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EARTHQUAKE RESISTANT ANALYSIS (RESPONSE SPECTRUM ANALYSIS METHOD) AND DESIGN OF G+2 BUNGALOW BY USING SOFTWARE SAP 2000

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Abstract: Seismic design techniques today enable structural engineers themselves to design buildings with different types of earthquake safety levels in line with the various demands of society. However, the design goal is basically limited to a relatively short period of time, i.e. to secure the service life of each building. Aspects of building sustainable and strong cities that recover quickly, including long-lived buildings, are not generally considered. Powerful earthquakes occur at regular intervals that are larger than individual buildings or people's lives. On the other hand, city life is clearly long-lived, just as seismic action is stronger than design action, and can only cause serious damage to a building designed for their life. Although multi-storey buildings with floors are in danger of collapsing due to natural earthquakes, their construction is still in a developing region like India. Vehicle parking area services are required to be provided at the ground level and the office does not need to be wary of such buildings from the engineering community. Due to the ease of high-speed computers, the use of software in civil engineering has greatly reduced the complexity of various aspects of project analysis and design. The aim of the project is to design and analysis a residential building by using the well-known software SAP2000.

KEYWORDS: SAP 2000, residential building, static load analysis, base shear, structural elements, response spectrum analysis

I. INTRODUCTION

"Basic needs" refers to those basic needs that obey as the foundation for survival. A regular list of immediate "basic needs" is food, shelter and clothing. Everyone has the basic human right to life, which is guaranteed access to a safe, secure, usable and affordable home free from forced evictions. Digital computers have taken the world by storm. Future society is certainly going to be technology driven. Almost everything is being computerised and digitalised. Software has become the order of the day. Amidst such a scenario, it is but natural that analysis and design work in any field of engineering is being carried out by using software.

Be that as manual calculations will always have their own importance software and programs have the uncanny knack of turning upside down. This is because the software is only good as the user and the results will always depend on accuracy of the input data.

The aim of the project is to design and analysis a residential building with the help of popular software SAP2000. For this purpose, a residential building with a 2BHK bungalow is considered.

A detailed planning and analysis is carried out for different loading combination including earthquake loading. Also 13 load combinations were analyzed and the worst load combination was detected and designed to the worst load combination using SAP 2000. We used SAP 2000 to design and analysis the structure and manual calculation for slab and staircase design.

II. RESPONSE SPECTRUM

In the response spectrum method of analysis, several modes of vibration were used in the frequency domain. The response of a multilevel structure is defined as a combination of different special modes i.e. corresponding to "harmonics" in a vibrating string. A computer program is used to determine the method of this special structure. For each mode, the response is recorded from the design response spectrum, based on the model mass and model frequency; They are then combined to estimate the overall response of the structure. According to the present study, the dimensions of the forces in all directions i.e. X, Y and Z were calculated and then the effect of the lateral forces on the building was analyzed. The design acceleration coefficient for different soil types and response spectrum graph obtained from the IS 1893:2016 (part 1) used in the present study is shown in the Fig. 1.

$$\frac{S_a}{g}=\begin{cases}\text{Rock or Hard soil} & \begin{cases}1+15T & T<0.10\text{ s}\\ 2.5 & 0.10\text{ s}<T<0.40\text{ s}\\ \dfrac{1}{T} & 0.40\text{ s}<T<4.00\text{ s}\\ 0.25 & T>4.00\text{ s}\end{cases}\\ \text{Medium/stiff soil} & \begin{cases}1+15T & T<0.10\text{ s}\\ 2.5 & 0.10\text{ s}<T<0.55\text{ s}\\ \dfrac{1.36}{T} & 0.55\text{ s}<T<4.00\text{ s}\\ 0.34 & T>4.00\text{ s}\end{cases}\\ \text{Soft Soils} & \begin{cases}1+15T & T<0.10\text{ s}\\ 2.5 & 0.10\text{ s}<T<0.67\text{ s}\\ \dfrac{1.67}{T} & 0.67\text{ s}<T<4.00\text{ s}\\ 0.42 & T>4.00\text{ s}\end{cases}\end{cases}$$

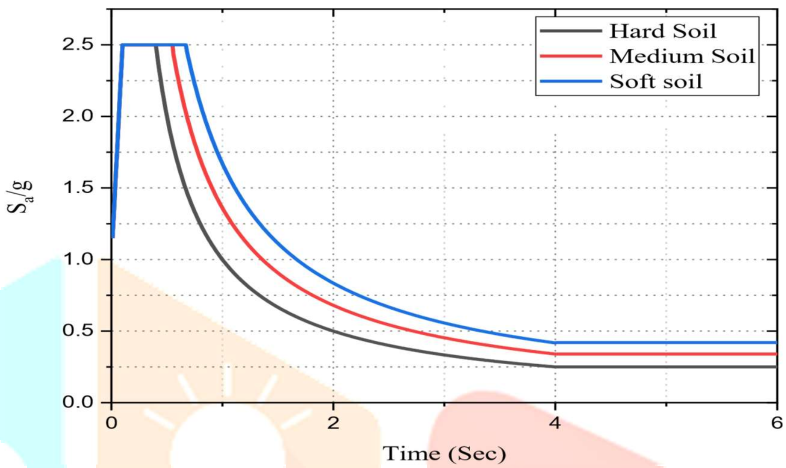


Figure 2: Design Response Spectrum for different soil (5% damping)

III. Literature Review

1. **V. Varalaxmi:** The analysis and design of G+4 residential building at a Kukatpally, Hyderabad, India. This research study contains analysis & design of structural member like columns, beam, footing & slab using the software SAP2000.
2. **Vijay N. Khose:** The analysis and design of G+4 RC structure which is site located in earthquake zone IV. Analysis and 3D modelling of the structure is done by using SAP2000 Software. The study include step by step procedure of analysis and design of building structural elements with the help of SAP2000 software.
3. **L. Kalurkar:** The analysis and design of G+4 structure which is site located in seismic zone III using composite structure. Analysis and 3D modelling of the structure is done by using SAP2000 Software. In this study, response spectrum analysis method and and equvivalent static method of analysis used for both RCC and composite structure.
4. **P. Jayachandran:** The analysis and design of G+4 residential building at Salem, Tamilnadu, India. This research study contains analysis & design of structural member like columns, beam, footing & slab using the software SAP2000 and AutoCad.

IV. SAP2000 Features

- SAP 2000 software is principally useful for gravity design & analysis of any structure.
- For any smaller structure or portions of a bigger structure, this software is commonly used.
- SAP2000 is a good at conduct multifaceted geometry because it provide to operators many of various component types and a lots of modification with considering to meshing choices.
- SAP2000 also be used for wind analysis and make extra comprehensible earthquake design procedures. Though, it will take additional data post-processing to recover the required results for story shear, base shear, story drift etc.
- SAP2000 having absences about of the easiness that STAAD PRO & ETABS software has of discretizing the structure into macroscopic elements.

V. Objective

Analysis and Design of G+2 bungalow with the help of SAP2000 which contains following:

1. Making the building structural plan by selecting new model on SAP2000
2. Modelling of the structure
3. Application of Loading on the structure
4. Analyzing the structure and removing the structure that occurred
5. Designing the structure with the help of IS 450-2000

VI. Building Description

- G+2 structure.
- Depth of footing = 1.2m
- Plinth height above GL is 0.55m.
- Concrete Grade is M25 and Steel Grade is Fe415.
- Height between Floors = 3.1 m
- Height of parapet wall = 1.0m.
- Thickness of slab = 130 mm.
- Thickness of main wall = 230 mm and Thickness of internal wall = 150 mm.
- Column Size = 230mm x 450 mm
- Beam Size = 230mm x 380mm & 230mm x 300mm
- Live load = 3 kN/m2 and Roof Live load = 1.5 kN/m2.
- Floor finishe = 1.875 KN/m2
- Seismic zone of site = Seismic zone III
- Building rest on medium soil.
- SBC of Soil = 250 KN/m2
- Importance Factor = 1
- Type of Building Frame = Special Moment Resting Frame (SMRF)
- Concrete Density = 25 kN/m3
- Brick Density = 20 kN/m3

VII. Modelling using SAP2000

1. First step is that, open the SAP2000 software.
2. For creating the new model, click on File menu and then select the new model. **[File>New Model]**
3. Under the new model select the default unit as a [kN, m, c] and select the Grid Only template.
4. After that, provide the grid system data and story height (X, Y & Z Grid Data) as per the structural plan by clicking on **Define menu > Coordinate Systems/Grids**
5. Click on the **Define menu > Materials** for adding materials properties.
6. Define the frame sectional properties i.e. Column and Beams. Click on **Define menu > Sections Properties > Frame Sections.**
7. **Define menu > Sections Properties > Area Sections** for defining the Slab.
8. Now create the model by drawing frame object with the associate Beam & Column sections list are drawn using the snap to option and grid.
   Draw > Draw Frame/Cable/Tendon
9. Apply Support Condition. Click **the Assign menu > joint > Restraints** and select the fixed support.

7.1 Application of loading on the structure:

- Define various load pattern and load which bis consist of Dead, Dead Slab, Dead Wall, Dead FF, Live and Live Roof which acting in the gravity direction.
- For defining the load pattern click on **Define menu > Load Patterns.**
- The important thing is that, the self-weight multiplier is must be set to 1 for the default case for calculating the dead load of all members.
- For live load case self-weight multiplier is set to be default i.e. 0
- For assigning the loads, select the members where the load is to be applied then click on **Assign menu > Frame loads > Distributed.**

7.2 Response spectrum function:

- For defining Response spectrum function click on **Define menu > Respomnce Spectrum Functions**, then display the Response Spectrum Functions form.
- For defining Response spectrum load case click on **Define menu > Load cases.**
- Add new load case as EQ-X and EQ-Y and provide the scale factor by manual calculation.

7.3 Analysis of the structure:

- Now analysis the model by clicking on **Analyze menu > Run Analysis** and then click on **Run Now** button.
- The analysis information may be access by going to **File menu > Show Input/output Text File command** & select the .LOG extension.
-

VIII. Seismic weight and Base shear calculation

- We need to calculate base shear in X and Y direction by manually as per IS 1893:2002 provision.
- It is calculated to provide **Scale Factor** value in the SAP2000 software for application of correction.

8.1 Calculation of seismic weight:

A. Dead load calculation:

- Total dead load of 1st and 2nd floor slabs = **354.158 kN**
- Total dead load of Roof slab = **329.489 kN**
- Total self-weight of beams at 1st and 2nd floor = **135.994 kN**
- Total self-weight of beam at Roof floor = **87.804 kN**
- Total self-weight of 0.23 m thick wall = **185.334 kN/m** per meter ht.

- Total self-weight of 0.115 m thick wall = **40.078 kN/m** per meter ht.
- Total self-weight of all column = **31.05 kN/m** per meter height

B. Live load calculation:

- Live load on Roof = 0
- Total Live load on 1st and 2nd floor = **51.88 kN**

C. Seismic weight calculation:

- Seismic weight of Roof = **771.981 kN**
- Seismic weight of 2nd Floor = **1251.445 kN**
- Seismic weight of 1st Floor = **1392.416 kN**
- Total seismic weight of building:
  = Seismic wt. of 1st floor + Seismic wt. of 2nd floor + Seismic wt. of Roof
  = 1392.416 + 1251.445 + 771.981
  = 3415.842 kN……. Total Seismic weight of building

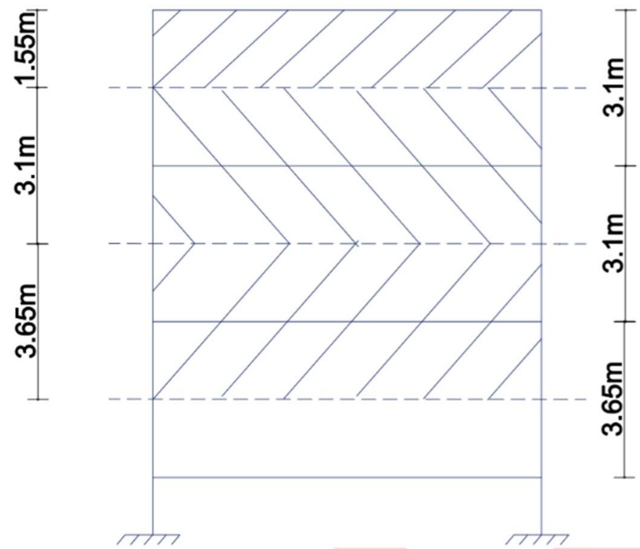


Figure 8.1: Zones of seismic weight

8.2 Calculation of base shear:

- As per IS 1893 (Part 1) : 2002 Cl. 7.5.3, the total lateral force or design seismic base Shear is given by, **VB = Ah X W**
  Where, W= Seismic weight of the building = **3415.842 KN**
- Along X-direction, VBx = Ahx X W
  = 0.040 X 3415.842 = **136.634 KN**
- Along Y-direction, VBy = Ahx X W
  = 0.040 X 3415.842 = **136.634 kN**
- **Design Storey Shear Calculation:**

  From IS 1893 (Part 1): 2002 Cl. 7.7.1, we have, $Q_i = \frac{W_i h_i^2}{\sum W_i h_i^2} * v_B$

  Where, Qi = Design lateral force at floor i.
  Wi= Seismic weight at floor i.
  hi = Height of the floor measured from base,
- Storey shear calculation is shown in following table:

Table 8.2: Storey Shear Calculation

FLOOR	W_i (kN)	h_i (m)	h_i^2	$W_i h_i^2$	$\frac{W_i h_i^2}{\sum W_i h_i^2}$	$V_{Bx} = V_{by}$	Q_i (kN)
First	1392.416	3.65	13.323	18551.158	0.123	136.634	16.806
Second	1251.445	6.75	45.563	57019.589	0.379	136.634	51.784
Roof	771.981	9.85	97.023	74899.913	0.498	136.634	68.044
$\sum W_i h_i^2$ = 150470.660					$\sum Q_i$ = 136.634		

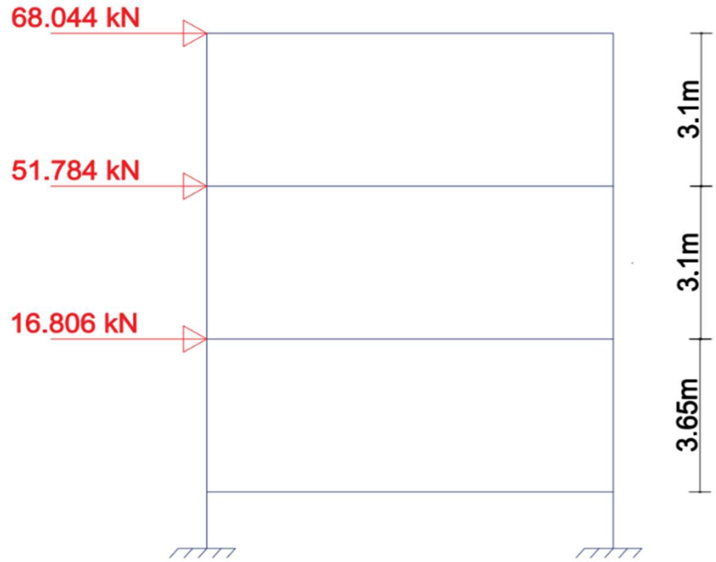


Figure 8.2: Design seismic force on the building for X-direction and Y-direction.

IX. PLAN, ELEVATION AND 3D VIEW OF THE BUILDING

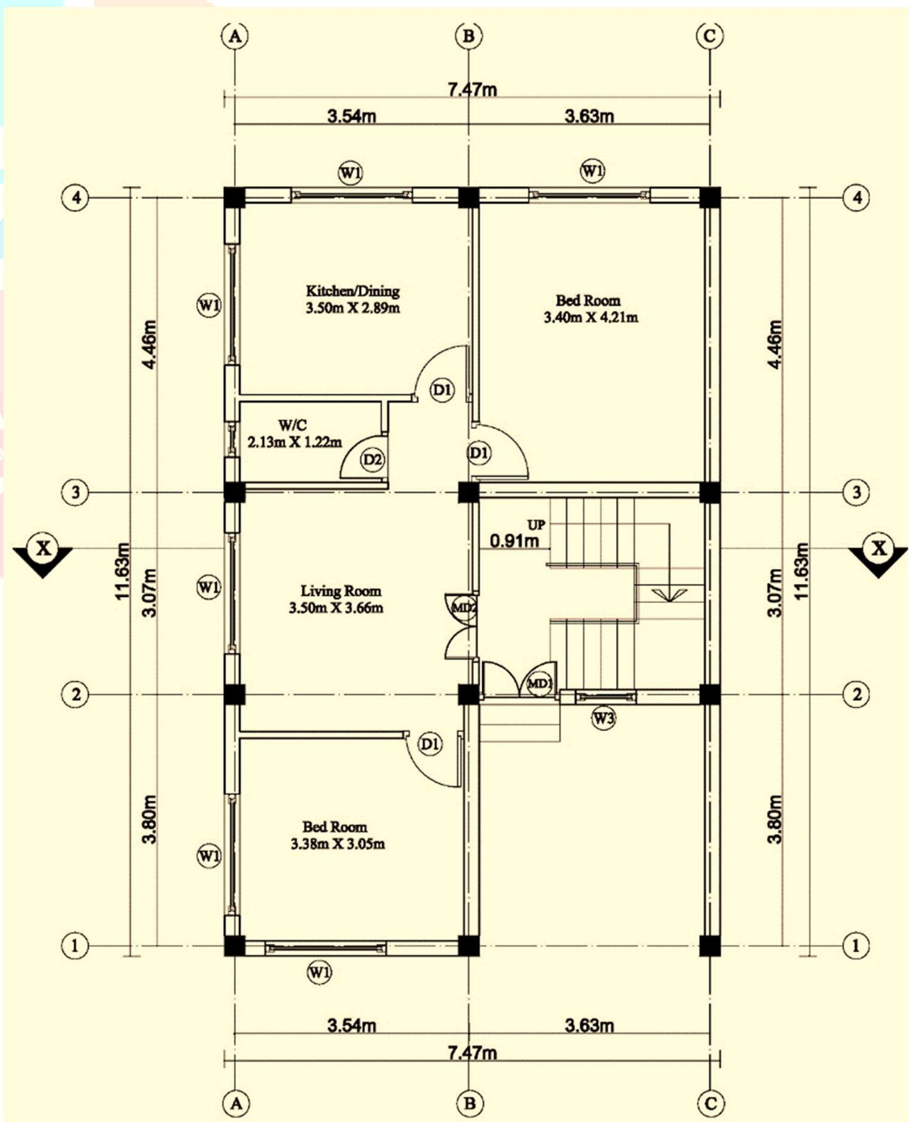
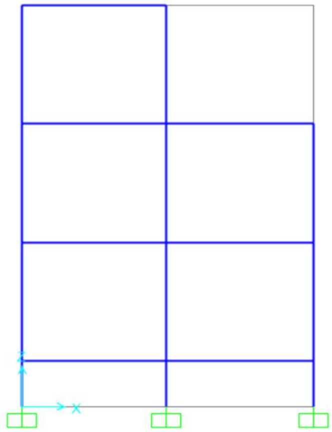
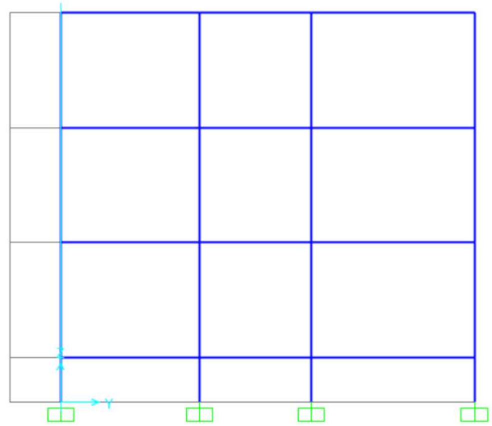


Figure 9.1: Plan of building



X-Z View



Y-Z View

Figure 9.2: Floor to floor line diagram

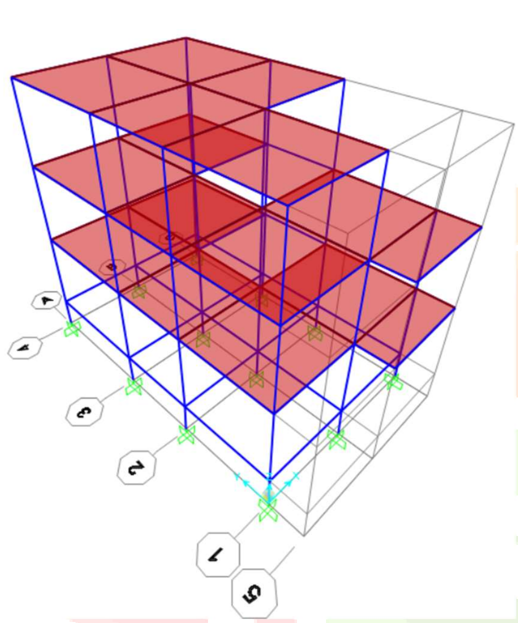


Figure 9.3: 3D modelling using SAP2000

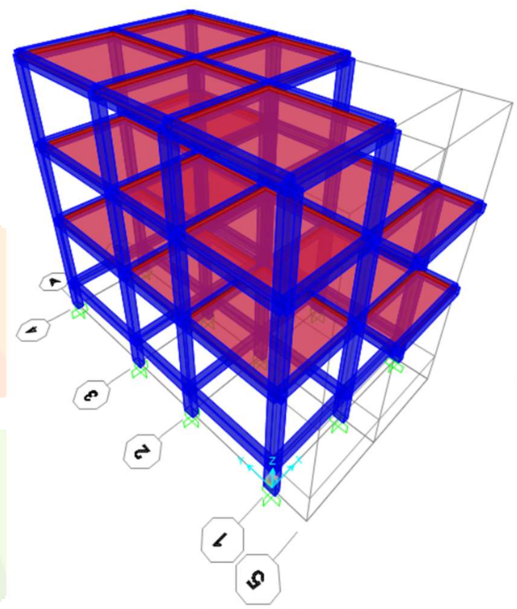
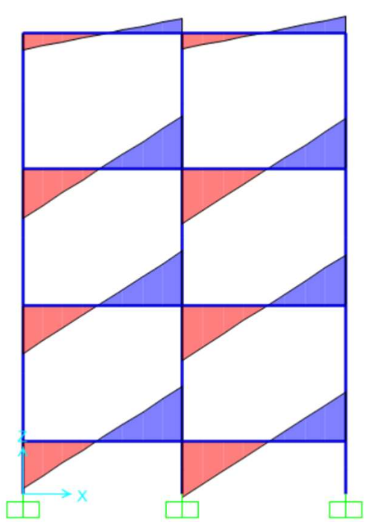
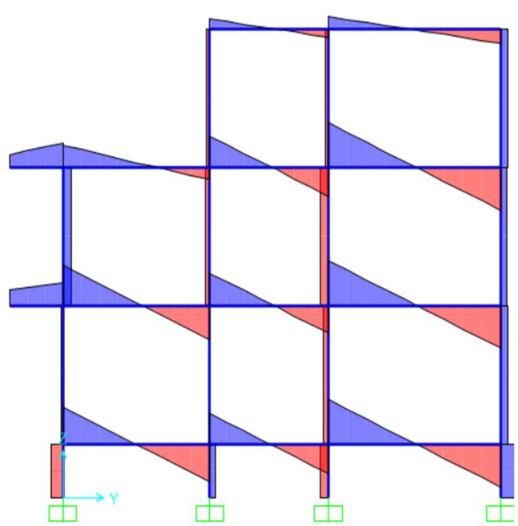


Figure 9.4: 3D rendered view

X. GRAPHICAL REPRESENTATION OF THE ANALYSIS RESULTS

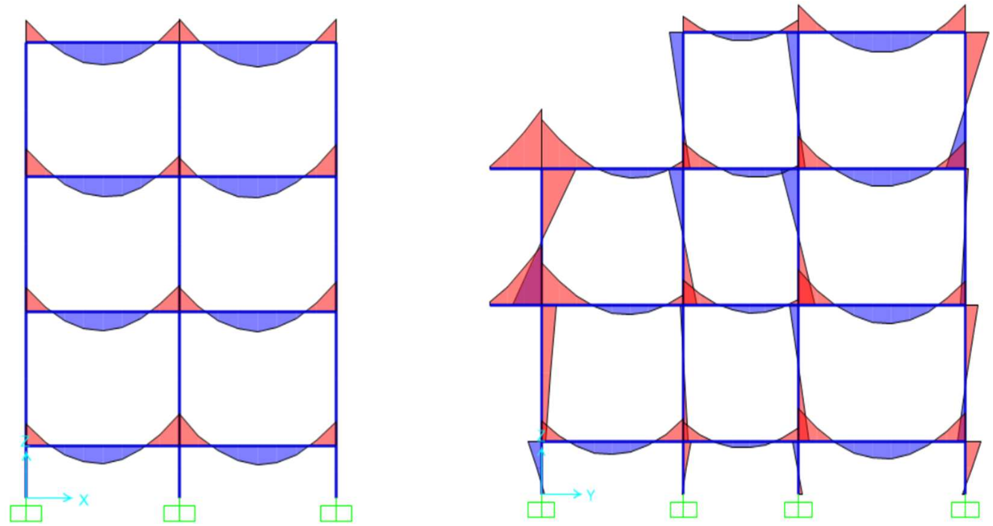


X-Z View



Y-Z View

Figure 10.1: Shear Force 2-2 diagram on the elevation view



X-Z VIEW Y-Z VIEW

Figure 10.2: Bending Moment 3-3 diagram on the elevation view

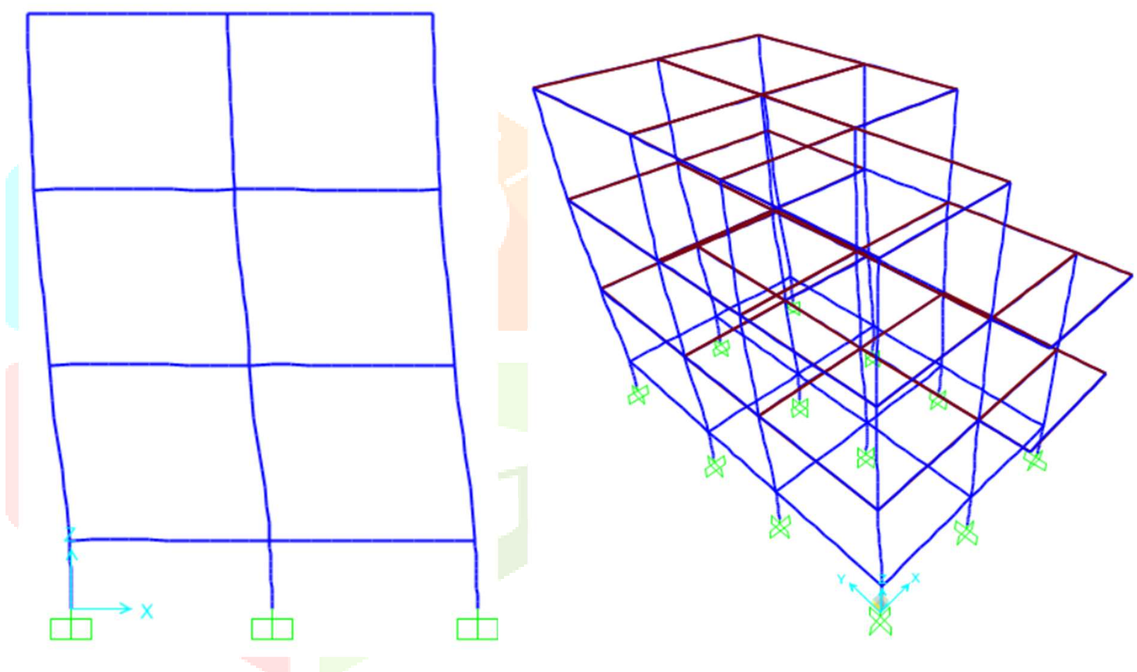


Fig. 10.3: Deformed shape of the building on elevation and 3D view

XI. Design of structural elements

11.1 DESIGN OF BEAM

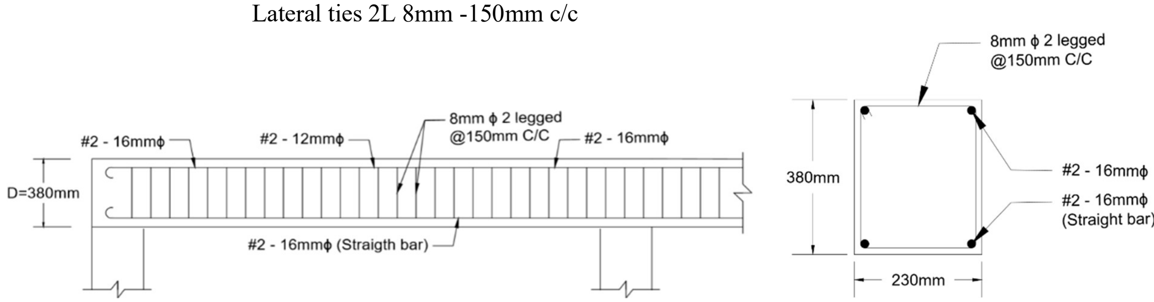
- First Floor Beam (Frame Id: 69)

  Ast at support = 399 mm2 (Provide #2-16mm Ø)

  Ast at mid = 167 mm2 (Provide #2-12mm Ø)

  Ast at bottom = 236 mm2 (Provide #2-16mm Ø)

  Lateral ties 2L 8mm -150mm c/c

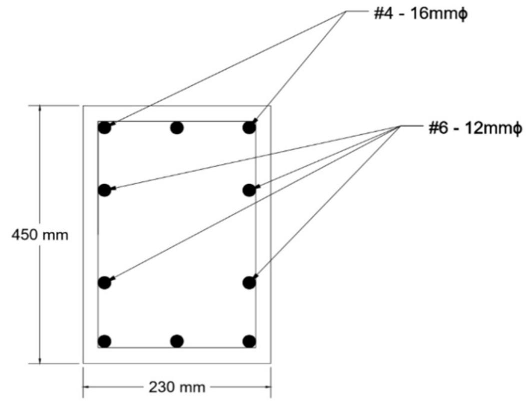


L- Section of Beam C/S of Beam

Figure 11.1: Details Reinforcement for Beam

11.2 DESIGN OF COLUMN

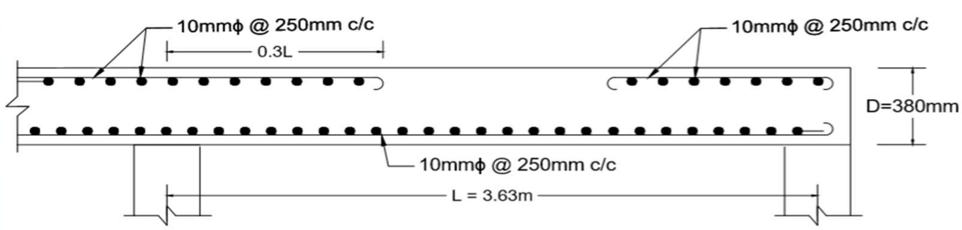
- Frame Id 30
  Max Ast = 1310 mm^2
  Min Ast = 828 mm^2
  Lateral Ties 2L 8mm Ø – 250 mm C/C



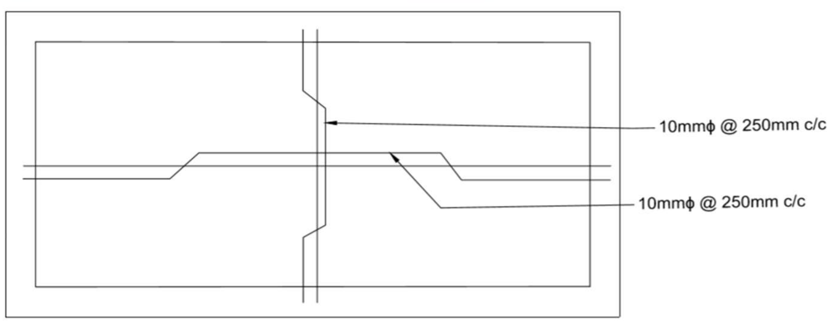
C/S of Column
Figure 11.2: Details Reinforcement of Column

11.3 DESIGN OF SLAB

- Design of Two way slab as per IS 456-2000
- Long Span = 4.21 m
- Short span = 3.40 m
- Slab thickness = 150 mm or 0.15 m
- Material properties: fck = 25 N/mm^2 and fy = 415 N/mm^2
- Panel type = Two Adjacent Edges Discontinuous



L/S of Slab



Top View of Slab
Figure 11.3: Details Reinforcement of Slab

11.4 DESIGN OF STAIR CASE

- The main aim of staircase is that safe and convenient going from one level to another level and also use for emergency purpose.
- The geometry shape of staircase may be quite dissimilar which depends on following factors
  1. Type of structure (Load bearing or Framed structure)
  2. Space availability.

- **Design of first flight:**
  - Going = 1.343m
  - First Landing = 0.91m
  - Second Landing = 1.0m
  - Tread (T) = 275mm
  - Rise (R) = 150nn
  - Live load (LL) = 3 kN/m^2

- Floor finish load = 1 kN/mm^2
- Fck = 20 N/mm^2
- Fy = 415 N/mm^2

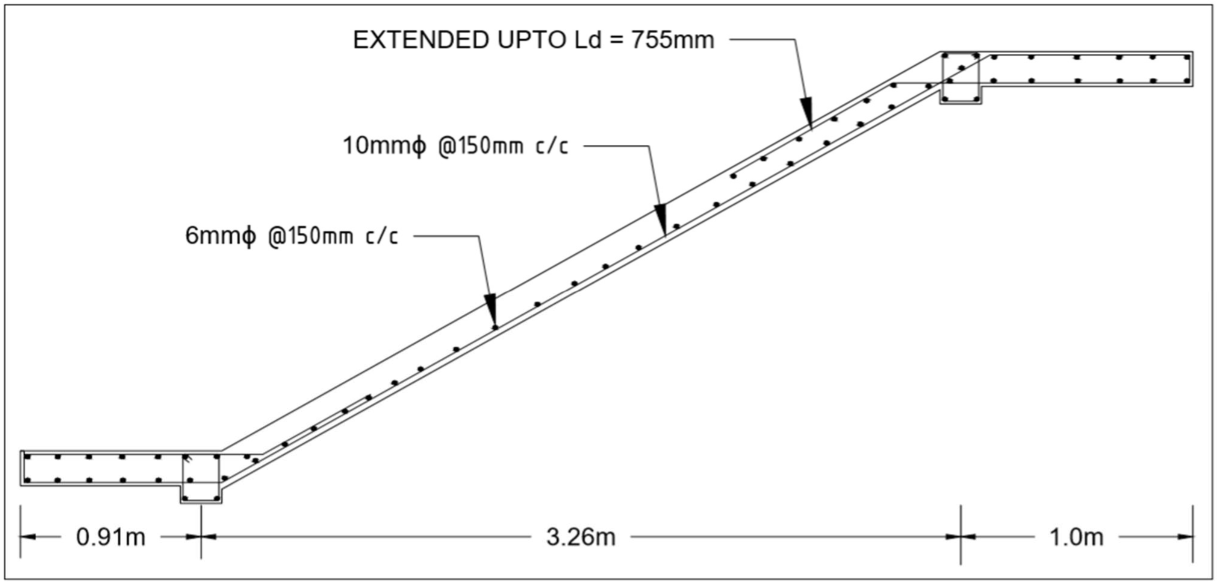


Fig 11.4: Details Reinforcement of Staircase

11.5 DESIGN OF FOOTING

- For Frame Id: 17,18,19,20.
- Column size = 230 X 450 mm
- Safe bearing capacity of soil = 250 kN/m^2
- Factored load coming from column Pu= 744.23 KN
- Servicve load coming from column = 496.14 KN
- Consider self weight of footing as 10% of column
- Size of footing = 1.275 m X 1.50 m
- Area of Footing = 1.92 m^2

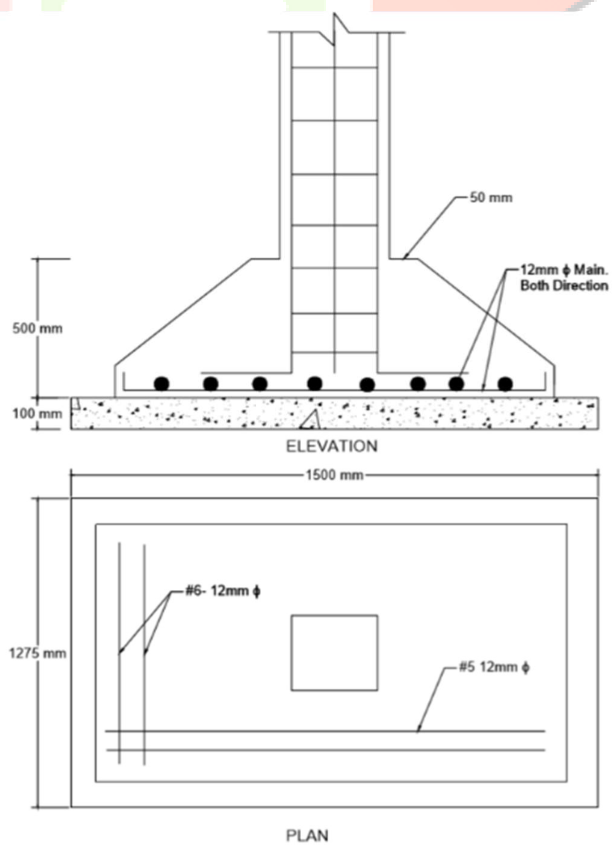


Figure 11.5: Details Reinforcement of Footing

XII. Conclusion

- Using SAP2000 software, the design consideration has been taken as per the codes. The design is safe in all condition.
- The design of slab, beam, column, footing and staircase are safe in all aspects.
- In this project to two type of calculation were performed
  - a) Software base calculation
  - b) Manual base calculation
- The manual calculation were performed for calculate seismic weight and base shear of the building and also manual design are performed for slab, footing & staircase design.
- Although very famous SAP2000 is user-friendly software and it is dedicated software for designing R.C.C. Structure.
- Unless the designer is well versed with manual calculation, he cant detect the misuse played by the software.
- The software is not fine-tuned for detailing. Because, reinforcement arrangement does not suggest by this software only reinforcement area has shown by this software.
- There are limitation of SAP2000 software also, i.e. this software cannot design staircase, slab and footing component.

XIII. References

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