



PRECAST AND PRE-STRESSED CONSTRUCTION TECHNOLOGY FOR HIGH- RISED RESIDENTIAL BUILDINGS

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Abstract: The precast concrete technology system is very versatile and is equally efficient and suitable for all types of construction, be it is a high rise or low-rise buildings, villas, commercial buildings, parking lots etc. Most of the construction activities in India take place by conventional cast in situ method of construction. But still there is a huge demand for housing in India. So, the construction activity has to take place in a much faster way. This cannot be achieved by conventional method of construction. It can be done possible with precast concrete of construction. Moreover, there are more advantages of precast concrete when compared with conventional one. So various literatures are studied and a review of those all has been given in this paper. Also, the advantages and disadvantages of precast construction are also discussed here. Precast elements can be quickly erected on the job site and precast thermal mass can also save energy and increase comfort. Major reasons and advantages to adopt this technology are structural stability, speedy and quality construction, flexibility, wastage control and less manpower requirement. Other than this, the strength of this technology is, low maintenance, seismic resistance and universal application. Precast concrete system which is mass produced either in factory or at site factory is widely used as building components. The components are usually designed according to the specified standard shapes and dimensions. The components will then be transported to the construction site to be placed according to the building design requirements.

Index Terms—Precast & Cast in situ construction, Review, Comparison, Cost effectiveness, Manpower reduction, Rapid Construction, Quality improvement, and Controlled Manufacturing condition.

I. INTRODUCTION

precast concrete is widely used in the construction industry. handling, transporting and erecting precast concrete elements are high-risk activities that have resulted in deaths and serious injuries to workers. every person working with precast concrete has health and safety duties. everyone should clearly understand their roles and responsibilities when working with precast concrete. important decisions at design stages determine the success of the project in terms of speed and quality of construction, environmental impact and aesthetic appeal of the structure, as well as, cost and economic viability. this paper discusses some of the challenges faced in the viaduct structures and how they were overcome in building constructions in india by the employment of precast concrete construction technologies. nowadays the precast concrete has been used extensively in many residential and commercial construction projects. it is because of the property of the precast concrete. it has higher durability, thermal properties and very easy to handle and so on. also, the quality of the precast concrete is higher as it is manufactured under great factory-controlled environment. but there is lack of awareness and knowledge regarding the precast concrete in india. this has to be changed and more study has to be done regarding precast. the connection details of the precast members also should be studied well. in this journal various literatures are studied and the results of various studies have been given

here. precast concrete is a **very sustainable building** material with regard to the energy consumption during its production and its characteristics during its useful life. concrete is a natural building material and 100% recyclable. concrete consists of water, sand, gravel and cement. water, sand and gravel naturally exist in our environment.



Fig.1 Precast Elements

2. LITERATURE REVIEW

2.1. INTRODUCTION:

Modern precast concrete plants are controlled and monitored by a master computer. The master computer exactly calculates the necessary amounts of cement, construction steel, water etc. and therefore allows for an optimal utilization of materials not only during the production of precast concrete elements are savings. The positive characteristics of the building material also take effect during the utilization of a precast concrete building. Minimum waste output in the production process and reduction of packaging material. The use of such technology helps in saving of the time taken for similar projects using normal construction methods and technology. Precast concrete is the new method concreting used all over the world extensively. It is also used in India as well but not very often. In this method concrete is prepared, poured in formwork and cured in controlled environment. In this method quality of concrete can be assured because concrete is prepared and cured in controlled environment. Precast construction system is generally a large panel system, modular system or a combination of both. Precast Large Construction Panel (PLCP) system consists of various precast elements such as walls, beams, slabs, columns, staircase, landing and some customized elements that are standardized and designed for stability, durability and structural integrity of the building. Precast residential building construction involves design, strategic yard planning, lifting, handling and transportation of precast elements. This technology is suitable for construction of high-rise buildings resisting seismic and wind induced lateral loads along with gravity loads. The building framing is planned in such a way that maximum number of repetitions of moulds is obtained. These elements are cast in a controlled factory condition. The factory is developed at or near the site which provides an economical solution in terms of storage and transportation. Two main types of precast concrete elements, namely precast reinforced concrete elements and precast pre-stressed concrete elements are used as per the details given below: *Precast concrete elements* – Concrete components of a building prefabricated in precast yard or site and shall be installed in the building during construction. Precast pre-stressed concrete elements. These shall consist of pre-stressing tendons with in the elements to provide a predetermined force needed to resist external loadings and cracks such as hollow core slabs, beams and planks.

- (I) **Mass-** Precast concrete products can act as effective barriers to vehicular traffic due to their size and weight. In the current world climate, precast concrete products such as planters, bollards and highway barriers increasingly are being used to provide protection for a wide variety of venues.
- (II) **Chemical Resistance-** Precast is resistant to most substances. However, no material is completely immune to attack from aggressive chemical agents. Thus, it is wise to choose the material with the longest expected service life. Precast concrete products can be designed to withstand anticipated corrosive agents.
- (III) **Quality Control-** Because precast concrete products typically are produced in a controlled environment, they exhibit high quality and uniformity. Variables affecting quality typically found on a jobsite-temperature, humidity material quality craftsmanship-are nearly eliminated in a plant environment.
- (IV) **UV Sensitivity-** Unlike some other materials, precast concrete does not degrade from exposure to sunlight. This is extremely beneficial for above-ground applications.
- (V) **Environmentally Friendly -** After water, concrete is the most frequently used material on earth, it is nontoxic, environmentally safe and composed of natural materials. Buried throughout the world, precast concrete products help convey water contributing to poor water quality.
- (VI) **Weather Resistance-** Precast concrete is well-suited for exposures to all types of weather conditions. Reduced Weather Dependency - Precast increases efficiency because weather will not delay production. In additional weather conditions at the jobsite do not significantly affect the schedule. This is because it requires less time to install precast compared with other construction methods, such as cast-in-place concrete. Precast concrete can be easily installed on demand and immediately backfilled-there is no need to wait for it to cure.
- (VII) **Water Tightness -** Standard watertight sealants are specially formulated to adhere to precast concrete, Making watertight multiple-seam precast concrete structures possible.
- (VIII) **Ease of Installation-** Since precast products are designed and manufactured for simple connection, many components can be installed in a short time.
- (IX) **Modularity -** Because of the modular nature of many precast concrete products, structures of systems of nearly any size can be installed in a short time.
- (X) **Efficiency-** Precast concrete products arrive at the jobsite ready to install. There is no need to order raw materials such as reinforcing steel and concrete, and there is no need to spend time setting up forms, placing concrete or waiting for the concrete to cure.
- (XI) **Aesthetics -** Precast concrete products are both functional and decorative. They can be shaped and molded into an endless array of size and configurations. Precast concrete can also be produced in virtually any color and a wide variety of finishes (acid-etched, sand blasted, smooth-as-cast, exposed-aggregate) to achieve the desired appearance for building and site application.
- (XII) **Low Maintenance-** Precast concrete requires no on maintenance, which makes it an ideal choice for nearly any design solution. Fire Resistance- Precast concrete is noncombustible, also, concrete does not lose its structural capacity nearly as quickly as steel. Other materials besides concrete and steel are flammable and / or do not perform well in elevated temperature.
- (XIII) **Fire Resistance-** Precast concrete is noncombustible, also, concrete does not lose its structural capacity nearly as quickly as steel. Other materials besides concrete and steel are flammable and / or do not perform well in elevated temperature.

2.2. DESIGN & CONNECTION DETAILS OF PRECAST ELEMENTS:

Precast concrete construction system has its own characteristics which influence the layout, span length, construction depth, and stability system to a great extent. In precast concrete construction, majority of structural members are manufactured in manufacturing plants away from the construction site. After that, they are delivered to the project site to be erected. Various connections have been developed to connect different types of structural elements like beam to column connection and panel to panel connection. In this manner, the imposed loads are transferred from superstructure to the foundation. Designers should consider the possibilities, restrictions, detailing, manufacturer, transport, erection and serviceability stages before finalizing the design of precast concrete structure. All loading & restraint conditions from casting to end use of structure are considered in design of precast members & connections. Connections are needed not only to transfer load but also to provide continuity and overall monolithic behavior of the entire structure. A complete system of precast elements is integrated to form a structure that behaves monolithically with sufficient strength, stiffness & durability to resist seismic & other dynamic loadings. The connection can be classified into horizontal & vertical joints. Some typical connections details are shown.

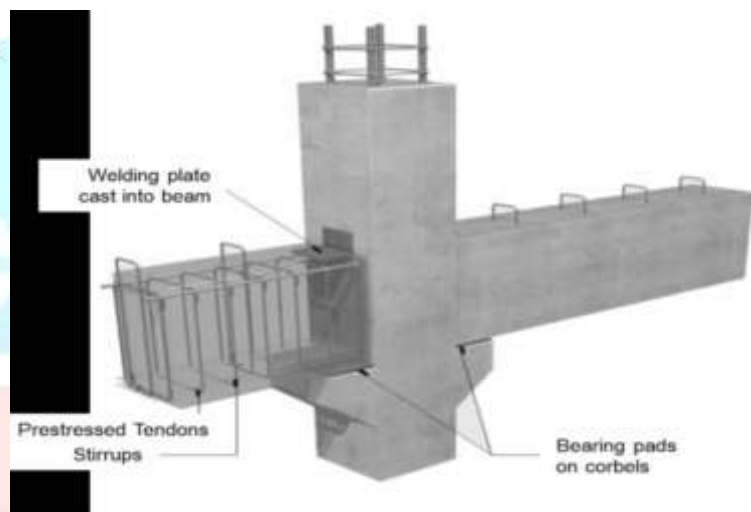


Fig.2 (a) Beam-Column

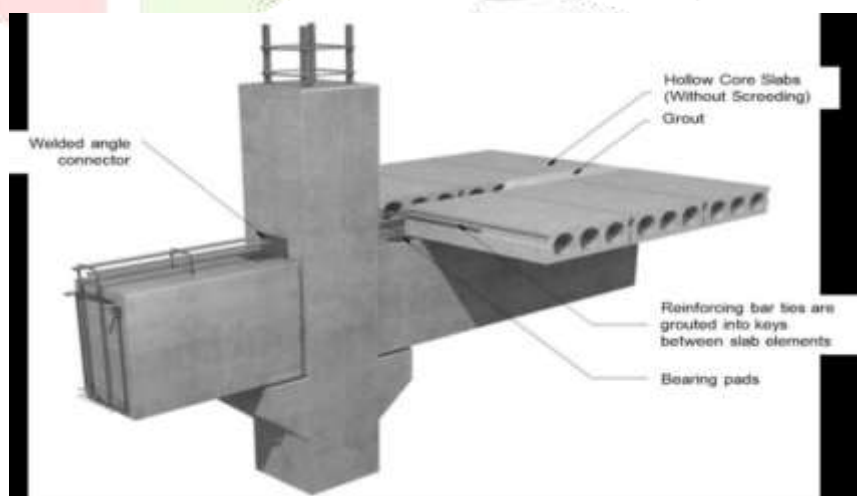


Fig.2 (b) Slab to Beam

FIGURE 2: CONNECTION ILLUSTRATION

3. METHODOLOGY

3.1 CASTING PROCEDURES OF PRECAST ELEMENTS:

1. When the mould is ready for casting the QC inspector checks the mould against the approved mould drawing.
2. Apply the mould release agent as thinly and as evenly as possible using fine-haired brush or roller. Any excess should be mopped up. Other application method will be in accordance with the manufacturer's instructions.
3. After the reinforcement checked against the approved reinforcement drawing, the reinforcements will be placed in the mould using over cranes.
4. All the cast-in parts i.e plates, dowel bars, cast in socket, PVC pipe, recesses, etc., shall be placed in their respective location as per shop drawings.
5. QC inspector checks the reinforcements and cast-in parts against the approved shop drawings prior to concrete pouring.
6. Concrete are monolithically poured at the mould and compacted using poker vibrator.
7. The top concrete surface will be leveled manually using hand trowel and straight edge ruler.
8. When the concrete has hardened, the top surface will be checked for evenness using spirit level. Dimensional tolerances will be as QCS 2002.



Fig.3 Casting of Precast Elements

3.2 DEMOULDING AND CURING:

Precast concrete elements are cast and cured in a controlled environment before being transported to their final location and installed. Curing is an essential process for these elements for several reasons:



Fig.4 :Demoulding of Precast Elements

- **Strength development:** The hydration process, in which the water in the concrete mix reacts with the cement, is responsible for the development of the concrete's strength. Curing ensures that this process can continue effectively, leading to a stronger and more durable final product.
- **Durability:** Proper curing reduces the occurrence of cracks, enhances resistance to freeze-thaw cycles and de-icing salts, and improves resistance to abrasion and erosion, which are important for the longevity of the precast elements.
- **Dimensional Stability:** Curing helps to improve the dimensional stability of the precast elements, reducing the risk of shrinkage or distortion, which can affect the fitting and alignment of the elements on site.
- **Quality Control:** As precast elements are produced off-site in a controlled environment, proper curing is part of a quality control process to ensure the consistency and reliability of the final product. Without proper curing, variations in strength and durability could occur, which can affect the overall performance of the construction project.
- **Speed of Production:** Precast concrete elements often need to be demolded and moved to make room for the next batch. Curing, particularly accelerated curing methods like steam curing, can help the elements reach their design strength faster, increasing the speed of production.

3.3 DELIVERY AND HANDLING PROCEDURE OF PRECAST CONCRETE ELEMENTS:

1. Once the curing period is completed, according to the loading sequence and as per the site requirements the elements will be loaded (Hollow Core Slabs, Columns, beams staircases etc. on flat bed trailers) by overhead cranes using chain slings.
2. Wooden supports will be provided for the proper seating of the elements on the trailer. All the elements on the trailer are secured with chain slings tightened to the trailer hooks. The tightened chains coming in contact with the elements will be protected to avoid damages.

3. The loading foreman ensures that the elements loaded are in accordance with the Erection sequence and also in a safe manner. The trailer driver rechecks the load for safety conditions and follows the traffic rules and regulations.
4. The driver will be provided with the site route map and the delivery notes.
5. After reaching the site, driver contacts the Company site-in-charge. Thereafter it is the responsibility of the site-in-charge to take care of load for offloading or erection.
6. It is the responsibility of the Main Contractor to provide proper, safe access for the trailer to the site premises.
7. Precast units will be handled and transported in a position consistent with their shape and design to avoid excessive stress which would cause damage.



Fig.5 Delivery of Precast Members by Trailor

3.4 STORAGE OF PRECAST ELEMENTS AT SITE:

Following points should be paid attention while storing precast concrete elements:

1. Elements should not be laid on a sloping ground as it could result in a abnormal loading thus resulting in overturning.
2. Ground should be inspected before placing the Element. In case of poor soil, the same should be replaced with a well graded soil and proper compaction be done under supervision of qualified and experienced personnel.
3. Proper care shall be taken while placing/ removing the elements so that the adjacent element is not hit/ disturbed.
4. A warning tape should be tied around the storage area.
5. Elements are to be stacked under supervision of an experienced gang leader and to be inspected by a senior foreman for any un-symmetrical stacking.
6. At the time of stripping, ensure that concrete achieved the specified stripping strength.
7. Cubes to be tested to check the stripping strength.

8. All detachable mould parts that could prevent the elements from release to be removed.
9. Ensure that lifting clutches attached to the elements are properly fixed onto the cast-in sockets or lifting anchors/inserts.



Fig.6 Stacking of Precast Elements at Factory

3.5 CONSTRUCTION TECHNIQUES FOR PRECAST BUILDING PANELS:

Precast Panels horizontal members present no special handling problems once their weight and length have been considered. Weight, combined with the erection or lift off radius, will dictate the capacity of the crane required on the job. A designer should consider this and attempt to keep his maximum weights in a pre-determined range during the design stage. No erection is impossible if the owner is willing to pay for it, but in-place costs are sometimes staggering if no consideration is given to the overall erection problem. A 100-ton crane cannot erect a 100-ton piece of precast concrete. Cranes are rated by the capacity they will pick up with the shortest possible boom and at the steepest angle that they will boom up. Thus, a 100-ton mobile crane could pick up the 100 tons only with 40 ft. of boom at a radius of 12 ft.



Fig.7 : Precast Panels Under Construction

A normal working condition would be 100 ft. of boom at a 40-ft. radius. Radius is measured from the center pin or center of revolution which is approximately 10 ft. from the rear of the crane. At a working radius of 40 ft., a 100-ton crane can lift only 44 percent more than a 60-ton crane, not 67 percent more as the capacities might indicate. Tower cranes are ideal for high, multi-story erection, but their design combines a small capacity with a large radius. Gulf countries techniques of construction combine smaller precast members with cast-in-place, Four-point pickup on 54-ft. long wall panels floor-by-floor construction using tower cranes for conventional erection. Vertical members present the most difficult pick-up problems because they are hauled flat and have to be turned into a vertical position. The best way to accomplish this is with the two-line technique this usually is done with the two lines of one crane although, when the member is extra-long or heavy, it might have to be done with a second smaller crane tailing the bottom for the larger crane.

Proper planning and preparatory works shall be required before the actual installation of precast concrete elements in order to ensure quality installation. The following items shall be planned in advance:

- i. Method of sequence of assembly and installation: Precast elements should be identified based on their location number and the tagged.
- ii. Method of providing temporary support: Elements should be supported temporarily before these get stabilized. Generally structural members with adjustable ends shall be used for securing the panels. Shims should be used to adjust the panels to ensure dimensional correctness.
- iii. Installation tolerances: Installation tolerances should be based on codal provisions and design considerations should be clearly indicated.
- iv. Handling and rigging requirements: Elements should be checked for handling stresses before lifting and the cranes should have sufficient capacity to handle the precast panels. At least 10% impact should be considered while calculating the lifting capacity of the crane.

At site locations, panels shall be first unloaded and stacked or directly lifted by the crane. The element shall then be installed on the site and supported by temporary jacks. The cranes shall be released for next lifting once the temporary supports are in place. Shims shall be used to carefully align the element before grouting. The panels shall be grouted after the final adjustments are done.

3.6 TYPES OF PRECAST ELEMENTS:

Two main types of precast concrete elements, namely precast reinforced concrete elements and precast pre-stressed concrete elements are used as per the details given below: Precast concrete elements – Concrete components of a building prefabricated in precast yard or site and shall be installed in the building during construction.

- i. Precast reinforced concrete elements:

These shall consist of reinforcement bars and welded wire meshes within the elements to provide the tensile strength and resistance against cracks such as façade walls, beams, columns, slabs, refuse chutes, staircases and parapet walls.

- ii. Precast pre-stressed concrete elements:

These shall consist of pre-stressing tendons within the elements to provide a predetermined force needed to resist external loadings and cracks such as hollow core slabs, beams and planks.



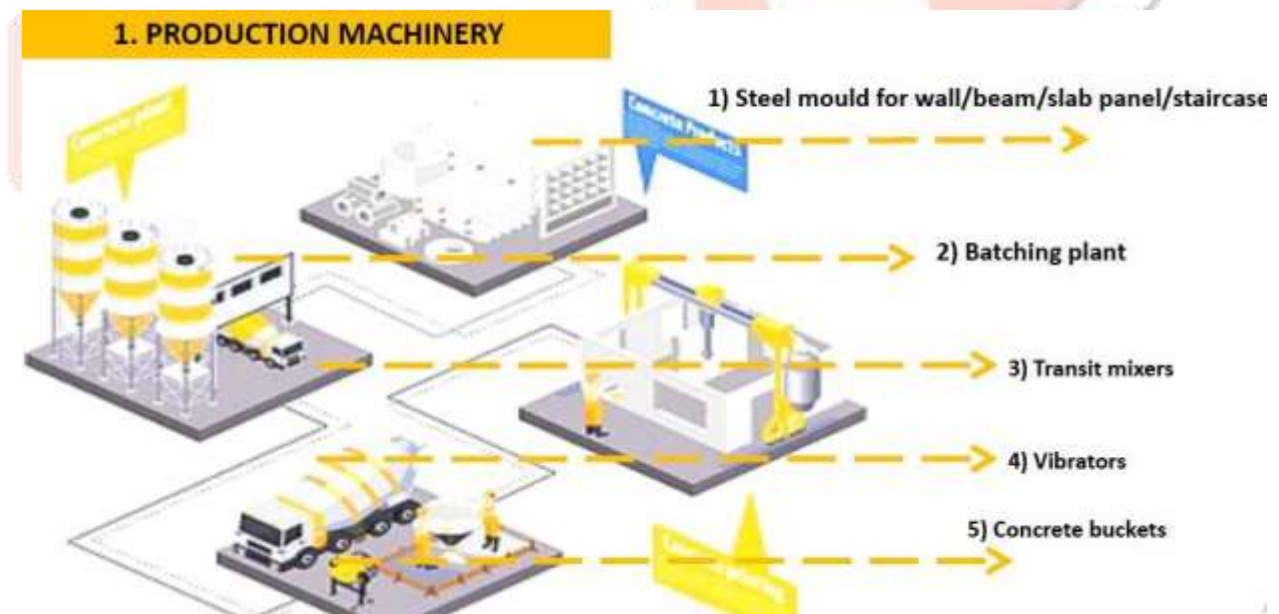
Fig.8 : Precast Column, Staircase and Landing

3.7 PRODUCTION, INSTALLATION AND TRANSPORTATION MACHINERY:

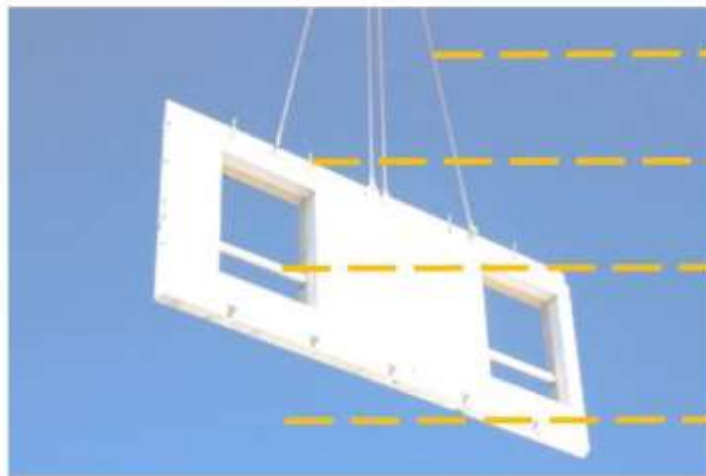
Production Machinery: 1) Steel mould for wall/beam/slab panel/staircase, 2) Batching plant, 3) Transit mixers, 4) Vibrators, 5) Concrete buckets.

Transportation Machinery: 1) Lifting beam/ lifting clamps, 2) Ropes & lifting hooks, 3) Trailer – 20 MT capacity, 4) Wooden runner of size 40 x 60 mm/ 100 x 125 mm.

Cranes and Loaders: 1) Tower crane of 5.7 MT, 6.9 & 7.2 MT load carrying capacity and operating radius of 40 to 45 m, 2) Gantry cranes of 10 MT, 20 MT & 30 MT capacity and span of 20 to 25 m, 3) Wheel loader of 1.9 cum capacity, 4) Skid steer loader, 5) Truck mounted knuckle boom crane of 7 MT capacity.



2. TRANSPORTATION MACHINERY



1) Lifting beam/ lifting clamps

2) Ropes & lifting hooks

3) Trailer – 20 MT capacity

4) Wooden runner of size 40 x 60 mm/ 100 x 125 mm

3. CRANES AND LOADERS MACHINERY



1) Tower crane of 5.7 MT, 6.9 & 7.2 MT load carrying capacity and operating radius of 40 to 45 m.

2) Gantry cranes of 10 MT, 20 MT & 30 MT capacity and span of 20 to 25 m.

3) Wheel loader of 1.9 cum capacity

4) Skid steer loader

5) Truck mounted knuckle boom crane of 7 MT capacity

Fig.9 : Production, Installation and Transportation Machinery

4. RESEARCH PAPER:

The Initial literature study started with carrying out a study on Journals, Books and Net case study. The basic study started with doing reviews on research papers. The Research Papers Identified was :

4.1 CASE STUDY ON USE OF PRECAST TECHNOLOGY FOR CONSTRUCTION OF HIGH-RISED BUILDINGS.

CHECK LIST: Checks are to be done mainly while erecting, transporting and manufacturing. So data has been collected regarding various checks need to be done in precast construction and a check list is prepared.

RISK ANALYSIS: A questionnaire is done to know about the various risks and their level of impact on and off the people on the site. It is prepared based on the factors or conditions that cause injury such as due to heavy lifting, structural collapse, improper barricades and braces, working with heavy equipment etc. The questionnaire was surveyed from various people working in the field of precast.

This paper highlights the case study for adoption of Precast Technology to achieve fast-track, sustainable, and cost-effective construction of high-rise buildings in Indian Scenario.

A REAL-TIME CASE STUDY- Dream Valley project is located in Greater Noida (West), Delhi NCR, India. It's a residential township with total 47 high-rise residential towers, 379 villas, commercial & institutional building, and other developments. The total built-up area of project is more than 10 million Sqft. The high-rise residential towers are divided into six series from A to F with further classification as A1 to A7, B1 to B6, C1 to C12, D1 to D2, E1 to E8, and F1 to F12. After a lot of brainstorming and feasibility study, Series A, D, E & F were planned to be constructed by using precast construction technology. To make the case easy to understand, this study will discuss the construction of series A having total seven towers. As of today, all the seven towers are completed. There are 12 apartments per floor with carpet area of about 430 Sq.ft. for 1BHK. All apartments at of series A are identical that made precast technology a viable option.

Dream Valley – Series A (Tower A1-A7), High Rise Residential Buildings	
Overall built-up Area (Precast+CIS)	10 Million Sqft
Built-up area planned in Precast	3.79 million Sqft
Built-up area of A series (A1-A7)	8.82 lacs Sqft
Structural frames	2B+G+18 Floors
Total apartments	1500 apartments; 12 apartments per floor
Structural system (Sub-structure)	Raft foundation (CIS)
Structural system (Super-structure)	Hybrid Precast Construction (Shear walls & Core in CIS)
Basement, Ground & terrace work	Cast In Situ
1 st to 18 th floor	Precast beams, wall panels, balconies, claddings, staircase, & hollow core slabs
Total precast concrete volume (m3)	~16000
Total Nos. of Precast elements (Tilts + HCS)	25000

4.2 CHALLENGES EXPERIENCED:

Following are some of the key learning challenges which were encountered on the way.

1. As the project was located in seismic zone IV, the suitable design was adopted.
2. Lack of skilled manpower with the knowledge of precast industry, operation of various machineries & erection, which was overcome by providing detailed training.
3. It was difficult to counter the typical mind-set of people to adapt to change in construction technology, patience & willingness to experiment with a new technology.
4. Although, European and other standards were available for ready reference but unavailability of IS codes was deemed important. The designers from India had only few Indian Standard to refer.

The knowledge and understanding acquired during this case were carried forward to the projects underway. Many improvisations were based on the experiences of this projects.

4.3 RESULTS ACHIEVED:

There are Some Overwhelming results along with learning experiences achieved through this landmark project are noted as follows:

1. 7 buildings of 2B+G+18 floors were completed in 18 months of timeline was made possible through precast technology.
2. Achieved a slab cycle of 10-12 days for a slab area of 7000 Sq.ft.
3. Superior quality & finish of construction.
4. Cost & time optimization with the use of hollow-core slabs.
5. Reduction in concrete & steel factor per Sqft of built-up area.
6. Elimination of brick work and plaster by the use of precast wall panels & cladding.
7. Automation & mechanization of construction project improved overall productivity.
8. Improved site safety & considerable reduction in wastage, dust & noise on site, thus reduced ecological footprint of project.

4.4 INFERENCE:

The precast concrete technology has already arrived in India, due to large size projects, need for quality construction with speed & reduced labour force. All these advantages can be exploited to the maximum by careful planning & designing. This case study was aimed to share the hands-on-experience, and to aware the people about the potential the precast offers. From the above case study, it can be concluded that precast construction, if designed and executed with thorough planning, has a great potential to respond to new market demands. Precast is smart way to achieve the sustainability objectives of Green Building.



Fig.10 : Dream Valley Overall Layout Plan



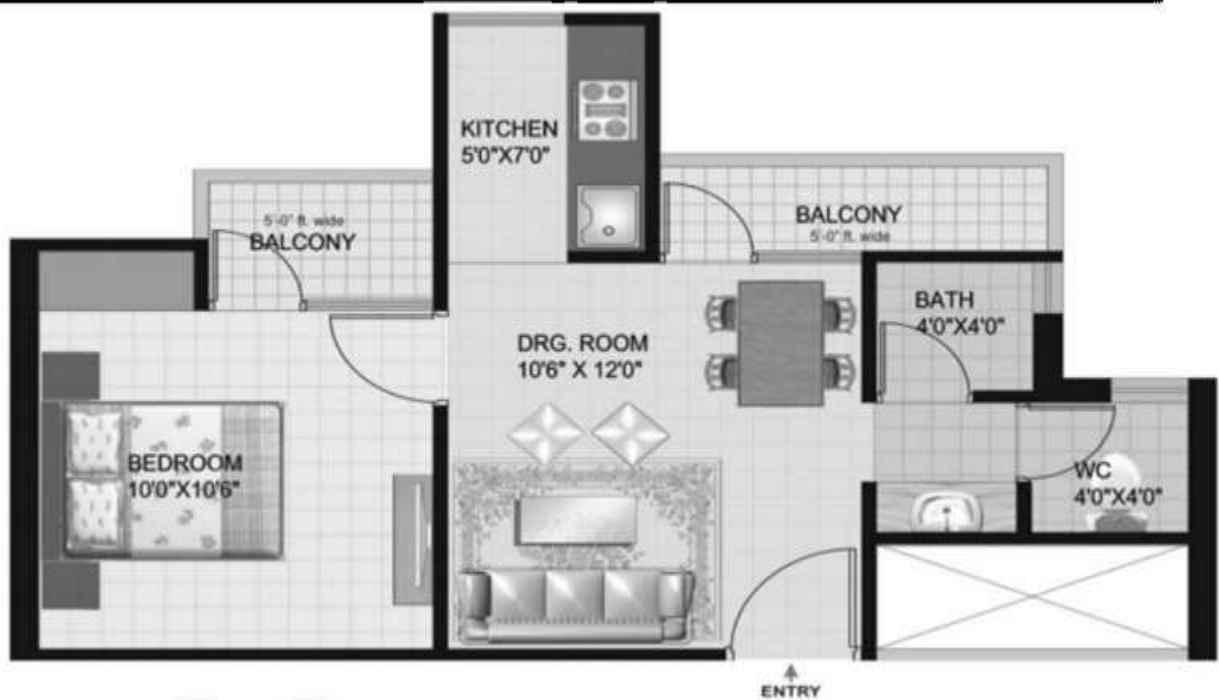


Fig.12 : Typical Apartment Floor Plan

5. CONCLUSIONS:

The precast concrete technology has already arrived in India, due to large size projects, need for quality construction with speed & reduced labour force. All these advantages can be exploited to the maximum by careful planning & designing. This case study was aimed to share the hands-on-experience, and to aware the people about the potential the precast offers. Following learnings could be the key takeaways though this case study:

1. From the above case study, it can be concluded that precast construction, if designed and executed with thorough planning, has a great potential to respond to new market demands.
2. Adopting mix of CIS & factory-made precast units wherever required, instead of usually considered 'all precast or no precast' approach offers more benefits in terms of time, cost, and quality.
3. Repetition of precast components is essential in order to meet quantity for cost effectiveness.
4. The adoption of precast compared with traditional construction demonstrated significant advantages, such as improved quality control, reduction of construction time, construction waste, dust & noise on site, and labour requirement on site. In addition, it results in higher useful gross floor area which contributed to significant cost benefits.
5. A considerable reduction in steel factor can be achieved even for seismic zones IV & V.
6. It becomes easy to perform non-destructive testing (NDT) if the need arises and becomes easy to mitigate.
7. Precast has evolved towards the use of non-standard design approach with modular elements optimising site opportunities & constraints.
8. For commercial construction and other standard products like boundary wall etc. precast has unprecedented benefits.
9. Precast technology allowed for flexible design and longer clear spans in the non-tower areas like parking.
10. Precast is smart way to achieve the sustainability objectives of Green Building.

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