G+7 Storeyed Prefabrication Structure Design and Implementation

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Abstract- *This study explains how to analyse and design precast buildings. Precast buildings react differently from cast-in-place structures. The primary goal of this research is to examine and record the behavior of precast structures under gravity and lateral stresses. For this reason, a reference project in Chennai is adopted and modelled in ETABS software to evaluate the structure. Individual precast parts, such as slab planks in Concise beam software, foundations in Safe software, and beams and columns in CSI detail, are designed separately. Assumptions are made in relation to a certain structure.*

Keywords- Slab plank, Etabs, Concise, safe, CSI detail etc.

I. 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.
- 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.
- 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.
- The overall behaviour 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.
- All structural elements forms stable structural system after the joints is connected.

II. OBJECTIVES

- To analyze and design the structure using **ETABS** software.
- To analyze individually for each precast elements like slab planks in **Concise beam** software, Foundation in **Safe** software.
- To do the detailing of beams and columns in **CSI detail.**

III. LITERATURE REVIEW

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.

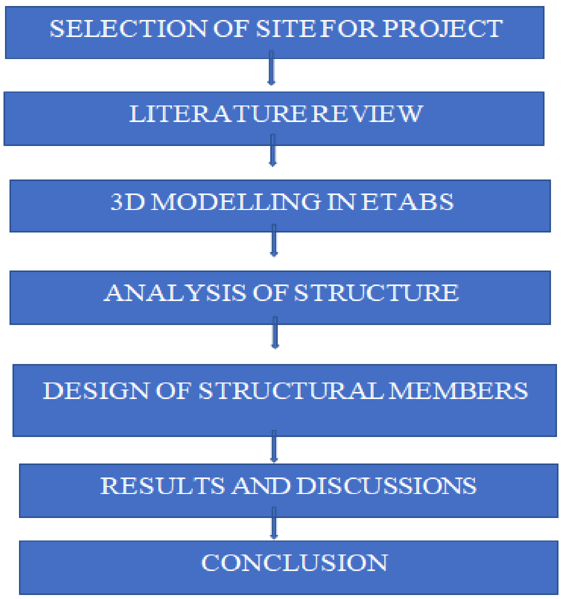
Capozzi et al (2008) - conducted experimental tests on beam-column connections of precast buildings. Both monotonic and cyclic load paths are programmed; the former ones are performed until the ultimate displacement using cyclic tests.

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.

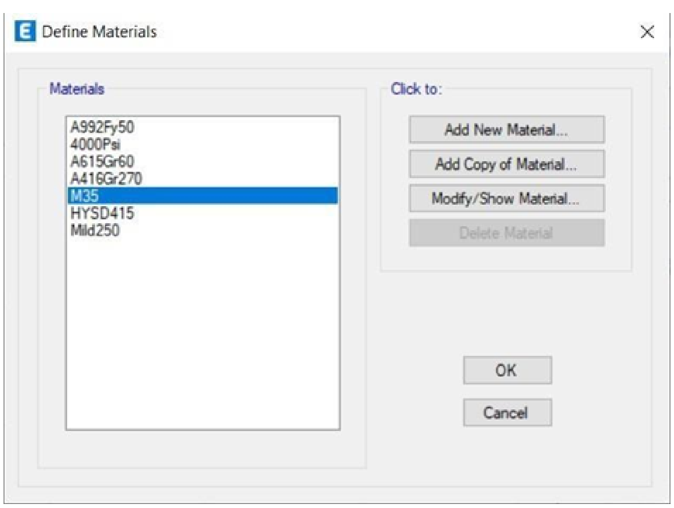
Chaitanya Kumar and Lute Venkat (2013) - analyzed G+11 storey residential building with precast reinforced concrete load bearing walls. The structural system consists of load bearing walls and one-way slabs for gravity and lateral loads have been taken for analysis using ETABS.

IV. METHODOLOGY



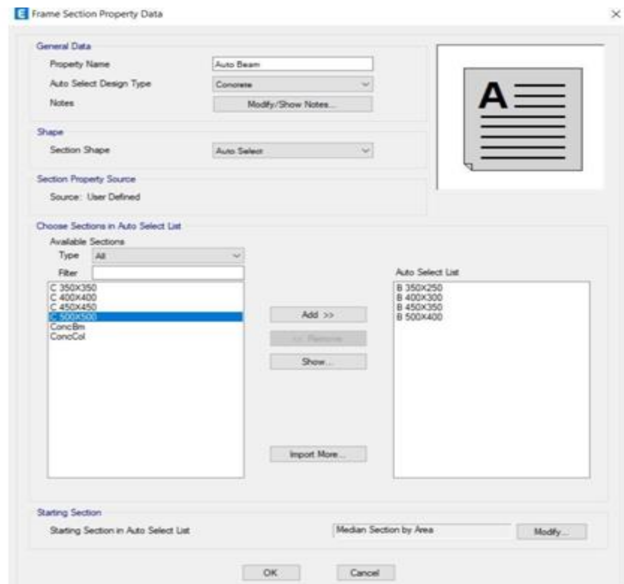
MODELLING

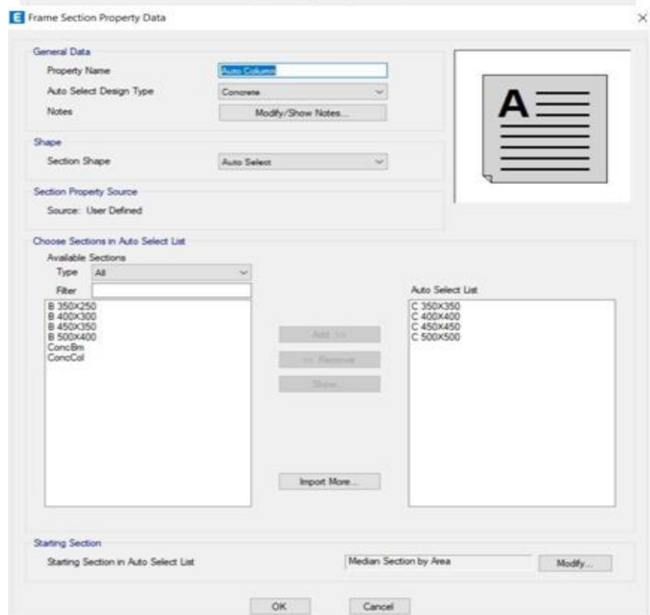
- First the materials in the structural members are defined.
- The grade of concrete is taken as M35.
- HYSD415 (For Longitudinal Rebar) and Mild250(For Tie Rebar) are taken.



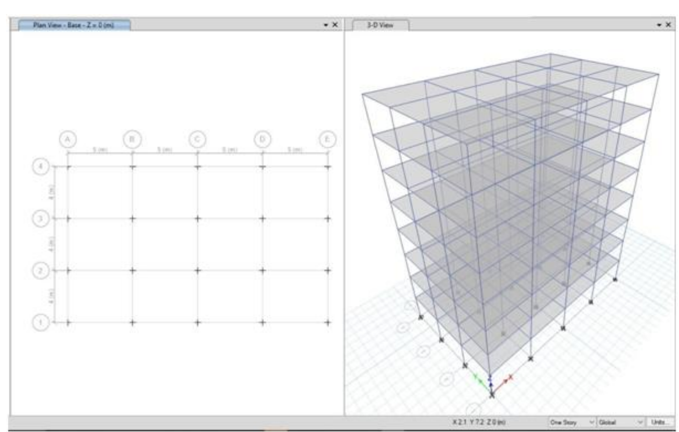
MODELLING

- For beam and column properties auto select option is selected.





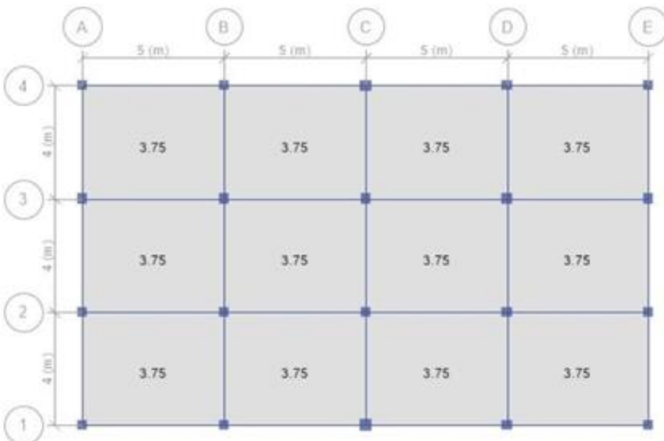
3D MODEL IN ETABS

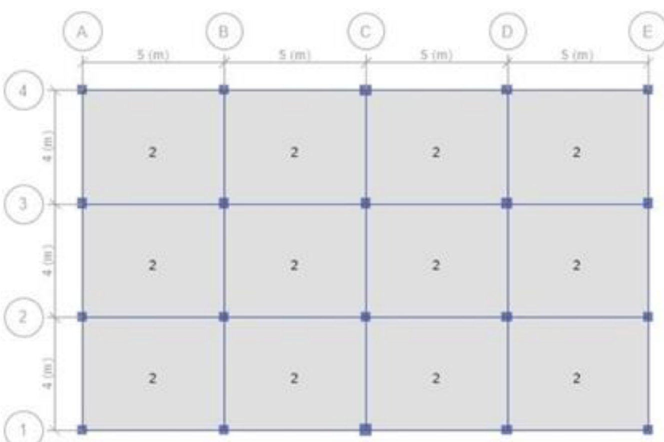


Utility of building: Residential building. Shape of the building: Rectangular.
No of storeys: G+7.
Total length of the building is 20 m. Total Width is 12 m.
Total height is 24 m.
Floor height: 3 m.
Total Built up area is 240 m^2

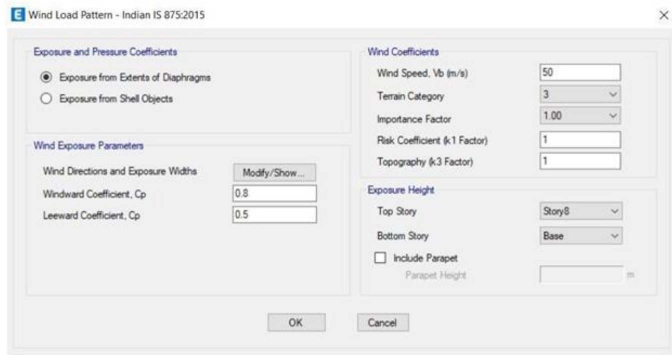
LOAD APPLIED

Dead load = 3.75 kN/m^2
Live load = 2 kN/m^2
Wind load
Seismic load



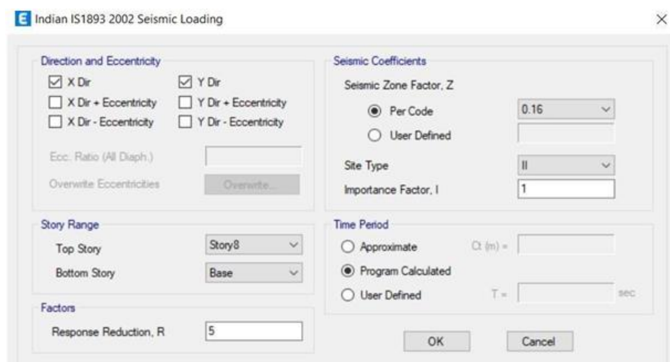


WIND LOAD



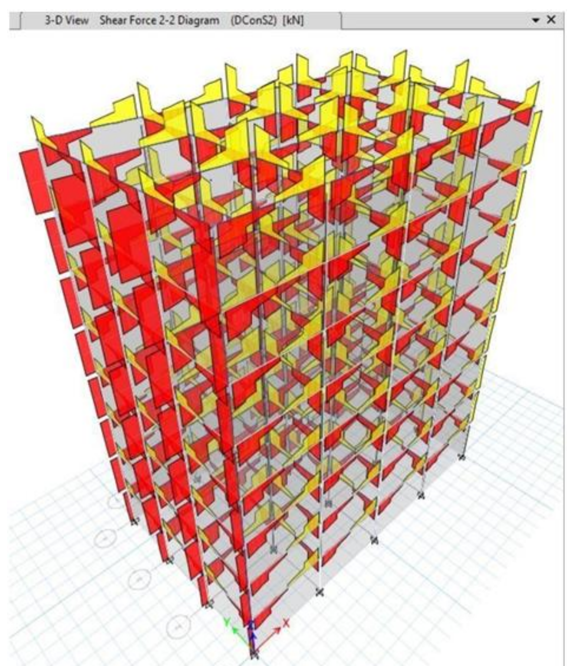
As the Location is Chennai So, wind speed is 50 m/s.

SEISMIC LOAD



As the Location is Chennai So, seismic zone is 3.

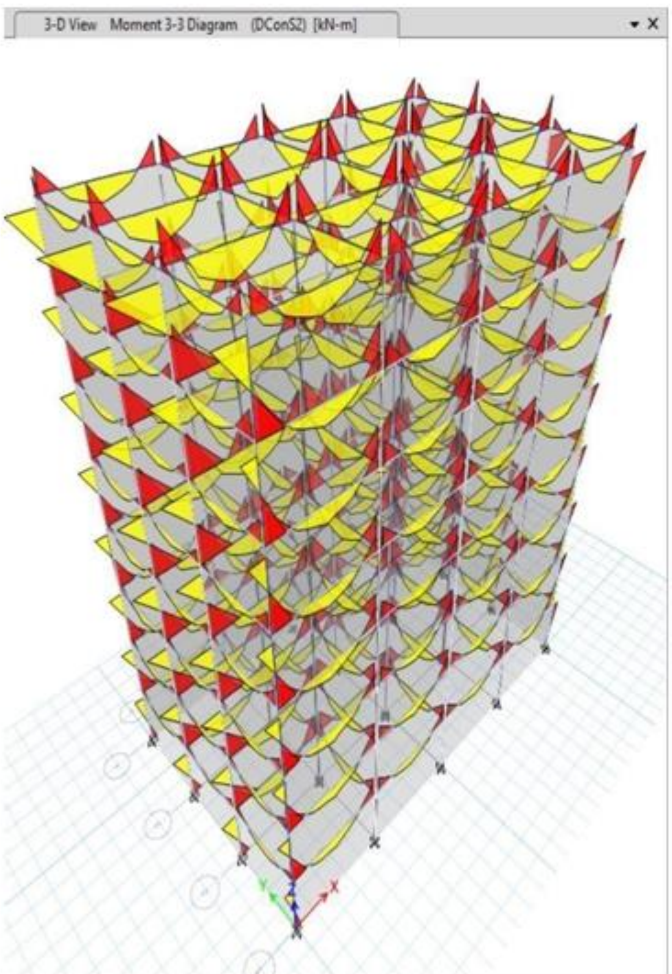
ANALYSIS



1	Story	Beam	Output case	V2 (KN)
2	Story1	B9	DConS9	46.5608
3	Story1	B8	DConS9	44.304
4	Story1	B7	DConS2	43.2052
5	Story1	B6	DConS9	42.8991
6	Story1	B5	DConS2	42.6637
7	Story1	B4	DConS2	41.5207

After the Analysis, this is the maximum shear force diagram we got, this are the maximum shear forces and the maximum shear force is 46.56 kN, that is on Beam 9 of storey 1.

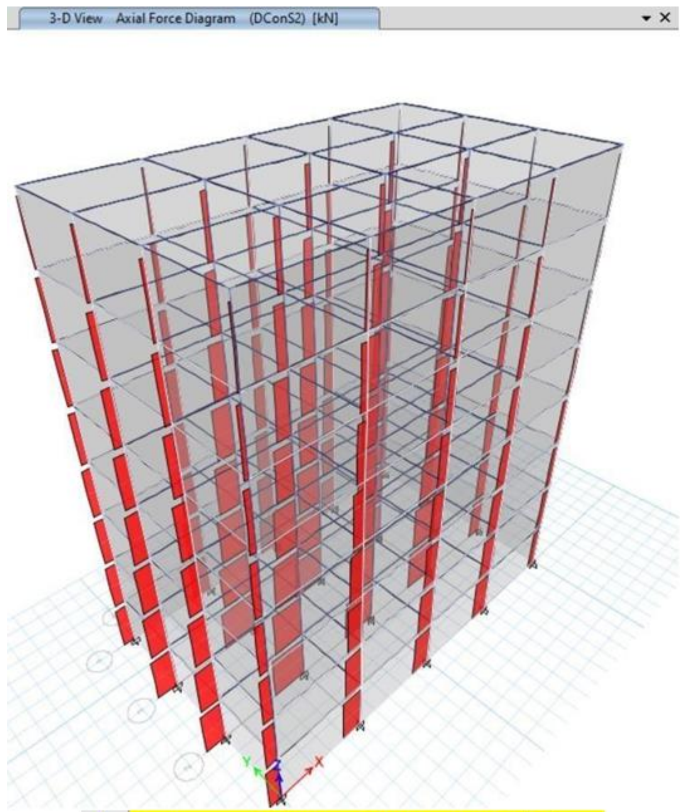
ANALYSIS



1	Story	Beam	Output case	M3 (kNm)
2	Story1	B9	DConS10	-35.0767
3	Story1	B8	DConS9	-34.9897
4	Story1	B6	DConS11	-33.3151
5	Story1	B7	DConS11	-32.5696
6	Story1	B5	DConS11	-32.3713
7	Story1	B4	DConS14	-27.4814

This is the Bending Moment diagram, we got after the analysis and this are the maximum bending moments.

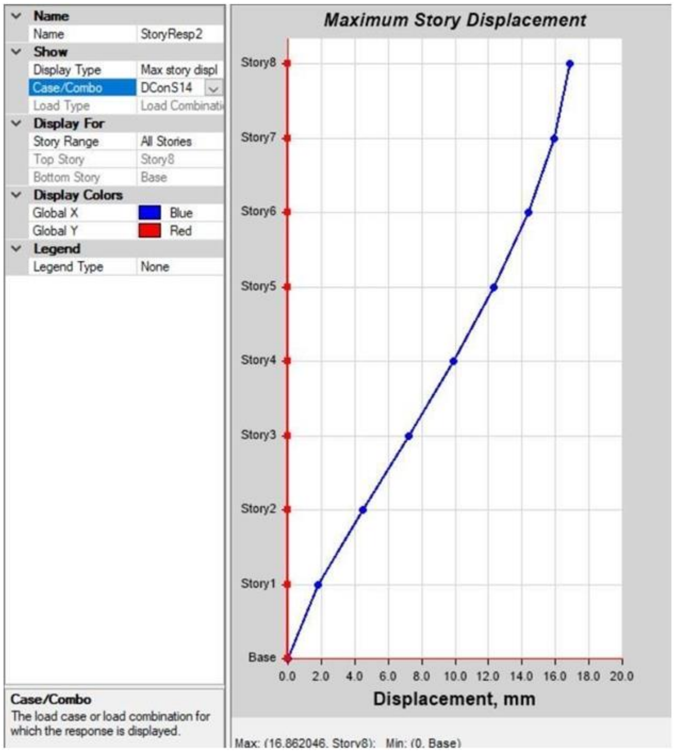
ANALYSIS



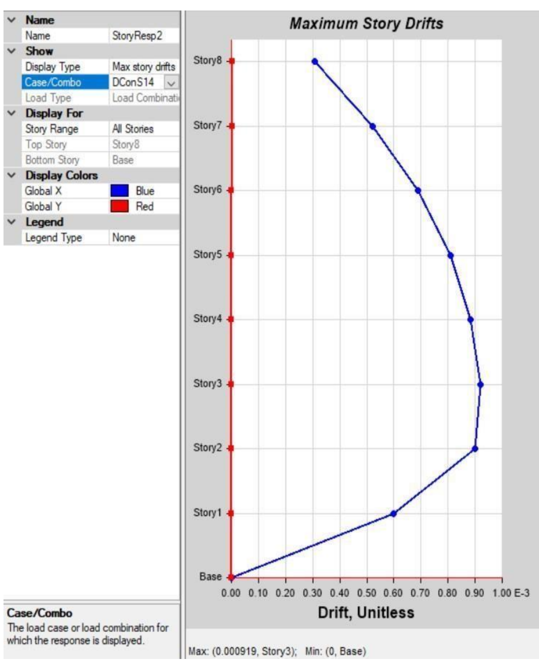
1	Story	Column	Output case	P (kN)
2	Story1	C10	DConS2	-2313.85
3	Story1	C11	DConS2	-2301.68
4	Story1	C14	DConS2	-2299.92
5	Story1	C15	DConS2	-2293.84
6	Story1	C12	DConS2	-1398
7	Story1	C13	DConS2	-1386.81

This is the Axial force diagram and this are the maximum axial force, the maximum axial force is -2313.85 kN that is on Column 10 of storey 1.

MAXIMUM STOREY DISPLACEMENT

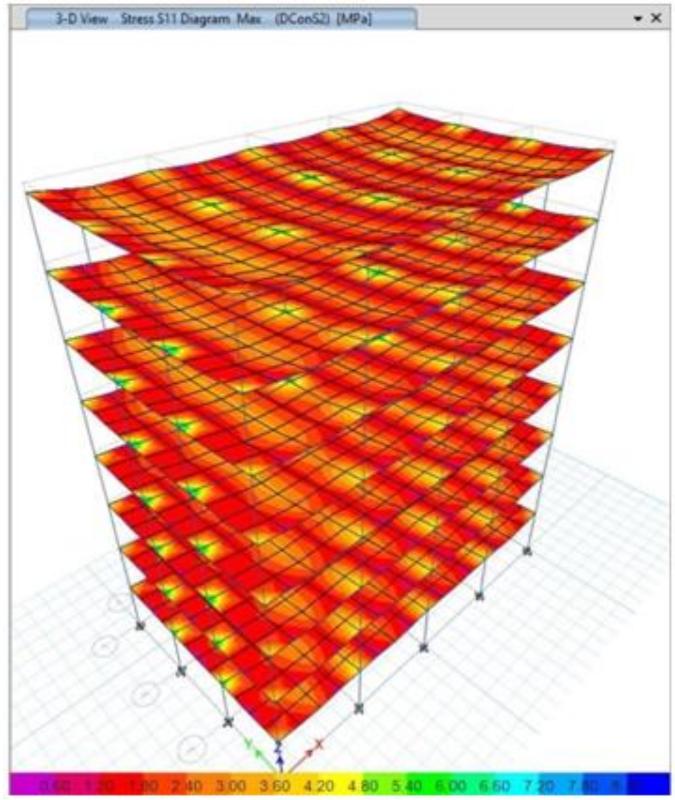


Maximum storey displacement is experienced on the topmost storey 8 and the maximum displacement we got is 16.8 mm.

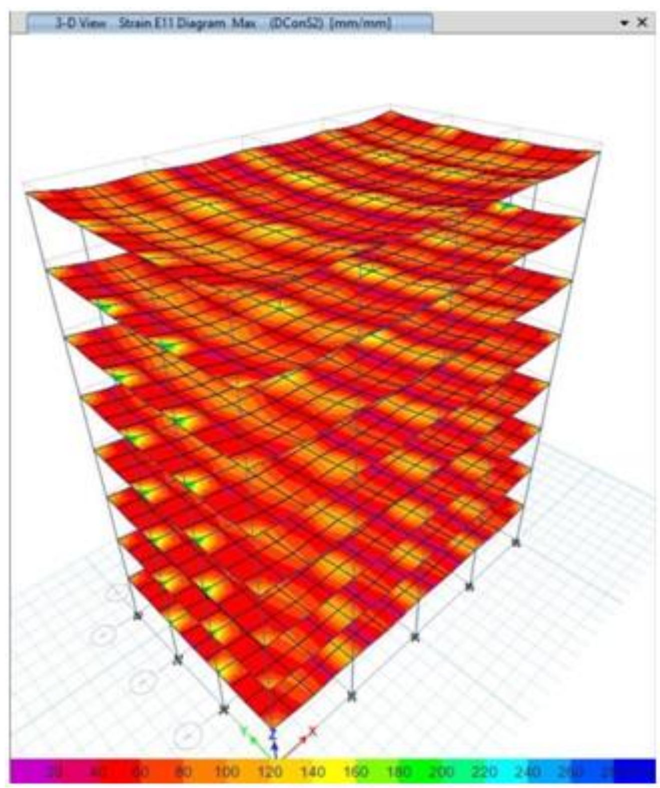


Maximum storey drift is experienced on storey 3 that is 0.000919, as per IS 1893, storey drift shall not exceed 0.004 times of storey height and our case storey height is 3 m, which gives the limit of 0.012 and the maximum storey drift is under the limit. So, it is safe.

MAXIMUM SHELL STRESS & STRAIN

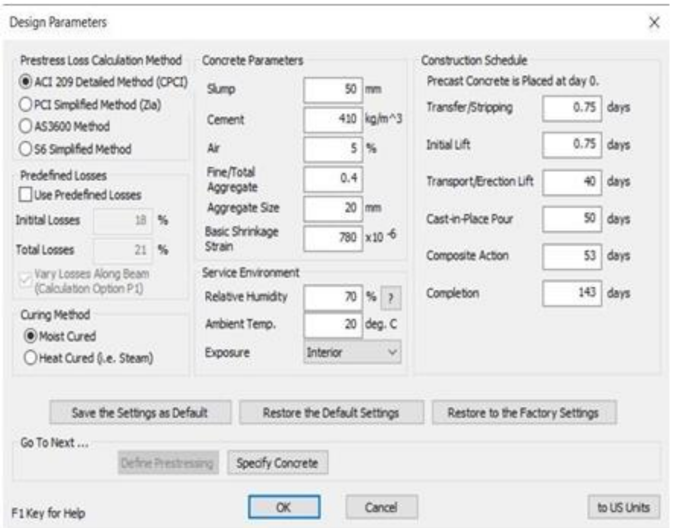


The Maximum principle shell stress value recorded is 6 MPa.

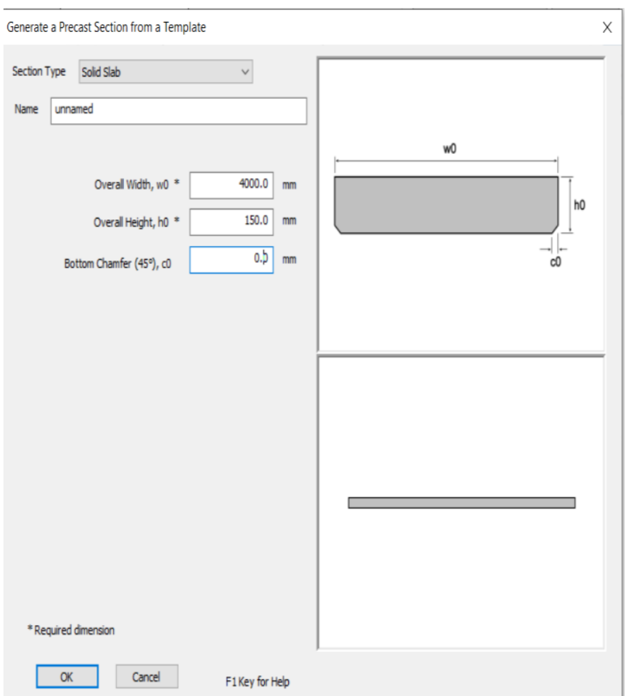


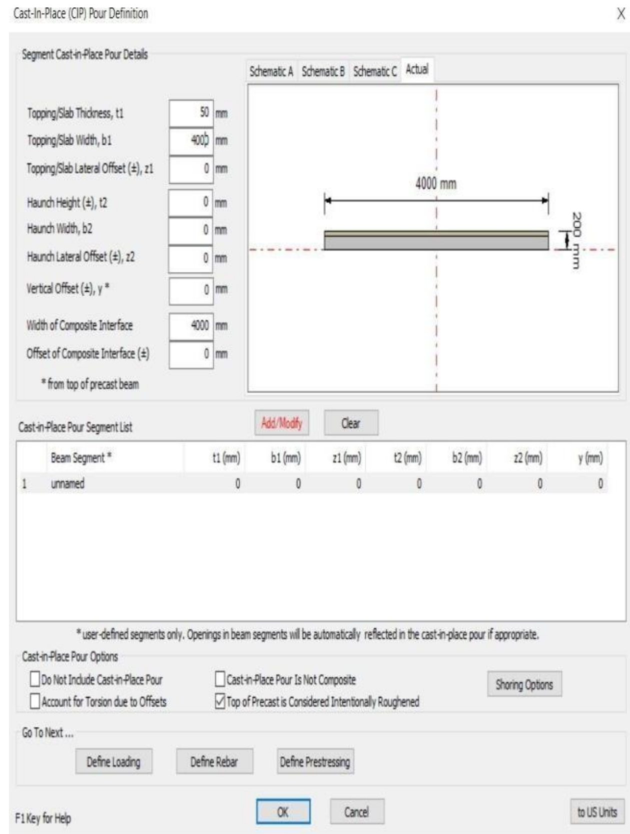
The Maximum principle shell strain value recorded is 200.

PRECAST SOLID SLAB ANALYSIS USING CONCISE BEAM SOFTWARE



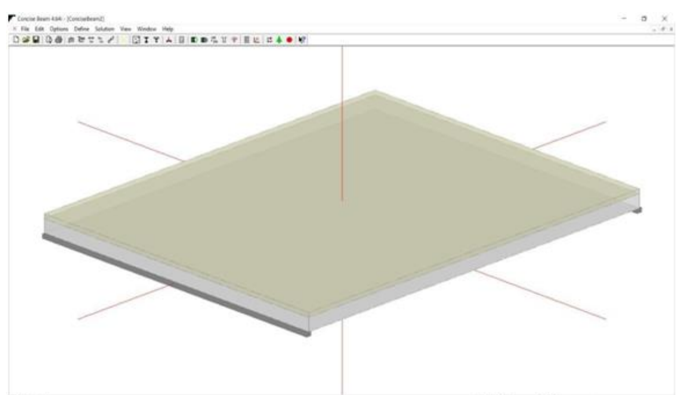
SLAB DIMENSION



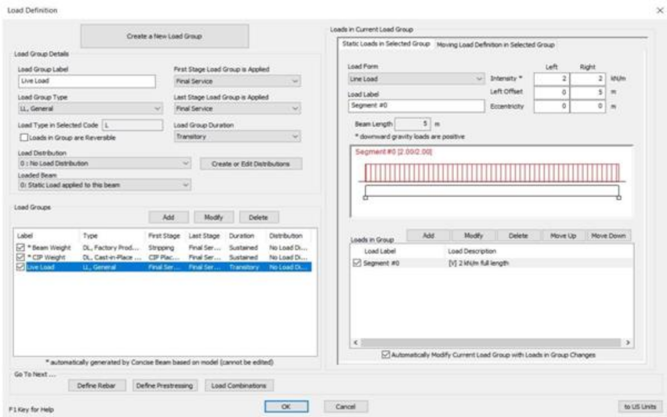


Width of the slab is 4m. Overall height is 0.15m. Length of the slab is 5m.

SLAB 3D VIEW



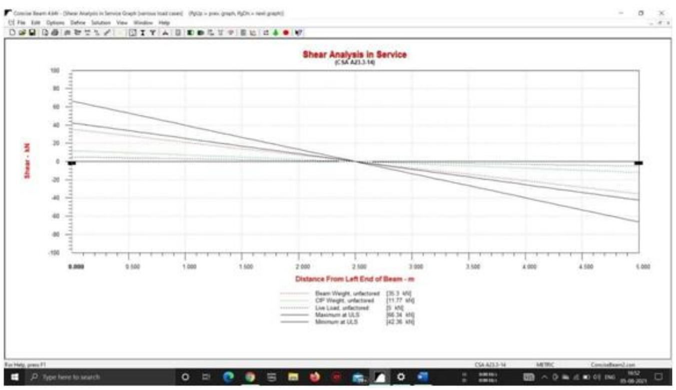
LOAD ASSIGN ON THE SLAB



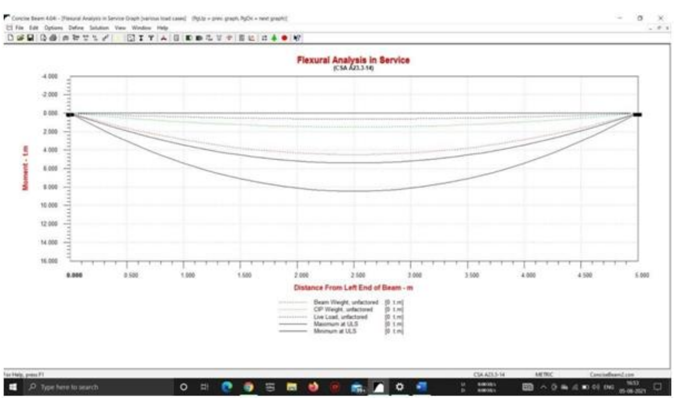
Live load is given as 2 kN/m^2

The software is calculating the beam self-weight.

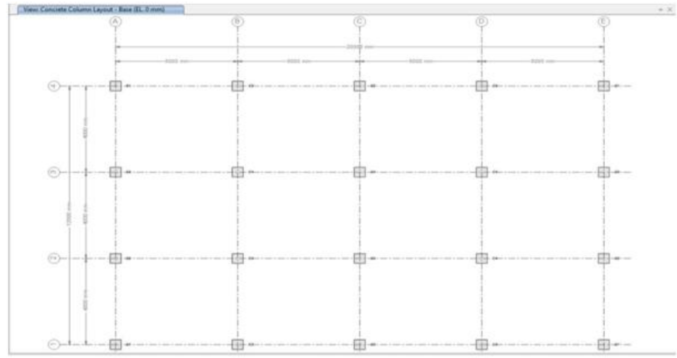
SHEAR ANALYSIS



FLEXURAL ANALYSIS



COLUMN LAYOUT



This is the column layout, spacing between the column is 5 m in x-direction, and 4 m in y direction.

MATERIAL QUANTITY OF COLUMN

SR. NO.	ITEM	QUANTITY	UNIT
1	TOTAL VOLUME, V	174.960	CU M
2	TOTAL REBARS WEIGHT, W	38,750	KG
3	REBARS RATIO, W/V	221.4784	KG/CU M

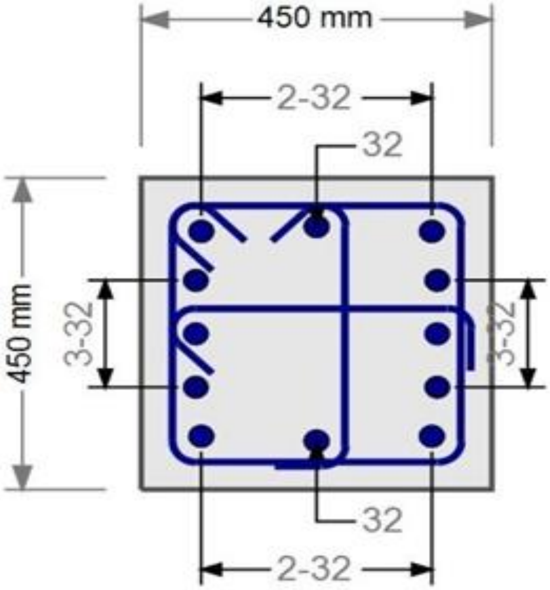
REBAR USED

REBAR QUANTITIES: CONCRETE COLUMN

SR. NO.	BAR SIZE	LENGTH (M)	WEIGHT (KG)
1	10	17,726.5	10,992
2	16	5,184.0	8,179
3	18	648.0	1,297
4	20	900.0	2,218
5	22	648.0	1,933
6	25	1,296.0	4,995
7	28	1,044.0	5,048
8	32	648.0	4,089

These are the Bar used, Maximum size of the bar is 32 mm, and the total length of bar used is 648 m.

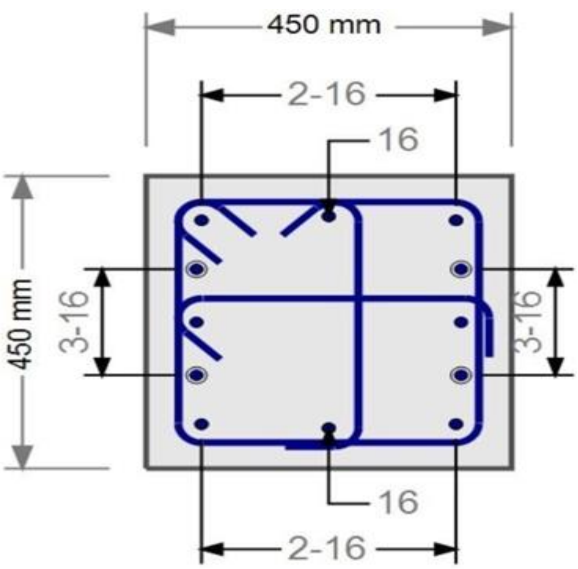
MAXIMUM REINFORCED COLUMN



C4:Section B
(Scale = 1:15)

This is the critical column where the column experienced the maximum force, 12 numbers of 32 mm dia bars are used, the stirrups is of 10 mm dia, at the corner the spacing of stirrups is 100 mm, and at the middle it is 150 mm.

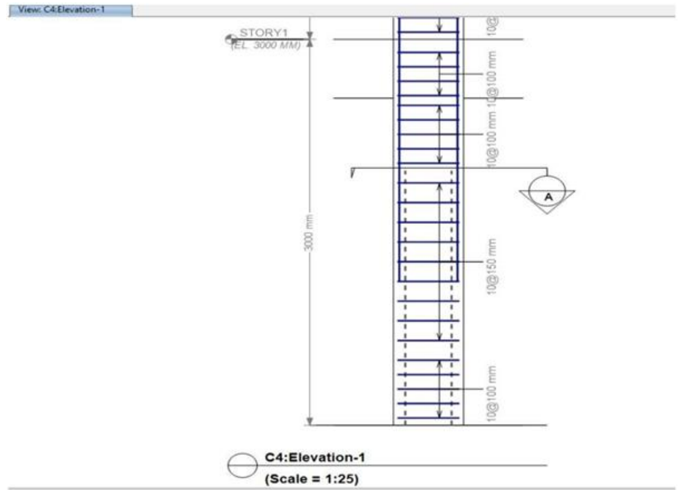
MINIMUM REINFORCED COLUMN



C1:Section D
(Scale = 1:15)

This is the minimum reinforced column when compare to all others column, 12 numbers of 16 mm dia bars are used, the stirrups are of 10 mm dia, at the corner the spacing of stirrups is 100 mm, and at the middle it is 150 mm.

COLUMN ELEVATION



This is the column elevation for C4 column 1st storey.

MATERIAL QUANTITY OF BEAM

SR. NO.	ITEM	QUANTITY	UNIT
1	TOTAL VOLUME, V	166.250	CU M
2	TOTAL REBARS WEIGHT, W	28,099	KG
3	REBARS RATIO, W/V	169.0178	KG/CU M

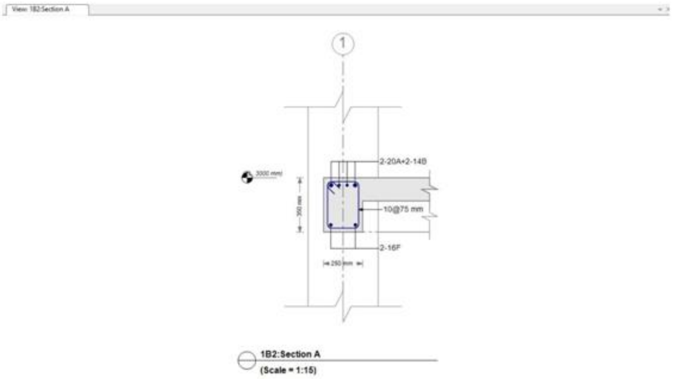
REBAR QUANTITIES

REBAR QUANTITIES: CONCRETE BEAMS

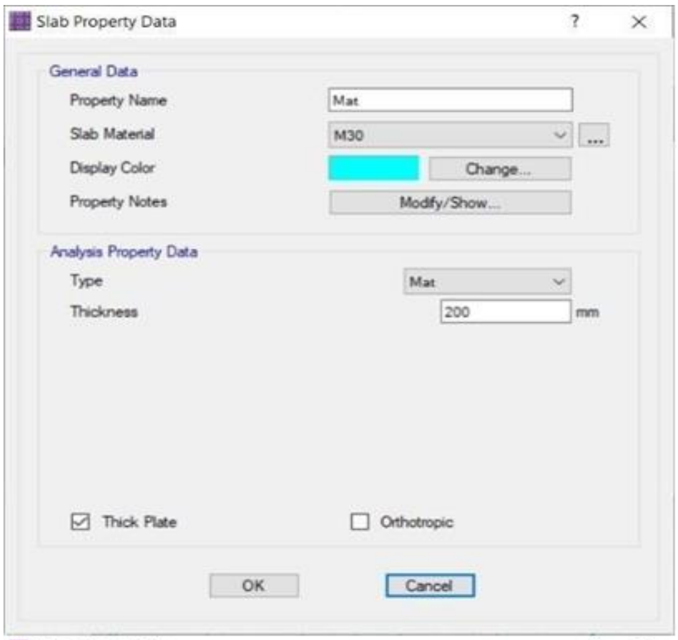
SR. NO.	BAR SIZE	LENGTH (M)	WEIGHT (KG)
1	10	19,815.9	12,287
2	14	4,684.9	5,663
3	16	3,018.0	4,761
4	18	864.3	1,730
5	20	1,484.1	3,658

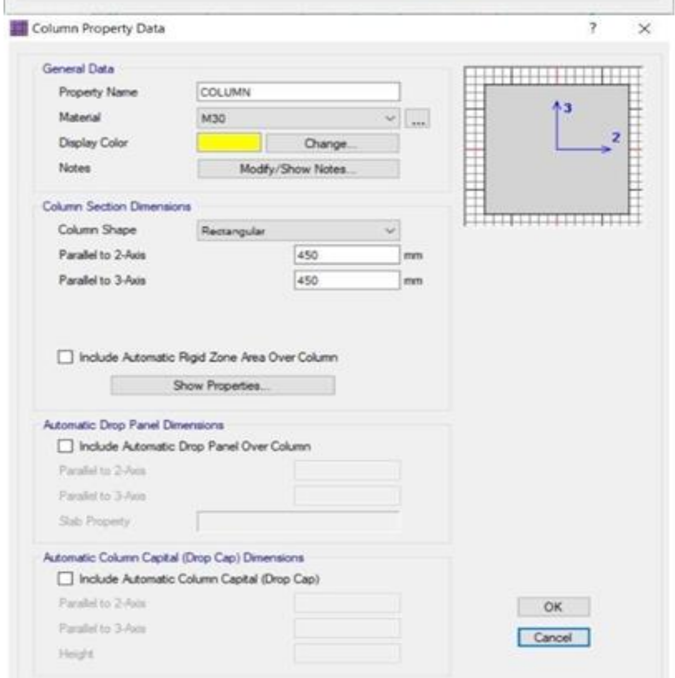
These are the Bar used, Maximum size of the bar is 20 mm, and the total length of bar used is 1484.1 m.

REINFOREMENT DETAILING OF BEAM

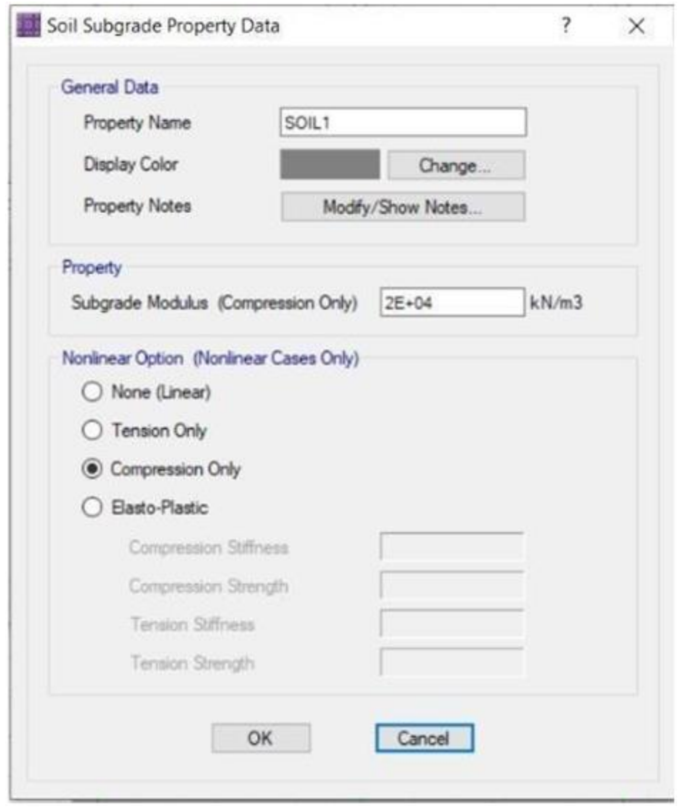


MEMBER PROPERTY





SOIL PROPERTY



SUBGRADE MODULUS

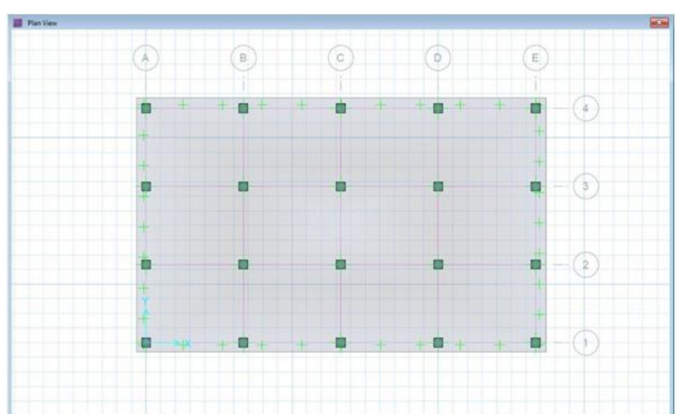
$$= \frac{SBC}{allowable\ settlement}$$

$$= \frac{200\ kN/m^2}{1cm}$$

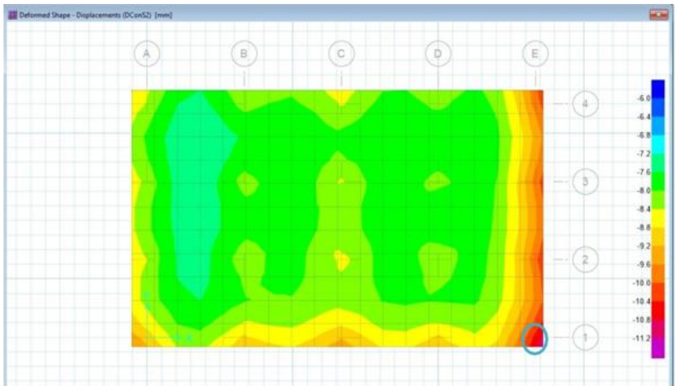
$$= \frac{200\ kN/m^2}{10^{-2} m}$$

$$= 2\times10^4\ kN/m^3$$

PLAN VIEW OF THE FOUNDATION

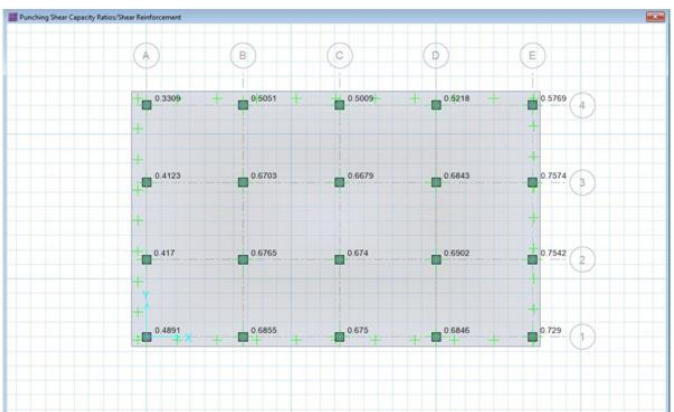


DISPLACEMENT OF THE FOUNDATION



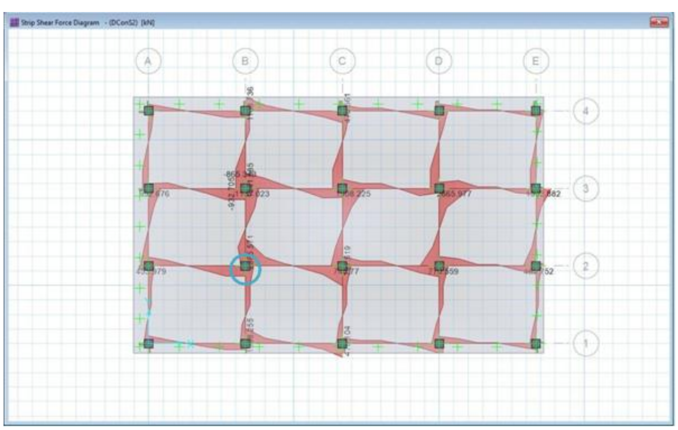
Maximum displacement is 10.74 mm this is within the permissible limit (75mm) so it is save.

PUNCHING SHEAR CAPACITY



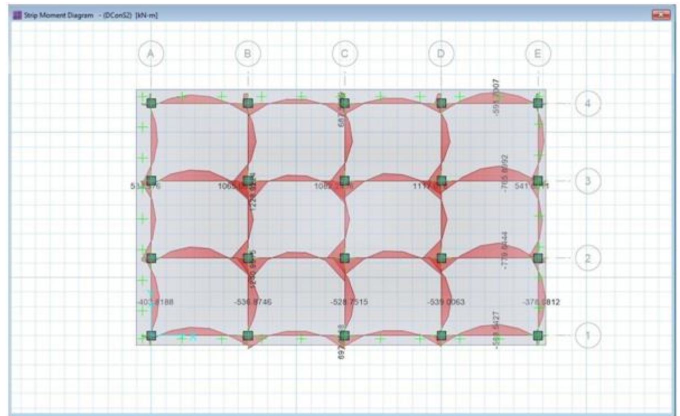
All the punching shear capacity are below 1. So, it is save.

STRIP SHEAR FORCE DIAGRAM



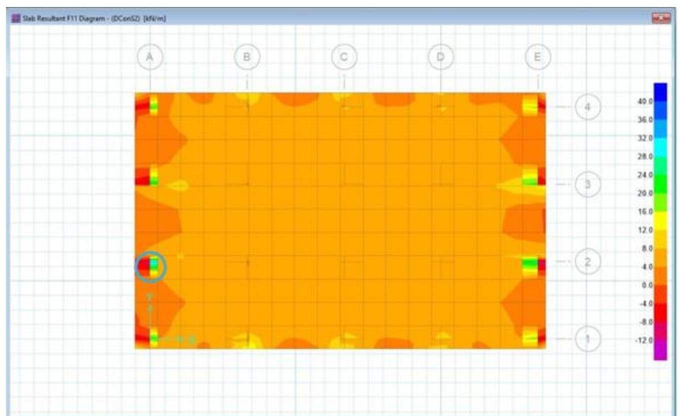
The maximum strip shear force is 2665 kN.

STRIP MOMENT DIAGRAM



The maximum strip moment is 1240 kNm.

RESULTANT STRESS



The maximum resultant stress is 32 GPa.

V. CONCLUSION

The Analysis and design methodology of precast building is different in comparison of cast in place building systems.

After analysing the G+7 storey building structure, concluded that structure is safe in loading like dead load, live load, wind load and seismic load.

All precast elements are designed considering forces during handling in addition to forces due to gravity load and lateral loading.

Member dimensions (Beam, Column, Slab, Footing) are changed by calculating the load type and its quantity applied on it.

The results give min. diameter of bars, thickness of slab and same for column, footing.

REFERENCES

[1] Can Bora, Michael G. Oliva, and Roger Becker "Development of a Precast Concrete Shear-Wall System Requiring Special Code Acceptance".
[2] Capozzi, V., G.Magliulo, G.Fabbrocino and G.M Anfredi, "Experimental tests on Beam-Column Connections of Precast Buildings" The 14 th World Conference on Earth Quake Engineering, October 12-17, 2008,
[3] Code of practice for Precast Concrete Construction 2003, Hong Kong and Handbook on Precast by Singapore.
[4] Chaitanya Kumar J.D and Lute Venkat, "Analysis of Multistoreyed building with precast walls", International Journal of Civil and Structural Engineering, Volume 4, No 2, 2013, pp 147-157.
[5] Design Guidelines for Connections of Precast Structures under Seismic Actions, JRC Scientific and Policy reports.
[6] Gopinathan, M.J., and K.Subramanian (2013), "High Performance and Efficiency of Joints in Precast Members" International Journal of Engineering and Technology. Vol 5 No 5, pp 4002-09.
[7] IS 1893 (Part 1) 2002, IS 875 part 1, 2, 3, IS 456-2000.
[8] IS: 13920, Ductile detailing of reinforced concrete structures subjected to seismic forces, Bureau of Indian Standards, New Delhi, 1987.
[9] Nicholas J. Brooke, "Improving the Performance of Reinforced Concrete Beam-Column Joints Designed for Seismic Resistance". Precast connections section.