Design and Analysis of A Multifunctional Building

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***Abstract*- The paper presents a new design of multifunctional building. We propose this building at Jagathy, Trivandrum. The manual designing of building includes the design of pile foundation, design of column, beam, slab, using a set of procedures and building codes such as IS 456. The design of multi-storey building 3B+G+6 by using the softwares AutoCAD 2019, STAAD PRO, SketchUp is carried out.**

Keywords: Deflection; Bending moment; Shear force; Multifunctional building.

I. INTRODUCTION

Multifunctional building is a structure that contains at least two different destination spaces. Development of modern urban structures follows the tendencies of efficient space management which manifests itself in the form of a multifunctional building. Multifunctional buildings are absorbing an increasing number of people through an ever-expanding service sector. Present day urban regions are characterized by using very intensive use of area. Nowadays, buildings are being constructed larger and contain greater diverse functions to fulfill the desires of a huge quantity of customers in a single capability. A multi-storey is a building that has multiple floors above the ground. In this project the analysis and design of multi-storey building 3B+G+6 by using the softwares AutoCAD 2019, STAAD PRO, SketchUp and manual designing. We propose this building at Jagathy, Trivandrum. Because waste from industries and community areas is disposed in this site.

II. OBJECTIVES

- Carry out a complete analysis and design of the structural elements of a multi storey building including foundation, beam, column, slab.
- Creating plan drawings using AutoCAD.
- Creating 3D model using SketchUP.
- Analysis of frame by STAAD PRO

III. METHODOLOGY

Jagathy is a place within the city of Thiruvananthapuram in the state of Kerala, is selected for the study and proposed a multifunctional building. Now it’s a waste dumping area, after the coming of this building the face of the area will change. Soil study and investigation must be done in order to know the strength of the soil and for proper design of the building. The optimum moisture content was obtained as 34%, Liquid limit 3.2%, Specific Gravity 2.7. Loose very fine sand was found upto more than 3m depth.

3 Basement + Ground Floor + 6 Floors are planned and design the structure can be done with the help of AutoCAD and SketchUp software. Multi storied building is to be designed using design codes and analysis with use of STAAD PRO software. The cost estimation of building is done with the help of data obtained.

IV. BUILDING INFORMATIONS

In this project the building is the combination of public and private sectors. This building consists of 6 stories. Ground floor is for public space and they are car showroom and restaurant, from 1st floor to 6th floor is for private spaces like IT companies.

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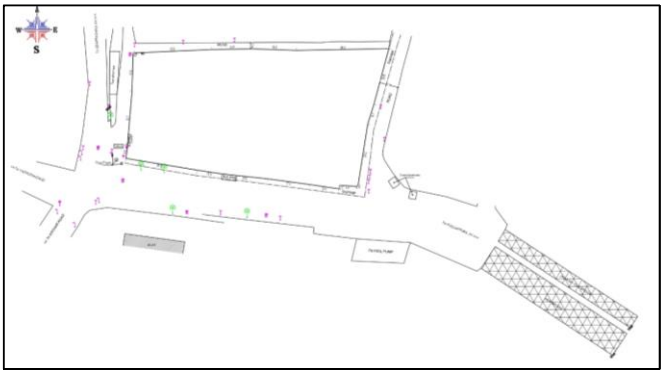

Fig. 1. Site plan of proposed site

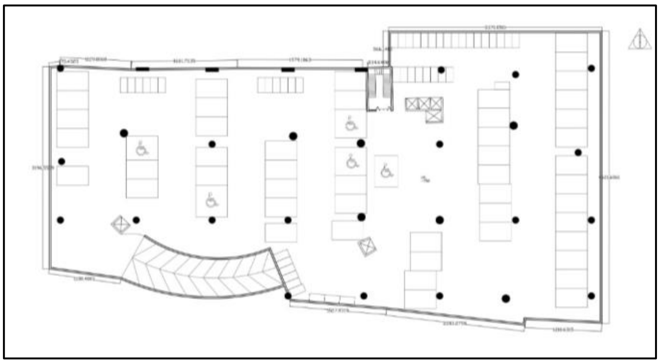

Fig. 2. 3rd Basement plan

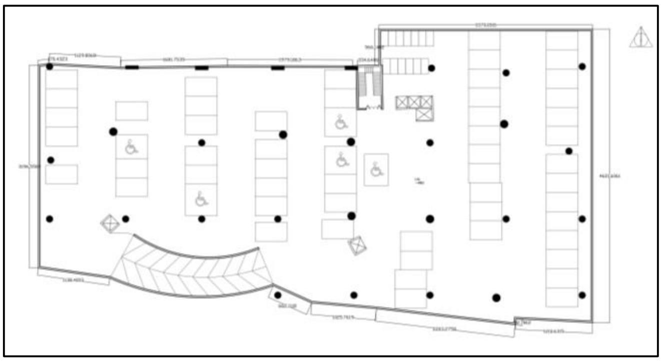

Fig. 3. 2nd Basement plan

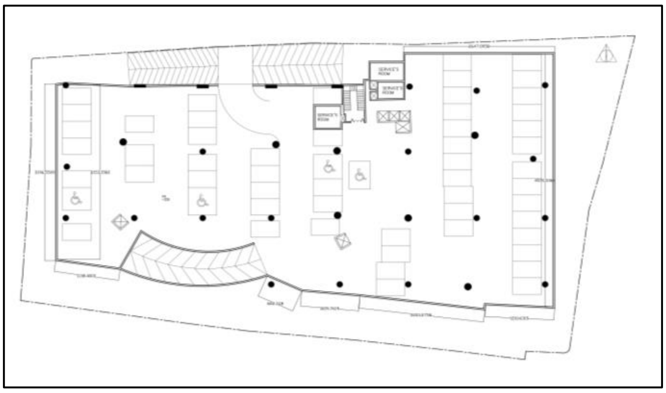

Fig. 4. 1st Basement plan

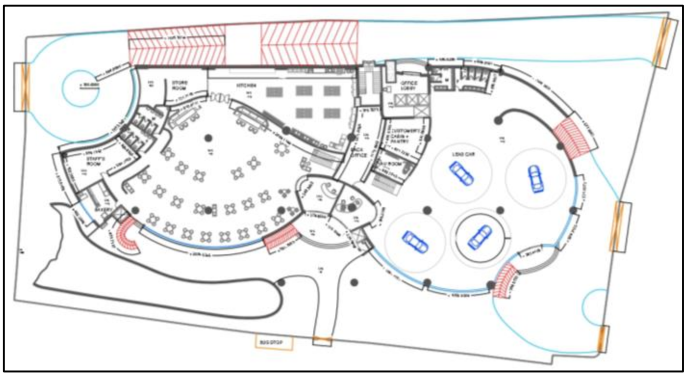

Fig. 5. Ground Floor plan

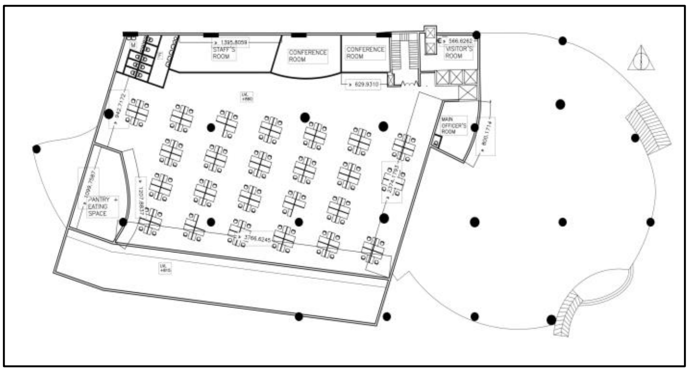

Fig. 6. 1st Floor plan

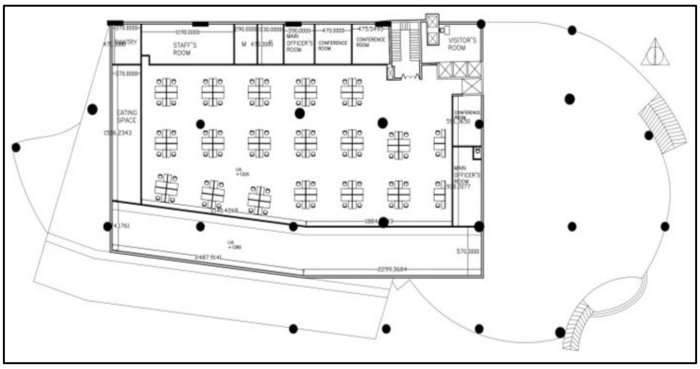

Fig. 7. 2nd Floor plan

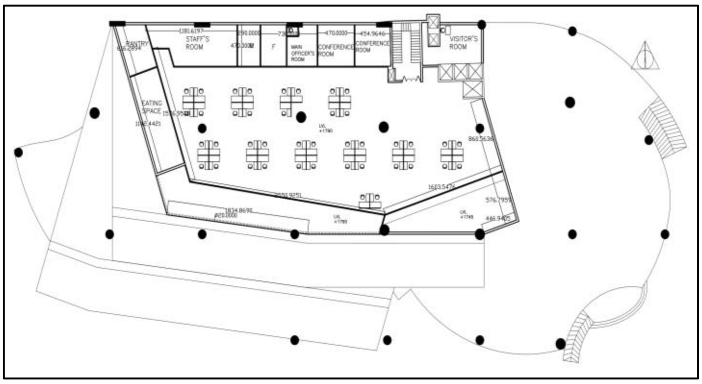

Fig. 8. 3rd Floor plan

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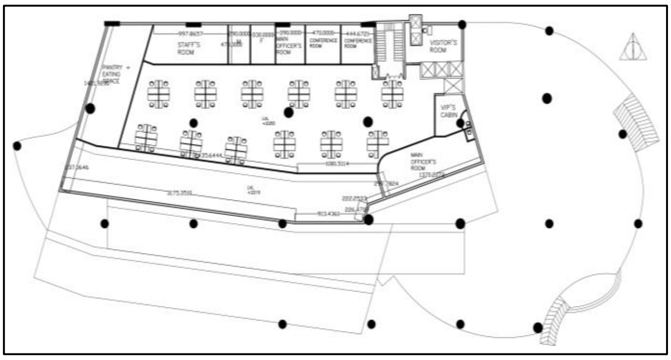

Fig. 9. 4th Floor plan

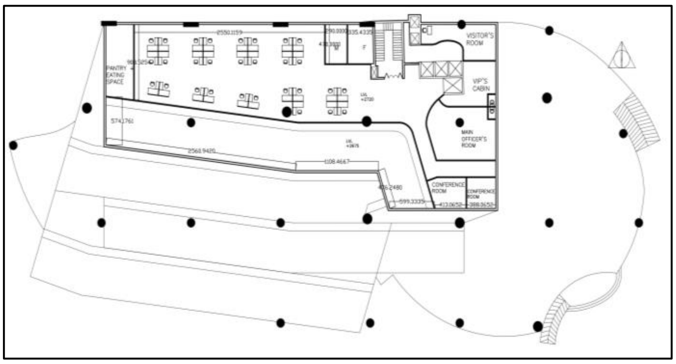

Fig. 10. 5th Floor plan

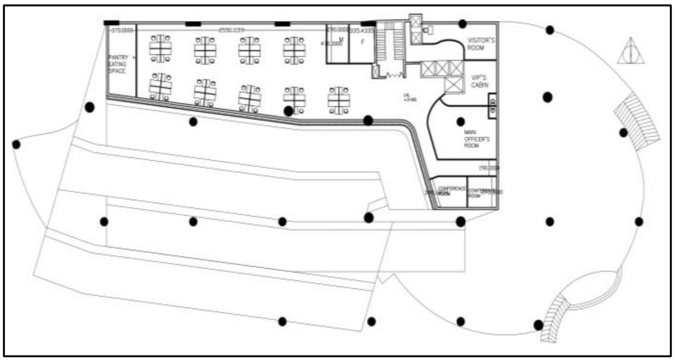

Fig. 11. 6th Floor plan

V. 3D MODELLING IN SKETCHUP

The proposed building structure was modelled using SketchUP software. The model is prepared as the plan and other details.

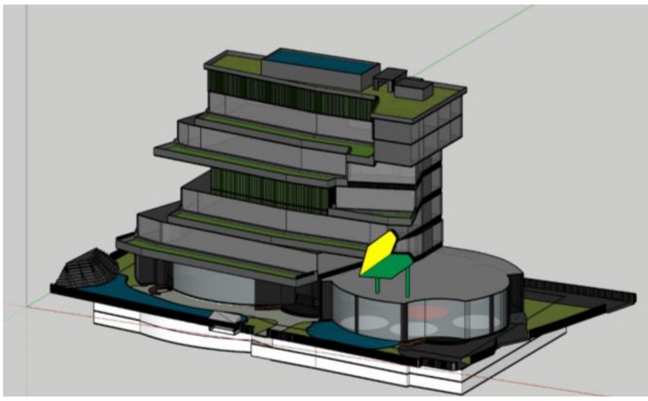

Fig. 12. 3D Modelling by SketchUP

VI. MODELLING IN STAAD PRO

The proposed building structure was modelled using STAAD. Pro. The geometric properties of various members such as slab, beams, columns etc and material properties were defined and assigned.

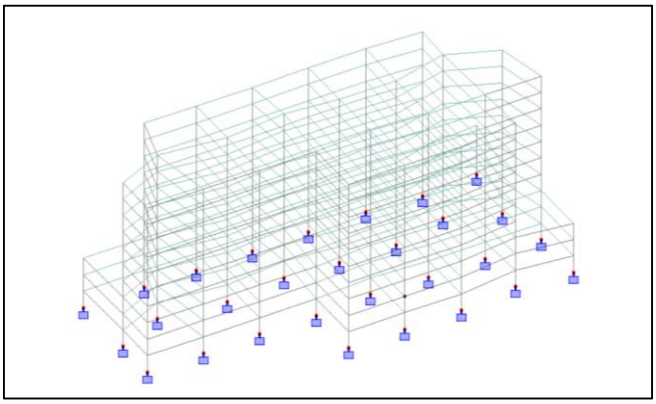

Fig. 13. Structural analysis diagram

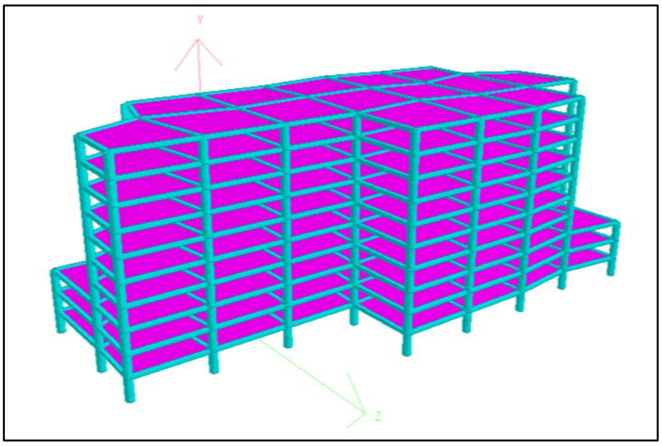

Fig. 14. 3D view of structure

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VII. LOAD ACTING

A. *Dead Load*

Dead loads consist of the permanent construction material loads compressing the roof, floor, wall, and foundation systems, including claddings, finishes and fixed equipment. Dead load is the total load of all of the components of the building that generally do not change over time, such as the steel columns, concrete floors, bricks, roofing material etc. In Staad pro assignment of dead load is automatically done by giving the property of the member. Dead load is calculated as per IS 875 part 1.

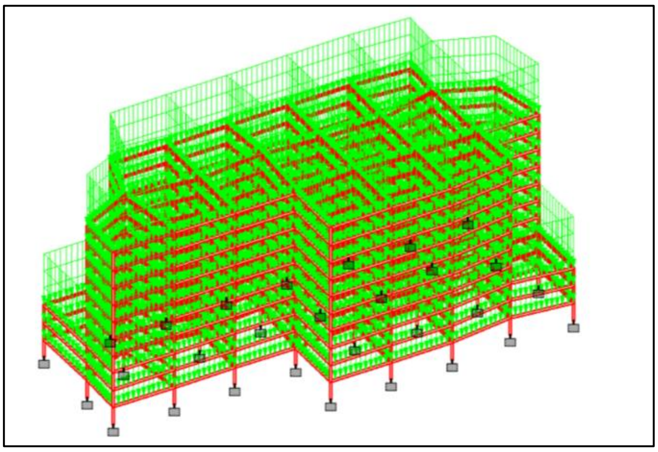

Fig. 15. Structure Under Dead Load

B. *Live Load*

The live load considered in each floor was 3KN/ m2 and for the terrace level it was considered to be 1.5 KN/sq m. The live loads were generated in a similar manner as done in the earlier case for dead load in each floor. This may be done from the member load button from the load case column. Live loads are calculated as per IS 875 part 2.

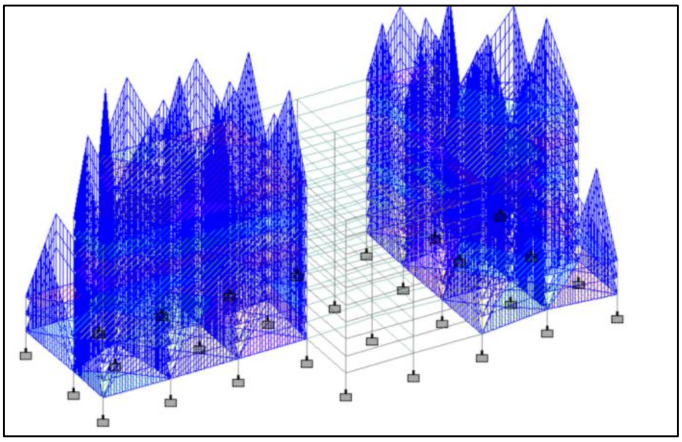

Fig. 16. Structure Under Live Load

C. *Wind Load*

The wind load values were generated by the software itself in accordance with IS 875. Under the define load command section, in the wind load category, the definition of wind load was supplied. The wind intensities at various heights were calculated manually and fed to the software. Based on those values it generates the wind load at different floors. The calculation of wind load is as per IS 875 part 3.

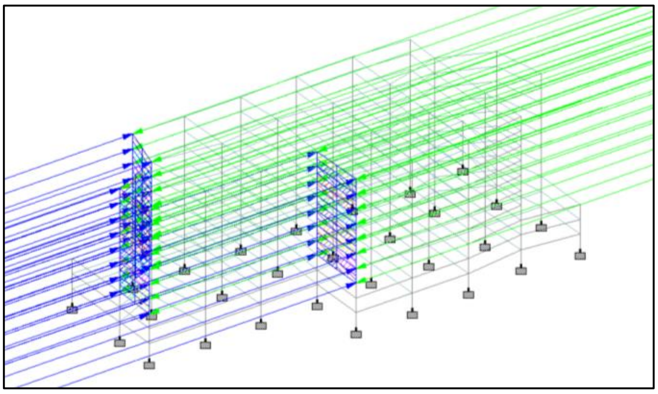

Fig. 17. Wind Load Effect Along X Direction

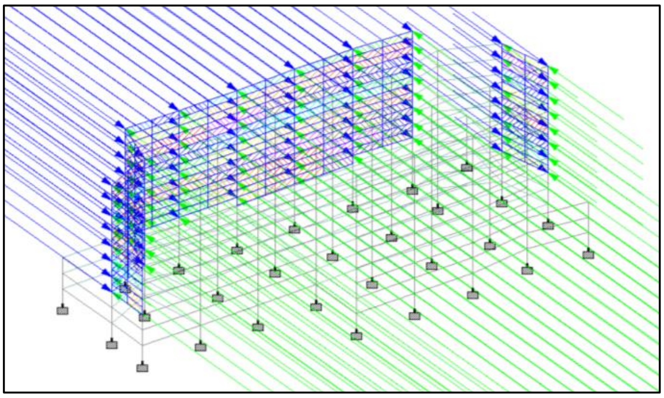

Fig. 18. Wind Load Effect Along Z Direction

VIII. MANUAL DESIGN AND STAAD ANALYSIS

A. *Design of Pile Foundation*

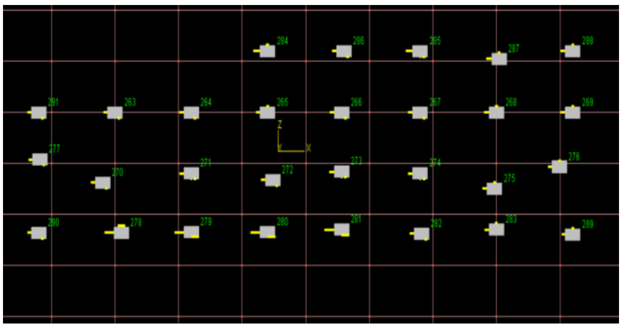

Fig. 19. Pile cap arrangement

Service Load = 300 KN

Ultimate Load = 300 × 1.5

= 450 KN

Depth of foundation = 6 m

F_{ck} = 40 N/mm^2

F_y = 500 N/mm^2

Length of pile above ground level is 0.6 m

Total length of pile = 6 + 0.6 = 6.6 m

Assume a pile of diameter 0.45 m

$P_u = 0.4\, F_{ck}\, A_g + (0.67\, F_y - 0.4\, F_{ck})\, A_{sc}$

$450\times10^3 = 0.4\times40\times\frac{0.45^2\times\pi}{4} + (0.67\times500 - 0.4\times40)\, A_{SC}$

$A_{SC} = 1410.39$ mm^2

For piles of length, L = 30 D = 30×450 = 13500 mm

Reinforement is 1.25% of cross section

$A_{SC} = \frac{1.25}{100}\times\frac{\pi\times0.45^2}{4} = 1987.03$ mm²

Hence provide 10 bars of 16mm Ø with a

clear cover of 50 mm

Ties

Lateral reinforcement in the central portion of the pile = 0.2% of gross volume.

Using 8mm dia ties

Volume of one tie = 50 [4 (450 – 100)] = 70000mm^3

If P = Pitch of ties

Volume of piles per pitch = $(\frac{\pi\times0.45^2}{4}\times P) = 158962.5\, P$

$70000 = \frac{0.2}{100}\times158962.5\, P$

P = 220.17 mm

Maximum permissible pitch = $\frac{D}{2} = \frac{450}{2} = 225$ mm

Provide 8mm ∅ ties at 200mm c/c

Lateral Reinforcement near pile ends

Volume of ties = 0.6 % of gross volume of concrete for a length of 3D = 3×450 = 1350mm.

Using 8mm Ø ties A_S = 50.24 mm²

Volume of ties = 70000 mm^3

$70000 = 0.006\times\pi\times\frac{450^2}{4}\times P$

P = 73.39

Provide 8mm Ø ties at 75mm c/c.

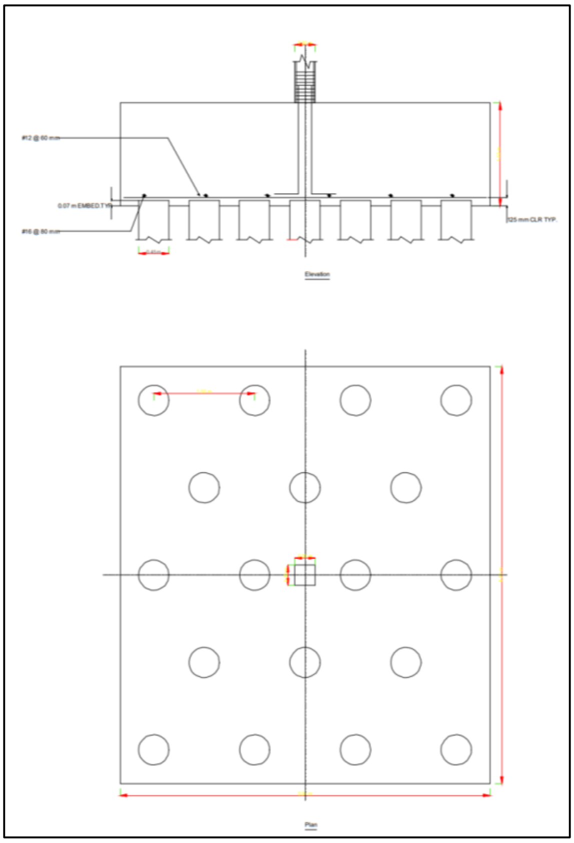

Fig. 20. Pile cap detailing

B. Design of circular column

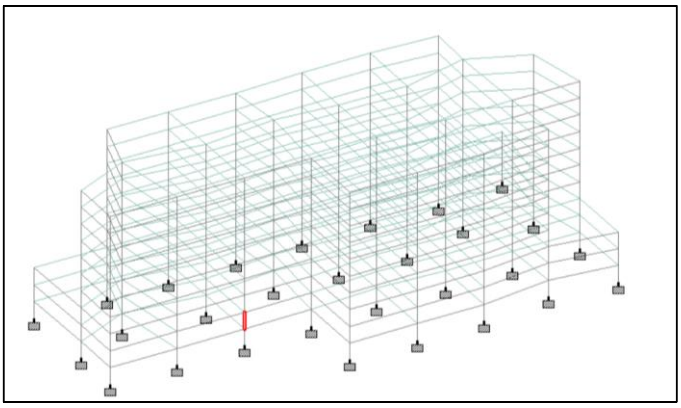

Fig. 21. Column no. 563 in the structure

Column no. 563

Span = 3m

Diameter D = 1.2m

F_{ck} = 40 N/mm^2

F_y = 500 N/mm^2

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Service Load = Self weight × No. of floors

= 20.3472 KN

Factored Load = 1.5 × 20.3472

= 30.5208 KN

Slenderness Ratio = $\frac{L}{D} = \frac{3000}{1200}$ = 2.5

Hence column is designed as short column.

Minimum eccentricity,

$e_{min} = \left[\frac{L}{500} + \frac{D}{30}\right] = \left[\frac{3000}{500} + \frac{1200}{30}\right]$ = 10mm < 20mm

Also 0.05 D = 0.05 × 1200 = 60 mm

<u>Main Reinforcement</u>

According to clause 39.4 of IS 456- 2000

$P_u = 1.05[0.4\ F_{ck}\ A_g + (0.67\ F_y - 0.4\ F_{ck})\ A_{sc}]$

$= \frac{30.52\times10^3}{1.05} = [\frac{0.4\times40\times\pi\times1200^2}{4}] + [\ (0.67\times\ 500) - (0.4\times\ 40)\ A_{sc}]$

A_{sc} = 5660 mm^2

A_{sc} min = 0.8 % of cross section

$= (\ 0.008\times\pi\times\frac{1200^2}{4}\ )$ = 9043.2 mm²

Provide 45 bars of 16 mm diameter

Adopting clear cover 50 mm over spirals

Core diameter = [1200 – (2×50)] = 1100 mm

Area of core , $A_c = [\ (\ 3.14 \times \frac{1100^2}{4}\ ) - 9043.2\ ]$

= 940806.8 mm²

Volume of core, $V_c = 940806.8\times10^3$ mm^2

Gross area of section , $A_g = (3.14\times\frac{1200^2}{4})$ = 1130400 mm²

Use 8 mm diameter helical spirals at a pitch pmm

$V_{us} = \pi$ (1200-100-8) 50× 1000/p)

= 30144000/p mm³/m

According to clause 39.4.1 of IS 456

$V_{us} / V_c < 0.36[(A_g / A_c) - 1]\ (F_{ck} / F_y)$

P < 75 mm core dia / 6 = $\frac{1100}{6}$ = 183.33 mm

P < 3×8 =24 mm

Provide 8 mm diameter helical spirals at a pitch of 30 mm.

The STAAD diagrams are following,

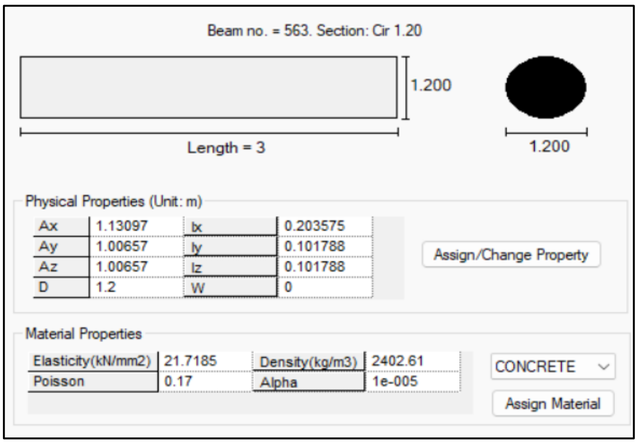

Fig. 22. Dimensional details of Member 563 in the structure

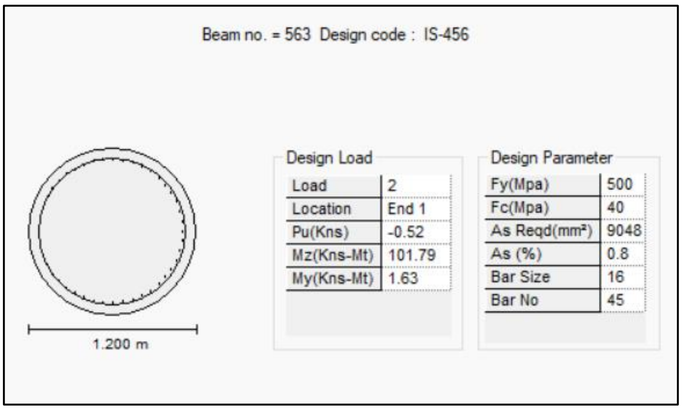

Fig. 23. Reinforcement details of Member 563 in the structure

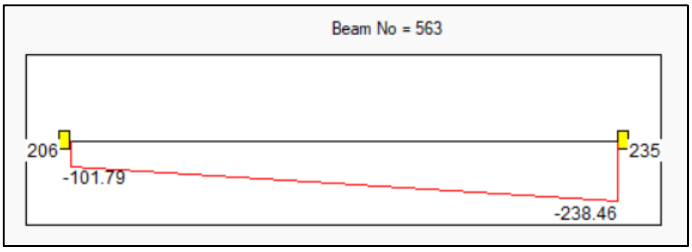

Fig. 24. Shear bending diagram of Member 563 in the structure

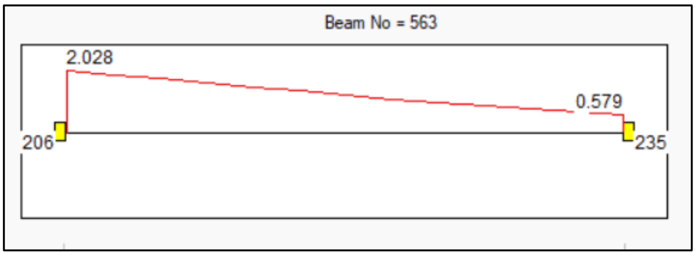

Fig. 25. Deflection diagram of Member 563 in the structure

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C. Design of beam

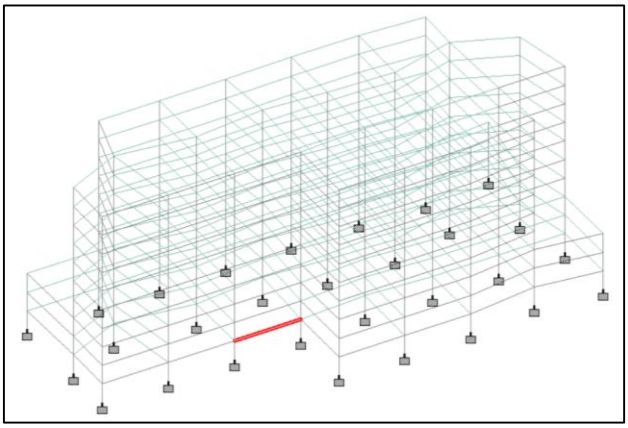

Fig. 26. Beam no. 621 in the structure

Beam no. 621

Span = 12 m

Service load = 3 KN

F_{ck} = M40

F_y = 500 N/mm^2

Load Factor = 1.5

Effective span = $\frac{span}{20} = \frac{12000}{20}$ = 600 mm

Adopt , d = 500 mm

b = 500 mm

Effective span = clear span + effective depth

= 12 + 0.5 = 12.5 m

<u>Loads</u>

Self weight = 0.5 × 0.5 × 25 = 6.25 KN/m

Live load = 3 KN/m

Total load = 9.25 KN/m = 9.25 ×1.5 = 13.875 KN/m

$M_u = 0.125\ W_u\ L^2$

= 0.125×13.875×12.5 ² = 270.99 KNm

$V_u = 0.5\ W_u\ L$

= 0.5×13.875×12.5 = 86.71 KN

M_u limit = $0.138\ F_{ck}\ bd^2$

= (0.138×40×500×500²) 10^{-6} = 690 KNm

$M_u < M_u$ limit , section is under reinforced

$M_u = (0.87\ F_y\ A_{st}\ d)\ [1- \frac{Ast\ Fy}{bd\ Fck}]$

$= 0.87×500\ A_{st}\ ×500\ [\ 1- \frac{500Ast}{500×500×40}]$

A_{st} = 1205.76 mm²

Provide 6 bars of 16 mm diameter

<u>Check for shear</u>

$\tau_v = \frac{Vu}{bd} = \frac{86.7×10^3}{500×500}$ = 0.3468 N/mm²

$P_t = \frac{100Ast}{bd} = \frac{100\ ×1205.76}{500×500}$ = 0.482

Refer table 19 of IS 456 – 2000

$\tau_c = 0.63 > \tau_v$

Provide nominal shear reinforcements using 8 mm diameter stirrups.

$S_v = \frac{Ast\ 0.87\ Fy}{0.46} = \frac{2×50.24×0.87×500}{0.4×500}$ = 218.544 mm

0.75d = 0.75×500 = 375 mm

S_v < 0.75d

Adopt spacing of stirrups 210 mm c/c

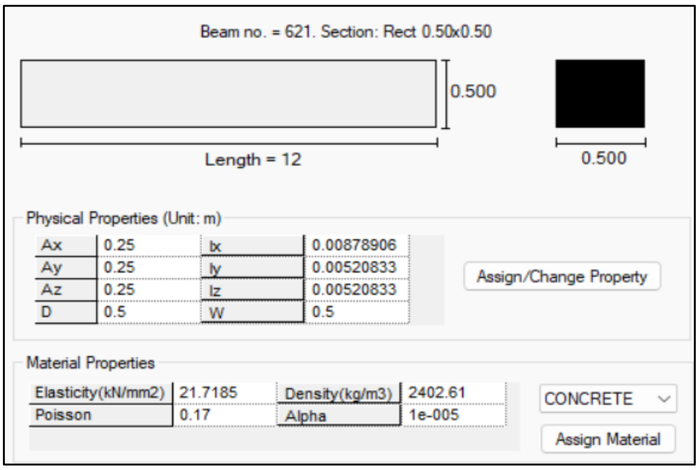

Fig. 27. Dimensional details of Member 621 in the structure

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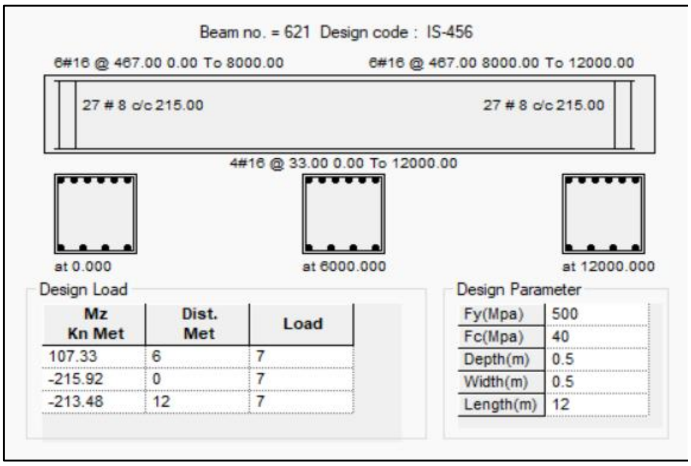

Fig. 28. Reinforcement details of Member 621 in the structure

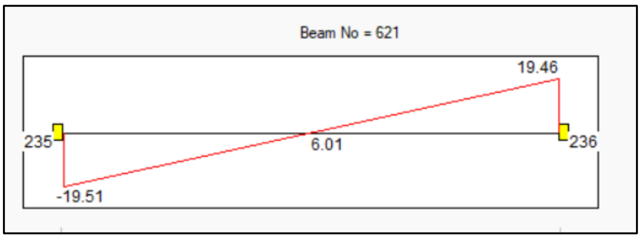

Fig. 29. Shear bending diagram of Member 621 in the structure

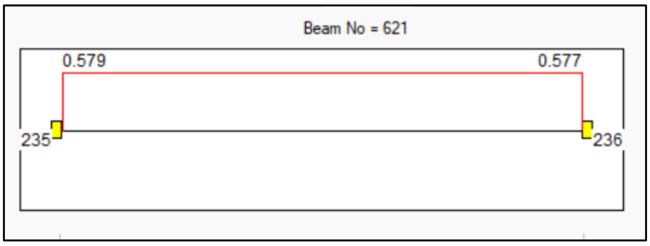

Fig. 30. Deflection diagram of Member 621 in the structure

D Design of Slab

Clear span = 12 m

Width of support = 500 mm

Floor finish = 1 KN/m²

F_{ck} = 40 N/mm²

F_y = 500 N/mm²

Depth of slab, d = $\frac{Span}{25} = \frac{12000}{25}$ = 480 mm

Assuming a clear cover of 20 mm and using 8 mm dia bars

d = 480 mm

Effective span = clear span + effective depth

= 12 + 0.48 = 12.48 m

L = 12.48 m

Loads

Self weight = 12 KN/m

Floor finish = 1

Total service load = 13 KN/m

Ultimate load = 19.5 KN/m

Ultimate moment and Shear force

$M_u = 0.125\ W_u\ L^2$

= 379.64 KN/m

$V_u = 0.5\ W_u\ L$

= 121.68 KN

M_u limit = $0.138\ F_{ck}\ bd^2$

= 1271.808 KNm

$M_u < M_u$ limit, section is under reinforced

Use 10 mm dia bars adopt a spacing of 160 mm & alternate bar are bent up at support.

Distribution bars

A_{st} = 0.12% of gross cross sectional area

= 576 mm^2

Provide 8 mm dia bars @ 250 mm c/c.

IX. CONCLUSION

- All the drafting was done using AutoCAD
- The analysis and design of the entire structure has been completed using STAAD.Pro.
- The structural components of the building are safe in shear and flexure.

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