SSRG International Journal of Civil Engineering
ISSN: 2348-8352/ https://doi.org/10.14445/23488352/IJCE-V11I6P103

Volume 11 Issue 6, 18-23, June 2024

Original Article

Recent Developments in Affordable High-Rise Buildings - A Case Study

Rajesh Kumar[1], Vanita Aggarwal[2], S.M. Gupta[3]

[1]*M.M. Engineering College, M.M. (Deemed to be University), Haryana, India.*
[2]*Department of Civil Engineering, M.M. Engineering College, M.M. (Deemed to be University), Haryana, India.*
[3]*Department of Civil Engineering., NIT Kurukshetra, Haryana, India.*

[1]*Corresponding Author : raj1rathee@gmail.com*

Received: 06 April 2024 Revised: 18 May 2024 Accepted: 06 June 2024 Published: 30 June 2024

***Abstract** - Developments towards imperishable has been a serious issue in the last few years as the construction sector, specially building construction, creates a portion of the yearly surroundings deterioration. As high-rise buildings' demand is increasing, enhancing the exhaustion of extra raw materials, energy, and resources are straight away accountable for the increase in hazardous content in the environment, which is also dangerous to occupant well-being and surroundings. To control these several surrounding impacts, it is needed to construct additional imperishable substances which will minimize the influence on surroundings. Design and planning of a high-rise building is necessary to make it more effective and it becomes tougher when the concern is about imperishable housing. India requires not only imperishable living, but the house also that are well planned energy consumption and constructed using imperishable techniques. Sustainable building planning and design should start with the selection and use of imperishable substances that have superior features to conventional building substances. The paper focused on recent developments in sustainable high-rise buildings with speed-oriented procedures and techniques to bring down the entire cost and time of the project.*

***Keywords** - Sustainability, Affordable housing, Construction, Environment, Development.*

1. Introduction

The high - rise building of the residential / commercial / institutional construction sector is a key factor of the financial system but has a noteworthy unfavorable influence also on the surroundings. One of the biggest consumers of substance assets, water and energy is construction, and also, it is an alarming deter orator by considering its volume. Buildings have a noteworthy influence on the surroundings, depleting almost 70% of the power supply and 12% of clean water, using about forty percent of natural substances pulled out in the industrialized country, and generating between forty-five percent and sixty-five percent of the garbage/scrap dumped in the junkyard. The shortlisting of substances and planned blueprints are essential for the common imperishability of affordable high-rise buildings. The research groups across the globe have accomplished substantial enterprise, to find out the substitute imperishable building substances and economical technology process, which comes out in a more durable and budgeted construction required today. Implementation of sustainable building substances and sustainable techniques is a superior process to achieve this target. The construction substances having low environmental thrust are impactful in the imperishable development of a nation. The building construction's complete life process (construction design, planning, construction, material resources, operation and handling) exercise to attain well-planned use of assets (energy, water, substances) with low influence on the surroundings of high-rise structures, also known as imperishable/ sustainable high-rise building.

In the west, steel is a major building material. However, in an Indian context, the trend is shifting from concrete to steel or composite structures for high-rise buildings. Such materials result in an economy for developers and affordable housing for the masses. A precast concrete structure is a combination of precast concrete components. This type of precast structure is capable of bearing horizontal and vertical loads, even dynamic loads also. The '3-S' technology of pre-fab components consists of pre-cast beam, column, slab, and infill concrete walls. These structural components are produced in the factory and then assembled at the site. This technology conserves natural resources as it eliminates the use of any timber. On the other side, this technology increases sustainability by using GGBS and Fly-ash. It also facilitates energy reduction within enclosed living spaces by controlling comfort level temperature.

2. Research Need

Precast Concrete structures are not very popular or well-used in India. The main reason is the connection of precast structure which is very important for stability and durability of any concrete structure. Precast elements are connected to each other, forming a 3D framework that is self-sufficient to sustain wind, gravitation, and earthquake loads. To attain trust to use precast concrete elements frequently is a need. To save natural resources, moving forward to sustainable construction by eliminating the use of timers in precast concrete structures is also a need in today's scenario. The unique challenge is to design a lightweight structure, wind and earthquake-resistant and structural safety. The precast technology is not fully implemented in our country because of a lack of knowledge about the technology.

3. Recent Developments in Building Construction Sector

The Sustainable techniques and substance use are the most constructive ways for the high-rise building construction sector to put up to conserve the surroundings, which has developed the principal attainable infusion to decrease the surrounding's influence and get imperishable development. Conventionally, in India, house units are built using traditional technology. With the enormous construction need to proceed into deliberations, the key factors such as speedy consuming natural assets, achievement of Sustainable Development Goals (SDG), and worldwide promises to minimize the footprints of carbon, there is an acute requirement to get alternate for energy concentrated building substances such as red bricks and lower the use of sparse natural assets such as river sand, clean water, wood/timber etc. worldwide, there has been high-tech professional development in the field of construction building substances and speedy execution of pre-engineered/ prefabricated construction exercises.

The substitute technologies are used in our country in a finite area so far. Several Indian real estate developers use prefab technologies to construct modular and affordable homes. All precast concrete elements are manufactured in bulk, then transported to the construction site and finally erected on-site using this prefab technology. This method saves money, labor, material and time with good construction quality. This technology offers speedy construction with tailor-made design, safer construction and lower impact on the environment as compared to traditional construction technology. First and foremost, an enormous quantity of affordable high-rise buildings mandates design standardization and high-speed construction with good quality, all of which is possible in this type of construction technology. Advanced methodologies of design and advanced analysis permit more efficient high-rise construction. Concerned governments and bodies encourage developers by giving incentives to developers who implement advanced sustainable technologies. Pursuing the inspiration to metamorphose the dwelling construction sector, the Ministry of Housing and Urban Affairs commence a Global Housing Technology Challenge to recognize and conserve the suitable available sustainable construction technologies from all over the universe.

3.1. Essential to Develop Sustainable Building Construction

- Constructing a residential building starts at the beginning step. After the completion of construction tenure, it is difficult to build a building sustainable as desired.
- A high-rise construction should be pinpointed in a consolidated location so that occupants can utilize public vehicles and low or non-renewable energy-consumption vehicles. Apart from this, Energy discharge should be distinguished.
- Water utilization should be null. Whole disposed water should be recycled after purification biologically. Detailing of High-rises should permit for reaping of the water collected from rain. The water after treatment should be used for landscaping and flushing.
- Reprocessed substances should also be used to the maximum extent as much better as can.
- As an alternative to ordinary walling material, for better insulation as well as heat declining, aerated concrete blocks should be used.
- Thermal insulation of the roof is to be done with soil paste instead of chemicals.

3.2. Innovations in the Construction of High-Rise Buildings

Numerous innovative techniques have been in place to improve the construction of high-rise buildings without affecting resources in the neighborhood and in a cost-effective manner. A few such techniques include:

- Use of high strength concrete: This helps in reducing the size and self-weight of all the members of the structure.
- Use of ready-mix concrete: Switching from conventional concrete to RMC is an innovative method to increase the speed of construction and hence save in cost and time.
- Use of waterproofing compounds: The basement of high-rise buildings needs to be waterproofed by admixtures and waterproofing components for sustainable structures.
- Precast structures: For efficient and faster construction, the use of precast fabricated elements is an innovative method for the construction of high-rise buildings.
- Use of steel: Steel construction is always better than conventional construction due to its allied safety, stability, and energy efficiency. The same may easily be adapted for high-rise structures.
- Other techniques: Some techniques like the use of high-speed lifts, aluminum shuttering, elevators, ultra ropeways, hybrid control systems, use of facades can further improve the quality of construction.

3.3. Recent Sustainable Technologies

During Construction Technology India (CTI) 2019, fifty-four technologies were selected by a Technical Evaluation Committee (TEC) set up by the Ministry of Housing and Urban Affairs. The below mentioned techniques have been collected into six broad categories, namely:

1. A Construction System (Precast concrete) - 3D Precast volume based
2. A Construction System (Precast concrete) - components assembled at the site
3. A Structural System (Light Gauge Steel) - a Structural System of Steel with pre-engineered
4. Prefabricated Panel System - Sandwich-type
5. Concrete Construction Type - Monolithic
6. Formwork System (Stay in Place)

3.4. Light House Projects

In order to showcase these technologies, out of the shortlisted 54 technologies, 6 Projects of the Light House pattern using six separate techniques were finalized. Mr Narndera Modi -The Hon'ble Prime Minister of India put down the base stone on 1st January 2021 of six Light House projects. The six LH projects in India are mentioned in Table 1.

Table 1. Six light house projects in india

S.no	Location	Technologies	No of Houses
1	Madhya Pradesh - Indore	Prefabricated Panel System Sandwich-type	1024
2	Gujarat – Rajkot	Concrete Construction Type - Monolithic	1144
3	Tamilnadu - Chennai	Construction System (Precast concrete) – components assembled at the site	1152
4	Jharkhand - Ranchi	A Concrete Construction System (Precast) – 3D Precast volume based	1008
5	Tripura - Agartala	A Structural System (Light Gauge steel) - a Structural System of steel with pre-engineered	1000
6	Uttar Pradesh - Lucknow	Formwork System (Stay in Place)	1040

Out of the six projects, LHP Chennai consists of 1,152 dwelling units, with all primary and communal edifice facilities being finished in all respects in a record 12 months. This project has been finished in all respects, in spite of the COVID-19 pandemic. Light House projects are model residential projects with houses being constructed with finalized substitute techniques convenient to the geo-climatic and dangerous situations of the concerned area.

These indicate the construction of all set to live homes with the best speed, best wealth and superior construction quality in an imperishable manner. Six entities of technology providers have been shortlisted through a diligent hybrid bidding procedure for developing Light House Projects (LHPs) at six separate places in six regions of our country. The duration of completion of these projects is a maximum of twelve months after all statutory approvals.

4. Case Study

To examine and evaluate the potency of these techniques and materials, a case study was attempted [8].

Project: Light House Project for MoHUA, Govt. of India

Location: Nukkampal Road, Chennai, Tamil Nadu [8]

Contractor Company: B.G. Shirke Construction

Technology Pvt. Ltd

Project Duration: 12 months

Plot Area: 29222 Sqm

Carpet Area of every Flat: 26.78 Sqm

Total Built-up Area: 43439.76 Sqm

Technology being used: Precast concrete construction

System – 3S System [9]

No. of Flats: 1152 (G+5)

Broad Specifications

Foundation: RCC isolated footing

Structural Frame: RCC precast beam/columns

Walling: AAC Blocks

Floor Slabs/Roofing: RCC precast slab

Buildings in the process of examination are G+5 developed as per GHTC (Global Housing Technology Challenge –India) for imperishable development in budgeted housing by using 3S Prefab technology.

3S system incorporates precast opaque RCC hollow key columns, structural RCC shear walls, stairs, roof solid precast RCC beams, slabs, lintels, chajjas and parapets. For partition walls, aerated blocks are used. Hollow core columns are assembled above the foundation over which beams are combined in the column engrave after assembling of slabs.

Structural robustness and continuity are attained by wet joining using dowel bars or reinforcement placed in continuation at connection. The jointing of various structural framing components is accomplished through in-situ self-compacting concrete/ micro concrete/ non-shrink grout as per design requirements.

A detailed analysis of the project indicates that the project proved to be a success in terms of affordability, strength and durability due to the use of recent developments of techniques in high-rise buildings. As stated in the literature, the use of precast members enhanced the speed of construction, and it could be completed in a record time.

Further, the use of aerated hollow blocks for partition resulted in lightweight construction and a reduction in the weight of members. Besides, the use of waterproofing compounds has enhanced the durability of the structures, environment friendly; overall, the project is a live implementation of modern sustainable techniques for high-rise buildings.

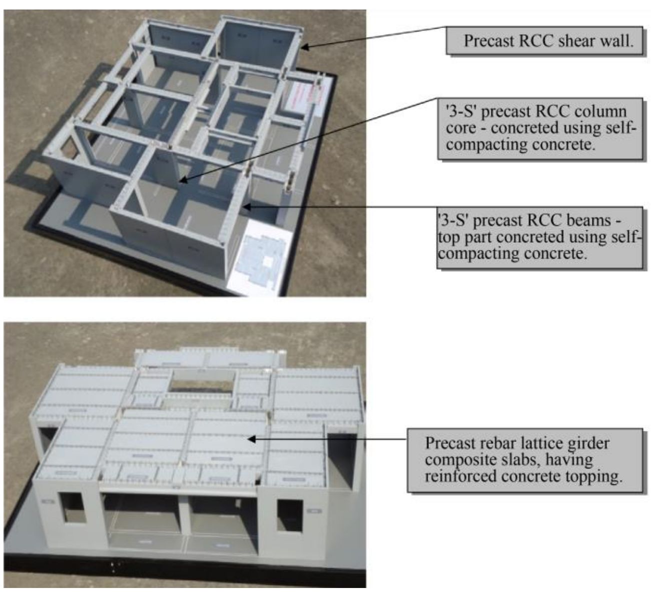

Fig. 1 3-S Precast concrete construction system components

Fig. 2 Precast slab components assembly

Fig. 3 Building after assembly of 3-S precast concrete construction system

5. Results

After examining plans and procedures in detail, discovering the assets required, sequencing the process activities and carrying out the tentative prediction of costing, and differentiating the techniques to others from the above brought up, i.e. traditional construction technique with respect to precast construction technique, the outputs are introduced in Table 2.

Table 2. Comparison of conventional construction and precast construction system – 3S System

Criteria	Precast Concrete Construction	Conventional Construction
Reinforcement economizing	15%	No
Red/Fly-ash Brick used	No	25-30%
Partition of Wall	AAC Block	Brick
Slab/Roofs	Precast	Cast in situ
Time-Saving	Near about 67% according to Seven days cycle of slab	21 days cycle of slab casting
Initial Investment	Less	Average
Practicability	Yes	No
Manpower Cost	minimal	maximal
Appropriateness of High-Rise	Yes	Tough
Environmental Concern	Yes	No
Formwork Required	No	Yes

Considering major elements required for the structure, the specific grade of concrete for RCC hollow columns and beam is based on the structural design requirements as per IS 456:2000. Fe 550 grade of reinforcement steel conforming to IS 1786:2008 used in this prefab construction technology.

Precast concrete slab having a density of 551-650 kg/m^3 conforming to IS 6073:2006.

Vertical load, seismic load and wind load were performed by Tor Steel Research Foundation, IIT Mumbai, and design load tests by IIT Roorkee and CBRI on full scale high-rise buildings to investigate the behaviour of all elements under all loading conditions. Fire ratings are also considered as per NBC norms. Thermal behaviour and acoustic comfort are considered for habitat.

6. Conclusion

From the current case study, the below-mentioned conclusions can be easily presented.

- 3S Prefab technology eliminates the use of timber and forest produce of any category. On the contrary, the use of fly ash and GGBS enhances sustainability. The thermal and acoustic insulation provided by the AAC block masonry facilities reduces energy towards maintaining comfort level temperature with in enclosed habitat space. Also, a considerable reduction in dead load is achieved due to the use of form finish precast components and AAC material, resulting in better performance under seismic loads.
- Every one of the structural components is pre-engineered and constructed in manufacturing units with quality control objectives result comes out of dimensional perfectness, correcting and distancing of reinforcement, equal defensive cover, and guaranteeing the strength of design by using design mix concrete; RMC has less water-cement ratio which eventually results into the long-lasting structure.
- Construction speed can be increased with precast concrete construction techniques. Also, the requirement for labor is minimal as compared to traditional construction techniques. This technology is easy to implement with skilled, minimal manpower and machinery.

References

[1] Narender Singh, "Sustainable Design for Developing Affordable Housing," *Indian Buildings Congress*, vol. 23, no. 1, pp. 97-102, 2016. [Google Scholar]

[2] Usman Aminu Umar, M.F. Khamidi, and Hassan Tukur, "Sustainable Building Material for Green Building Construction, Conservation and Refurbishing," *Management in Construction Research Association (MiCRA) Postgraduate Conference*, Malaysia, pp. 1-5, 2012. [Google Scholar]

[3] Akshay B. Mokal et al., "Green Building Materials – A Way Towards Sustainable Construction," *International Journal of Application or Innovation in Engineering & Management*, vol. 4, no. 4, pp. 244-249, 2015. [Google Scholar]

[4] M. Sandeep et al., "Comparison of Conventional Building and Mivan Formwork Building Based on Scheduling," *International Journal of Intellectual Advancements and Research in Engineering Computations*, vol. 6, no. 2, pp. 1297-1299, 2018. [Publisher Link]

[5] Paratibha Aggarwal et al., "Self-Compacting Concrete-Procedure for Mix Design," *Leonardo Electronic Journal of Practices and Technologies*, vol. 12, no. 2, pp. 15-24, 2008. [Google Scholar]

[6] Arvind Chel, and Geetanjali Kaushik, "Renewable Energy Technologies for Sustainable Development of Energy Efficient Building," *Alexandria Engineering Journal*, vol. 57, no. 2, pp. 655-669, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[7] Griha for Affordable Housing, Griha, pp. 1-94, 2017. [Online]. Available: https://www.grihaindia.org/files/griha-abridged-manual.pdf

[8] Light House Project at Chennai, Tamil Nadu, Nukkampal Road, Global Housing Technology Challenge India, pp. 1-18, 2021. [Online]. Available: https://ghtc-india.gov.in/Content/pdf/16022021/02_LHP_Chennai_Booklet_15Feb2021_final.pdf

[9] Global Housing Technology Challenges-India, GHTC. [Online]. Available: https://www.ghtc-india.gov.in/

[10] K. Krishna Bhavani Siram, and K. Arjun Raj, "Concrete + Green = Foam Concrete," *International Journal of Civil Engineering & Technology*, vol. 4, no. 4, pp. 179-184, 2013. [Google Scholar] [Publisher Link]

[11] Prerna Nautiyal, Saurabh Singh, and Geeta Batham, "A Comparative Study of the Effect of Infill Walls on Seismic Performance of Reinforced Concrete Buildings," *International Journal of Civil Engineering & Technology*, vol. 4, no. 4, pp. 208-218, 2013. [Google Scholar] [Publisher Link]

[12] D.V. Prasada Rao, and G.V. Sai Sireesha, "A Study on the Effect of Addition of Silica Fume on Strength Properties of Partially Used Recycled Coarse Aggregate Concrete," *International Journal of Civil Engineering & Technology*, vol. 4, no. 6, pp. 193-201, 2013. [Google Scholar] [Publisher Link]

[13] Akash Lanke, and D. Venkateswarlu, "Design, Cost & Time Analysis of Precast & RCC Building," *International Research Journal of Engineering and Technology*, vol. 3, no. 6, pp. 343-350, 2016. [Google Scholar] [Publisher Link]

[14] B. Anvari, P. Angeloudis, and W.Y. Ochieng, "A Multi-Objective GA-Based Optimisation for Holistic Manufacturing, Transportation and Assembly of Precast Construction," *Automation in Construction*, vol. 71, no. 2, pp. 226-241, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[15] V.C. Castilho, and M.C.V. Lima, "Comparative Costs of the Production, Transport and Assembly Stages of Prestressed Precast Slabs Using Genetic Algorithms," *International Journal of Optimization in Civil Engineering*, vol. 2, no. 3, pp. 407-422, 2012. [Google Scholar] [Publisher Link]

[16] N. Dineshkumar, and P. Kathirvel, "Comparative Study on Prefabrication Construction with Cast In-Situ Construction of Residential Buildings," *International Journal of Innovative Science, Engineering & Technology*, vol. 2, no. 4, pp. 527-532, 2015. [Google Scholar] [Publisher Link]

[17] F. Givssani, and F. Mola, "Precast and Cast in Situ Slab Systems for Residential Building," 2016. [Google Scholar]

[18] M.J. Gopinathan, and K. Subramanian, "High Performance and Efficiency of Joints in Precast Members," *International Journal of Engineering and Technology*, vol. 5, no. 5, pp. 4002-4009, 2013. [Google Scholar] [Publisher Link]

[19] AL. kulabi Ahmed, and Hakob Avetisyan, "Reducing Time and Cost of Construction Projects by Improving the Properties of Precast Normal-weight Wall Panels," *Procedia Engineering*, vol. 145, pp. 1066-1073, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[20] Kyuman Cho, Young-Su Shin, and Taehoon Kim, "Effects of Half-Precast Concrete Slab System on Construction Productivity," *Sustainability*, vol. 9, no. 7, pp. 1-15, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[21] Muhammad Abedi, Mohamad Syazli Fathi, and Norshakila Muhamad Rawai, "The Impact of Cloud Computing Technology to Precast Supply Chain Management," *International Journal of Construction Engineering and Management*, vol. 2, no. 4A, pp. 13-16, 2013. [Google Scholar] [Publisher Link]

[22] Ng Ban Kiong, and Zainal Abidin Akasah, "An Overview of Precast Concrete System for Building Maintenance: Malaysian Perspective," *International Journal of Engineering Science and Technology*, vol. 2, no. 6, pp. 2250-3676, 2012. [Google Scholar]

[23] B. Prakash Rao, Narayan Suresh Jartarghar, and Nagesh Ramamurthy, "A Study on The Perceptions of Clients, Contractors and Consultants Towards Precast Construction Technology," *International Journal of Emerging Technology and Advanced Engineering*, vol. 4, no. 5, pp. 291-300, 2014. [Google Scholar] [Publisher Link]

[24] B. Raghavendra K. Holla, Siddhant Anant, and Muzzammil Ali Mohammad, "Time, Cost, Productivity and Quality Analysis of Precast Concrete System," *International Journal of Innovative Science, Engineering and Technology*, vol. 3, no. 5, pp. 252-257, 2016. [Google Scholar] [Publisher Link]

[25] N. Rossley, F.N.A. Abdul Aziz, and H.C. Chew, "Behaviour of Precast Walls Connection Subjected to Shear Load," *Journal of Engineering Science and Technology*, pp. 142-150, 2014. [Google Scholar] [Publisher Link]

[26] Siva Priya, and S. Senthamil Kumar, "Building Cost Comparison of Precast vs Conventional Construction," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 5, no. 5, pp. 8037-8044, 2016.