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Analysis and Design of Precast Building with Load Bearing Walls and Looped Slabs

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ABSTRACT: The construction industry, which is extremely important economically anticipates rapid technological advancements in order to maintain its current growth rate. Precast construction is increasing popularity in general and in urban areas in particular, due to this rapid expansion of urban infrastructure. Despite the fact that the technology was developed many years ago and its implementation in our country is not up to the mark. Precast construction, along with standardization and mechanization, has got a significant impact on the construction industry's development over the last few decades. In this study, we studied different precast topics in detail, combed through a significant amount of literature, and found relevant information. The method for analysing and designing precast buildings is presented in this study. Analysis is done through ETABS to obtain gravity loads, lateral loads and moments. Precast load bearing wall and precast looping slab design require a lengthy, time-consuming, and complex design process, so in this project, an automated excel spread sheet is used to create a design of precast load bearing wall and a precast looped slab. Tie reinforcements, reinforced shear keys, and dowel bars give the structural integrity and emulative monolithic system that is suitable for moderate seismic zones.

KEYWORDS: Precast building, Precast load bearing wall, Looped slab, ETABS, Excel spreadsheet.

I. INTRODUCTION

Construction is a significant indicator of any developing country's prosperity, as it generates productivity in major economic sectors as well as many physical assets such as buildings and infrastructure. The construction sector in India contributes about 8% of the country's GDP. In India. If the infrastructure development gap (say, GDP planned 9% vs actual 6%) widens, as a result there will be negative impact and burden on various economic sectors such as cement, steel, housing and on the social employment sector. India has made significant advancements in the construction of concrete, steel, and mixed-type structures, Because of the massive demand for new homes and urban infrastructure in India, pre-engineered steel buildings with cold formed pieces have gained popularity. As a result, the time has come for pre-engineered concrete structures with precast components. By using prefabrication, the entire project completion time can be lowered to 1/5th of the actual in-situ construction time.

II. CONVENTIONAL IN-SITU AND PRECAST CONSTRUCTION

In a traditional in-situ technique, the majority of building tasks follow a sequential pattern. For example, after foundation works, major activities such as casting concrete columns with dowel reinforcement, shuttering arrangement at beams and slab levels, reinforcement transport to the floor level, placing and tying of main and shear reinforcement in beams, arrangement of floor slab reinforcement, placing of electrical conduits etc. Completion of each activity is determined by the amount of manpower physically available on site. In traditional in-situ construction, a 300-500 m² floor slab could take 30-45 days to complete. In traditional practice, productivity indices are strongly dependent on the type of labour, quantity of competent workers, job site environment, resource availability, and quality standards practiced, and will vary at random from site to site and floor to floor.

If the same procedure is followed with a precast floor slab construction system, the activities will be reduced, after casting of the elements at the precast yard, to major activities such as site transport of precast units, lifting and aligning, placing of a few temporary props, and completion of slab connection to columns and beams. The productivity indices of precast construction can be greatly increased over traditional approaches. Because the precast elements are



manufactured in a controlled environment, the quality of the concreting, installation of service ducts, curing, and other processes will be completed on time, on budget, and to the highest quality standards.

III. MERITS OF PRECAST CONSTRUCTION

The advantages of precast construction over cast-in-situ construction methods can be divided into three categories. ie Quality, Production time and Cost.

a. QUALITY

Because of the industrial production, high degree of repetition, dimensioning, and standardization in a well-protected environment, labour at a prefabrication plant or a precasting yard is considerably more structured in their work schedule and can do their work with ease, resulting in more efficient quality management and better craftwork.

All seasonal effects of hot, cold, or rainy weather site construction issues are minimized in an ideal manufacturing setting, resulting in a more stable environment for continuous production with constant quality.

b. PRODUCTION TIME.

Due to strong planning, simultaneous manufacturing and delivery of a variety of structural and architectural components in winter, high summer, or rainy seasons in the case of factory items, construction schedules can be cut to a very short period, even at the erection, crane handling, and very little on-site work, precast construction sites require minimal trained labour. Even unskilled personnel would be capable of doing repetitive work with quality after 10 to 15 castings.

Wall and floor panels can be produced in batteries and tilting moulds in the construction of tenements and multi-story buildings, boosting productivity and reducing the requirement for a large number of specialized workers. The building of such elements, on the other hand, necessitates the use of tower cranes, mechanization, efficient design, and joint execution.

c. COST

In contrast to formwork for cast in-situ concrete, the use of concrete, timber, and steel moulds for standardized goods will expand the scope for repetition. Concrete moulds can readily be repeated 100 times, plywood moulds 25-50 times, and steel moulds 500-2,000 times. This lowers the cost of converting the required shape to concrete. Even when compared to in-situ concrete, structurally beneficial sections such as the "I" section, "channel" section, and "hollow" section are achievable with precast concrete, reducing concrete reinforcing by 20% to 30% and delivering cost savings due to less dead load in structure design.

The best use of concrete, steel, with and without pre-stressing systems, limited use of temporary support scaffolding, better supply chain management in mass manufacturing in factories, faster project completion results in to affordability in construction.

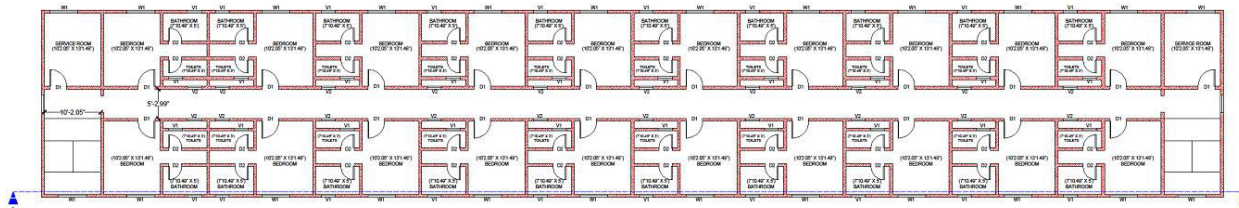
IV. MODELLING ANALYSIS AND DESIGN OF PRECAST STRUCTURE

In this present study, G+5 story precast load bearing wall structure is taken for analysis. The modelling and analysis has been done in using ETABS. Design of precast components are done with the excel spread sheets.

a. BUILDING DESCRIPTION.

Table 1 Building description

Utility of building	= University Hostel Building
Considered location	= Bangalore.
Number of stories	= G+5.
Building measures for typical floors	= 12,480 SQFT.
Typical floor height	= 3 m.
Number of Rooms/floor	= 22 rooms on each floor with attached washroom.
Type of construction	= Precast load bearing structure.
Structural components	= load bearing walls and looped slab.

b. ARCHITECTURAL PLAN.**Fig 2 Architectural plan****V. PRECAST STRUCTURAL COMPONENTS****a. PRECAST LOAD BEARING WALL PANEL.**

They are conventional reinforced manufactured cast on-site concrete panel know as tilt-up wall panels. The cumulative axial load, in-plane bending moment, and shear force are all considered while designing a panel. The horizontal and vertical joints between the panels are emulative, as indicated under large panel systems. When a panel contains openings, additional reinforcement is added around the openings.

b. PRECAST LOOPED SLAB.

These are solid components that span in two directions and have a notch along the slab's edges, where nearby wall rebar and a new concert will be placed. At the slab's edge, loop reinforcement has been added, which acts as a tie beam with the adjacent slabs.

VI. LOADS CONSIDERATION**a. DEAD LOAD:**

Dead Load is computed considering density of reinforced concrete as 25 KN/m³ in accordance with IS 875 (Part 1):1987.

b. LIVE LOADS:

Live load is taken as 2.55 KN/m² for room, bathrooms and corridor. 5.55 KN/m² for store room in accordance to the IS 875 (Part2):1987.

c. Seismic Load Parameters Considered as Per Is: 1893-2016 (Part 1) Are:

Zone factor, $Z = 0.10$

Importance factor, $I = 1.2$

Response reduction factor, $R = 3$

d. WIND LOAD PARAMETERS:

Basic wind speed, $V_b = 33$ m/s,

Terrine category = 2,

Structure class = 3.

VII. STRUCTURAL ANALYSIS.

The wall is designed considering M30 concrete and Fe-500 steel. Wall thickness considered is 170mm and defined as shell-thin element. Whereas slab thickness is 125mm and assigned as a membrane element. Story height is 3m. Openings in the walls due to doors and windows are incorporated at the time of structural design. Walls have been automatically meshed to a maximum mesh size of 1m and Slabs are also meshed using default meshing option in ETABS. Each wall is assigned with a pier label individually to make exact identification and also for extracting results easily, so that axial loads, shear force and bending moment are accounted for the design of walls. shows the 3D model of the building.

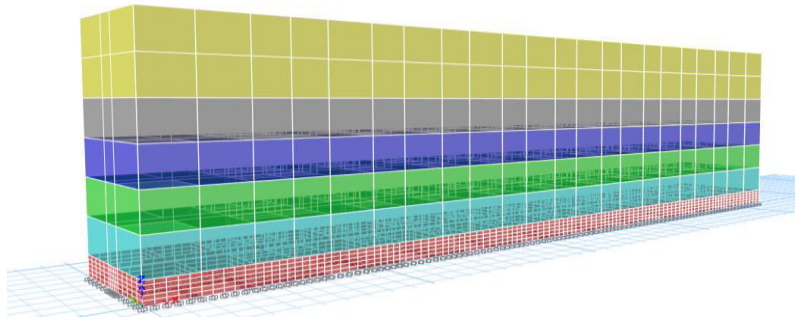


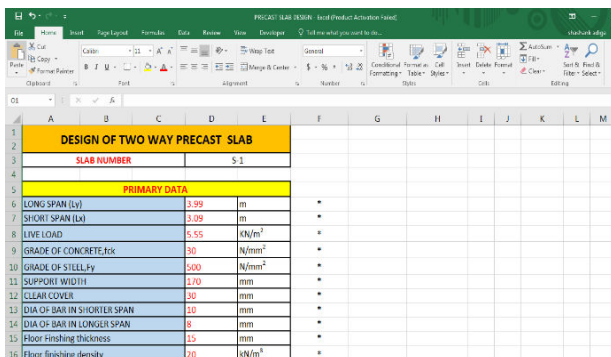
Fig 3.3D view in ETABS

VIII. DEVELOPMENT OF AUTOMATED EXCEL SPREAD SHEET

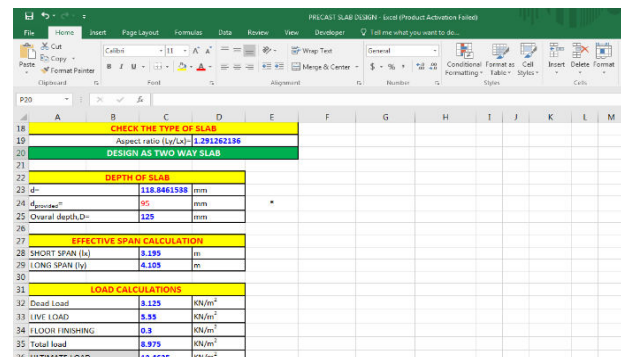
The manual design of precast components even for a small structure is laborious and time consuming. The use of specific precast design software involves high cost, unsupported version for Indian codes and software skill. Thus This project deals with the development of simple tool using excel spread sheet which is an automated for designing the precast components like load bearing walls and notch looped slab, using an analysis results, which is done for the precast structure from the ETABS 2018 software.

a. DESIGN OF PRECAST LOOPED SLAB USING AUTOMATED EXCEL SPREADSHEET.

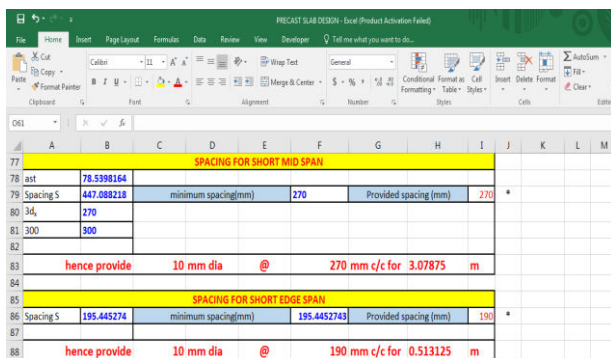
Below are the sample automated excel spreadsheet snapshot, where only primary data is going to be inputted, rest other it is going to calculate automatically.



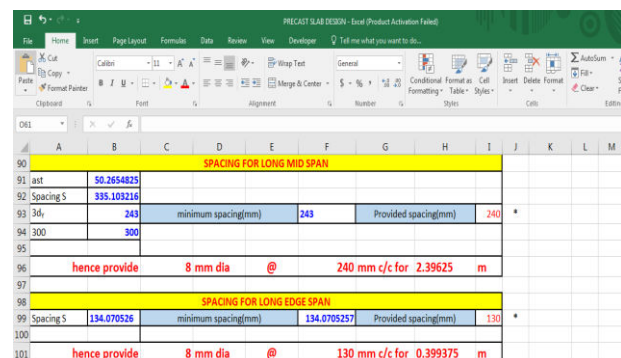
DESIGN OF TWO WAY PRECAST SLAB			
SLAB NUMBER S.1			
PRIMARY DATA			
LONG SPAN (Lx)	5.09	m	*
SHORT SPAN (Ly)	5.09	m	*
LIVE LOAD	5.55	kN/m ²	*
GRADE OF CONCRETE	30	N/mm ²	*
GRADE OF STEEL	500	N/mm ²	*
SUPPORT WIDTH	170	mm	*
CLEAR COVER	30	mm	*
DIA OF BAR IN SHORTER SPAN	10	mm	*
DIA OF BAR IN LONGER SPAN	8	mm	*
Floor Finishing thickness	15	mm	*
Floor finishing density	20	kN/m ³	*



CHECK THE TYPE OF SLAB			
DESIGN AS TWO WAY SLAB			
DEPTH OF SLAB			
Effective depth (d)	118.846158	mm	*
Overall depth (D)	125	mm	*
EFFECTIVE SPAN CALCULATION			
SHORT SPAN (Ly)	5.09	m	*
LONG SPAN (Lx)	4.105	m	*
LOAD CALCULATIONS			
Dead Load	0.125	kN/m ²	*
LIVE LOAD	5.55	kN/m ²	*
FLOOR FINISHING	0.3	kN/m ²	*
Total load	6.975	kN/m ²	*
ULTIMATE LOAD	19.4625	kN/m ²	*



SPACING FOR SHORT MID SPAN			
ast	78.5396164		
Spacing S	447.086218	minimum spacing (mm)	270
3d _s	270	Provided spacing (mm)	270
300	300		
hence provide 10 mm dia @ 270 mm c/c for 3.07875 m			
SPACING FOR SHORT EDGE SPAN			
Spacing S	195.445274	minimum spacing (mm)	195.4452743
		Provided spacing (mm)	190
hence provide 10 mm dia @ 190 mm c/c for 0.513125 m			



SPACING FOR LONG MID SPAN			
ast	50.2654825		
Spacing S	935.109216	minimum spacing (mm)	243
3d _s	243	Provided spacing (mm)	240
300	300		
hence provide 8 mm dia @ 240 mm c/c for 2.39625 m			
SPACING FOR LONG EDGE SPAN			
Spacing S	134.070526	minimum spacing (mm)	134.0705257
		Provided spacing (mm)	130
hence provide 8 mm dia @ 130 mm c/c for 0.399375 m			

Fig 3 snap shot of precast looped slab design in excel spreadsheet

b. Design of precast Load bearing wall using automated excel spreadsheet.

Get the pier forces of each walls from the several load combinations from ETABS analysis. Get the maximum axial force, maximum shear force and maximum bending moment values of each walls from the pier force table. The maximum values from the pier forces table, to be input to the automated excel sheet for the designing of precast load bearing wall.

Below are the sample automated excel spreadsheet snapshot, where only primary data and the maximum pier forces values to be inputted, rest other it is going to calculate automatically.

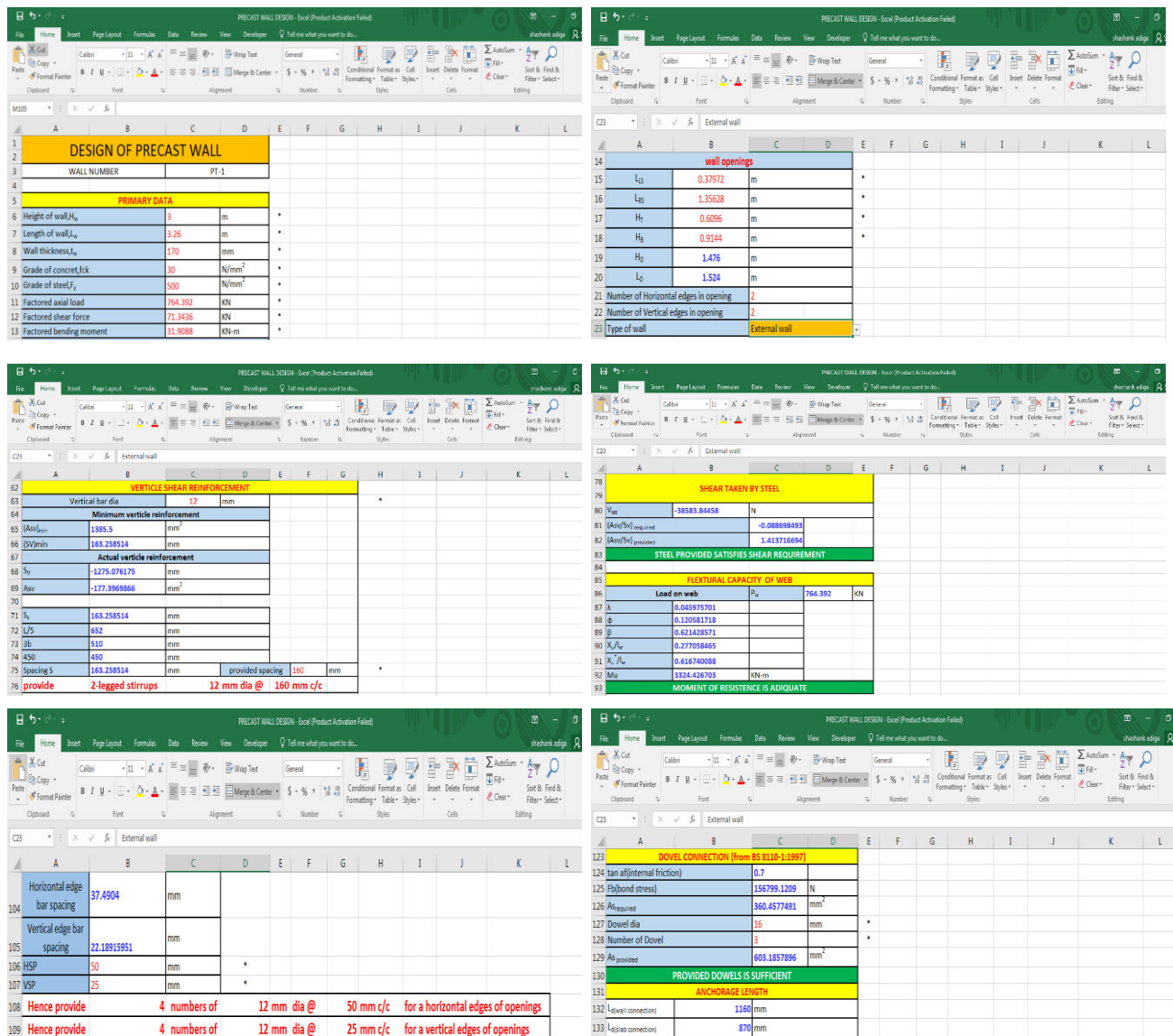
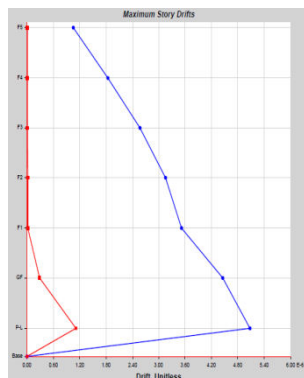
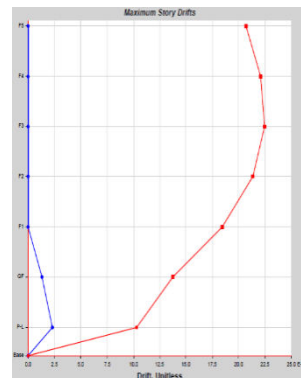


Fig 4 snap shot of precast load bearing wall design in excel spreadsheet

IX. ANALYSIS AND DESIGN RESULTS.



Story Response Values				
Story	Elevation	Location	X-Dir	Y-Dir
m				
F5	19.7	Top	0.000001	1.174E-08
F4	16.7	Top	0.000002	1.317E-08
F3	13.7	Top	0.000003	1.453E-08
F2	10.7	Top	0.000003	1.591E-08
F1	7.7	Top	0.000004	1.573E-08
GF	4.7	Top	0.000004	2.896E-07
P-L	1.7	Top	0.000005	0.000001
Base	0	Top	0	0



(d)

(e)

Fig .5 Maximum story Drift in X-direction

Fig .6 Maximum story Drift in Y-direction

a. PRECAST LOOPED SLAB DESIGN DATA.

Table 2 Precast looped slab design data

SLAB NO	EFFECTIVE SLAB DIMENSION (m)	SPACING FOR SHORT MID SPAN FOR A DISTANCE	SPACING FOR SHORT EDGE SPAN FOR A DISTANCE	SPACING FOR LONG MID SPAN FOR A DISTANCE	SPACING FOR LONG EDGE SPAN FOR A DISTANCE
F2	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 230mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 150mm c/c for 0.4046875m
F1	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m
F5	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m
F3	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m
F9	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m
F11	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m
F12	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 230mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 150mm c/c for 0.4046875m
F15	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m
F17	4.105 X 3.195	10mm ϕ 270mm c/c for	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m

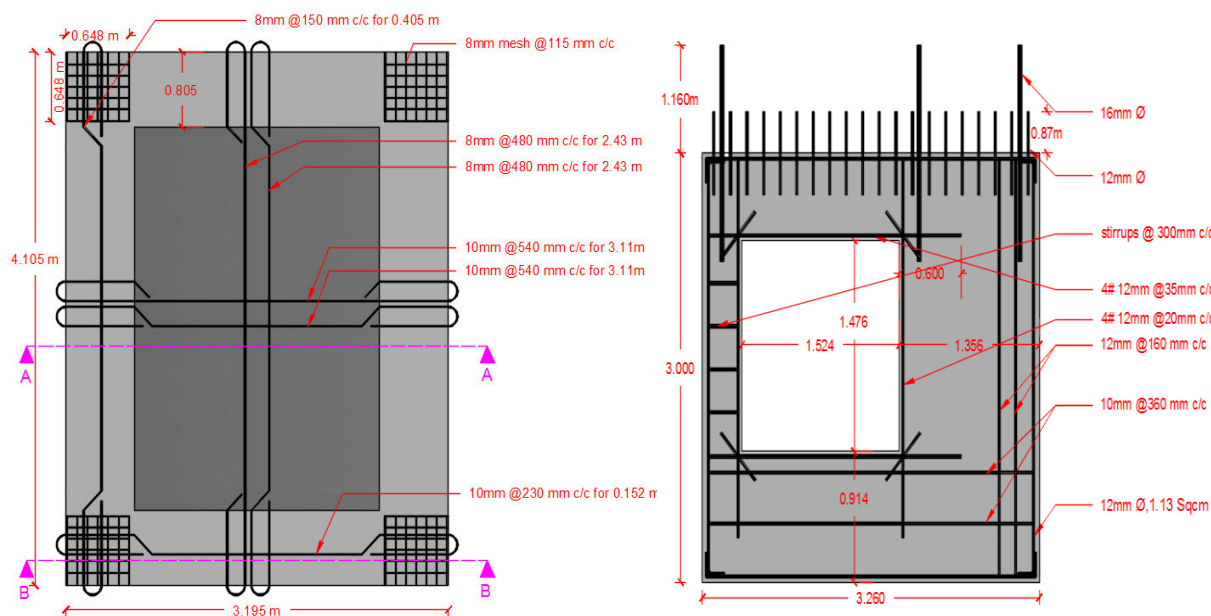
		3.109125m			
F19	4.105 X 3.195	10mm ϕ 270mm c/c for 3.109125m	10mm ϕ 270mm c/c for 0.5181875m	8mm ϕ 240mm c/c for 2.428125m	8mm ϕ 220mm c/c for 0.4046875m

b. PRECAST LOOPED SLAB DESIGN DATA.

Table 3 Precast load bearing wall design data

PIER LAB LE	P(KN)	V(KN)	HORIZONTAL SHEAR REINFORCEMENT	VERTICLE SHEAR REINFORCEMENT	REINFO RCEME NT AT THE HORIZ ONTAL EDGE OF OPENIN GS	REINFO RCEME NT AT THE VERTIC AL EDGE OF OPENIN GS	NUMBE RS OF DOWEL S
PT-23	583.28 32	63.457 4	10mm ϕ 360mm c/c	12mm ϕ 160mm c/c	5 # 12mm ϕ @ 60mm c/c	5 # 12mm ϕ @ 10mm c/c	3 # 16mm ϕ
PT-24	592.40 58	111.28 04	10mm ϕ 360mm c/c	12mm ϕ 160mm c/c	5 # 12mm ϕ @ 60mm c/c	5 # 12mm ϕ @ 10mm c/c	4 # 16mm ϕ
PT-25	482.63 64	44.059 5	10mm ϕ 360mm c/c	12mm ϕ 200mm c/c	2 # 12mm ϕ @ 20mm c/c	2 # 12mm ϕ @ 25mm c/c	3 # 16mm ϕ
PT-26	492.26	26.499	10mm ϕ 360mm c/c	12mm ϕ 200mm c/c	2 # 12mm ϕ @ 20mm c/c	2 # 12mm ϕ @ 25mm c/c	3 # 16mm ϕ
PT-27	638.18 55	53.368 8	10mm ϕ 360mm c/c	12mm ϕ 160mm c/c	5 # 12mm ϕ @ 60mm c/c	5 # 12mm ϕ @ 10mm c/c	4 # 16mm ϕ
PT-28	505.45 01	24.149 9	10mm ϕ 360mm c/c	12mm ϕ 200mm c/c	2 # 12mm ϕ @ 20mm c/c	2 # 12mm ϕ @ 25mm c/c	3 # 16mm ϕ
PT-29	649.91 32	49.308 7	10mm ϕ 360mm c/c	12mm ϕ 160mm c/c	5 # 12mm ϕ @ 60mm c/c	5 # 12mm ϕ @ 10mm c/c	4 # 16mm ϕ
PT-30	510.26 7	24.150 2	10mm ϕ 360mm c/c	12mm ϕ 200mm c/c	2 # 12mm ϕ @ 20mm c/c	2 # 12mm ϕ @ 25mm c/c	3 # 16mm ϕ
PT-31	653.62 42	49.003 1	10mm ϕ 360mm c/c	12mm ϕ 160mm c/c	5 # 12mm ϕ @ 60mm c/c	5 # 12mm ϕ @ 10mm c/c	4 # 16mm ϕ

PT-32	511.87 83	24.158	10mm ϕ 360mm c/c	12mm ϕ 200mm c/c	2 # 12mm ϕ @ 20mm c/c	2 # 12mm ϕ @ 25mm c/c	3 # 16mm ϕ
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X.CONCLUSIONS

The following are some of the conclusions reached as a result of this project:

- 1) Precast concrete components, such as load bearing walls and looped slabs, are joined together to form a structural system or a full structure using in-situ concrete joints or other joining devices and means in this project.
- 2) In this project, the analysis methodology in ETABS is similar to the cast in situ structure. Shell elements are allocated only with pier labelling. Because the percentage of wall opening is smaller than the entire section of wall. If the percentage of wall opening is more than the whole section of the wall, the analysis should include spandrel labelling above the wall opening point.
- 3) Slab elements with restricted depth are used as membrane because the slab span between the slab supports is less. If the slab span between the supports is longer, the deflection will be larger, hence that type of slab should be designed as a pre-stress slab with restricted depth.
- 4) The provided story drift is substantially smaller than the allowable story drift, which is appropriate, according to the precast structure analysis.
- 5) An automated excel spread sheet has been designed to carry out the design calculations for precast looped slab and precast load bearing wall, which helps in the reduction of time, the elimination of large software costs, and the potential of collaboration multiple code parameters in one area.
- 6) The use of a looped slab and an RC wall helps in the monolithic design of the structure because it is internally connected to the adjacent structural components, which appears to be adequate in moderate seismic zones. Internal tie reinforcements, reinforced shear keys, and dowel bars offer the structural stability required for the precast system, allowing for the same result output as a cast-in-place building.
- 7) Depending on the type of component, production/construction process, and functions, the design methodology for various types of precast concrete structures may differ or need to be updated. Although a number of extra structural parameter elements such as effective span, support moment, and connection details must be closely considered in the case of precast structural design, the design principles are essentially the same as those that apply to in-situ construction.
- 8) It is important that the designer, manufacturer, and builder understand and accept the fundamental difference in the design of in-situ and precast concrete structures. While in an in-situ construction, because of the redistribution of forces made feasible by the monolithicity of construction, isolated sections of a structural element showing inadequacy of strength or bad detailing cannot have major implications on the structure as a whole. this is not the



case in precast construction. Individual precast components may have been properly designed and may have the required strength, but if they are not properly assembled and connected together to satisfy the assumptions made in their analysis and design, the overall structure's or a significant portion of its safety may be jeopardized, especially in situations where lateral loads play a dominant role. As a result, the overall structure's stability is essential.

- 9) Indian code for precast design has several limitations due to the lack of revision edition in accordance with the present practice like number of dowels for horizontal wall to wall connection, spacing of opening edge reinforcement and so on. As a result, there will be a collaboration of other codes also.
- 10) From this project we identified that standard & repetitive work precast is the best option to choose, which helps in economical design.
- 11) Shear key connections are commonly used in vertical joints. Different companies have different shear key models, and the vertical shear design parameter varies greatly depending on the shear key brand.
- 12) In this project the horizontal joint between the wall panels is generally made by projecting dowel bars from lower walls, inserted into the dowel tubes of upper wall and grouted using high strength non-shrink, non-metallic grout and because of the looping slab, the horizontal joints between the slabs usually do not have shear key.

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