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ANALYSIS AND DESIGN OF REINFORCED CONCRETE STRUCTURES-A G+5 BUILDINGMODEL

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ABSTRACT

The foremost basic in structural engineering is the design of simple basic components and members of a building viz., Slabs, Beams, Columns and Footings. In order to design them, it is important to first obtain the plan of the particular building that is, positioning of the particular rooms (Drawing room, bed room, kitchen toilet etc.) such that they serve their respective purpose and also suiting to the requirement and comfort of the inhabitants. Thereby depending on the suitability; plan layout of beams and the position of columns are fixed. Thereafter, the loads are calculated namely the dead loads, which depend on the unit weight of the materials used (concrete, brick) and the live loads, which according to the code IS:875-1987 is around 2kN/m 2 . Keywords: Slab plank, Etabs, Concise, safe, Prokon etc.

1. INTRODUCTION

The concept of precast (also known as "prefabricated") construction includes those structures where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components are manufactured by industrial methods based on mass production. Entire conventional construction process is to enable interaction between the design phase and production planning in order to improve and speed up the construction. Many precast components have thinner cross sections than that cast in place concrete. Precast structures are sound in construction practices due to there are no restrictions on the use of skeletal framed or irregular shaped or Architectural challenging designs are more suitable for precasting. For Precast structures there must be conscious effort to ensure the structural continuity such as slabs, beams and columns are connected effectively. All structural elements forms stable structural system after the joints is connected. The overall behavior of precast structure depends on all design forces, ductility to deformations and load distribution. Load distribution can be determined through structural stiffness or rigidity. The design, construction and performance of precast concrete structures are greatly influenced by behavior of connections between the elements. Nakaki (1999) explains the experimental and analytical studies of ductile connection precast elements for frame and wall structures, a distinct 5 storeyed frame is considered for analysis. He suggested that the strong-connection in precast structures emulates monolithic reinforced concrete construction. Habibullah (2007) has worked on physical object based analysis and design modeling of shear wall system using Etabs. Capozzi et al (2008) conducted experimental tests on beam-column connections of precast buildings. Both monotonic and cyclic load paths are programmed; the former ones are performed until the ultimate displacement using cyclic tests. Patrick et al (2011) reviewed the most appropriate type of beam-column connections to be introduced to precast concrete industry, particularly for regions of low to moderate seismicity. Gopinathan and Subramanian (2013) analysed the G+5 storeyed

frame subjecting to lateral loading with strong connections by specially designed bolts and L angles gives that Precast structure reaches nearly the ultimate load of control frame and variation is small. Chaitanya Kumar and Lute Venkat (2013) analyzed G+11 storey residential building with precast reinforced concrete load bearing walls. The structural system consists of load bearing walls and one-way slabs for gravity and lateral loads have been taken for analysis using ETABS.

2. MODELLING AND ANALYSIS OF PRECAST STRUCTURE

Precast structure is analysed as moment resisting frame in Etabs 2013. Structural elements like shear walls, core walls, slab, and beams are only considered and if any balcony exists their loads are considered in the frame analysis. Frame with G+ 7 storeys with head room for lift allowance is modelled. Since precast structures have minimum C35 grade concrete, hence all the material properties and sections are assigned to the structure. Slabs are considered as membrane elements in Etabs; that transfer load via one-way slab action. Figure 1 show the Etabs model the precast structure under study and the section and material properties are given in Table 1 to 3.

Assumptions considered in the analyzing of building are; a) Shear walls are considered instead of columns with 1.8x0.2 m throughout the building b) The building is suitably located in Chennai; loads for wind, quake and geotechnical aspects are related to it c) Building has heavy loads at the ground floor hence foundation and podium slab are made cast in-situ d) Since water table is at 2 m below the earth raft foundation is preferred for the building e) Using space for residential room's beams are restricted with 0.15 m width along with precast walls f) Building is assumed for commercial from stilt to 2nd floor and residential from 3rd to 7th floors g) Core walls are provided at 2 locations hence their width is

0.25 m h) There is podium drive way for fire engine and heavy cranes which are being constructed as an in-situ concrete. Structural frame system is adopted for entire structure. Loads from solid slab planks is transferred to beam and from beam loads are transferred to continuous shear walls which transfer to foundation. All the joints at beam and wall are taken as moment restraint connection. Table 1 shows slab and wall properties, table 2 shows material properties for shear walls, columns and core walls. Table 3 shows auto generated wind and seismic loads.
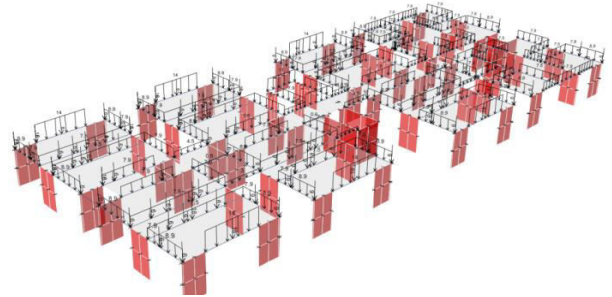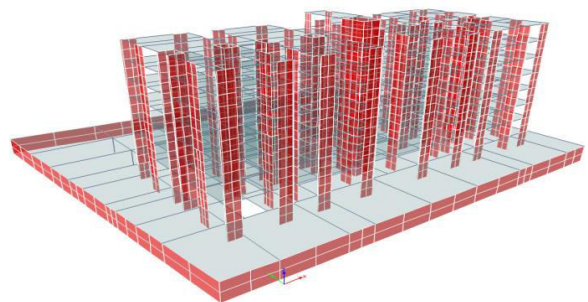

Fig 1: Structural frame modelled in ETABS

Fig 2: Typical floor with loads

Section	Material Name	Type	Membrane Thickness (m)
W200	C40	Shell-Thin	0.2
Slab85	C35	Membrane	0.085
Slab80	C35	Membrane	0.08
Head room	C35	Membrane	0.15
Ret. Wall	C35	Shell-Thin	0.10
W250	C40	Shell-Thin	0.25
GF300	C35	Shell-Thin	0.3

able 3: Wind		Seismic	
Direction Angle = 0&90degrees		R = 3	
Windward Cp		= 0.8	Z = 0.16
Leeward Cp		= 0.5	Soil Type = II
Exposure: Rigid diaphragm		I = 1.25.	

Table 2: Column and Beam Properties

Section	Material Name	Shape
C 250x600	C 35	Concrete Rectangular
GB 500x150	C 40	Concrete Rectangular
GB A 900x400	C 35	Concrete Rectangular
GB B 450x250	C 35	Concrete Rectangular
HB01	C 40	Concrete Rectangular
HB02	C 40	Concrete Rectangular
PB 600x150	C 40	Concrete Rectangular
PB 600x200	C 40	Concrete Rectangular
PB 600x250	C 40	Concrete Rectangular
PB 900X150	C 40	Concrete Rectangular
PST 600x150	C 40	Concrete Rectangular

Analysis: For analysis of frame all the balcony loads, and wall loads are taken on the frame. All the

slabs are taken in one way since planks are hollow core units are simply supported and assigned for

a shorter direction. Analysis is done for the frame with all the loads imposed on the structure. Rigid diaphragm is given to the floor elements. All the loads are distributed to the shear walls and core walls through floor frame action. Analysis results are shown in Figure 5.
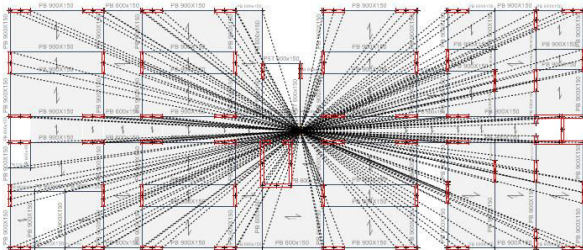

Fig 3: Rigid diaphragm for 1st floor.
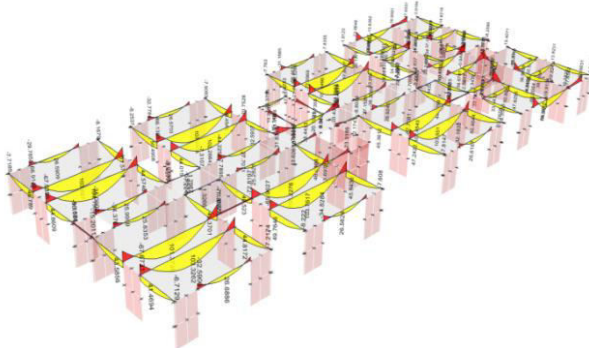

Fig 4: B.M diagram for a 5th floor plan.

3. RESULTS AND DISCUSSION

Design of slabs: Concrete slab planks are used as permanent formwork for in-situ topping. Performance of planks merely acts to that of cast in-situ construction. Precast planks are usually 75 mm to 120 mm thick based on the

load carrying capacity and spanning length. These can bedesigned with ordinary reinforced or Prestressed with minimum grade of C35 and C45. Steel meshes normally provided on topping concrete which also acts as negative reinforcement in case of continuous slabs. These are designed only as one way slab and 1 m wide planks are used for construction. During the temporary installation stage, the planks are designed as simply supported without props about 4 m to 6m for 75 mm and 100 mm thick. For longer spans if load is more and deflection is more props are suggested. Design is done for propping and, number and distance of props are assumed. Design is done for temporary and permanent stage. At temporary stage the weight of wet concrete (topping) [at transfer] + Live loads. Live loads are considered as permanent loads designed for service. In permanent conditions hardened concrete provides the resistance for flexural and compression resistance
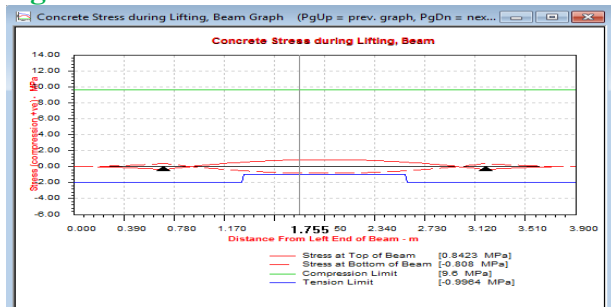
.
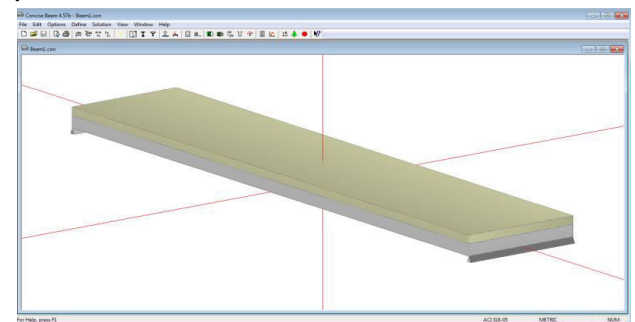
Fig 5: Precast slab plank in concise software.
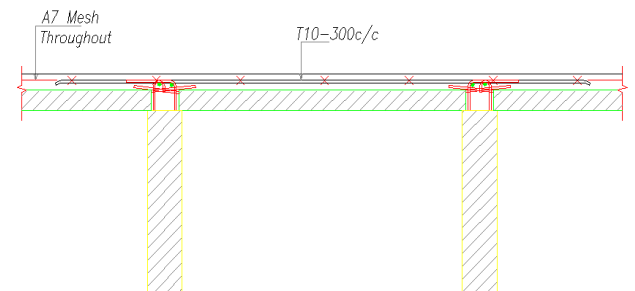
**Fig 6: connection between planks for shear transfer.**
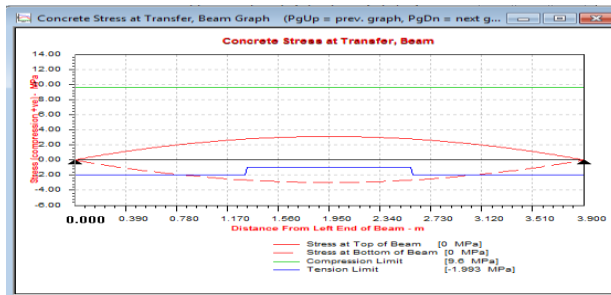
**Fig 7: Concrete stresses at transfer.**

Fig 8: Concrete stresses during lifting

If deflection exceeds shoring is done (Props), for negative B.M minimum reinforcement is provided (only if thickness 100 mm). Reinforcement from the plank will bend into top of plank for lateral loads distribution. Topping nominal reinforcement of T 10 bars with 300 mm c/c is provided.

Beams design: Precast beams are depend on section properties, construction methods, loads applied and beam behaviour at serviceable limit state. Precast beams may be designed by either full, semi precast or shell sections based on the fabrication, joints, handling, delivery and lifting capacities and, beams along with partition wall panels' combination.
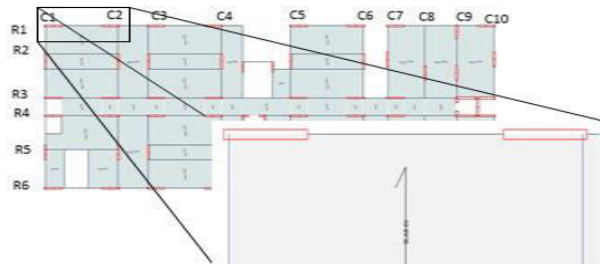

**Fig 9: Connection between walls and beams.**
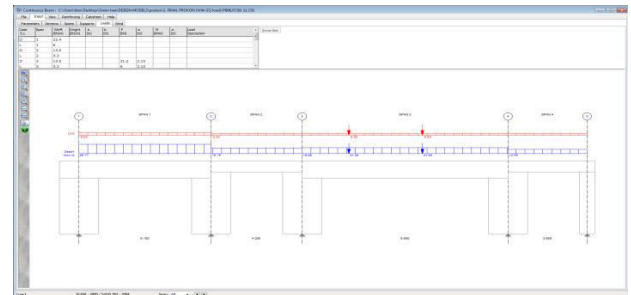
Fig 10: Loads taken in continuous frame

Since in Etabs modelling beams are connected to the exterior edge of shear wall there won't be distribution of loads through c.g of walls. Hence beams are designed using Prokon software, individually designing through grouping of continuous beams. Rows and columns are considered while designing continuous beams in prokon software. For lateral load resistance the maximum of EQ and WL in X and Y directions are considered and maximum fixed moments are taken and assigned to the beam. Continuous beams are designed by grouping in rows and columns; all the loads like floors constitute self-weight, imposed loads taken as uniform load and secondary beams self-weight and imposed loads are taken as point loads.
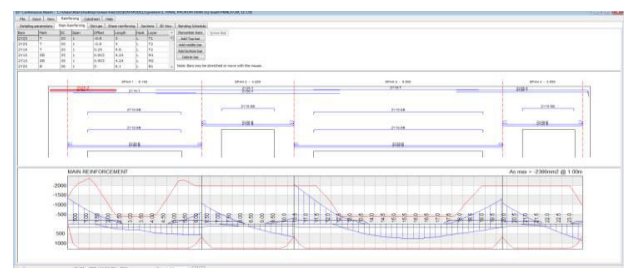

Fig 11: Design of beam for flexure
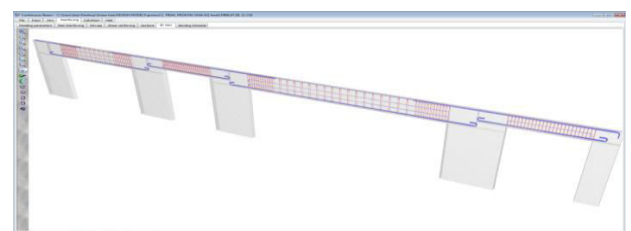
**Fig 12: Reinforcement details of beam**

Foundation: As the geotechnical reports say that water table is at 2 m below the earth and parking area at the stilt level it is necessarily require raft foundation. Raft foundation is modelled in Safe software. Material property for foundation is C35, E=27000, u=0.2, steel Fe 500. Mat with 350 mm thick is assumed for podium and 900 mm is assumed to precast storeys. Soil sub grade is 2, 50, 000 kN/m³. Forces from top of the Precast and in-situ slab are given at their nodes this can be done by importing base from Etabs model. A consecutive load of Live load 5 and 2.5 is considered for drive way and parking. Assuming the depth of slab and spreading area of 1.5 m on either sides and 1 m on top & bottom. Loads on slab like LL and water table pressure are assigned. For design of raft assign strip layers in X and Y direction with 1 m width. Design the raft for bottom and topreinforcement bars with spacing. Designing strip layers A and B for flexure and shear. Checking is possible for reinforcement and increase if necessary. Providing additional reinforcement for punching shear if exceeds 1.
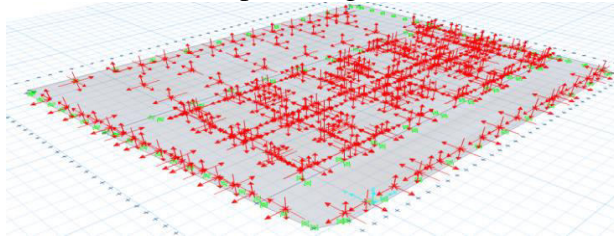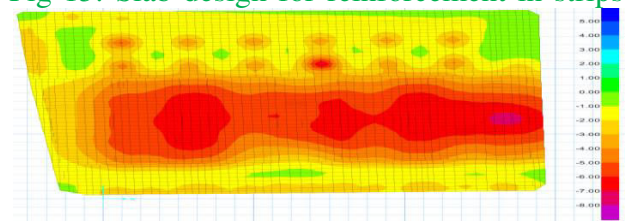

Fig 13: Forces taken for foundation design in Safe
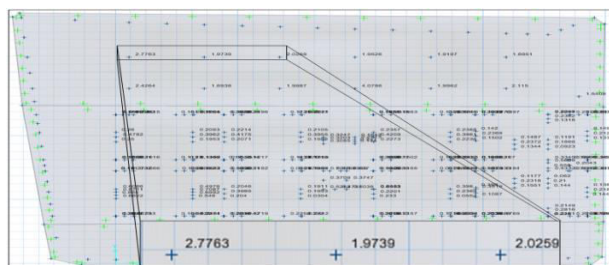
Fig 14: Punching shear values for the raft
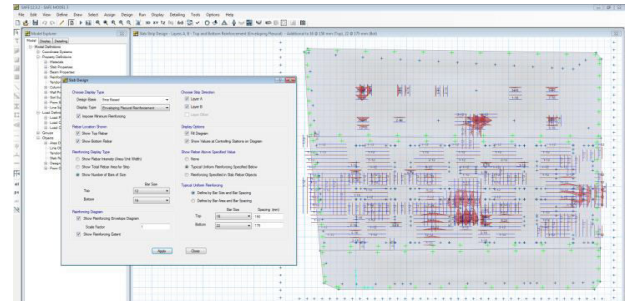
Fig 15: Slab design for reinforcement in strips

Fig 16: Slab deflection under SLS load combination

Shear wall Design:

Design of precast columns is similar to in-situ columns. Design of connections also decides the column design. Various connection methods are taken into consideration while connecting the col-col, col-beam and col-foundation, accordingly reinforcement is placed in the column. Instead of columns shear walls are taken in the building. Shear walls are finely discrete where beams are connecting to have load distribution. Hence when coming to results these walls will have different forces hence pier is assigned to have unique identification and unique forces for the wall. Precast shear walls provide large in plane stiffness and strength. Ultimate wind forces of the structure are transferred by diaphragm action of the floor to the stability walls. Additional vertical tie reinforcement is to be designed for the shear walls.

Precast Connections:

Designing for Precast connections is a challenge for the structure because the wall has 200 mm width restricted and core wall 250 mm width. Accommodating the connections at different joints like interior joints with four

beams, exterior joints with 1, 2 and 3 beams connecting. Connection between wall to wall and wall to beam to carry sufficient moment and at the joint to resist horizontal and vertical shear coming from gravity and lateral loads. Loop bars and Cottering bars are provided to cast-in place concrete at the joint. Cottering bars connect the loop bars with the shear wall and beam.

At some locations topping bars are bent into the wall reinforcement to have additional moment transfer from the beams. Fig 18 shows external wall to beam joint. Loop bars are accommodated at the bottom of beam and topping bars are bent to take negative moments. External joints are on the rear end of building positioned in X direction hence lateral moment at the joint governs the design. The joint is critical since moment at this joint due to gravity loads and lateral loads are higher; hence two loop bars are bent in Y direction to accommodate connection with cottering bars to resist the lateral loads at wall axis. Fig 19 shows the interior joint where two beams are joining. The topping bar reinforcement continues into the next beam and this bar takes care of negative moment and as internal tie which has the capacity ofresisting 60 KN against progressive collapse. Bearing of 20 mm is provided. 10 mm bars are provided on both sides of beam connecting loop bars, also at the edge of beam to resist bearing and shear failure at the joint.

Fig 20 shows the typical internal joint where it has to resist a moment of 242 kN-m of lateral load and 93.5 kN-m due to gravity loads. Hence cottering bars of 20 mm dia are provided that protrudes from column and connecting the loop bars from beams and peripheral bars coming in the joint. The moment of resistance is sufficient for connecting the beams and lateral loads are distributed in diaphragm action.
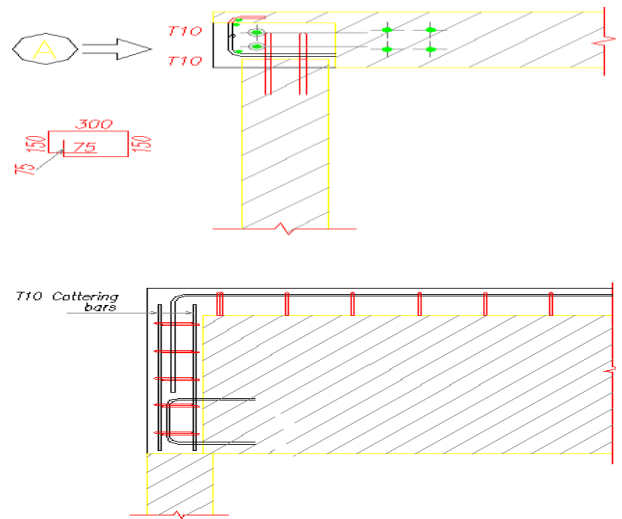

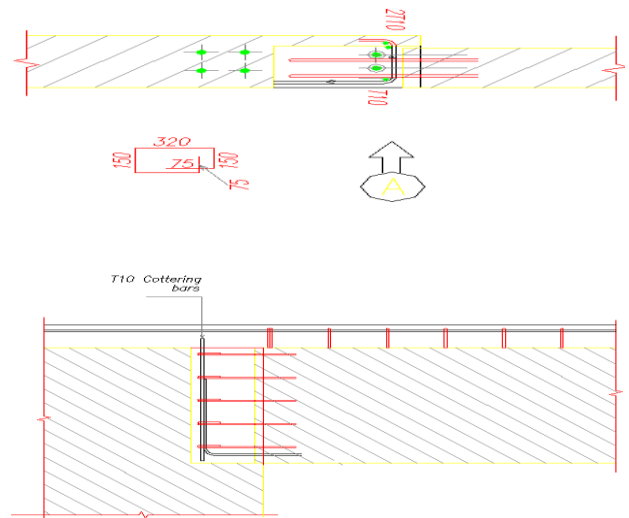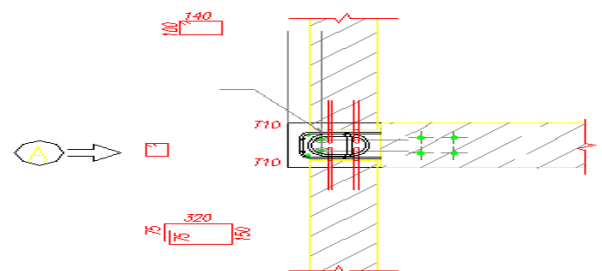Fig 17: Exterior wall beam connections with cottering bars and topping bars connection

Fig 18: Detailing Interior wall to beam connection having loop bars with cottering bars.
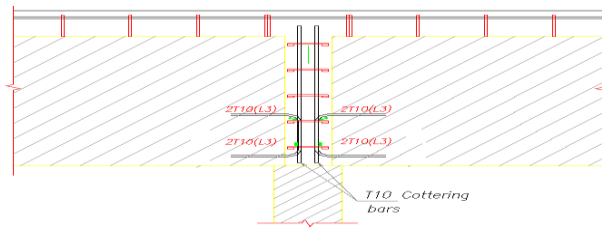
Fig 19: Typical Connection details

4. CONCLUSION

Precast buildings have challenges in design of elements to meet the requirement. Connection details are most challenging for the restrictions in their sizes. Design is done for the precast planks in concise beam, it is utmost necessary of shoring for the 5 m spanning slab plank since deflection criteria governs the design. Beams are semi precast and individually designed by considering transverse reinforcement for 900 mm depth. Shear walls are designed for pier forces. Foundation should be raft foundation as the water table is at 2m depth which exerts pressure on the slab. Connection details are accommodated for 900 mm deep beam with 200 mm shear wall with cottering bars and loop bars to resist the lateral and gravity moment by offering resistance to the design moment. Hence the entire structure is designed for lateral and gravity loads.

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