PRE-FAB CONSTRUCTION TECHNOLOGY: AN INNOVATIVE APPROACH TOWARDS AFFORDABLE MASS HOUSING

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ABSTRACT

Urbanization is India had been accelerating since independence due to the adoption of mixed economy that triggered the growth and development of private sectors. As per the UN prediction, 64.1% of developing countries and 85.9% of developed countries are expected to be urbanized by 2050. Within the limited resources of finance, labor and time, urban housing has become an unenviable situation which had resulted in slum development providing an inhabitable condition for the humans to survive and hence seeks a prior concern from the Government as well as private sectors.

To satisfy the housing needs in urban cities, a technique of building construction, referred to as pre-fab architecture is gaining potential in today’s context which encompasses off-site fabrication of building components to a higher degree of finish with their assembly on site. In this context of demand for affordable housing for all, pre-fab improves the ease of construction, with quality of architecture and material efficiency as well as workers safety and limiting environmental impacts of construction as compared to the onsite conventional construction practices.

The paper envisages the advantages of pre-fab construction technique to achieve efficiency in terms of economy and flexibility in design when compared to conventional methods. The design of any built up structure, irrespective of the type or method of construction system followed, should satisfy the basic needs of human within the guiding parameters of sustainability. The approach of how modular housing could also be a solution for a dream home satisfying the requirements of user groups irrespective of income and age is the intended outcome of the paper.

Key words: Material efficiency, Modular housing, Pre-fab construction, Sustainability, Urban Housing.
1. INTRODUCTION
1.1. Historical Background
The idea of pre-fab construction came into effect with the foundation of Hindustan Housing factory in 1950 as a solution for housing crisis due to the influx of refugees from Bangladesh. It pioneered pre-stressed concrete production of railway sleepers replaced the conventional wooden sleepers on Indian Railways. Now located at Delhi, HPL mainly prefabricates pre-cast concrete for many civil and architectural projects throughout India.

In India, prefab materials are well known for their durability and quality. Building Information Modelling (BIM) techniques are used for pre-planning and visualization of the construction process prior to the construction. Such techniques enable to reduce the wastage where there is a scarcity of resources in countries like India. Such modern techniques of construction is an innovative approach towards addressing the problem of mass housing.

2. MASS HOUSING: A CASE FOR PRE-FABRICATION
There has been a huge crisis in housing sector worldwide which had left people to live in uninhabitable conditions without adequate hygiene and cleanliness. Due to increasing process of land and building materials along with labor charges, building a residence seem to be a dream for a common man. The solution of developing mass housing with a higher density and floor area ratio could be a promising approach to address the issue in a considerable way. This, in turn, will reduce the overall expenses on individual owners.

Sharing of the construction cost per cluster in mass housing shall reduce the cost considerably. Sharing the costs on services like common sewer lines, septic tanks, manholes etc. shall result in sharing the economy eventually. Likewise maintenance of common facilities like parks, parking lots etc. shall reduce considerably.

The prior advantage of mass housing can be summed up by defining it as affordable housing which economized the cost by reducing standardized materials and components which eventually shall result in efficient management of resources and materials. A comparative analysis of advantages of pre-fab construction vs. traditional method of construction is summarized below (Table-1):

<table>
<thead>
<tr>
<th>Pre-fabricated construction</th>
<th>Traditional methods of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Significantly lower than traditional methods</td>
</tr>
<tr>
<td>Speed</td>
<td>Faster method of construction</td>
</tr>
<tr>
<td>Wastage</td>
<td>Less wastage of materials due to group practices and controlled environment in prefabrication construction</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Less flexibility due to standardization of units</td>
</tr>
<tr>
<td>Quality</td>
<td>Higher quality control due to production under controlled environment</td>
</tr>
<tr>
<td>Labour</td>
<td>Less labor intensive due to Computer Integrated Manufacture (CIM)</td>
</tr>
</tbody>
</table>
Table 1 Comparative Analysis of Pre-Fab Construction Process and Traditional Process

<table>
<thead>
<tr>
<th>PREFABRICATION</th>
<th>CONVENTIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential project for Karnataka Housing Board at Kengiri</td>
<td>Mohmedrha Co-Operative Housing society at Hapur, Uttar Pradesh</td>
</tr>
<tr>
<td>No. of dwelling units : 2500</td>
<td>No. of dwelling units : 2500</td>
</tr>
<tr>
<td>Cost reduces by 20% in superstructure</td>
<td>Cost reduction was possible by 30-35% if units are &gt; 2500</td>
</tr>
<tr>
<td>Time period for concrete to set in factory is 1 day</td>
<td>Time period for concrete to set on site is 28 days</td>
</tr>
<tr>
<td>Waste material is used again</td>
<td>Waste material can’t be used</td>
</tr>
<tr>
<td>Labor force reduced (40%) and unskilled labor requirement is minimum</td>
<td>Labor force requirement is high compared to prefab construction</td>
</tr>
</tbody>
</table>

**COST ANALYSIS:**
- 20% reduction in cost in terms of labor, material, transportation
- Transportation cost is 4.25% if the distance between site and factory is 50 kms
- Total cost Rs. 66,00,00,000
- Savings of Rs. 16,25 Crore only in RCC superstructure

**COST ANALYSIS:**
- No. of units -2500
- Average area of a unit - 150 sq.m
- Total area - 3,75,000 sq.m
- RCC in superstructure including column + beam + slab
- Assuming slab thickness 150mm
- Cost of RCC - Rs. 3500/ sq.m
- Yld. of RCC - 1,50,000 cum
- Grade of concrete - M20
- Total cost Rs. 82,50,00,000

40% labor reduces saves money | Very high labor charges as large no. of labor is deployed
Work process is not hampered because of any festivities, etc. | Work is severely hampered during these seasons

3. PERCEPTION OF DREAM HOME: A SURVEY OF DIFFERENT USER GROUPS WITH THEIR PREFERENCES FOR DREAM HOME

A survey of 100 people was conducted of different age groups irrespective of income and occupation to understand and analyze their preferences both internal (within the home) and external (other auxiliary facilities). There were few observations which were categorized in broad three aspects i.e. hectic time, leisure time and vulnerable time. Few families and their lifestyle were also taken into account to understand the activities happening in and out throughout the day (Graph-1).
Based on the survey conducted, conclusions were drawn which includes different typologies of families with their preferences. (Fig-1). These categories further gives an idea of hierarchy of family type based on the no. of users and their choice of lifestyle.

4. LITERATURE REVIEW

An intensive study on various aspects of housing design keeping in mind the parameters of “affordable housing for all” have been conducted. The key contents and analysis are summarized below. (Table-2). The intent of the study is to get an idea about the various aspects of “dream home” and to establish a framework for design.
Table 2 Literature Review

<table>
<thead>
<tr>
<th>Sl.no:</th>
<th>BOOK</th>
<th>REVIEW (KEY CONTENTS)</th>
</tr>
</thead>
</table>
| 1.    | ADAPTIVE SKINS AND MICRO CLIMATE - By Simos Yannas | • Use of adaptive topography in response to daily and seasonal variations in environmental parameters, with an aim for better condition for outdoor activity.  
• Study of micro climate conditions using EnviMet and EcoTest Softwares (e.g. London).  
• Option for creating dynamic landscape with variable topographic features and surface properties.  
• Various activity layers in site combining architectural elements and outdoor furniture with complimentary climate properties (e.g. bio climatic shelters). |
| 2.    | An Introduction to urban housing design AT HOME IN THE CITY - By Graham Towers | 1. Contact for housing development:  
• Climate change  
• Cut in greenhouse emissions  
• Population change: rise in demand for homes  
2. New policy for housing:  
• Re-use of land and buildings  
• New densities for future  
• Integrated transport: reduce private vehicles, foster walk, cycling and use of public transports  
• Mixed use land uses and communities: for social integration, reduced need of travel  
3. Standards:  
• Dividing spaces (1944 Housing Manual for minimum room areas, minimum dwelling size/sq.m.)  
• Range of options: detached house/semi-detached house/terrace house/flats  
4. Infrastructure:  
• Community facilities: urban neighborhood - open space, education, health, shops and communal activities, entertainment etc.  
• Hierarchy of facilities at different travel distance  
• Housing for new needs: elderly and disabled, young people, live/work etc.  
5. Green Agenda in construction:  
• Energy conservation: passive solar gain, improved ventilation strategies, renewable energy sources like solar power, wind power, bio-fuels, fuel cells etc.  
• Water management systems: collection and recycling strategies  
• Sewerage treatment  
• Conserving environmental resources: embodied energy - low energy materials, local materials, recycled materials etc.  
6. Design Quality:  
• A question of taste: image of house- traditional vs modernism  
• Design codes: maintaining quality standards  
• Customization of housing spaces  
• Degree of choice, color, material etc.  
• Democratic Design |
| 3.    | ARANYA TOWNSHIP, INDORE - By B.V Doshi | • Classical architectural approach towards large scale low cost dwelling for poor  
• Housing for EWS within a socially balanced matrix of middle and high income groups  
• Design considerations:  
• Planning service core: featuring importance of service areas like kitchen, bathrooms etc.  
• Concept of EWS dwelling: emphasis on creating inviting comfortable homes in harmony with surroundings  
• Planning at street/cluster level: street must assume a unique identity on human scale with spaces for group activities  
• Planning at sector level: sectors to be designed as viable, autonomous, sub communities  
• Planning at township level: focus on well ordered hierarchy of amenities in balance and cohesive environment  
• Population density: 400 persons/hectare  
• Land use: 21% road area, 8-10% open space, 2-4% commercial  
• KEY ATTRIBUTES: flexibility and elasticity in all levels of planning  
• Affordability by the people |
<table>
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<th>REVIEW (KEY CONTENTS)</th>
</tr>
</thead>
</table>
| 4.    | DEAR HOUSE: AN EXPLORATION OF HOME AND THE INNER SELF  
       + By Christina Freelandell | Exploring house (from childhood memories) – climbing for a better view, floor as a massive entity to play  
Home as a piece of security and belonging: a relief from outside pressure and obligations, creating the intimacy lost by reworking on interior spaces |
| 5.    | THE HOUSE AS SYMBOL OF THE SELF  
       + By Clare Cooper | Concept: Revelation of nature of self  
Design understanding human psychology  
House is a space that reflects how man sees himself  
Examples of contemporary designs  
Houses are invested with human qualities  
Houses are sacred: giving man a fixed reference point to structure the world around him |
| 6.    | FERROCEMENT SUPER-INSULATED SHELL HOUSE  
       Design and Construction  
       + By Jan Leygowki | Ferrocement as building technique, for sustainable housing  
Suitable for this shell structures where geometry immerses bending loads  
Architectural flexibility: is the main priority in sustainable housing, resistance to seismic and tornado events  
Energy efficiency, affordability and durability |
| 7.    | LOW COST HOUSING  
       + By Rishiour and Vidyasagar | Low cost housing using pre fab. technology: its economic advantages  
Key features: structural block walls, mortar-less block walls, pre-fab roofing components, pre-cast hollow concrete panels, pre-cast ferro-cement panels |
| 8.    | EDUCATION FOR SUSTAINABLE ARCHITECTURE  
       + By Simos Yannas | Sustainable architecture:  
Performative: capable of providing occupant comfort at lowest carbon emission  
Expressive: reflect the architectural programme and its context in terms of climate, site and culture. |
| 9.    | AN INTRODUCTION TO HOUSING LAYOUT:  
       GLC STUDY | Design considerations: Major two factors to be considered; factors within the boundary of the site (on site), and those relating to the wider environment (offsite)  
Organization of space, access roads, parking, pedestrian movements, |
| 10.   | INTER-GENERATIONAL LIVING: open building architecture and the importance of choice & independence  
       + By Ian Kippatrick | Open Building: Promoting Inter-Generational Households.  
Open Building has the opportunity to allow greater flexibility and change over time within the apartment, in turn would allow for a plethora of living arrangements (whether one chooses to live with multiple generations of their family, or a roommate situation). |
| 11.   | DYNAMIC STRUCTURES  
       + By Simos Yannas | Idea to explore the architectural potential of adaptive comfort in the extreme climatic conditions  
Application using a dynamic thermal simulation model |

**PRIORITY SETTING:** (to establish a framework for design of PERFECT DREAM HOME)

<table>
<thead>
<tr>
<th>ASPECTS (PRIORITY)</th>
<th>CONSIDERATIONS FOR DESIGN</th>
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<tbody>
<tr>
<td>1. SPATIAL CONFIGURATION</td>
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</table>
Flexibility of spaces  
Barrier free aspects  
Interconnectivity of common and private spaces (visual connectivity wherever required)  
Spaces for quality time  
Features for safety and security  
Follow design code to maintain quality standards  
Degree of choice in materials, colors and textures etc. |
| 2. SUSTAINABLE DESIGN CONCEPT |  
Construction technology  
Climate responsive design  
Eco-friendly materials and finishes  
Energy efficiency in design  
Zero carbon emission |
| 3. SUPPORTIVE INFRASTRUCTURES |  
Strong road networking with hierarchy of roads  
Integrated transportation (facilitating public transport)  
Design for pedestrians  
Neighborhood planning (considering walking distance)  
Establishing hierarchy of facilities (markets, open spaces, temples, healthcare, education etc.)  
Services (pump water disposal, electrical, water supply)  
Parking spaces  
Mixed use concept  
Design supporting future density of population (scope for future expansion) |
5. GOVERNMENT INITIATIVES FOR URBAN POOR: PRADHAN MANTRI AWAS YOJNA

AREA REQUIREMENTS AS PER PMAY

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>CARPET AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWS</td>
<td>30 SQ.MT</td>
</tr>
<tr>
<td>LIG</td>
<td>60 SQ.MT</td>
</tr>
<tr>
<td>MIG-I</td>
<td>90 SQ.MT</td>
</tr>
<tr>
<td>MIG-II</td>
<td>110 SQ.MT</td>
</tr>
</tbody>
</table>

PMAY Benefits

<table>
<thead>
<tr>
<th>Particulars</th>
<th>MIG I</th>
<th>MIG II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household annual income (Rs.)</td>
<td>6-12 lakh</td>
<td>12-18 lakh</td>
</tr>
<tr>
<td>Eligible Loan Amt for Interest Subsidy (Rs.)</td>
<td>9 lakh</td>
<td>12 lakh</td>
</tr>
<tr>
<td>Interest Subsidy (%)</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>Dwelling Unit Carpet Area (Sq.m)</td>
<td>90 sq.m.</td>
<td>110 sq.m.</td>
</tr>
<tr>
<td>Max loan tenure (in yrs)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>NPV subsidy</td>
<td>Rs 2.35 lakh</td>
<td>Rs 2.30 lakh</td>
</tr>
</tbody>
</table>

Discount Rate for Net Present Value (NPV) calculation of interest subsidy (%)

<table>
<thead>
<tr>
<th>particulars</th>
<th>MIG I</th>
<th>MIG II</th>
</tr>
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<tbody>
<tr>
<td>Household Income (Rs. p.a)</td>
<td>12,00,000</td>
<td>18,00,000</td>
</tr>
<tr>
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<td>4.00 %</td>
<td>3.00 %</td>
</tr>
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<td>Maximum loan tenure (in years)</td>
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</tr>
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</table>

Different income groups will get housing loans for a tenure of 20 years with subsidy along with a considerable monthly as well as yearly savings under PMAY scheme to get affordable homes.

The cost analysis for a typical layout has been taken as a reference and design followed by the pre-fab construction method is calculated. The intent of the analysis is to propose a dream house for an EWS (set under PMAY) which is not limited to the defined area of 22 sq.mt but the budget of the unit is restricted as per the guidelines formulated by PMAY.
In prototype proposed modular design there has been a flexibility given in terms of space as all the interior spaces are not partitioned by walls rather are set free so that the same group of people can further modify or alter the interior as per his preference and the financial feasibility in future. The new proposed design gives a flexibility by increasing the carpet area up to 30 sq.mt with a provision of free space and terrace garden. (Fig- 3).

Figure 3 Layout of A Single Modular Unit

The design also allows the provision to harness solar energy and re-use waste water from kitchen for landscaping in terrace garden. (Fig-4).
6. MODULE LAYOUT

The intent of the design is to propose a prototype layout which can be repetitive and at the same time shall have the flexibility to combine two units to make it into a single unit based on the requirements of all categories of people in accordance to the structure of their family.(fig-5).

The basic idea is to show that the prefabricated housing innovation system provides a useful organizing tool to enhance the standard of living of all income groups together irrespective of caste and income factors.

The TATA housing group is working on a housing project based on innovative construction method using prefabricated technologies. These houses will cost as low as INR 32,000. Tata Group will provide a kit consisting of structural elements which can be erected or assembled. These houses have an area of 20-30 sq. mtrs and lifespan of 20 years. The project is still in pilot stage and will soon be implemented across the country.

Based on the same line, modular units can be erected which shall not only give economy in design that will cater all income groups but also to create a better option to dream a better home with ample space and circulation providing a better option in design.
Figure 5 Module Detail Of A Single Unit And Consecutive Units
7. CONCLUSIONS

Considering the current crisis in housing sectors, it is imperative that the importance of alternative construction technology need to be considered by the stakeholders with reference to the improvement of health and safety factor in the construction industries as well as the users. 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.

REFERENCES


