



Affordable housing in India with Precast Construction



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Introduction

India is facing a housing shortage which is currently estimated to be more than twenty five million homes in the country, out of which, EWS (economically weaker sections) and LIG (lower income groups) account for 95%. In 2015, the Indian government launched the Housing for All mission with an aim to provide affordable

housing to urban poor. It is proposed to build twenty million houses for the urban poor by the year 2022. To achieve this goal, the government and private real estate developers have to launch large scale affordable housing projects all over the country. However, the construction industry is facing issues with manpower shortage and rising cost of construction materials. The cost of labor has gone up significantly and availability of construction workers has become problematic. Furthermore, the pressure on developers has increased as customers are demanding on-time delivery of their homes with good quality construction work. Conventional construction methods will not be able to exploit the advantages of mass housing and in the current scenario, it is evident that new construction technologies should be utilized to deliver homes fast with minimum labor and zero wastage of materials. Especially in Europe, after the Second World War, the housing shortage was solved by implementing new technologies like

precast concrete construction. Precast concrete construction is a building method where building components are prefabricated off site on an assembly line using advanced tools and equipment and thereafter transported to the building site where they are erected using building cranes. Precast concrete construction has evolved over the past five decades towards a flexible building technology which is used in many infrastructure projects and building projects throughout the world. This article describes the technical details and specifications of three different housing projects in India which are being constructed with precast concrete technology. The first project is an affordable group housing project with medium-rise apartment towers located in Ghaziabad, Uttar Pradesh. The second project is also an affordable group housing project with medium-rise apartment towers but located in Bangalore, Karnataka. The third project is consisting of low-rise villas located in Greater Noida, Uttar Pradesh.

Project 1. Medium-rise apartment buildings, Bharat City, Ghaziabad



(Picture 1. Bharat City phase 2, Ghaziabad)

This first project is located in Ghaziabad on the outskirts of Delhi, where the real estate prices are at an affordable level. The project is being developed on 60 acres of land by real estate developer BCC Infrastructure Pvt. Ltd., and the first phase of the project which was launched in 2011, comprised of almost 1800 apartments of 1, 2, 3, and 4BHK. Phase one was constructed using conventional cast in place of reinforced concrete structures with apartment towers of ground plus fourteen floors. Although achieving an affordable costing, the real estate developer was not satisfied with the speed and quality of construction. A technical feasibility study was prepared for phase two of the project to investigate the possibilities of constructing the remaining 39 apartment towers with precast technology. The purpose of the study was to present objective information regarding several precast systems and prepare a comparison between the advantages and disadvantages of the systems. Based on the performed investigation and research, it was concluded that a large

precast panel system would be the most suitable with respect to structural safety, economics, aesthetics, and constructability.

Building system

In this project, the foundations and basement structure are made entirely as conventional cast in-situ reinforced concrete structure. The basement areas below the towers are utilized for car parking, while the driveways are situated in the extended basement areas. The apartment towers which come on top of the basement are made

with load bearing precast concrete with the use of large precast elements like slabs and walls. The precast walls are considered to be shear walls and are part of the lateral load resisting system and are adequately connected to the floor diaphragm to achieve an earthquake-resistant structure. Due to manufacturing and transportation limitations, the precast wall panels are made as one storey high elements and will be jointed at floor level (picture 2). The horizontal and vertical connections between the precast walls are established at the building site only.

Adequate buttressing of the external wall panels has been achieved by connecting the internal wall panels to the external wall panels by grouted shear key joints and reinforced wire loop connections. All load bearing elements at the corners of the building have been stiffened by jointing structural elements perpendicular to it (picture 3). The load bearing precast walls are placed on top and are properly connected to each other at floor level and adequately connected to the floor slab with protruding reinforcements. The precast shear wall system is



(Picture 2. Precast concrete wall erection)



(Picture 3. Precast concrete load bearing structure on top of basement)



(Picture 4. Precast half slabs with lattice girders)

designed to emulate the behavior of cast in-situ concrete construction in terms of stiffness, strength, ductility, and energy dissipation. Because of the provisions for car parking, the layout of the basement structure is somewhat different from the superstructure and wherever possible, the precast load bearing shear walls of the superstructure are supported by cast in-situ RCC walls at basement level and only at a few locations, the precast walls are supported on short span transfer beams.

The vertical dead loads and live loads are carried by the floors and transferred towards the load bearing structural elements. The floor slab system of the superstructure is made of precast concrete planks on which

a reinforced cast in-situ concrete topping will be poured. This system is commonly known as the precast half slab system (picture 4). The slab bottom reinforcement is placed within

the precast planks and the slab top reinforcement is placed within the RCC topping. Proper connection between the precast planks and the RCC cast in-situ topping is achieved by providing lattice girders made of reinforcement bars which are partially placed inside the precast plank and partially sticking out at the top. The composite slab system provides continuity and connection to all the shear walls and the slab behaves as a rigid floor diaphragm. The precast planks are made as room-sized slabs and are supported on the interior and exterior load bearing walls or beams. Due to continuation of the top reinforcement over the interior supports, the slab system has structural behavior of continuous floor span system. The bottom reinforcement of the slabs will be anchored at interior supports by placing extra bottom reinforcement directly on top of the precast slabs. At exterior supports, the extra bottom reinforcement shall be provided in the form of protruding bars from the walls which will bend down directly on top of the precast slab.

All the balconies are cantilevered precast solid slabs and are connected by protruding reinforcement to the cast in-situ RCC topping of the floor (picture 5). Bathroom slabs are also made of a precast solid slabs to achieve a



(Picture 5. Cantilever precast balconies)



(Picture 6. Erection of load bearing precast wall panel)

waterproof slab and are connected to the half slab system by protruding reinforcement at the slab edges.

The lateral load path of the precast superstructure is formed by a large number of precast concrete shear walls which are placed in x and y direction. The precast shear walls are solid reinforced concrete panels and due to their large in plane stiffness, most of the lateral forces are resisted by these structural elements. Load transfer at horizontal joints is achieved by filling the 20mm gap between the precast panels with non-shrink high strength grout. Furthermore, reinforcement starter bars are passing through the horizontal joints which will ensure a proper connection between one precast wall panel to the next precast wall panel. The starter bars are placed in the center of the precast walls and are connecting inside oversized steel corrugated dowel tubes which are later fully filled with non-shrink grout (picture 6). The starter bars are anchored inside both the precast walls and are lapping indirectly with the reinforcement meshes of the precast wall panels. At the horizontal joints, the shear forces between the precast concrete wall panels are transferred by the friction

of the joint interfaces and by the dowel action of the starter bars.

The precast buildings have been designed with proper structural integrity to avoid situations where damage to small areas of the structure or failure of single elements may lead to collapse of major parts of the structure. This has been achieved by effectively providing continuous peripheral tie reinforcement near the edge of the building perimeter. Furthermore, internal tie reinforcement has been provided at each floor and

roof level in two directions at right angles. The peripheral and internal tie reinforcement has been placed as extra reinforcement inside the RCC cast in-situ topping. Also, all the external load-bearing members such as precast walls have been anchored or tied horizontally into the structure at each floor and roof level by providing uniform reinforcement protruding from top of precast walls and bend down inside the RCC cast in-situ topping (picture 7). Each precast wall carrying vertical load has been tied continuously from the foundation to the roof level. At all horizontal precast joint locations, the starter bars have been placed staggered by using a combination of normal length grout tubes and longer grout tubes in combination with continuous dowel reinforcement running from bottom to top inside the precast wall panels.

The staircases are made of precast solid slab landings at floor level and mid landing level. The flights are made as precast stair elements which are resting on the precast landings and connected by dowel connections (picture 8).



(Picture 7. Half slab top reinforcement lapped with protruding wall and balcony reinforcement)



(Picture 8. Precast staircase with landings and stair flight)

Overview of precast components for the superstructure

Item	Specifications
Load bearing precast walls	160mm thick solid precast walls 200mm thick solid precast walls
Partition walls	100mm thick solid precast walls
Shaft walls	160mm thick L-shaped precast walls
Slabs	50mm thick precast half slab with lattice girders
Bathroom slabs	Solid precast slabs with protruding reinforcement
Balconies	Precast solid balcony slabs with protruding reinforcement
Staircase	Precast stair flights Precast solid slab landings
Beams	Precast beams 200x600mm



(Picture 9. Completed precast building structures of Bharat City phase 2)

BCC Precast plant – fabrication, storage, and transportation

The precast plant is located within the boundaries of the project site which makes it easy and fast to transport and erect the precast elements. The precast plant has been designed in such a way that it can be dismantled in future and be relocated to another construction site. The plant has been divided in two parallel bays in which different activities take place. The first bay is utilized for the precast wall panel production and has two battery moulds of twenty cells each and several tilting tables. The battery mould system is used for manufacturing of precast walls in vertical position and the tilting tables are utilized for manufacturing complicated wall panels in horizontal position and tilting them later (pictures 10 to 12).

Bay two of the plant is used for manufacturing precast slabs, balconies, solid slabs, beams and L-shaped walls. This bay has two 40m-long steel casting beds for the slab production and several customized moulds for the production of other precast elements (picture 13).

Precast balconies are made in special customized moulds with formliners which creates a texture finish at the top surface of the balcony slabs. Both bays, each have three overhead gantry cranes with 10 ton lifting capacity for activities like lifting rebar cages, lifting concrete casting buckets, and demoulding the precast elements. The gantry cranes have an extended rail system which leads in the stockyard to lift and store the precast elements. Precast walls are stacked vertically in steel storage racks while precast slabs are stored horizontally stacked on top of each other (picture 14). The precast half slabs with lattice girders are lifted by special lifting frames.



(Picture 10. Battery mould for vertical production of precast wall panels)



(Picture 11. Precast wall panel reinforcement cage inside battery mould system)



(Picture 12. Tilting tables for horizontal production of precast wall panels)



(Picture 13. Steel casting beds for precast slab production)



(Picture 14. Stockyard for precast elements)



(Picture 15. Transport of precast wall panels)



(Picture 16. Transport of precast slabs)

The concrete batching plant is located just outside the precast plant and a trolley system transports the concrete casting buckets to the precast plant. Raw materials are stored in storage bays, next to the batching plant. Rebar cages are prepared in an adjacent area to bay one and two, and gantry cranes from both bays can access this area. The precast plant is equipped with an advanced laboratory for strict quality control. Precast walls are transported in vertical position on trailers with A-frames. All other precast elements are transported in horizontal position on flat trailers (pictures 15 and 16).

Project 2. Medium-rise apartment buildings, Sobha Dream Acres, Bangalore



(Picture 17. Sobha Dream Acres, Bangalore)

This second project is located in Bangalore and is being developed by real estate developer Sobha Ltd., which is mainly operating in the middle segment and luxury housing segment. Due to major demand for affordable housing in the Bangalore region, the developer started exploring the possibilities of diversifying in this field and attract new customers. The project is being developed on 81 acres of land, where more than 6,500 apartments

will be constructed. Customers can choose from 3 different types of affordable housing units in the sizes of 1BHK, 2BHK regular, and 2BHK large. Before the start of the project, a technical feasibility study was conducted to investigate the possible precast systems and to provide input regarding quantities and specifications of the precast construction materials. After final estimations, the developer decided to set up a state-of-the-art

precast plant for the production of the precast buildings.

Building system

In this project only, the foundation footings and rafts are made as cast in-situ concrete and the rest of the structure is precast concrete. The underground basements are made with load bearing precast walls, columns, beams, and half slabs. The apartment towers which come on top of the basement, are made in load bearing precast concrete with a similar precast system as explained in the first project. Reinforcement starter bars are protruding from top of the foundations for the connection of the load bearing precast walls and columns (pictures 18 and 19). The starter bars are connecting inside oversized steel corrugated dowel tubes which are fully filled with non-shrink grout. The starter bars are anchored inside the precast elements and are indirectly lapping with the reinforcement.

Because of the provisions for car parking, the layout of the basement structure below the apartment towers



(Picture 18. Foundation raft with starter bars for precast columns and walls)



(Picture 19. Basement precast walls and columns)

is somewhat different but wherever possible, the precast load bearing shear walls of the superstructure are supported by precast basement walls. Due to the increased basement height, the precast basement walls had to be manufactured in different sizes with different joint locations as the superstructure. Driveways and additional car parking bays are situated in the extended basement areas which are constructed using a precast frame system with columns, half beams and half slabs. In this system, the precast half slabs with lattice girders are making one way spans from beam to beam, thereby, avoiding the use of secondary beams

(pictures 20 and 21). The precast half beams top reinforcement has to be tied at site together with the half slab top reinforcement. At the ends of the precast half beams, the bottom reinforcement is projecting out towards the column-beam junction which will be a wet joint and form a moment resistant connection.

The basement retaining walls are made as solid precast wall panels with special joint connections to ensure the water tightness at these locations (picture 22). The bottom horizontal joint detail has the grout tube dowel connection with the foundation footing in combination with protruding

reinforcement, which is lapping with protruding reinforcement from the footing, thereby, creating a monolithic concrete connection. The vertical joints have groove shape profiles with wire loop connections with vertical locker bar filled with non-shrink grout and are later covered from the outside by bitumen sheets.

The superstructure has a similar precast system as explained in the first project, however, the staircases have precast stairs with attached top and bottom landings (picture 23). These precast stair elements are resting on corbels attached to the precast staircase walls.



(Picture 20. Extended basement structure with precast columns and half beams)



(Picture 21. Extended basement structure with precast half beams and half slabs)



(Picture 22. Basement structure with precast retaining walls)



(Picture 23. Precast stairs with attached bottom and top landings)

Overview of precast components for the basement structure	
Item	Specifications
Load bearing precast walls	200mm thick solid precast walls
Shaft walls	200mm thick L-shaped precast walls
Retaining walls	250mm thick solid precast walls
Slabs	60mm thick precast slab with lattice girders
Staircase	Precast stair flights with attached bottom and top landings.
Columns (tower area)	300x750mm 300x1600mm
Columns (non tower area)	350x750mm
Beams	Precast beams 300x600mm Precast half beams 750x370mm

Overview of precast components for the superstructure	
Item	Specifications
Load bearing precast walls	160mm thick solid precast walls 200mm thick solid precast walls Exterior walls with attached sunshades.
Partition walls	100mm thick solid precast walls
Shaft walls	160mm thick L-shaped precast walls
Slabs	60mm thick precast slab with lattice girders
Balconies	60mm thick precast slab with lattice girders
Staircase	Precast stair flights with attached bottom and top landings.

Sobha Precast plant – fabrication, storage, and transportation

This precast plant is located within the boundaries of the project site and is equipped with an automated circulation system for the horizontal

production of precast wall panels and slabs. These precast elements are manufactured on steel production pallets (moulds) of size 4m x 12.5m, which are mounted on a roller system that enables the pallets to move to various work stations inside the plant

(picture 24). The plant has a total of 33 production pallets within the circulation system.

At each work station, a standard activity takes place like cleaning of the pallets, fixing of shuttering, placing reinforcement cages, fixing



(Picture 24. Circulation system for horizontal production of precast wall panels and slabs)



(Picture 25. Special stationary mould for L-shaped walls)



(Picture 26. Special stationary mould for precast columns)



(Picture 27. Reinforcement workshop and lattice girder welding machine)



(Picture 28. Concrete spreader for pouring of concrete)



(Picture 29. Stockyard for stacking of precast elements)

inserts and provisions, pouring concrete, finishing of concrete, curing, demoulding, and tilting. The system is equipped with a plotter which can plot with water-soluble markings the exact contours 1:1 of each precast element on the production pallets which makes it easy and quick to fix the shuttering. The plant has a

separate bay with various stationary special moulds for the production of volumetric wall panels like L-shaped walls and external walls with attached cantilever sunshades (picture 25 and 26). Furthermore, staircase moulds, column moulds and beam moulds which have been specially designed for this project, are located in this

area. This bay also has space for the preparation of the reinforcement cages and the automated welding machine for the fabrication of the lattice girder reinforcement (picture 27).

EOT cranes run in each bay of the plant to perform various lifting activities. The concrete batching plant is situated right next to the plant and has an extended overhead rail system through which a concrete spreader machine can move in and out the factory for the pouring of the concrete (picture 28).

In the stockyard, the precast wall panels are stacked vertically in steel storage racks which can contain several panels. These racks can be lifted in a single operation by the 40 ton gantry crane. Slabs are stacked on top of each other in multiple layers (pictures 29 and 30.).



(Picture 30. Stacking of half slabs)

Project 3. Low-rise villas, Supertech Upcountry, Greater Noida



(Picture 31. Supertech Upcountry villas)

This project is located in Greater Noida and is being developed by Supertech Ltd. and comprises of 59 villas build on 90 sq. yd. plots. Similar villas were under construction using conventional building methods when the developer decided to speed up the work and use precast construction for the remaining villas which were still to be build. This was the first housing project where the developer started using precast building components which were manufactured in their newly opened precast plant in Greater Noida. The

villas have a basement, ground floor, first and second floor with a total build-up area of 2,795 sqft. per villa. Although, this is not an affordable housing project, the technology showcased in the project can be used for affordable housing as well.

Building system

The foundation footings are made as cast in-situ concrete and the remaining structure as precast concrete with large precast panels (pictures 32 and 33).

The structural system of these villas is similar as described in the first project except for the floor system which is very much different. In this project, hollow core floor slabs are used which are prestressed floor slabs with longitudinal voids. The presence of the voids results in material savings and weight savings. With hollow core slabs, large spans can be achieved and no temporary propping is required. Hollow core slabs only have longitudinal prestressing reinforcement and no other reinforcement. Diaphragm action is achieved through special joint design in combination with the application of a reinforced concrete topping to join the slabs and achieve proper diaphragm action. All the load-bearing members such as precast walls have been tied horizontally into the structure by providing uniform reinforcement protruding from top of precast walls and bend down inside the RCC cast in-situ topping and inside pockets created at the end of the hollow core slabs (picture 34.). Furthermore, peripheral and internal tie reinforcement has been placed as extra reinforcement inside the RCC cast in-situ topping.



(Picture 32. Villas constructed with large precast panels)



(Picture 33. Erection of precast partition wall panel)



(Picture 34. Precast hollow core slabs with connection to precast walls)



(Picture 35. Precast staircase)



(Picture 36. Villas constructed with large precast panels)



(Picture 37. Completed precast villas at Supertech Upcountry, Greater Noida)

Overview of precast components	
Item	Specifications
Load bearing precast walls	150mm thick solid precast walls
Partition walls	100mm thick solid precast walls
Slabs	150mm thick prestressed hollow core slabs
Balconies	150mm thick precast solid slabs
Staircase	Precast stair flights Precast solid slab landings
Parapet walls	150mm thick precast solid walls

Other building components like the staircase, balconies and parapet walls have all been made as precast concrete and have been integrated in the building design (pictures 35 and 36).

Supertech Precast plant – fabrication, storage, and transportation

The developer decided to establish a centralized precast plant located nearby their upcoming projects in Noida and Greater Noida. The

distance from the plant to this particular project site is around 40km. The precast plant has two main buildings in which the precast production takes place. Building A is having long line beds for the production of hollow core slabs. These slabs are made by spanning prestressed strands over the production beds and casting the concrete with a slipformer machine. The production beds have inbuilt heating pipes through which hot water can be pumped which will accelerate the curing process. After proper curing, the concrete must have achieved the required strength to cut the slabs with a diamond saw blade machine. The concrete batching plant is located next



(Picture 38. Prestressed hollow core production with slipformer machine)



(Picture 41. Individual work stations for precast production)



(Picture 39. Prestressed hollow core slabs)



(Picture 42. Concrete distributor)



(Picture 40. Central shifter with production pallets)

to the plant and a flying bucket system supplies the concrete to the slipformer (pictures 38 and 39).

Building B is equipped with an automated central shifter system for the horizontal production of precast wall panels. These precast elements are manufactured on steel production

pallets (moulds) of size 4m x 12.5m which are mounted on rollers. The plant has three bays where the central shifter machine operates in the middle bay and serves as a central transport unit for the production pallets and can move them to the individual work stations which are located in the adjacent bays (picture 40). At each work station, standard activities can take place like cleaning of the pallets, fixing of shuttering, placing reinforcement cages, fixing inserts and provisions, pouring concrete, finishing of concrete, curing, demoulding and tilting (picture 41).

EOT cranes are operating in the first bay and third bay of the plant where they can access all the

individual work stations. The batching plant is located right next to the plant and has a concrete distributor which is mounted on an overhead rail system through which it can move in and out of the plant and get fresh concrete from the batching plant (picture 42.)

About the author

Mr. Bob van Gils is a Dutch national and director and co-founder of the structural engineering firm WBK Engineering Services Pvt. Ltd. which has established an experienced precast design and detailing team in their Gurgaon office. The company is involved in design and detailing of some of the state-of-the-art precast building projects in Europe, USA, and India. For further information, visit www.wbkengineering.in or email to info@wbkengineering.in ●