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Assessment of Expanded Polystyrene (EPS) Core Panel System for Mass Housing in India

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ABSTRACT

Objectives: To compare the Expanded Polystyrene (EPS) core panel system in comparison with the conventional construction system for mass housing projects by showing its impact on project completion time and cost.
Methods: A mass housing project proposed by the Tamilnadu slum clearance board is selected which is designed using the EPS core panel system. The cost and project completion time has been calculated for this project. For the same project, using the conventional method, the cost estimation and project completion time are calculated.
Findings: It is found that the EPS core panel system costs 21.30 percent less than the conventional method of construction. The project completion time of the EPS core panel system is 448 days earlier than the conventional construction method. This paper concludes that the EPS core panel system is more efficient for mass housing projects in terms of project cost and project completion time.
Novelty: The novelty of this research is that no previous studies have been done to assess the suitability of the EPS core panel system for mass housing projects at this particular location. Also, the projects selected for case studies were not on large scale. In this study, a mass housing project on a 13.40 acre site is selected.

Key Words: *Comparative analysis, Conventional construction method, EPS core panel system, Indian construction industry, Mass housing*

INTRODUCTION

People, after food and clothing, have a basic need for housing. Housing facilities also have an impact on infrastructure, employment, healthcare, education, level of poverty, maternal and infant mortality, and a variety of other indices of well-being [1]. Housing is the most essential element of the economic and building sectors. Many financial analysts and organizations estimate that real estate will contribute 13% to GDP by 2025, although it is a figure before the covid pandemic. Rapid housing and urbanization would have an impact on the economic growth of the country and the living environment. Congestion in cities puts a strain on fundamental services such as sewerage, shelters, and water. The government is looking for solutions to create affordable mass housing for the socio-economic progress of the country. Since construction technologies have such a strong influence on a project's outcome, choosing the right construction technology is critical to the project's success. The sector should employ emerging construction technologies to address the large demand for sustainable and affordable mass housing. However, time & cost certainty, construction pace, energy efficiency, material efficiency, ease of processing and needs of maintenance up to the building life cycle, client satisfaction, adherence to building codes & standards, and other factors all play a role in determining which of these innovative technologies is best. As the need for affordable mass housing in India grows, housing availability has become a worldwide concern. This has arisen as a result of many economic, socio-cultural, and environmental reasons that have raised pressure on conventional construction systems, resulting in the development of alternative building materials and technologies which have to be durable, energy-efficient, strong, time-saving, green, and cost-effective that can be used along with the conventional materials used for construction. So, the adoption of new construction techniques is needed to overcome the drawbacks of conventional construction systems. Expanded Polystyrene (EPS) core panel system is one of such kind emerging construction technologies in India.

Aim

To assess the EPS core panel system in comparison with the conventional construction system for mass housing projects by showing its impact on project completion time and cost.

Objectives

To achieve the above-said aim following objectives have been set:

- To study the EPS core panel system, its benefits, and applications in the construction industry.
- To compare the project cost using conventional construction system and EPS core panel system for a mass housing project.
- To compare the project completion time using conventional construction system and EPS core panel system for a mass housing project.

Research Gap

The research gap is that no previous studies have been done to assess the suitability of the EPS core panel system for mass housing projects at this particular location. Also, the projects selected for case studies were not on large scale. In this study, a mass housing project on a 13.40 acre site is selected.

Limitation

Thisresearchfocusesontheassessmentofthe EPScorepanelsystemonlyformasshousinginIndia.EPScorepanelsystemofconstructionisapplicableonlyforG+3orlessstorieds tructures.Ifitis a hybridconstructionwithsteelorRCCframe,wecanbuildanynumberoffloors.So,consideringthis,amasshousingprojectisselecte dforthisstudy.

METHODOLOGY

Data on the EPS core panel system from various recent literature sources are collected and reviewed. This study is a comparative analysis between the conventional method of construction and EPS core panel system of construction for a mass housing project to find out the suitability of EPS core panel system for mass projects. Hence, a mass housing project proposed by the Tamilnadu slum clearance board in Chennai is selected which is designed using the EPS core panel system. The cost estimation and project completion time calculation have been done for this project. For the same project, using the conventional method, the cost estimation and project completion time calculation have been done. Conclusion and recommendations are drawn from the analysis, thereby suitability of the EPS core panel system for mass projects is assessed.

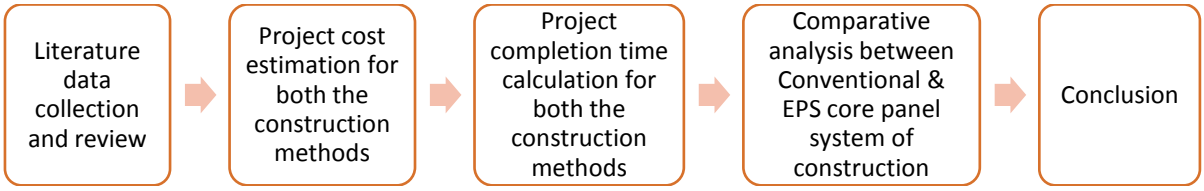


Figure-1 Methodology flow diagram

EPS Core Panel System

The Expanded Polystyrene (EPS) Core Panel System is made up of industry-made panels made of expanded polystyrene corrugated sheet with at least 15 kg/m^3 density and minimum 60 mm thicknesssandwiched between two sheets of welded wire mesh of fabric made of high strength GI wire with 2.5 to 3 mm diameter. A diameter of 3 to 4 mm GI wire is inserted into the polystyrene core and welded at an angle of offset to each of the outer layer steel sheets for increased strength. On-site, a minimum 30 mm thick shotcrete comprising cement and coarse sand poured under pressure at a 1:4 ratio is applied to the panels. EPS Core is encased in shotcrete with a steel welded wire fabric mesh in the centre. With the assistance of several agencies and brand names, the technology (created roughly 30 years ago) has been effectively employed in numerous countries such as Algeria, Morocco, South Africa, Austria, Kenya, Malaysia, Romania, Ireland&Australia [1].Panels can be used to finish reinforced concrete or steel structures, making it a very adaptable building technology that is compatible with all other existing construction systems. Other building materials, such as steel, wood, and concrete, can also be simply fastened to the EPS panels.

The Expanded Polystyrene core Panel system is a modern building construction technique which is safe, cost-effective, and efficient. EPS core panels can be used as load-bearing as well as non-load-bearing components. This panel is a three-dimensional panel with a polystyrene insulating core and a three-dimensional welded wire space frame. Shotcrete is placed on both sides of the panel once it is installed. A 3D welded space frame made of wire with a truss design for transfer of stiffness and stress makes up the EPS panels. The EPS panel is formed on the construction site using shotcrete and reinforced welded meshes of high-strength wire, self-extinguishing expanded polystyrene uncoated concrete, and diagonal wire.

The five components of an EPS panel after shotcreteare as follows [2]:

- The shotcrete outer layer.

- Reinforced welded mesh made of high wire.
- EPS core sheet.
- Diagonal wire (Galvanized or stainless wire).
- The inner layer of shotcrete.

A steel wire truss welded angle to the mesh welded fabric joins penetrating polystyrene with a steel wire truss. It offers spatial rigidity while also preventing movement of the polystyrene core.The typical EPS panel measures 1200 mm wide by 3000 mm long, with an overall thickness of 80-230 mm. On-site, at least30 mm thick shotcreting of cement and coarse sand in a 1:4 ratio is applied well under pressure to finish the EPS panels. The core made of EPS is encased in a shotcreting layer with steel welded wire mesh in the centre.

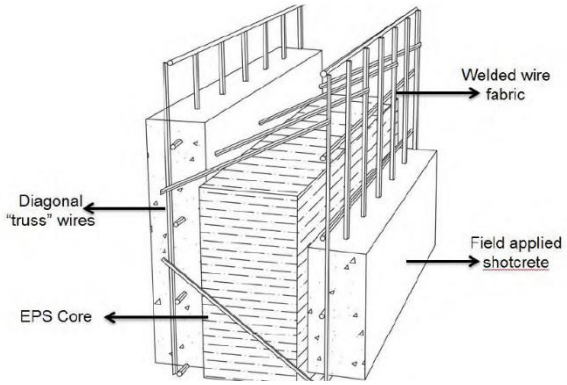


Figure-2 Typical cross-section of EPS panel [2]

Structural elements of EPS Core Panels

The various structural elementsavailable in the EPS core panel are single wall panel, roof/ floor panel, double wall panel, and EPS stairs which are shown in Figure-3.

Wall panel (Single) *Roof / Floor panel* *Wall panel (double)* *EPS Stairs*

Figure-3 Structural elements of EPS Core Panels

Handling, Marking, Storage & Identification

- The panels should be stored on a clean, flat, and solid surface on the job site. To avoid getting filthy and causing plaster adhesion concerns, the panels should not be placed directly on the ground.
- The panels should not be exposed to sunlight for more than one month, either in storage or during construction, to prevent changing the appearance of the polystyrene.
- Panels should be stored and transported to the site in a way that prevents damage to the polystyrene, buckling or sprawling of the polystyrene, or bending of the mesh reinforcing.
- Panels must be adequately braced to offer rigid temporary support to the walls during erection, concrete spraying, and slab installation, as specified in the Operational Manual.
- Walls and slabs should be propped in accordance with the Operational Manual. The panels must be delivered to the job site with a manufacturer-issued identification card that includes the element height.

Recycling of EPS

EPS is a 100% recyclable and ecologically friendly project. Mechanical crushing, recovered dissolved EPS, filtering slurry,precipitation of polystyrene, and end product are the five primary phases of EPS recycling for greater sustainability. The EPS waste is collected at a single location. During mechanical crushing, the EPS recovered is crushed and converted into tiny parts. These tiny pieces are dissolved in the first phase. By using a unique solvent, only polystyrene is dissolved by leaving all other impurities in the slurry in a solid phase. By the process of multistage filtration, from the slurry, solid impurities are removed. Inthe following stage, only the solvent and dissolved polystyrene (PS) are recycled. Then the PS gel is removed from the solvent. The solvent and precipitant are both collected, then reintroduced into the processingcircuit. The result is recycled PS granules of high quality. The finished product has been approved by the necessary authorities. When compared to other means of EPS disposal, such as burning and landfill

dumping, this recycling approach is the most cost-effective option. [3] recognized that because EPS is made up of 98 percent air and 2% polystyrene, disposing of polystyrene waste (PSW),it might be a challenge due to its bulk shape and its mobile properties. It claims that the air content may be liberatedby dissolving EPS in supercritical solvents. This method of disintegration is one of the most efficient and cost-effective ways of disposing the EPS trash.

Using dissolved EPS as a building material is an ecologically advantageous alternative and sustainable practice because these materials do not have chlorofluorocarbons and are unlikely to contribute to ozone layer depletion. Instead of using more usual furniture adhesives, dissolved polystyrene waste might be used as wood glue. It's also possible to use EPS waste to increase the performance of hot mix asphalt. The addition of EPS waste to the mixture of asphalt concrete enhanced the workability and deformation resistance. [4] observed that the addition of EPS waste to Construction and demolition waste (CDW) decreases the density by 34% and increases the gypsum composites' thermal behaviour by 8%.

Advantages of EPS Core Panel System

- Reduce construction costs.
- Shorten the construction timeframe.
- Lower transportation costs. Lightweight panels eliminate the necessity of cranes or any other heavy equipment. (A panel of 1.23 m without a shotcrete layer weighs 20 kg)
- The installation of EPS panels does not necessitate the use of heavy construction equipment.
- Make sure there's enough thermal and acoustic insulation, as well as sanitary and fire protection.
- At no extra cost, EPS 3D panels may be used to build structures in regions with shifting soil, such as isolated areas.
- Strength and Sturdiness - EPS is inert completely, does not absorb moisture, and is decay-resistant.

Limitations of EPS Core Panel System

- An EPS Panel building technique may only be used in the construction of foundation walls supporting four stories or less until created by a competent engineer.
- According to the American Concrete Institute's ACI 506 R-85, "Guide to Shotcrete," concrete should be placed by either "shotcrete dry" or "shotcrete wet" process [4].
- Concrete should have minimum 20MPa compressive strength.
- The steel reinforcement shall have minimum allowable stress (fy) of 415 MPa. The EPS Core panel technology is both ecologically friendly and appealing to the eye. It can be constructed quickly, saving both money and time. This technology has been successfully employed in a number of African and European countries thanks to the participation of different agencies.

CASE STUDY

Study Area

Chennai's population is drastically growing over the past 2 to 3 decades from 32.6 lakhs in 1981 to 70.8 lakhs in 2011 and it is 1.12 crore in 2021 as per UN world population prospects. Due to urbanization, there is a housing shortage in the city. The most affected category of people is EWS (economic weaker section). Hence various government schemes were implemented to provide housing facilities for all the people. One of the schemes is PradhanMantriAwasYojana (PMAY), which was started on 25th June 2015. By 2022, when India celebrates its 75th year of independence, this scheme aims to resolve the housing shortage in urban areas for all groups of people, including dwellers of the slum, by providing concrete houses for all eligible households. To meet this need, speedy construction is needed. The conventional way of construction takes more time and cost to accomplish this need. So, already in some parts of Chennai city, some builders and government bodies like Tamilnadu slum clearance board started constructing buildings using alternative construction technologies for the quick completion of the projects. In this particular study, a mass housing project proposed by the Tamilnadu slum clearance board in Chennai has been selected to carry out the research.

Project Details

The project taken for this study is proposed as a part of slum rehabilitation by Tamilnadu Slum Clearance Board. The project is designed using EPS core panel system. There are 16 residential blocks which are G+3 structures. The total site area is 54210 sq.m and the total built-up area is 42279.68 sq.m. In addition to the 16 residential blocks, the project has various amenity spaces.

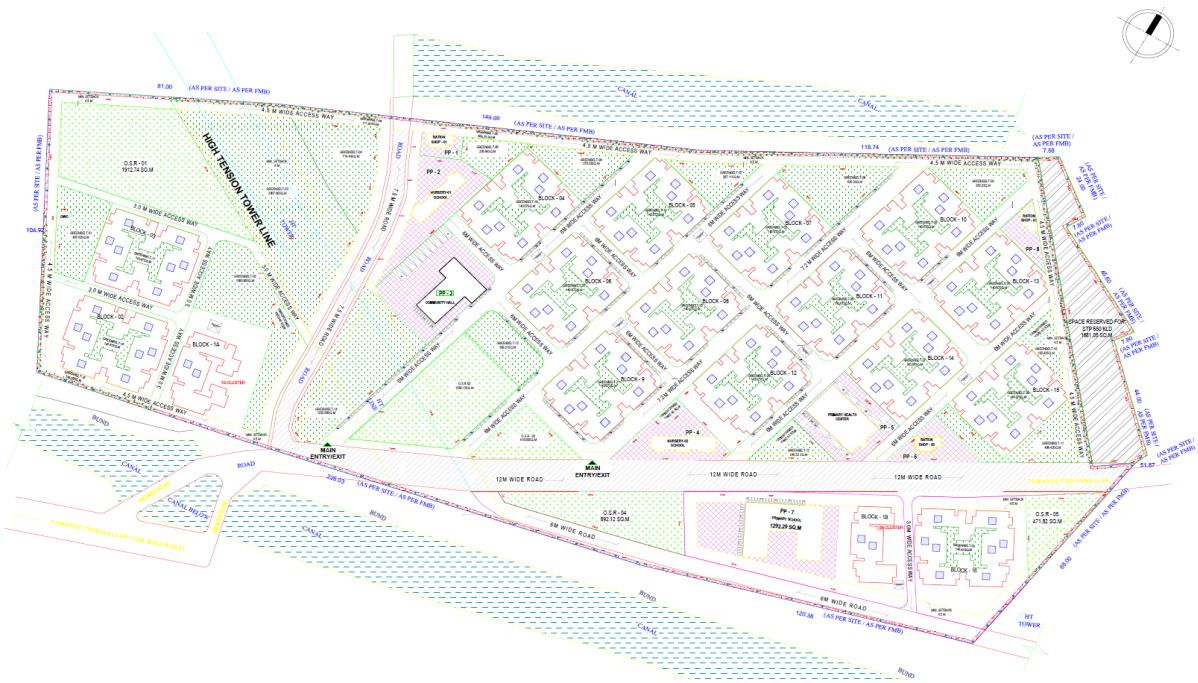


Figure-4 Site plan - Mass housing project

Project Cost Estimation

The Cubic Contents Method is useful to determine the total volume of any construction activity. The length, width, and depth of the construction elements are multiplied to give the total quantity of that particular material/item in this precise technique. In the case of surface plastering and other surfacing work like painting, the total surface area is calculated by multiplying the length by the breadth of the area. The cost necessary to complete the work is calculated by multiplying the rate per unit of construction activity by the entire quantity of the activity. This method is more commonly utilized in the construction of multi-story buildings. It is more accurate than the plinth area technique and the unit base technique. The total cubical contents, which is the volume of the structure multiplied by the available local area rates, are used to estimate the cost of construction activity. The unit rate of the items is taken from the Delhi Schedule of Rates, 2021 which is the standard rate for construction of Government projects, and also the local market rates were taken into consideration to estimate the project cost of the mass housing project.

Table-1 Cost Estimation - Conventional method

CONVENTIONAL METHOD					
S.NO	**ITEMS**	**UNIT**	**QUANTITY**	**RATE (₹)**	**AMOUNT (₹)**
1)	**SITE**				
1.1	Site preparation	sqm	2149.50	99.40	213660.30
2)	**SUB-STRUCTURE**				
2.1	Earthwork	cum	1075.50	672.25	723004.87
2.2	Reinforcement	ton	15.07	93500.00	1409045.00
2.3	Concreting	cum	337.705	10997.30	3713843.20
3)	**SUPER STRUCTURE**				
3.1	Reinforcement	ton	65.57	93500.00	6130795.00
3.2	Formwork	sqm	2059.36	852.05	1754677.69
3.3	Concreting	cum	614.56	13900.85	8542906.37
3.4	Brickwork	cum	88.64	5795.15	513682.09
3.5	Interior plastering	sqm	860.08	466.85	401528.34
3.6	Exterior plastering	sqm	120.41	657.16	79128.64
3.7	Interior painting	sqm	2621.36	494.25	1295607.18
3.8	Exterior painting	sqm	896.48	367.55	329501.22
3.9	Flooring	sqm	1562.04	1591.55	2486064.76
				TOTAL	2,75,93,444.68

For 16 blocks - 44.15 crores

Table-2 Cost Estimation - EPS Core Panel System

EPS CORE PANEL SYSTEM					
S.NO	**ITEMS**	**UNIT**	**QUANTITY**	**RATE (₹)**	**AMOUNT (₹)**
1)	**SITE**				
1.1	Site preparation	sqm	2149.50	99.40	213660.30
2)	**SUB-STRUCTURE**				
2.1	Earthwork	cum	1054.23	672.25	708706.1175
2.2	Reinforcement	ton	11.43	93500.00	1068705.00
2.3	Concreting	cum	296.25	10997.30	3257950.125
3)	**SUPER STRUCTURE**				
3.1	EPS wall panels	sqm	1396.47	3446.15	4812445.091
3.2	EPS slab panels	sqm	438.24	3636.35	1593594.024
3.3	EPS Stairs	sqm	64.23	4723.47	303388.4781
3.4	Reinforcement	ton	29.32	93500.00	2741420.00
3.5	Scaffolding	sqm	1845.32	652.31	1203720.69
3.6	Shotcreting	cum	212.37	9400.85	1996458.51
3.7	Interior painting	sqm	2530.14	415.32	1050817.745
3.8	Exterior painting	sqm	815.23	325.23	265137.25
3.9	Flooring	sqm	1634.28	1523.24	2489400.67
				TOTAL	2,17,05,404.00

For 16 blocks - 34.73crores

Project Completion Time Calculation

In this study, to calculate the project completion time of the selected project, detailed scheduling is done. The first step is,that all the activities involved in the project are listed. These listed activities are grouped under the appropriate topic in the Work breakdown structure (WBS). For all the activities, quantification of the materials involved in the activity is done using the drawings of the project. For each activity under the WBS, the total number of labours and time required to complete the particular activity is found using the materials quantification. For this calculation, the productivity of labour is taken from the 'Schedule of rates' published by the Central Public Work Department and the State Public Work Department. Using the calculated time, scheduling is done. Through this process, we get the project completion time of the selected project.

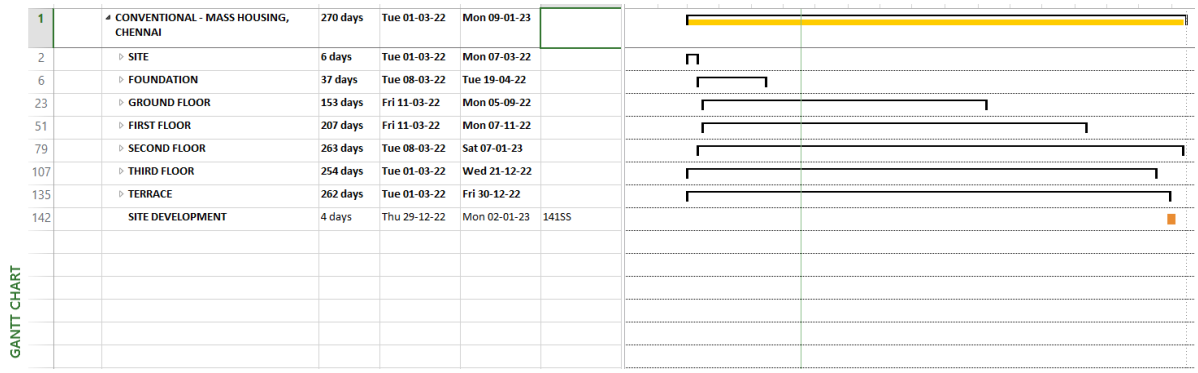
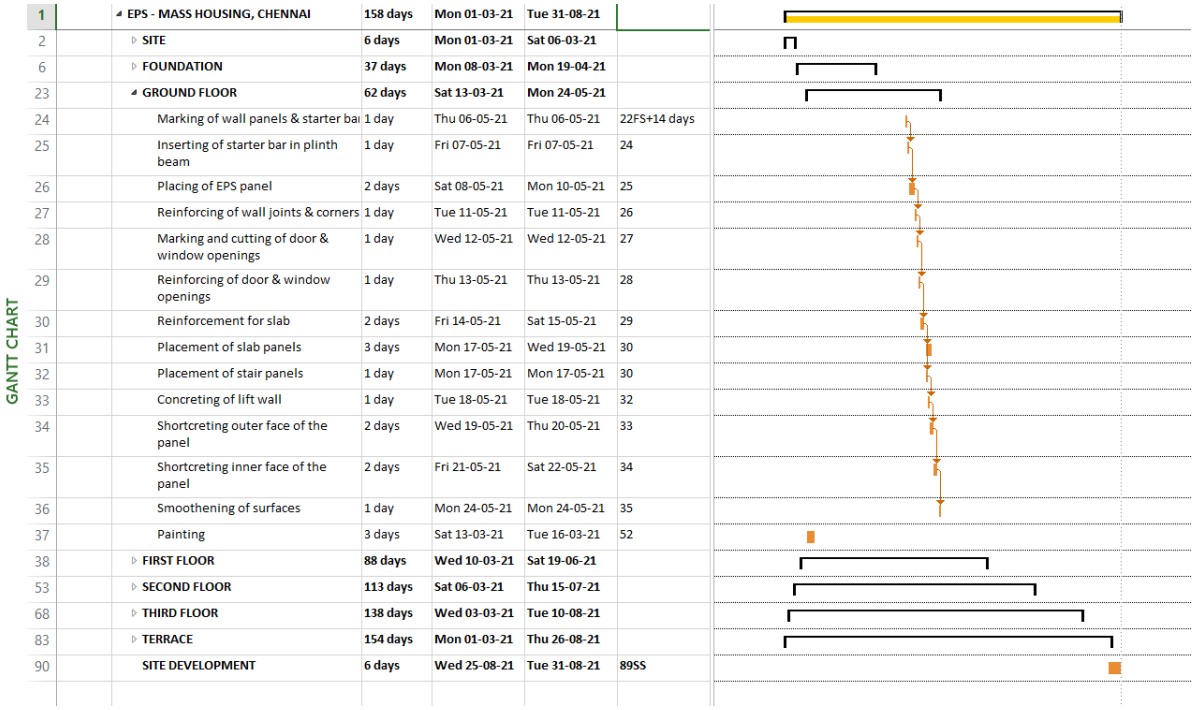


Figure-5 Schedule - Conventional method

Total no. of days required to complete a single block = 270 days

Considering the labour requirement and material availability, the construction is going in phases. It is taken that 4 blocks of construction are going in parallel. So, the total construction of 16 blocks happens in 4 phases.

So, the total number of days required to complete the 64 blocks using the conventional method of construction is = 1080 days



1	EPS - MASS HOUSING, CHENNAI	158 days	Mon 01-03-21	Tue 31-08-21	
2	SITE	6 days	Mon 01-03-21	Sat 06-03-21	
6	FOUNDATION	37 days	Mon 08-03-21	Mon 19-04-21	
23	GROUND FLOOR	62 days	Sat 13-03-21	Mon 24-05-21	
24	Marking of wall panels & starter bar	1 day	Thu 06-05-21	Thu 06-05-21	22FS+14 days
25	Inserting of starter bar in plinth beam	1 day	Fri 07-05-21	Fri 07-05-21	24
26	Placing of EPS panel	2 days	Sat 08-05-21	Mon 10-05-21	25
27	Reinforcing of wall joints & corners	1 day	Tue 11-05-21	Tue 11-05-21	26
28	Marking and cutting of door & window openings	1 day	Wed 12-05-21	Wed 12-05-21	27
29	Reinforcing of door & window openings	1 day	Thu 13-05-21	Thu 13-05-21	28
30	Reinforcement for slab	2 days	Fri 14-05-21	Sat 15-05-21	29
31	Placement of slab panels	3 days	Mon 17-05-21	Wed 19-05-21	30
32	Placement of stair panels	1 day	Mon 17-05-21	Mon 17-05-21	30
33	Concreting of lift wall	1 day	Tue 18-05-21	Tue 18-05-21	32
34	Shortcreting outer face of the panel	2 days	Wed 19-05-21	Thu 20-05-21	33
35	Shortcreting inner face of the panel	2 days	Fri 21-05-21	Sat 22-05-21	34
36	Smoothening of surfaces	1 day	Mon 24-05-21	Mon 24-05-21	35
37	Painting	3 days	Sat 13-03-21	Tue 16-03-21	52
38	FIRST FLOOR	88 days	Wed 10-03-21	Sat 19-06-21	
53	SECOND FLOOR	113 days	Sat 06-03-21	Thu 15-07-21	
68	THIRD FLOOR	138 days	Wed 03-03-21	Tue 10-08-21	
83	TERRACE	154 days	Mon 01-03-21	Thu 26-08-21	
90	SITE DEVELOPMENT	6 days	Wed 25-08-21	Tue 31-08-21	89SS

Figure-6 Schedule - EPS Core Panel System

Total no. of days required to complete a single block = 158 days

Considering the labour requirement and material availability, the construction is going in phases. It is taken that 4 blocks of construction are going in parallel. So, the total construction of 16 blocks happens in 4 phases.

So, the total number of days required to complete the 64 blocks using the conventional method of construction is = 632 days.

RESULT & DISCUSSION

Inference

The details collected about the EPS core panel system from the case study are compiled and listed in the Table-3.

Table-3 Comparative analysis

S.NO	FACTORS	CONVENTIONAL SYSTEM	EPS CORE PANEL SYSTEM
1	Foundation	As per design	20% savings than conventional
2	Dead loads	Brick wall - 1680 kg/cu.m RCC roof - 400 kg/cu.m	EPS is a Light weight material Wall panel - 1000 kg/cu.m Roof panel - 1600 kg/cu.m
3	Cracks	No settlement crack & plastering crack	No settlement crack & plastering crack
4	Lintel	Required for all the openings	Not required
5	Steel reinforcement	As per the structural consultant's instructions	50-60% savings than conventional
6	Labour	Required double the time than the EPS core panel system	Less labour is required than conventional
7	Wastage	More wastage - bricks tend to break easily & other wastes	Very less wastage

8	Water usage	More amount of water is required for mortar & curing	A very less amount of water is required only for shotcreting
9	Weathering coarse	Weathering coarse should be provided	Since it is a thermal insulation material, weathering coarse is not mandatory
10	Plastering	Due to non-uniformity in bricks, plastering thickness is more	Since the panel is 100% plumb, plastering thickness is less
11	Building life	It has Corrodible steel reinforcement. The building life is 60 - 65 years	EPS panel is non-degradable with non-corrodible GI mesh. The building life is 70 - 75 years
12	Errors	Due to poor workmanship, errors may be there	EPS panel is 100% plumb, there is no chance of any error in the plumb line
13	Temperature	Brickwork emits heat	It is a thermal insulation material. The room temperature is nominal. So, there will be savings in the energy consumption
14	Carpet area	As per plan. The finished wall thickness is 9”	The finished wall thickness is 5”. So, 10% extra carpet area than conventional

Project Cost Comparison

The total project cost for the selected mass housing project using the conventional method of construction is 44.15 crores whereas the project cost using the EPS core panel system is 34.73 crores. On comparing the total project cost of the EPS core panel system with the conventional method of construction, EPS core panel system costs 9.42 crores less than the conventional method, which is a huge saving. The major reason for the cost reduction between the EPS core panel system and the conventional method is the less usage of steel in the EPS core panel system. On comparing to the conventional method, only 50% of steel quantity is used in the EPS core panel system of construction.

Project Completion Time Comparison

The total project completion time for the selected mass housing project using the conventional method of construction is 1080 days whereas the project completion time using the EPS core panel system is 632 days. On comparing the total project completion time of the EPS core panel system with the conventional method of construction, EPS core panel system of construction finished 448 days earlier than the conventional method, which is a huge time-saving. The major reason for the time reduction between the EPS core panel system and the conventional method is, EPS core panel system is fully manufactured in a controlled environment i.e. factory. In site, just installation is only required. So, the EPS core panel system takes shorter time for the completion of the project.

CONCLUSION

As a consequence of the findings, the EPS panel system is determined to be more cost-effective and time efficient than the conventional building approach. Expanded polystyrene can be one of the alternative materials used in the building industry to achieve sustainability and affordability. When erecting a structure using EPS as an infill and slab material, we save 21.3 percent on overall construction costs, and the EPS core panel system of construction finished 448 days earlier than the conventional method. This outcome is dependent on the selected mass housing project; if the area of construction decreases, so will the savings. There is also a significant time difference when we replaced the brick with the EPS panel. In this research, a detailed study ofthe EPS core panel system, its benefits, and applications in the construction industry is done. The comparison of project cost and project completion time between the conventional system and EPS core panel system is done for the selected mass housing project and the results were discussed. Therefore, all of the research objectives were achieved. According to this research, the usage of the EPS core panel system is not widely used since people are unaware of this technology. However, correct usage of this technology in construction projects will result in a building with a long life cycle and the ability to be a green building structure. In this research, the assessment for the EPS core panel system is done only for the mass housing project, further, it can be done for various typologies of projects, and also detailed research can be done about the sustainability of the EPS core panel system.

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