executed projects rather than prescriptive design philosophy. The data for each system on the durability, structural strength, fire resistance and other properties is available and specific to each manufacturer and can be compared with the traditional systems to arrive at a conclusion.

The industrial manufacturing process means that the cost of production is lower. A conventional building tends to focus on the materials like cement, bricks or block masonry, steel, aggregates, etc. which are derived from natural resources. This means dependence on finite reserves, and thereby higher costs indirectly. The alternative methods, in most cases, use the disposed material from other processes after being treated to be used as a structural material for construction. The cost is significantly less. The faster completion of erection also means lesser cost of execution.

### ***Comfort level of occupants***

The Indoor Environmental Quality refers to provide comfort, well-being, and productivity of occupants. Indoor Air Quality seeks to reduce volatile organic compounds, or VOCs, and other air impurities such as microbial contaminants. The alternate systems employ construction materials and interior finish products with zero or low VOC emissions during the design and construction process which enhance indoor air quality. Also, well-insulated and tightly sealed envelope reduce moisture problems which often leads to dampness.

The occupants' comfort levels have not been mapped in India yet, since only a few of the structures have been completed and detailed post occupancy studies have not been conducted.

### ***Disaster resilience and structural efficiency***

The alternate systems follow optimization. The performance-based design method instead of prescriptive design method is the key for design efficiency while dealing with these alternate construction systems. The alternate construction systems designed to be resilient in terms of natural hazards as it entails performance-based design of buildings (Alternative and innovative construction systems for housing, 2021).

### ***Environmental impact***

Alternate construction systems often include measures to reduce energy consumption that is, the embodied energy required to extract, process, transport and install building materials and the operating energy to provide services such as heating and power for equipment.

The buildings with alternate systems use less operating energy, embodied energy. These buildings will have a lower embodied energy than those built primarily

with brick, mortar, concrete, or steel (Alternative and innovative construction systems for housing, 2021).

### ***Life-cycle costing***

The most criticized issue about alternate construction systems is the price. The cost of a building is defined as follows:

$$\text{Total Cost} = \text{Initial construction cost} + \text{Running cost during life of building} + \text{disposal cost}$$

This is the life-cycle cost.

Most of the time, the criterion in selection of technology is cost per sq. m, which is initial cost but this is not enough if green aspects are to be considered. The buildings with alternate systems may cost 10-15% higher initially because they are not mainstream methods as of now, but will be less by a few times over the entire life of the building. During life span of building, the financial payback will exceed the additional initial cost of using alternate systems several times (Alternative and innovative construction systems for housing, 2021).

### ***Manufacturing in India***

Building materials typically considered to be sustainable, if they are based on renewable/waste resources and can be reusable and recyclable. Most of the alternate construction systems either make use of industrial waste, renewable resources, energy efficient building materials or optimizes the use of basic raw materials - cement, sand, aggregates, and steel consumption.

For example, The GFRG panels makes use of phospho-gypsum which is a by-product of fertilizer plant, sandwich panels make use of EPS beads which are energy efficient.

The specialist vendors for each type have their production units in the Northern part of the country and the transportation to

most cities across the country is now possible. The PMAY housing schemes chosen for the implementation are spread across regions and delivery of the systems has been possible to these areas (Alternative and innovative construction systems for housing, 2021).

**Logistical and procurement feasibility**

The construction systems identified are based on factory made building

components which are manufactured with high precision under strict quality control and therefore, more durable requiring minimum maintenance (Alternative and innovative construction systems for housing, 2021). The logistics and procurement in areas catered to by the current manufacturers is fairly easy. Structures with these technologies have come up in Mumbai, Pune, Tirupati, Chennai, etc.

**Literature case studies****Global context: West Village Student Housing at Texas University**

*Fig.4:-View of the housing*

BGK Architects and Mackey Mitchell Architects designed this 230,000-square-foot West Village student housing complex at Texas Tech University, where fast paced construction methods were employed. The project was completed in 16 months – design and delivery. A traditional construction can be estimated to take more than two years in this case, depending on the location, availability of other resources, etc.

Opened in 2014, this project had costed \$54.8 Million. It contains 455 beds, community lounges, conference rooms, as well as designated study rooms (Lemay, 2019).

Tech's newly adopted sustainability initiatives made sure that the project was sustainable as well. The standards for LEED certification were met.

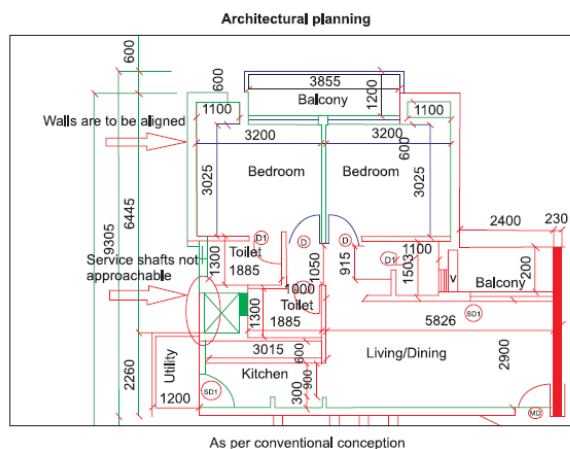
The expected energy reduction was calculated at 20% when compared to a traditional construction of a typical residence hall program building. ICF walls were used with precast hollow-core slabs. The result was energy-efficient, structurally stable, fire-resistant, and acoustically sound (Lemay, 2019).

**Indian Context: Case study with tunnel formwork**

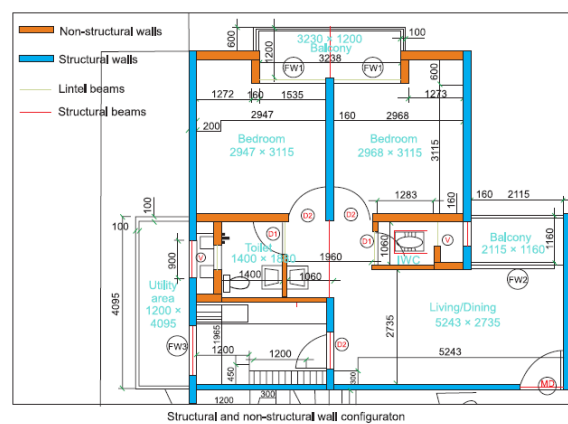
A project had been done by CPWD in Anna Nagar, Chennai for construction of

532 quarters for income tax department having a sanctioned cost of Rs 208.95 crores. There are 4 towers of G+18 floors of Type II (1 tower having 8 quarters on each floor), III (2 towers having 8 quarters on each floor) and IV (1 tower having 4 quarters on each floor) quarters, having 8, 8 and 4 quarters on each floor respectively. Total plinth area of buildings is 57706 sqm. The buildings have a pile foundation. Tunnel formwork was imported from

Turkey for this project. The traditional architectural plans drawn had to be revised to match the tunnel formwork dimensions so as to achieve the modularity, thereby saving time in the construction process [2]. (This project has not been studied at the site and the data from the occupants is not extensively available online. It was expected to be completed as on December 2021 [1].



**Fig.4:-** Plan as per initial design of spaces



**Fig.6:-** Plan as per tunnel formwork

## CONCLUSIONS AND INFERENCES

The systems mentioned have multiple advantages, as seen the case study examples as well. There are a few points to be studied further with the help of occupant surveys, manufacturer data etc. which could not be retrieved as yet. The summary is as follows:

- The possibility of modular construction for low-cost housing as seen with the amount spent in the case study.
- The error in the material is of very less probability, since it is being manufactured, so this means that all the units will have the same quality of the final construction.
- The faster pace than traditional construction is because the units are manufactured off-site and only assembled on site. The storage and

transport may be a few factors to consider when comparing the feasibility in a certain area.

- The life-cycle costing of these systems is lower than traditional as stated in the examples, but the initial investment is higher. Affordability and funds allocated may be a factor to consider.
- Since the formwork and other systems are manufactured, the raw material used is more efficiently utilised with minimum wastage. The embodied energy of each of these systems will need to be considered in detail to arrive at a conclusion on the sustainability aspect.

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