Comparing construction cost between Prefabricated and conventional construction system for Mass Housing: A comparative study-Pune

Bachelor of Architecture Research Thesis dissertation
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Approval

The following study is hereby approved as a creditable work on the subject carried out and presented in the manner, sufficiently satisfactory to warrant its acceptance as a prerequisite towards the degree of Bachelor of Architecture for which it has been submitted.

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Thesis Title: Comparing construction cost between Prefabricated and conventional construction system for Mass Housing: A comparative study-Pune
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Declaration

I, **Vatsal Avasthi, 19BAR045**, give an undertaking that this research thesis entitled "**Comparing construction cost between Prefabricated and conventional construction system for Mass Housing: A comparative study-Pune**" submitted by me, towards partial fulfilment for the Degree of Bachelor of Architecture at Institute of Architecture and Planning, Nirma University, Ahmedabad, contains no material that has been submitted or awarded for any degree or diploma in any university/school/institution to the best of my knowledge.

It is a primary work carried out by me and I give assurance that no attempt of plagiarism has been made. It contains no material that is previously published or written,
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found subsequently with any published work or any dissertation work elsewhere; I would be responsible.

This research thesis includes findings based on literature review, study of existing scientific papers, other research works, expert interviews, documentation, surveys, discussions and my own interpretations.

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Content:

1. Abstract

Prefabrication involves manufacturing building components in a factory and assembling them on-site, offering a faster and more efficient alternative to traditional construction. Mass housing refers to large-scale residential projects aimed at addressing the housing needs of a growing urban population. Types of prefabricated housing include modular homes, panelized homes, and manufactured homes. Globally, mass housing is crucial due to rapid urbanization, and in India, the need is particularly acute due to a severe housing shortage. Prefabricated mass housing reduces construction time, labor costs, and material waste while ensuring higher quality and sustainability. Despite higher initial costs, the long-term benefits make prefab construction an effective solution for mass housing. This study demands to understand if prefab is affordable then conventional construction system for Mass Housing in India .

Keywords: *Prefabrication , Conventional Construction system, Precast Concrete ,Cost, Mass Housing*

2. Introduction:

India, faces housing challenges due to rapid growth. To tackle this, Government had started taking the initiative to introduce precast system in India like LHP projects by GHTC, PMRDA EWS projects in Pune. This study examines if prefabricated or traditional methods are more cost-effective for mass housing in India.Prefabrication might save money by needing less on-site work and being quicker. But, setting up factories and transporting parts could cancel out these savings. Conventional methods offer flexibility but might be slower and cost more for labor.

Our research aims to help housing developers and planners make informed choices about which construction method to use in India.Precast construction uses standardized parts made off-site and assembled on site. It's cost-effective and swift, ensuring high quality and safety.

2.1 Need for Prefabrication in Mass Housing - India:

Rapid urbanisation: India's urban population is expected to reach 600 million by 2031. Prefabrication can quickly meet the urgent need for housing in growing cities.

Affordable Housing: With a housing shortage in urban areas of approximately 10 million units, prefabrication provides a cost-effective way to build affordable homes for low- and moderate-income families.

Labour Shortage: The Indian construction industry is facing a shortage of skilled labour. Prefabrication requires fewer workers on site, ensuring projects are completed on time.

Consistent quality: Prefab homes are built to ensuring factory standards, ensuring consistent, high quality across all units.

Environmental Sustainability: Prefabrication reduces construction waste by up to 30% and supports recycling, in line with India's Sustainable Development Goals.

Government support: The Indian government is promoting prefabrication under programs such as the Pradhan Mantri Awas Yojana which aims to build 20 million urban homes by 2022. LHP projects in six different cities (Ranchi, Lucknow, Chennai, Indore, Rajkot, Agartala) with six different technologies one of which LHP Chennai is my secondary case study.Prefabrication offers a quick, cost-effective and sustainable solution to India's housing crisis, making it an ideal choice for mass housing projects.

2.2 Peculiarities of Construction Projects (GHTC.India.Gov.In):

- Conformity with Indian Codal provisions, Master Plan, NBC provisions, Environmental Clearance etc.

- roven and Time tested technology, buildings to be durable for min. 50 years

- Speedy execution, modern/quality Construction material etc.

- Minimal supervisory control and maintenance

2.3 Grey Areas – To be addressed while adopting Modern Technologies (GHTC.India.Gov.In):

- Time Tested and Proven Construction Technology in Indian Geoclimatic Conditions

- Availability of Skilled manpower

- Performance evaluation and Certification

- Eligibility of executing agency

3. Research Questions:

Which construction system is affordable between conventional one and prefabrication?

4. Aim:

To compare construction Cost of prefab construction against conventional construction system for Mass housing

5. Objective:

- To understand mass housing construction methods employing both prefabrication and conventional methods.

- To determine the factors influencing the expenses of both procedures.

-To evaluate and compare the expenses of these both construction methods in order to make conclusions

6. Scope:

-Understanding the conventional and prefabricated construction methods .

-The research is focused on comparing the costs associated with building construction between both (Prefab and In-situ construction) not including Flooring, Plumbing fixtures, Electrical fixtures ,Paint. (note: Count just the naked construction cost)

7. Limitation:

-Access of all the site data was unable due to companies policies

-Foundation of the particular case study chosen is constructed through conventional construction system so we will be calculating cost of naked typical structure only.

-NOTE: I'm only comparing the price of the building's unfinished structure, which consists of the following: walls with chajja , slab, beam, column, and staircase.

-The data which is concluded in this thesis is derived based on assuming the volume of both Precast and conventional structural components same. Reason behind this is that I couldn't find the same exact building as the one there is made with Precast technology . So I tried comparing the components first and then calculated overall building cost according to that.

8. Need for the study:

8.1 Introduction

This chapter reviews the existing literature on the cost comparison between prefabricated (prefab) and conventional construction systems for mass housing. The aim is to present a comprehensive understanding of the economic, time, and quality aspects of both construction methods, highlighting the benefits and challenges associated with each.

8.2 Global Perspectives on Prefabrication

8.2.1 Prefab in the UK Housing Market

Isabelina Nahmens (2011) studied the UK housing market and found that low-cost prefab techniques can significantly reduce initial construction investments, potentially making homeownership more accessible. These techniques might also increase the market value of prefabricated homes, enhancing their appeal.

8.2.2 Prefabricated Steel and Modular Units

Prajjwal Paudel et al. (2016) reported a rise in the use of prefabricated structures, particularly steel and modular units, due to their strength, speed of construction, and sustainability. Prefabricated steel and modular units can quickly create earthquake-resistant structures with lower environmental impact and construction waste.

8.3 Prefabrication in Urban Contexts

8.3.1 Addressing Housing Shortages

Krish R. Villaitramani and Dhruv P. Hirani (2014) examined the viability of prefabricated construction for mass housing in Mumbai. Prefabrication, with its potential to rapidly produce affordable housing, could address the city's significant housing shortage. The authors emphasized the importance of efficient planning and design to maximize space utilization and minimize costs.

8.3.2 Environmental and Societal Impact

Evanjaline Libie (2016) discussed the environmental benefits of prefabrication, highlighting its potential to reduce on-site waste and improve sustainability. However, she stressed the need for further research to optimize waste handling throughout the construction process. Prefabrication can positively impact the environment, society, and economy, making it a crucial innovation for sustainable development.

8.3.3 Societal Acceptance and Cultural Factors

Implementing prefab construction in urban contexts also involves addressing societal acceptance and cultural factors. In some regions, there might be a stigma associated with prefab homes being perceived as low-quality or temporary solutions. Community engagement and education about the benefits and durability of prefab construction are essential to overcome these barriers (Jackson, 2015).

8.4 Cost-Effectiveness of Prefab Construction

8.4.1 Cost Comparisons

N. Dineshkumar and P. Kathirvel (2015) investigated the cost-effectiveness of precast concrete construction for residential buildings in India. Their study revealed that for a single two-story residential building, prefab construction is 13% more expensive than conventional construction. However, the prefab method saves significant time, reducing project duration by 63 days compared to similar conventional projects.

Vaishali Turai and Ashish Waghmare (2015) conducted a case study comparing cast-in-place and precast concrete. They found that precast construction reduces material waste and requires less on-site labor, leading to indirect cost savings. Precast components, produced in controlled factory conditions, minimize rework and maintenance costs, further reducing overall construction expenses.

8.4.2 Economic Feasibility

(Akash Lanke and Dr. D. Venkateswarlu (2016) designed and analyzed a building using both traditional cast in-situ and precast construction methods. Their analysis showed that precast buildings are significantly cheaper and faster to construct than traditional buildings. They emphasized the importance of considering factors such as building type, construction volume, and the distance between the construction site and manufacturing unit when evaluating the feasibility of precast systems.

8.5 Time and Productivity

(B. Raghavendra K. Holla et al , 2016) highlighted the importance of time, cost, quality, and productivity in construction. They noted that precast construction results in minimal waste and high productivity. However, they also pointed out challenges such as the need for skilled labor and the costs associated with transporting structural components from factories to construction sites.

8.5.1 Labor Efficiency

Prefab construction requires fewer skilled workers on-site, which can mitigate labor shortages. The assembly line production in factories is more controlled and efficient, reducing the chances of delays caused by weather conditions and other on-site issues . This efficiency is crucial in regions with unpredictable climates or labor market volatility. (Kamali, Mohammad & Hewage, Kasun , 2017)

8.6 Customization vs. Standardization

(Baghchesaraei Alireza et al , 2015) discussed the balance between standardization and customization in prefab construction. While customization can meet specific needs, standardization significantly reduces costs and construction time. Finding the right balance is crucial for maximizing the benefits of prefab construction.

8.6.1 Advances in Modular Design

Recent advances in modular design allow for greater customization within a standardized framework. Modular units can be designed to accommodate various architectural styles and functional requirements, enhancing the appeal of prefab homes without significantly increasing costs (Knaack and Chung-Klatte, 2012).

8.7 Conclusion

The literature indicates that while prefab construction can be more expensive upfront than conventional methods, its benefits in terms of time savings, reduced labor costs, and sustainability make it a viable option for mass housing. The key challenges include the need for skilled labor, transportation costs, and balancing customization with cost-effectiveness. Ongoing research and development are essential to optimizing prefab methods and expanding their applicability in various contexts.

This review synthesizes existing research, providing a foundation for understanding the economic and practical implications of prefabricated versus conventional construction systems for mass housing. Further studies should continue to explore these dynamics to enhance the efficiency and affordability of Housing solutions

9. Methodology:

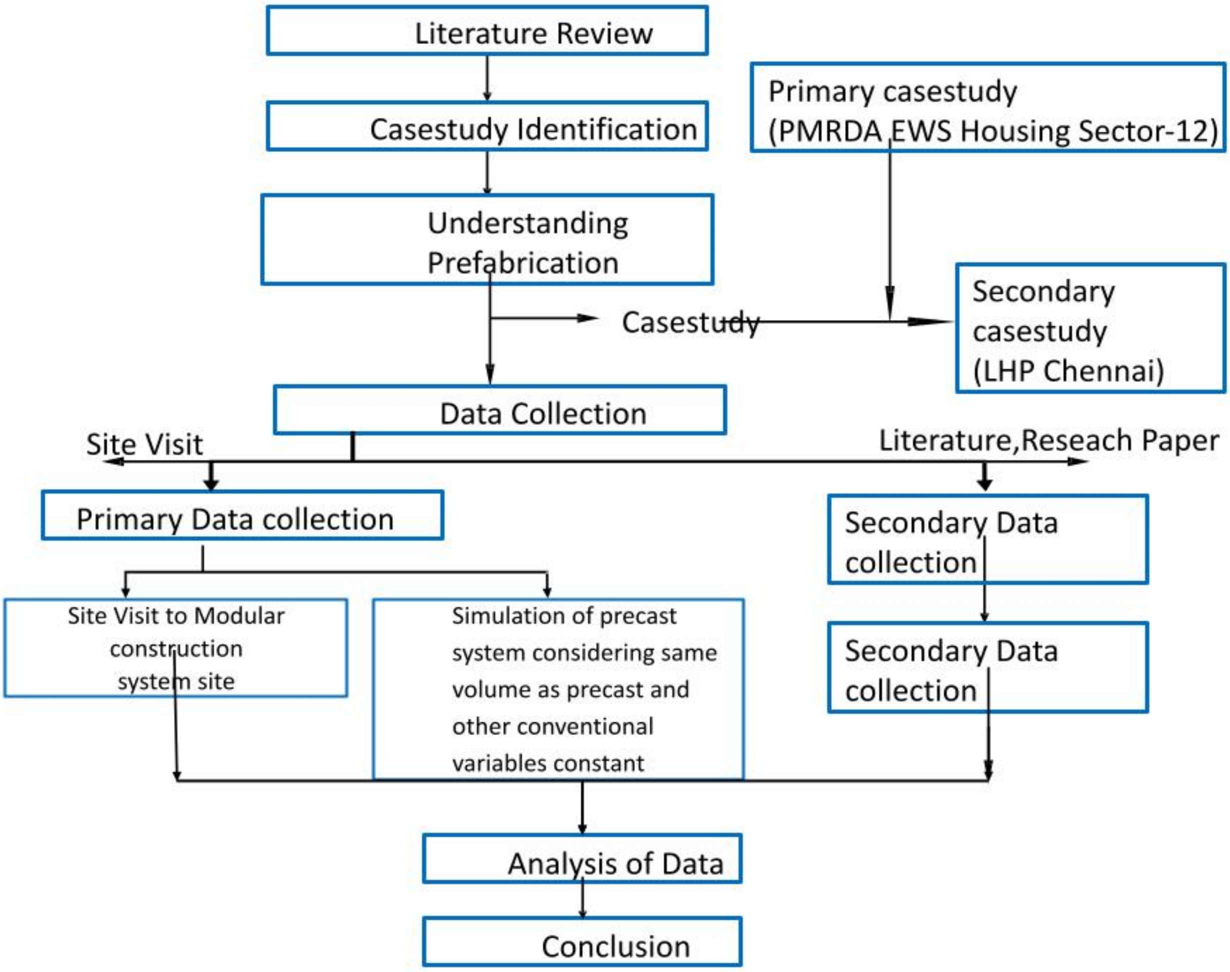


*Figure 1, **Source**: Author*

10. Research study framework:

10.1 : Stages of precast construction process:

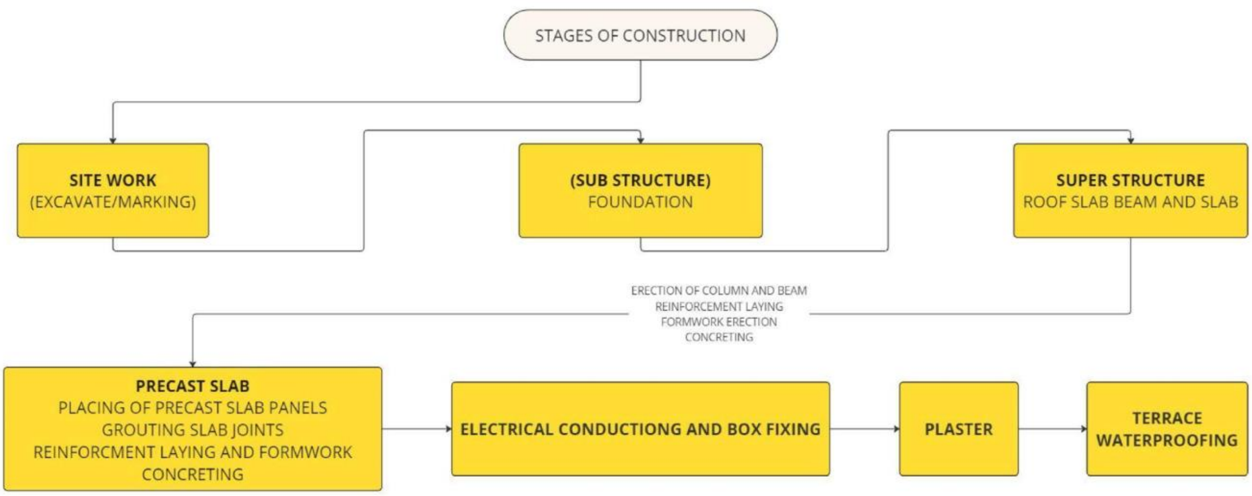


*Figure 2, **Source**: Author*

10.2 : Stages of precast manufacturing process:

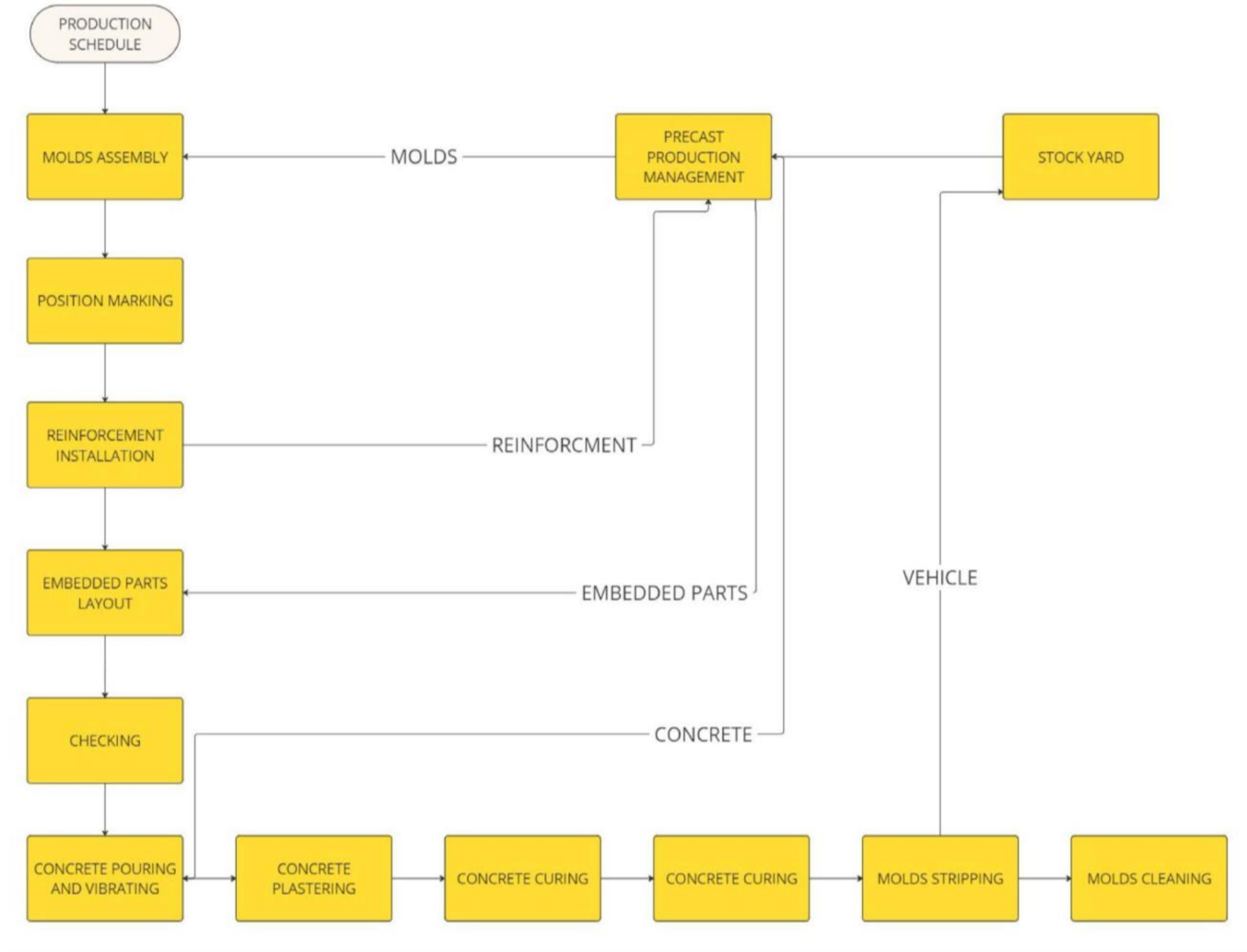


*Figure 3, **Source**: Author*

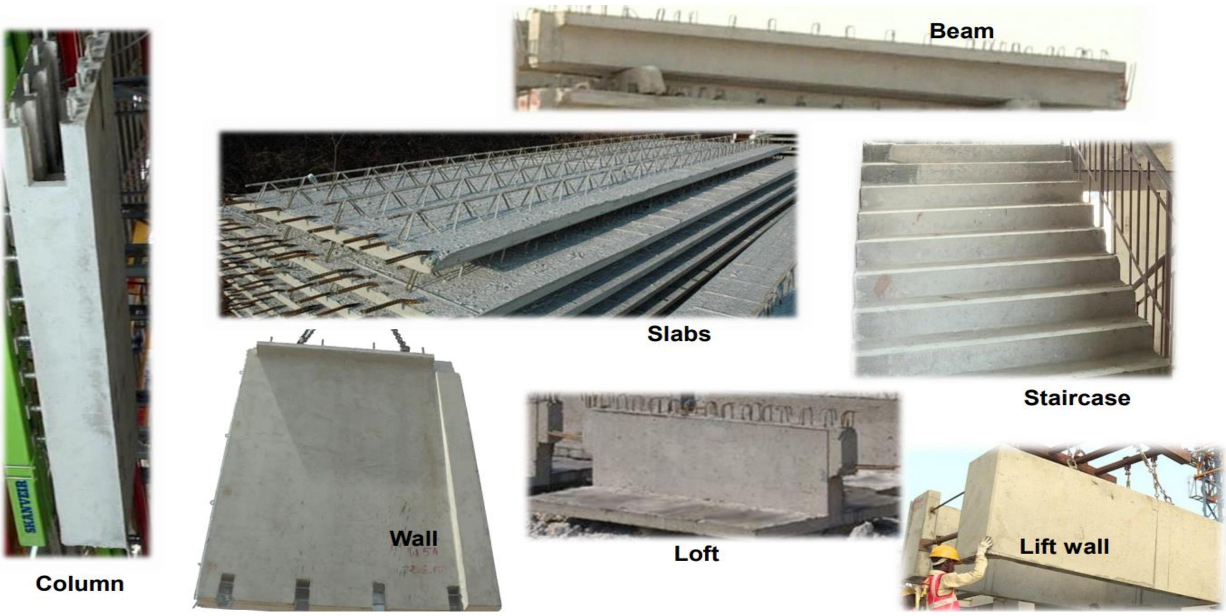


*Figure 18: Components of Precast , **Source**: Author*

10.3 Factors affecting cost:

STAGE	FACTORS
DESIGN	Repetitiveness, qualified civil engineers, specialised architects, poor design, design alteration, unable to freeze the design early on, standardisation design, repetition ratio of PC, experience, specification of design.
PRODUCTION	Higher capital cost, economies of scale, mould types, turnover rate, proficiency of the workers, employee empowerment, procurement method, mass production
TRANSPORTATION	Transportation cost of precast elements, collaborative efforts, distance
ONSITE INSTALLATION	Plant and production management, erection practices, labour productivity, skilled worker's wages, scale of construction projects, construction time, complexity between joints, mismatching between on and off-site joints, experience, project management
THEWHOLE PROCESS	Material cost, labour cost, machinery cost and factory, mould cost, training, communication, cooperation, management mode, technological innovation.

11. Case study Identification:

11.1 Primary Case Study :

EWS HOUSING BY PMRDA IN SECTOR-12

BHOSARI, PUNE

PROJECT BRIEF : PMRDA SECTOR 12 PHASE 1 & 2

SITE LOCATION: PLOT G1&G2 - SECTOR 12

BHOSARI , PUNE

NO OF TOWERS: 47

Figure 18: Site

FSI: 2.5

NO OF FLOORS: G+14 FLOOR

PLOT AREA G1: 2.50 Ha

PLOT AREA G2: 1.74 Ha

NO OF UNITS IN PHASE 1 : 4833

NO OF UNITS IN PHASE 2 : 6452

1BHK TYPICAL UNIT AREA: 29.55 SQ MT

1RK TYPICAL UNIT AREA: 25.70 SQ MT

2BHK TYPICAL UNIT AREA: 59.27 SQ MT

2 BHK TYPICAL UNITE AREA (TYPE 2): 48.89 SQ MT

TOTAL PROJECT COST : 730 CRORES

Figure 15: Site Location

***Figure 17** : site photo*

***Figure 16**: site layout*

***Source**: https://ceplpune.com/portfolio-item/pcntda-sector-12/*

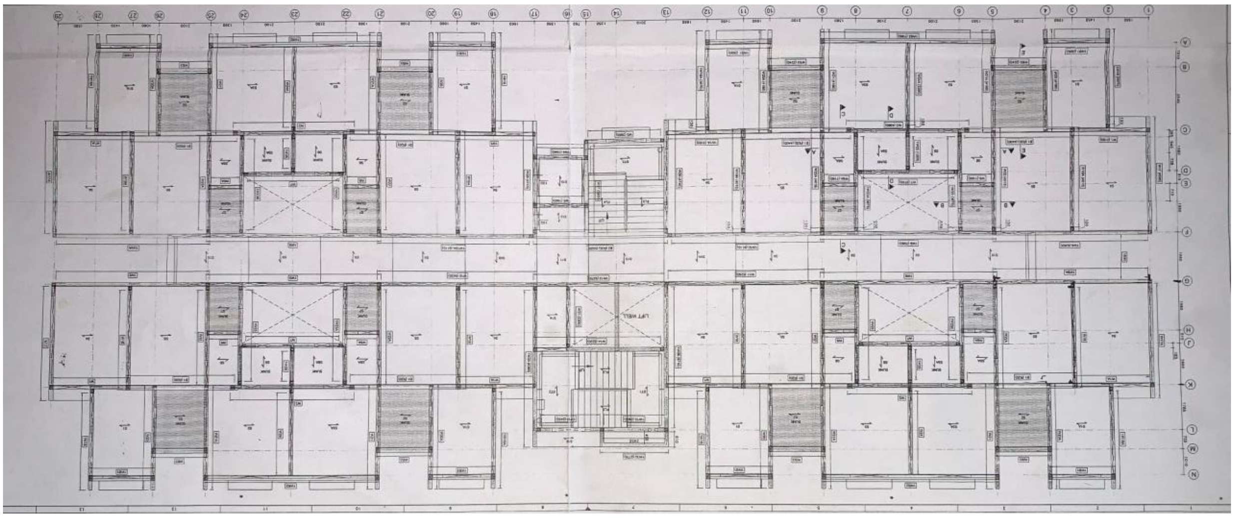


***Figure 19**: PMRDA sector 12 Bhosari Phase - 2 (2BHK TYPICAL UNIT PLAN)*

***Source**: B.G Shirke Construction Company Limited*

11.1.1 Economically Weaker Sections (EWS):

To cater to the requirements of the Economically Weaker Sections, PMRDA has planned the construction of 3,320 1BHK houses with a floor area of 29.55 sq. m. Additionally, the project includes 332 1 RK houses with a floor area of 25.70 sq. mt.

11.1.2 Low-Income Groups (LIG):

PMRDA plans to construct 1,456 2 BHK houses with a floor area of 59.27 sq. m**.** Furthermore, 1,344 2 BHK houses with a floor area of 48.89 sq. m have been allocated for LIG beneficiaries.

The Pune Metropolitan Region Development Authority (PMRDA) has determined on a vision to address housing needs by announcing the construction of 6,452 affordable houses in the Bhosari Peth 12 area.

11.1.3 Phased Development Approach:

PMRDA has successfully completed Phase 1 of the Bhosari Peth No 12 project, delivering 4,833 houses to deserving individuals. Currently, the authority is actively engaged in the construction of Phase 2, which will add an additional 6,452 houses to the project.

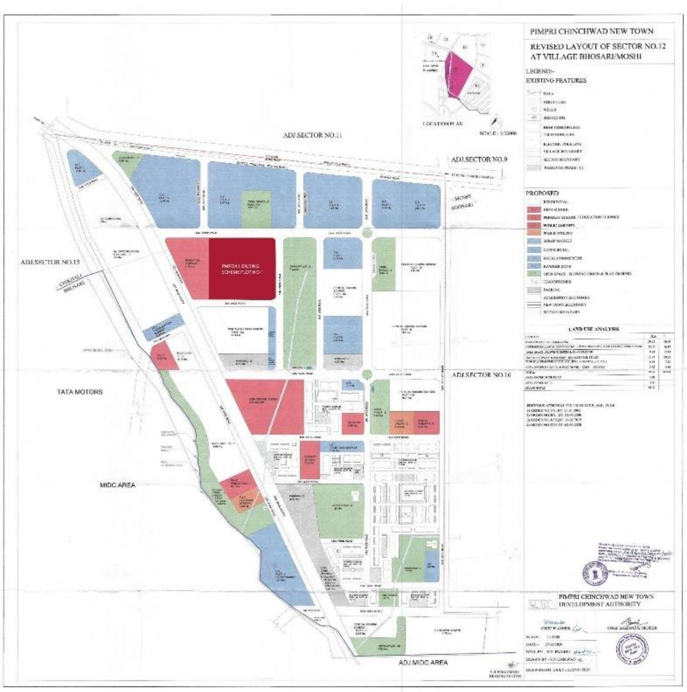


Figure 31 : *Site location*

Figure 32 : *2 BHK Unit Layout Plan*

Figure 33 : *2 BHK Block Layout Plan*

Source*: https://dtp.maharashtra.gov.in/en/content/development-plan-pimpri-chinchwad-navnagar- development-authority*

11.1.4 Overview of construction system :

The construction system used in LHP at Chennai is also popularly known as _3S system, 3S stands for Strength, Speed and Safety including sustainability_. 3Ssystem incorporates precast dense reinforced cement concrete hollow core columns, AAC blocks for masonry (outer and partition walls), T/L/Rectangular shaped beams, stairs, floor/roof solid Precast RCC slabs, lintels, parapets and chajjas.

11.1.5 Precast Structural Components Used:

Shear Walls: Walls are crucial because they transfer loads from beams to the foundation. They come in square, rectangular shapes and are initially cast with dowel connections.

Beams: Typical beam dimensions are 16 to 40 inches deep and 12 to 24 inches wide. Prefabricated beams and columns offer flexibility in design and application. They are made with high-strength concrete for a clean, finished look.

Slabs: . During installation, silicon oil is applied to the surface, and a metal mesh is placed over it. This is then covered with a 40 mm thick layer of M25-30 grade slurry concrete, providing strength to the slabs.

Staircase**:** Pre-cast staircases consist of two flights, from floor landing to mid-landing and mid-landing to floor landing. The reinforcements are arranged according to the design, and the moulds are oiled before placement. The mould allows for casting two flights of stairs at once.

11.1.6 Transportation of Components:

Lifting and Loading**:** Precast pieces are lifted at designated points according to factory plans to avoid stress cracks.

Trailer Prep: They are carefully loaded onto trailers with spacers to prevent stains and secured with straps and supports to prevent damage during transport.

Organized Stacking: Pieces are stacked on trailers based on size and shape, with separation and support to prevent damage.

Delivery Check: Upon arrival, the site crew inspects each piece for shipping damage and verifies it matches the delivery list.

Defect Handling: Damaged pieces are flagged for a quality check on-site to decide if they can be used or need to be returned to the factory.

Safe Unloading: Straps and securements are carefully removed to avoid harming remaining pieces.

Trailer Departure: Once unloaded, straps are stored properly, and the empty trailer is sent back.

Delayed Unloading: If unloading isn't possible, the trailer is parked securely and disconnected from the truck until unloading is clear.

11.1.7 Casting of Structural components:

Precast Beams

Precast walls

Precast slab

Precast Staircase

11.1.8 Installation of components:

The foundation is built based on soil conditions using the cast-in-situ method. Precast plinth beams and Core Shear Walls are erected with a crane. Beams fit into the slit created with in the wall , followed by slab installation. Structural integrity is achieved with dowel bars and self-compacting concrete.

Reinforced Walls are made with chajja instead of columns . Primary beams are placed and levelled, then reinforced with steel bars. Secondary beams and slabs are installed and reinforced to create a stable structure.Plaster finalise the components dimensions..

For staircases, slit in wall support mid-landing beams, and prefabricated staircases are placed between landings.

11.1.9 Stages of Construction:

Sub structure:

Excavation work for Foundation

PCC and Shuttering for Footings

Shuttering and Reinforcement work for Footing

Casting of Footings

Super Structure:

Erection of Precast walls from the footings

Precast plinth beam connects with wall

Placement of Partially Precast Slab

Reinforcement for screed concrete on partially Precast Slab

Rcc frame is constructed after screed concrete and wet joinings of beam, walls and slab

Erection of Beam, walls and Slab in upper floors.

External Painting

11.1.10 Construction method used is 3s prefab technology (precast columns,beams,slabs and walls):

Prefab structural configuration:

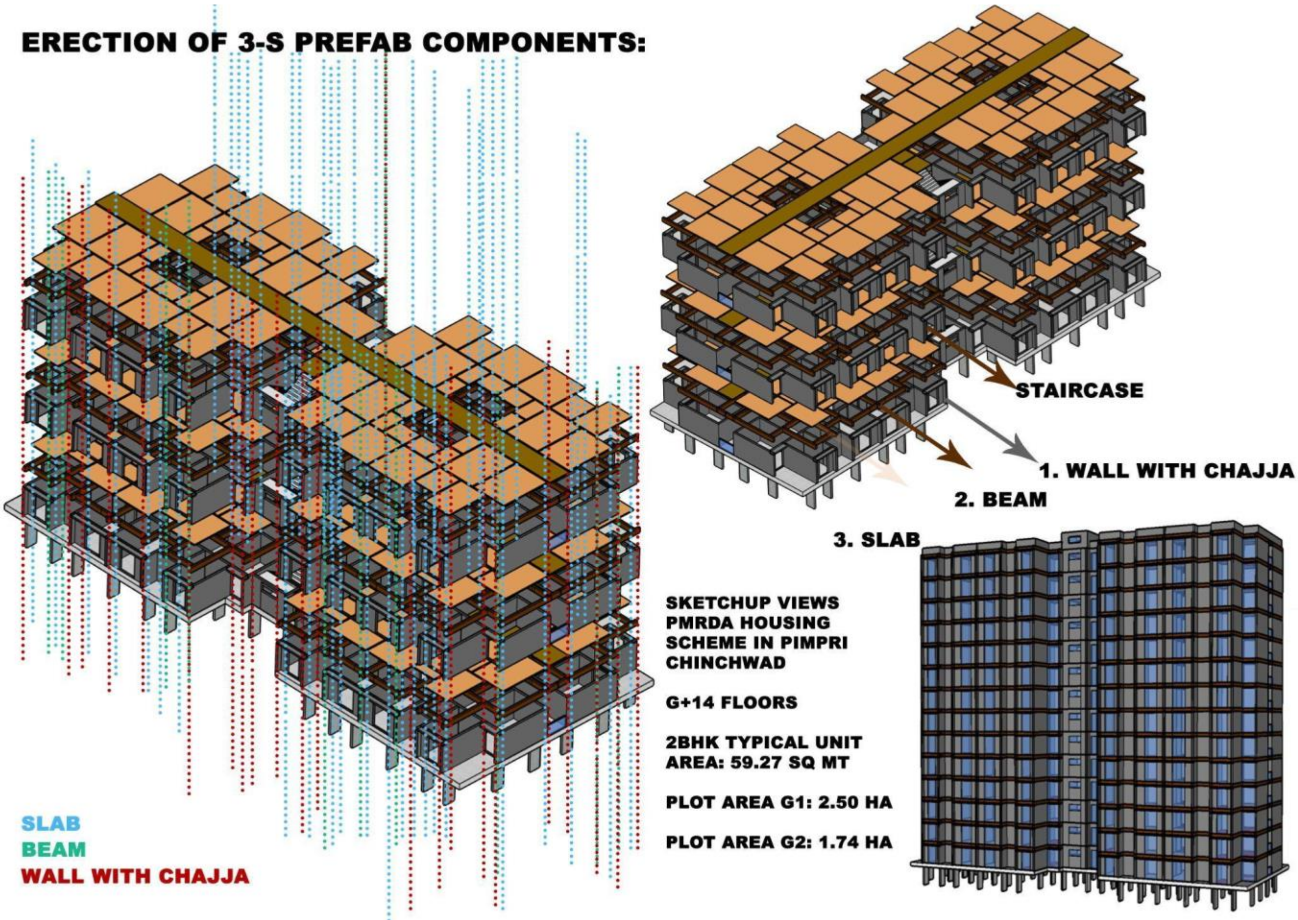
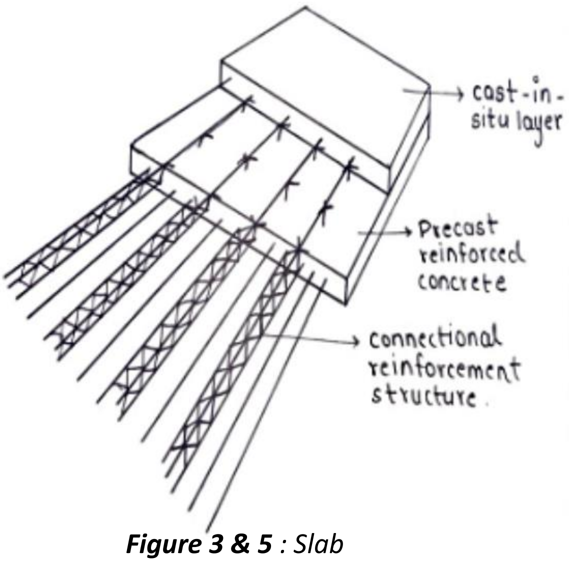


***Figure 4** : Isometric view of prefab components coming together as whole*

***Source**: Author*

Beams, Slabs and Walls with chajja



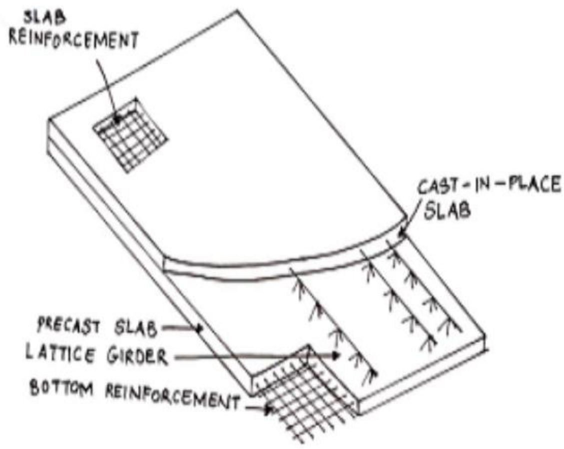


***Figure 3 & 5** : Slab*

***Source**: https://ghtc-india.gov.in/Content/pdf/Chennai_Compendium.pdf*

Precast Staircase Detail:

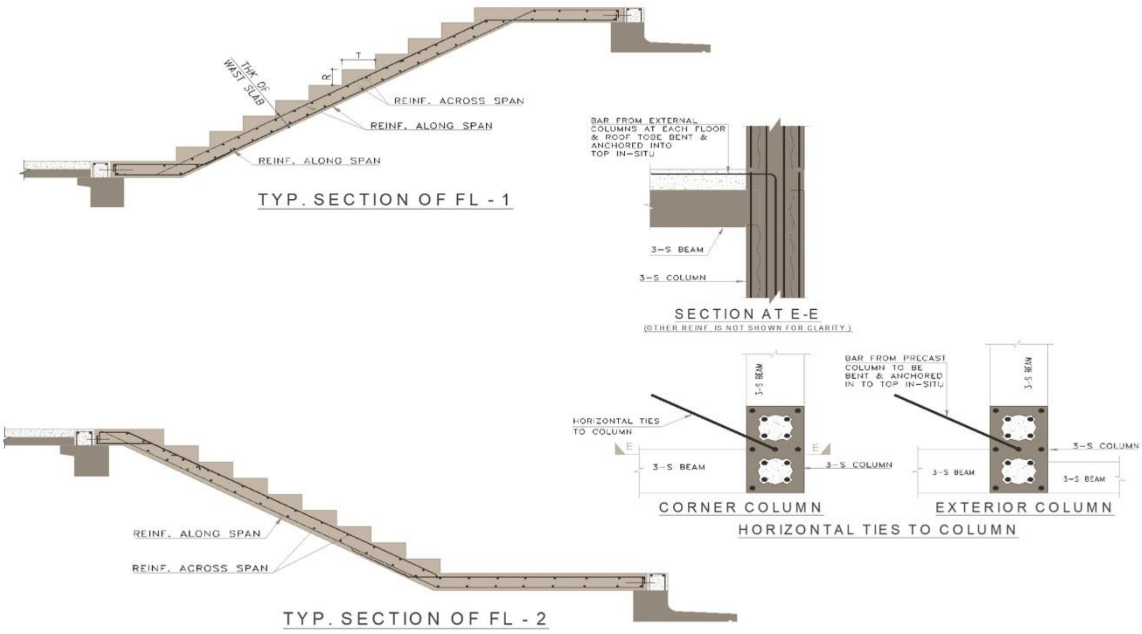


Fig 34: Staircase,

Source: *https://ghtc-india.gov.in/Content/pdf/Chennai_Compendium.pdf*

Wall with Chajja

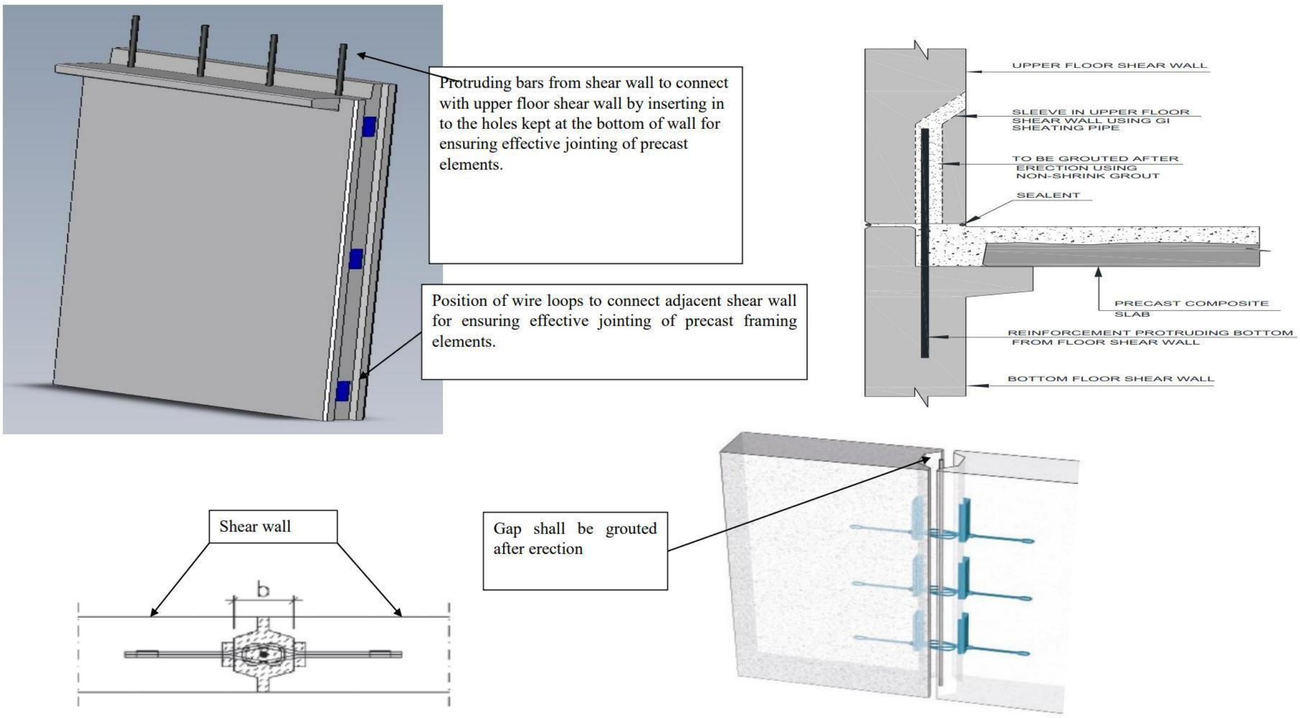


Figure 6: *Wall with chajja*

Source: *https://ghtc-india.gov.in/Content/pdf/Chennai_Compendium.pdf*

***Precast RCC Pardi Detail section*:**

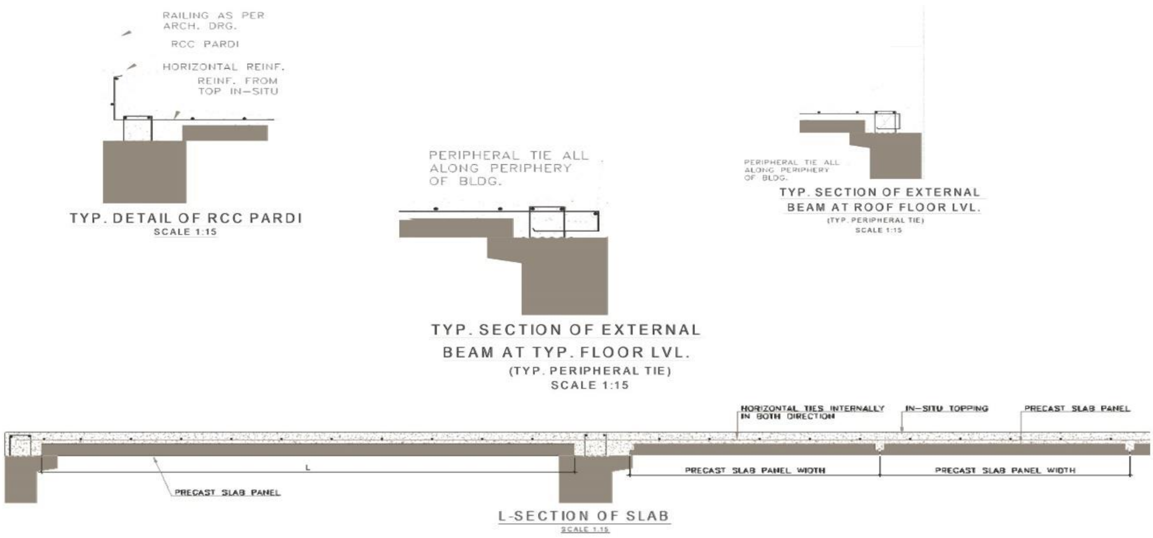


Figure 7: *Rcc precast chajja detail*

Source: *https://ghtc-india.gov.in/Content/pdf/Chennai_Compendium.pdf*

11.1.11 PMRDA Mass Housing Sketchup views

2BHK TYPICAL UNIT AREA: 59.27 SQ MT

Figure 8: *Elevation of PMRDA HOUSING scheme*

Source: *Author*

11.1.12 Factory visit : B.G SHIRKE CONSTRUCTION PVT.LTD , Pune, Pimpri Chinchwad

Wall with chajja

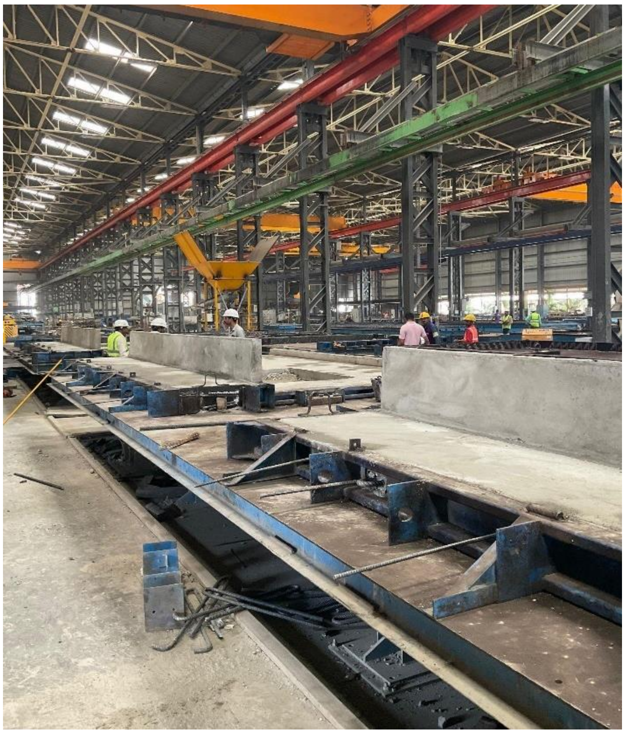


Figure 9 &10 : *wall with chajja* , ***Source***: *Author*

Beam

Figure 11 :*Beam* , ***Source***: *Author*

Slab

Figure 13: *Slab* , ***Source***: *Author*

Figure 12 **:** *Beam,* ***Source****: Author*

Figure 14*: Slab,* ***Source****: Author*

11.1.13 Advantages of Precast Construction over Conventional Construction:

The Precast concrete Technology has a number of advantages over conventional construction. Some of the important advantages are listed below:

• Precast construction use causes reduction in construction time.

• The controlled factory environment brings resource optimization, and improved quality, precision & finish.

• Increased safety on site

• Reduced wastage and non-generation of construction debris

• Minimal requirement of water for construction

• Elimination of use of timber / wooden scaffolding/ Shuttering.

• Cost saving due to compressed completion time and rental cost reduction.

11.2 Secondary Case study: LHP Chennai

11.2.1 Overview :

LHP-Chennai is the first completed project out of total six LHPs across country whose foundations were laid by Hon'ble Prime Minister on 1st January 2021. In LHP Chennai, 1,152 (Ground +5) houses along with physical and social infrastructure facilities have been constructed at Perumbakkam, Chennai. Hon'ble Prime Minister inaugurated the LHP Chennai on 26th May 2022 and dedicated this project to the nation.

11.2.2 Project Brief:

Location of Project	Nukkampal Road, Chennai, Tamil Nadu
No. of DUs	1,152 (G+5)
Plot area	29,222 sq.m
Carpet area (per DU)	26.78 sq.m.
Total built up area	43439.76 sq.m
Technology used	Precast Concrete Construction System - 3S System
Other provisions	Anganwadi, shops, milk booth, library and ration shop Broad Specifications
Foundation	RCC isolated/Combined footing
Structural Frame	RCC precast beam/columns
Walling	AAC blocks
Floor Slabs/ Roofing	RCC precast slab

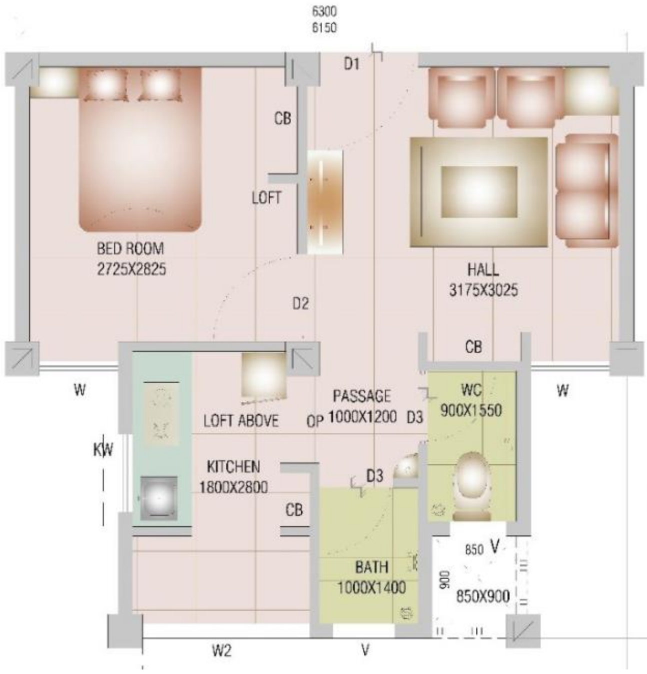


__Figure 34:__ LHP Chennai Layout Plan *__Figure 35:__ LHP Chennai Unit Plan*

__Figure 36:__ LHP Chennai Block Layout Plan

Source: *https://ghtc-india.gov.in/Content/pdf/Chennai_Compendium.pdf*

11.2.3 Overview of construction system :

The construction system used in LHP at Chennai is one of the technologies from the broad group of Precast Concrete- Concrete Components Assembled at Site. It is also popularly known as ***3S system, 3S stands for Strength, Speed and Safety including sustainability***. 3S system incorporates precast dense reinforced cement concrete hollow core columns, AACblocks for masonry (outer and partition walls), T/L/Rectangular shaped beams, stairs,floor/roof solid Precast RCC slabs, lintels, parapets and chajja.

11.2.4 Precast Structural Components Used:

Columns: Columns are crucial because they transfer loads from beams to the foundation. They come in square, rectangular, or circular shapes and are initially cast hollow with dowel connections.

Beams: Typical beam dimensions are 16 to 40 inches deep and 12 to 24 inches wide. Prefabricated beams and columns offer flexibility in design and application. They are made with high-strength concrete for a clean, finished look.

Slabs: . During installation, silicon oil is applied to the surface, and a metal mesh is placed over it. This is then covered with a 40 mm thick layer of M25-30 grade slurry concrete, providing strength to the slabs.

Staircase: Pre-cast staircases consist of two flights, from floor landing to mid-landing and mid-landing to floor landing. The reinforcements are arranged according to the design, and the moulds are oiled before placement. The mould allows for casting two flights of stairs at once.

11.2.5 Comparison with Conventional Construction:

In India, conventional construction methods include Load Bearing Structures and Reinforced Cement Concrete (RCC) Structures, both of which use raw materials like cement, sand, aggregates, and bricks.

Load Bearing Structure:

Walls are made of bricks, stone, or blocks.

Floors and roofs are made of RCC, stone, composite, or truss.

This is an on-site construction method where the load is transferred to the foundation through the walls.

RCC Framed Structure:

The structure's skeleton is made of RCC columns and beams with RCC slabs.

Infill walls can be made of bricks, blocks, stone, or panels.

The load is transferred to the foundation through beams and columns.

11.2.6 Concrete Mix Design:

Mix Design for M35 (C/PC43) Grade concrete	
Grade of Concrete	M35
Grade of cement	OPC 43 (ACC Cement)
Maximum Size of Aggregate	20 mm
Characteristic Strength, Fck	35 N/sqmm
Target M can Strength	43.25 N/sqmm
Basic Data	
Specific Gravity of Cement	3.15
Type of Fine Aggregate	M - Sand
Specific Gravity of Sand	2.59
Sand in Total Aggregate	44.5%
Type of Coarse Aggregate	Crushed rock
Specific Gravity of Coarse Aggregate	2.75
Coarse Aggregate (20 mm) in Total Aggregate	33.3%
Coarse Aggregate (12.5 mm) in Total Aggregate	22.2%
Material for 1cum of Concrete	
Cement (75%)	300 Kg
G.B.B.S – JSW (25%)	100 Kg
Water	164 lit
Admixture content (forsoc conplast SP430)	2.80 lit
Sand	820 kg
Coarse Aggregrate 12.5 mm nominal size	612 kg

11.2.7 Transportation of Components:

Lifting and Loading: Precast pieces are lifted at designated points according to factory plans to avoid stress cracks.

Trailer Prep: They are carefully loaded onto trailers with spacers to prevent stains and secured with straps and supports to prevent damage during transport.

Organized Stacking: Pieces are stacked on trailers based on size and shape, with separation and support to prevent damage.

Delivery Check: Upon arrival, the site crew inspects each piece for shipping damage and verifies it matches the delivery list.

Defect Handling: Damaged pieces are flagged for a quality check on-site to decide if they can be used or need to be returned to the factory.

Safe Unloading: Straps and securements are carefully removed to avoid harming remaining pieces.

Trailer Departure: Once unloaded, straps are stored properly, and the empty trailer is sent back.

Delayed Unloading: If unloading isn't possible, the trailer is parked securely and disconnected from the truck until unloading is clear.

11.2.8 Casting of Structural components:

Precast Beams

Precast Columns

Precast slab

Precast Staircase

***11.2.9 Installation of components*:**

The foundation is built based on soil conditions using the cast-in-situ method. Precast plinth beams and hollow core columns are erected with a crane. Beams fit into column notches, followed by slab installation. Structural integrity is achieved with dowel bars and self-compacting concrete.

Columns are temporarily secured with wire ropes, then partially filled with concrete. Primary beams are placed and levelled, then reinforced with steel bars. Secondary beams and slabs are installed and reinforced to create a stable structure. Shuttering and screeding finalise the components' dimensions. For staircases, Slit in walls support mid-landing beams, and prefabricated staircases are placed between landings.

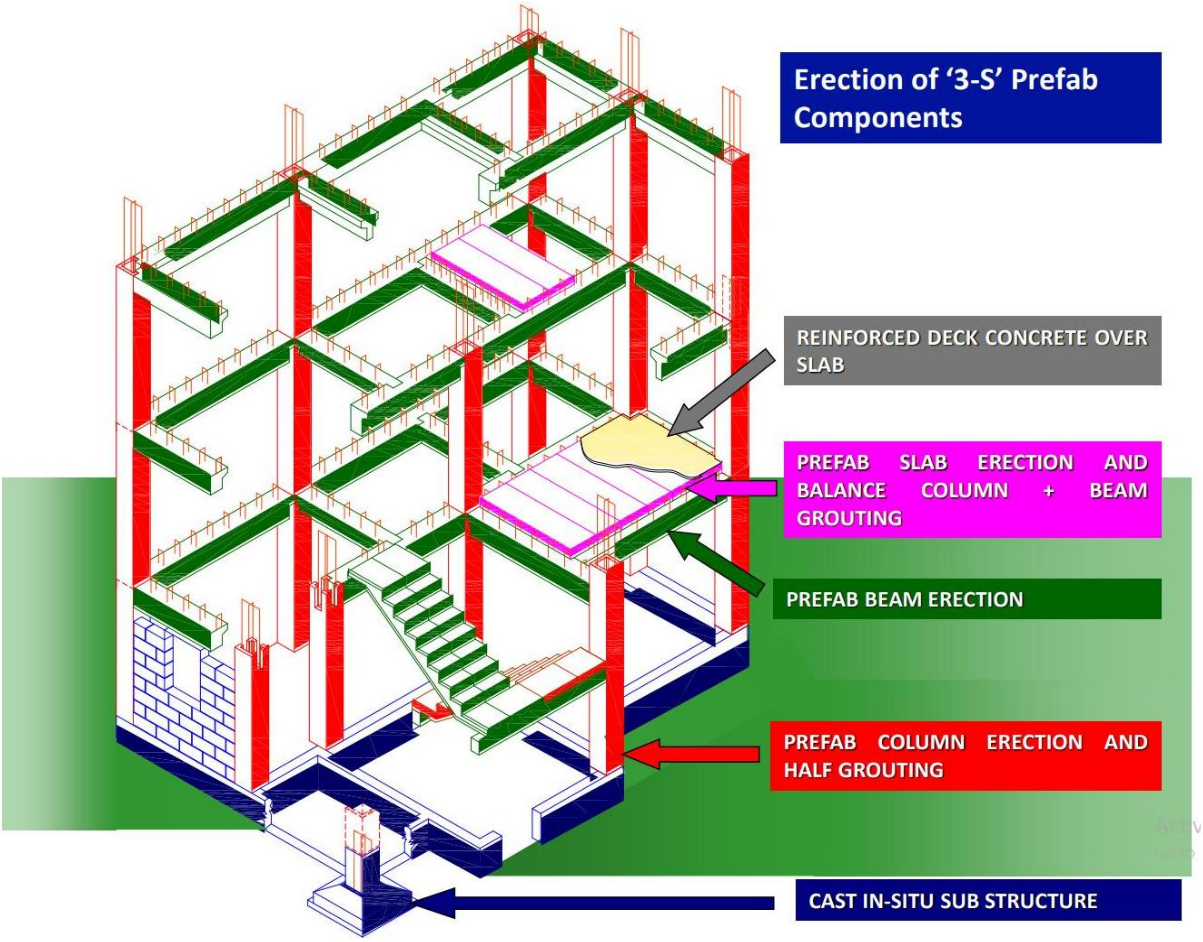
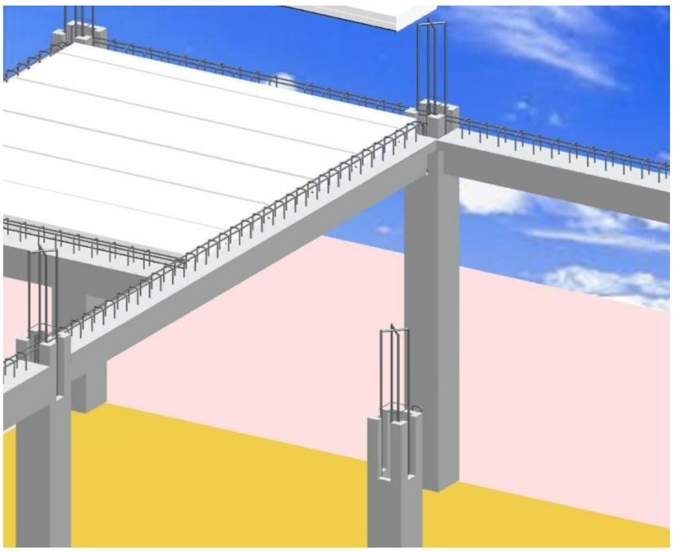


Figure 30th

Prefab structural configuration



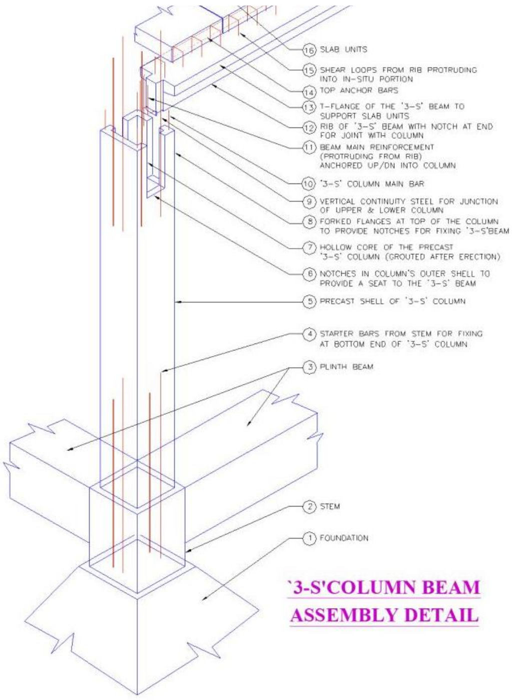


Figure 31th

Beam,column jointing

Figure 32th

Column,beam assembly detail

Source: *https://ghtc-india.gov.in/Content/pdf/Chennai_Compendium.pdf*

11.2.10 Construction Process:

***Mobilization of Plant and Machineries*:**

Being industrialised precast technology, heavy equipment and machineries are required for proper execution of work. Necessary machineries/ equipment was mobilised by the agency as required. The list of the Plant and Machinery deployed at the LHP Chennai is given below:

S.R. N.O	Particulars	Quantity Available
1	Tower Crane	05
2	Backhoe loader	02
3	Total Station	02
4	Auto level	02
5	TIpper	01
6	Soil Compactor -12T	01
7	Needle Vibrator	06
8	Bar Cutting Mahine	03
9	Bar Bending Machine	04
10	Stirrup making machine	02
11	Welding Equipment	07
12	Frequency converter	02
13	Plate Compactor	01
14	Transit mixture	06
15	Concrete Pump	01
16	Hydra	05
17	Tractor	01
18	Open Truck	07

19	Batching Plant	01
20	Weight Bridge	01
21	Pick Up	01
22	Mud Pump	06
23	Water Pump	04
24	Submersible Pump	11
25	Ambulance	01
26	D.G Set 125 KVA	05
27	D.G Set 62.5 KVA	01
28	QTK Crane	02
29	Skid Steer Loader	01
30	Winger	01
31	Front loader	01
32	Winch Machine	04

11.2.11 Placement of Manpower Resources:

Being EPC project, it was tender requirement that a multi-disciplinary project team of professionals including civil engineers, electrical engineers, mechanical engineers, management and IT was deployed for smooth operation of the various activities involved in the execution of the project from the start of the project.

No of Manpower Required for this particular project is given in the table below:

B G SHIRKE CONSTRUCTION TECHNOLOGY PVT. LTD.
Construction of 1152 EWS (G+5) units at LHP site at Chennai

Sl.No		Requirement of Staff Qualification	List of Technical Strength (No)	Technical Minimum E (years)	Representative at site Required Designation of Technical staff	Designation of Technical Staff deployed at site	Total Experi (years)
1		Graduate	1	20	Project Manager	Sr. DGM	31
2	a	Graduate (Civil/ Billing Engineer)	1	12	Deputy Project Manager	Construction Manager	22
	b	Graduate (MEP) Engineer	1	12	Deputy Project Manager	Sr. Engineer	12
3	a	Civil Graduate Engineer or Diploma Engineer	2	5 to 10	Project	Dy. Construction Manager	22
					site Engineer	Asst. Engineer	9
	b	Civil Graduate Engineer or Diploma Engineer	1	5 to 10	Quality Control Engineer	Sr. Engineer	23
	C	Electrical Graduate Engineer or Diploma Engineer	1	5 to 10	Project/site Engineer	Asst. Engineer	10
	d	Graduate Engineer/ MBA in project Management	1	5	Planning Engineer	Jr. Engineer	5
4	a	Civil Diploma	4	5	Supervisors	Asst. Engineer	10
		Engineer				Jr. Engineer	10
						Jr. Engineer	7
						Jr. Engineer	5
	b	Electrical Diploma	2	3	Supervisors	Asst. Engineer	8
		Engineer			Supervisors	Jr. Engineer	8
	C	Mechanical	2	5	Supervisors	Asst. Manager	23
		and Plumbing Engineer				Asst. Engineer	7
	d	IT/ Communication / MCA	1	5	IT Engineer	IT Manager	26

11.2.12 Setting up of casting yard:

The technology used in the project requires casting of various components like columns, beams, slabs, staircase, sunshades and some other small components. A casting yard was set up by the agency near the project site (within 0.5 km) for casting of columns, beams, staircase, sunshades etc. Partially precast slabs were produced in another precast yard few kilometres away from the site. All the precast components were transported to site as per the erection schedule

One Tower crane was provided at Pre-casting yard for Shifting of PRECAST Components. There were 32688 number of Precast components in Superstructure of the project which took about 127 days (from February 2021- July 2021) to construct. There was 318 Moulds deployed at site. A total of 6 pallets used for Slab Casting. On an average 260 components were casted on a daily basis in the casting yard. About 5 Tower cranes were erected near the buildings for erection of pre-casting Components constructed in the casting yard. The Prefab components were erected, aligned and connected using SCC i.e. Self-Compacting Concrete of appropriate grade along with secured embedded reinforcement.

11.2.13 Casting of Structural Components

Each building in the LHP Chennai project is constructed using prefabricated components like beams, columns, slabs, and staircases. These components are manufactured based on the structural designs and then transported to the construction site for assembly.

Precast Beams

Different types of beams (roof, floor, plinth, lintel) were manufactured. Specifically, 2,724 plinth beams and 13,260 typical floor beams were cast. The process involved placing reinforcement, pouring concrete, curing, and testing.

Precast Columns

The project included single-core and multi-core hollow columns. A total of 1,272 stem columns and 8,208 typical floor columns were produced. The columns were reinforced, concreted, vibrated to remove voids, finished, and cured before being transported to the site.

Precast Slabs

A total of 8,064 slabs were cast. The process involved placing reinforcement (a mesh and lattice girder), pouring concrete, compacting, curing for seven days, and marking for identification before dispatch.

Precast Staircase

The staircases, which include two flights per unit, were cast, cured for seven days, and then transported to the site. Each staircase unit was inspected and registered before dispatch.

11.2.14 Sub-Structure Work

Excavation

Due to heavy rains, waterlogged areas required dewatering with pumps. Since the local soil was unsuitable for filling, soil was brought from outside.

Foundation Work

Plate Load Test: Conducted at a depth of 3 meters using a 0.3m x 0.3m plate. The test confirmed a safe bearing capacity of 25t/m².

RCC Footing: Typical isolated and combined footings were provided based on soil investigations.

Stem Columns

Precast stem columns were placed on RCC footings, painted with bitumen, and connected with precast plinth beams.

11.2.15 Super Structure

Construction Method: Used an industrialized 3-S (Strength, Safety, Speed) prefab method with mass-produced precast components.

Components: Included precast RCC hollow columns, beams, slabs, and stairs.

Jointing: Wet jointing with self-compacting concrete ensured rigid joints.

Material Standards: Used minimum M35 grade concrete for floor elements and M40 grade for vertical load-bearing elements.

Thermal Comfort: Ensured by selecting wall materials with thermal transmittance within 2.56 W/m²K.

Precast Columns in Superstructure

Hollow core columns filled with self-compacting concrete after beam placement.Columns included a 60mm diameter sleeve for lifting and a mild steel mesh for sacrificial formwork.

Precast RCC Solid Beams

Composite precast RCC beams and slabs were manufactured under strict quality control.The jointing process involved wet jointing with self-compacting concrete.

Floors/Slab

Partially precast slabs were placed on beams and topped with 55mm screed concrete to ensure monolithic behaviour. Structural integrity was achieved through dowel bars and in-situ self-compacting concrete in column cores.

11.2.16 Stages of construction:

1. FIGURE 20TH
EXCAVATION WORK FOR FOUNDATION
SOURCE : AUTHOR

2. FIGURE 21 ST
PCC AND SHUTTERING FOR FOOTINGS
SOURCE : AUTHOR

3. FIGURE 22 ND
SHUTTERING AND REINFORCEMENT WORK FOR FOOTINGS
SOURCE : AUTHOR

4. FIGURE 23RD
CASTING OF FOOTINGS
SOURCE : AUTHOR

5. FIGURE 24TH
ERECTION OF PRECAST STEM COLUMNS FROM FOOT-INGS
SOURCE : AUTHOR

6. FIGURE 25TH
PRECAST PLINTH BEAM CONNECTION WITH STEM COLUMNS
SOURCE : AUTHOR

7. FIGURE 26TH
PLACEMENT OF PARTIALLY PRECAST SLAB
SOURCE : AUTHOR

8. FIGURE 27TH
REINFORCEMENT FOR SCREED CONCRETE ON PARTIALLY PRECAST SLAB
SOURCE : AUTHOR

9. FIGURE 27TH
MONOLITHIC RCC FRAME AFTER SCREED CONCRETE AND WET JOINTING OF BEAM, COLUMN AND SLAB
SOURCE : AUTHOR

10. FIGURE 28TH
ERECTION OF BEAMS, COLUMNS AND SLAB IN UPPER FLOORS
SOURCE : AUTHOR

11. FIGURE 28TH
EXTERNAL PLASTERING
SOURCE : AUTHOR

12. FIGURE 29TH
EXTERNAL PAINTING
SOURCE : AUTHOR

Figure 33: *Stages of construction shown through pictures* **,** ***Source:*** *Author*

12. Case study Analysis :

ELEMENTS	**FACTORS**	**PRECAST**	**CONVENTIONAL**	**DIFFERENCE**
BEAM	BEAM SIZE	7.340 MT X 0.2 MT X 4 MT	-	
	TOTAL VOLUME.	0.587 m3	0.263 m3	
	STEEL REQUIRED	123 Kg	37 Kg	
	STEEL REQUIRED CONSIDEING 0.587 m3	123 Kg	83 Kg	
	STEEL COST	7974 RS	5395 Rs (CONSIDERING 0.587 m3)	
	CONCRETE COST	2465 RS	3522 Rs(CONSIDERING 0.587 m3)	
	LABOR COST	1251 RS	5000 RS	
`	SHUTTERING COST PER COLUMN	-	100 RS	
	ERECTION COST	150 RS	-	
	LABOR COST @SITE	1251 RS	1000	
	ERECTION COST @SITE	150 RS		
	COST PER BEAM	***13191 RS***	***15017 RS***	1826
BEAM PER FLOOR				
	TOTAL BEAM VOLUME	58.748 m3	14.202 m3	
	BEAM PER UNIT	654144	-	
	LIFT AND STAIRCASE BEAM	261704	-	
	TOTAL STEEL COST	3,83,565 RS	540762 RS	
	TOTAL CONCRETE COST	2,46,741 RS	352488 RS	
	TOTAL SHUTTERING COST	-	15803	
	TOTAL LABOR COST	2,50,404	20683	
	TOTAL ERECTION COST	30,024	-	
TOTAL COST PER FLOOR CONSIDERING 58.748 AS CONVENTIONAL BEAM VOLUME		***910,734 RS***	***929,736 RS***	***19,002***

SLAB				
	TOTAL VOLUME	0.607 m3	23.44 m3	
	STEEL REQUIRED	58.64 KG	2760 KG	
	STEEL REQUIRED CONSIDERING 0.607m3	58.64 KG	71.4 KG	
	TOTAL VOLUME SCREEDING	0.0607 m3	-	
	TOTAL SCREEDING COST	250.94	-	
	STEEL COST	3811 RS	3852 RS	
	CONCRETE COST	2549 RS	3642 RS	
	LABOR COST	1251 RS	5000 RS	
	SHUTTERING COST	-	100 RS	
	ERECTION COST	150 RS	-	
	LABOR COST @SITE	1251 RS		
	ERECTION COST @SITE	150 Rs		
COST PER SLAB		***9412RS***	***12594 RS***	***3182 RS***
SLAB PER FLOOR				
	TOTAL SLAB VOLUME	41.87	23.44	
	STEEL COST	261537	319766	
	CONCRETE COST	175854	250680	
	SHUTTERING COST	-	11238	
	SCREEDING COST	17244	-	
	LABOR COST	23166	14259	
	ERECTION COST	2750	-	
TOTAL SLAB COST CONSIDERING CONVENTIONAL SLAB VOLUME (41.87 m3)		***480551 RS***	***595943 RS***	***1,15,392***
LINTEL PER FLOOR	TOTAL VOLUME	-	0.94 m3	
	STEEL REQUIRED	-	72.16 KG	
	CONVENTIONAL RATE	-	6000 RS	

	FOR 1m3 CONCRETE			
	FOR 0.94 m3 CONCRETE COST	-	5640 RS	
	LABOR COST	-	1000 RS	
	STEEL COST	-	3889 RS	
	SHUTTERING 25 RS/SQFT	-	1000 RS	
TOTAL COST		**-**	***11529 RS***	
WALL WITH CHAJJA	WALL SIZE	5.170 MT X 2.840 MT X 0.160 MT	5.170 MT X 2.840 MT X 0.160 MT	
	TOTAL VOLUME OF 1 LINTEL WITH CHAJJA	2.349 m3	2.349 m3	
	STEEL REQUIRED	236 KG	236 KG	
	STEEL REQUIRED PER m3	100.46 KG	100.46 KG	
	RMC RATE FOR 1m3 CONCRETE	4200 RS	6000 RS	
	FOR 2.349m3 CONCRETE COST	9865.8 RS	14094 RS	
	LABOR COST	1251 RS	3000	
	SHUTTERING COST	-	630	
	ERECTION COST	150 RS	-	
	STEEL COST PER m3	6529.9 RS	-	
	STEEL COST PER WALL WITH CHAJJA	15338.73 RS	15338.73 RS	
	LABOR COST @SITE	1251 RS	-	
	ERECTION COST @SITE	150 RS	-	
TOTAL COST OF WALL WITH CHAJJA		***26605 RS***	***33,062 RS***	***6,457***
WALL WITH CHAJJA PER FLOOR				
	TOTAL WALL VOLUME PER FLOOR	247.14	247.14	
	STEEL REQUIRED	24827 KG	24827 KG	
	STEEL COST	16,13,799	16,13,799	

	CONCRETE COST	10,37,988	14,82,840	
	SHUTTERING COST	-	66,480	
	LABOR COST	92574	3,16,846	
	TOTAL ERECTION COST	11,100	-	
	PLASTER COST	-	5.5 RS PER M3	
TOTAL CONSTRUCTION COST		***27,55,461***	***34,81,324***	***7,25,863 RS***
STAIRCASE	TOTAL VOLUME OF STAIRCASE	0.583 m3	0.48 m3	
	STEEL REQUIRED	65 KG	36 KG	
	STEEL REQUIRED FOR VOLUME 0.583 m3	65 KG	43 KG	
	CONCRETE COST	2448 RS	3498 RS	
	RMC RATE FOR 1m3 CONCRETE	4200 Rs	-	
	LABOR COST	1251 RS	1000 RS	
	STEEL COST	4225 RS	2842 RS	
	ERECTION COST	150 RS	-	
	LABOR COST @SITE	1251 Rs	-	
	ERECTION COST @SITE	150 Rs	-	
	SHUTTERING 25 RS/SQFT	-	2000 RS	
	TOTAL COST PER STAIRCASE	***9475 RS***	***9340 RS***	***135 RS***
	TOTAL COST	***18950 RS***	***37360 RS***	***18410 RS***
Analysis				
CONSTRUCTION COST PER ELEMENTS	***BEAM***	13191 RS	15017 RS	
	SLAB	9412RS	12594 RS	3182 RS
	LINTEL PER FLOOR	-	11529	
	WALL WITH CHAJJA	26605 RS	33,062 RS	6,457 RS
	STAIRCASE	9475 RS	9340 RS	135 RS
TOTAL CONSTRUCTION		***45492 RS***	***87,069***	***7601 RS***

COST PER ELEMENTS				
TOTAL COST OF ELEMENTS PER FLOOR	***BEAM***	910,734 RS	929,736 RS	19,002
	SLAB	480551 RS	595943 RS	1,15,392 RS
	LINTEL PER FLOOR	-	11529 RS	11529 RS
	WALL WITH CHAJJA	27,55,461 RS	34,79,965 RS	7,24,504 RS
	STAIRCASE	18950 RS	37360 RS	18410 RS
TOTAL CONSTRUCTION COST PER FLOOR		***41,48,452 RS***	***50,54,555 RS***	***9,06,103 RS***
TOTAL BUILDING COST		***5,80,78,328***	***7,07,63,770***	***1,26,85,442***
	Erection cost	***1,74,23,498***		
	Logistics cost	***29,03,916***		
TOTAL BUILDING COST		***7,84,05,742***	***7,07,63,770***	***7641972***

13. Conclusion:

ELEMENTS	*PRECAST*	*CONVENTIONAL*	*DIFFERENCE*
Horizontal Member			
Beam Per floor	910,734 RS	929736 RS	*19002 RS (2%)*
Per Beam	13191 RS	15017 RS	*1826 RS*
Slab per floor	480551 RS	595943 RS	*1,15,192 RS (24% approx)*
lintel per floor	-	11529 RS	
Vertical Members			
walls with chajja	26605 RS	33062 RS	*6457 RS*
walls with chajja per floor	2755461 RS	3481324 RS	*7,25,863 RS (28 % approx)*
staircase	18950 RS	18680 RS	*270 RS*
Total Construction Cost Per Floor	*41,48,452 RS*	*50,54,555 RS*	*9,06,103 RS*
Logistics cost	*29,03,916*	-	
Erection Cost	*1,74,23,498*	-	
Total Project cost	*7,84,05,742*	*7,07,63,770*	*7641972 (Precast is approx 11% costlier then conventional)*

After analysing data of both the construction system it concludes that Precast is more Affordable when compared to particular elements but when u take the whole project cost into consideration precast gets 11% expensive then conventional construction system and this is because of Erection Cost which is approximately 25-30% of Total project cost.

But considering per element case precast turns out to be cheaper then conventional ,for eg :

Precast slab is 24% cheaper then conventional construction system

Precast Beam is 2% cheaper then conventional construction system

Wall with Chajja is 28% cheaper in precast then in conventional construction.

Hence, if we compare both the construction system on the basis of each element then Precast is more affordable then conventional but when we add all other factors *excepts structural elements which affects the cost then we get to know that total construction cost of Precast building is approx. 11% costlier then conventional if we construct the same precast building through conventional construction system.*

14. Way Forward:

Show the Money:

Develop a cost model that factors in the time saved via precast construction. Find interest saved on loans, earlier rental income, and reduced overhead costs due to a shorter build time.

Compare the total project cost (including erection) for both precast and conventional methods using this model. Highlight the point where faster completion with precast outweighs its slightly higher upfront cost.

Identifying factors affecting Erection Costs:

Identify the main culprits driving up erection costs (transportation, labour, etc.) for precast construction.Propose solutions to bring these costs down. This could involve optimizing precast element design for transport, exploring alternative erection techniques, or using connections that minimize on-site labour.

Learning from the Best:

Research successful mass housing projects that leveraged precast construction for significant cost and time savings.

Analyse their best practices in precast element design, logistics, and erection for achieving optimal results.

Looking Ahead:

Acknowledge limitations like not considering lifetime costs or factory setup.

Propose future research areas to further strengthen the case for precast in mass housing. This could include studying long-term performance, developing more detailed cost models, and analysing the environmental impact comparison of both methods.

By focusing on the time-saving benefits and potential cost reduction strategies for erection, this thesis can demonstrate the viability of precast construction as a compelling solution for cost-effective and time-efficient mass housing projects.

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