Comparative Study on Stress for Static Analysis and Frequency Analysis

Ismail [1], Dr. N. Jayaramappa [2]

[1]*PG Student, Civil Engineering, University of Visvesvaraya College of Engineering, Bangalore-560056, India*

[2] *Professor, Civil Engineering, University of Visvesvaraya College of Engineering, Bangalore-560056, India*

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Abstract: *This project focuses on the structural analysis of a G+8 reinforced cement concrete commercial office building with the help of ANSYS Workbench. The main aim is to understand how the building behaves under different loads such as dead load, live load, and wind or seismic effects. A 3D model of the structure is created, material properties are assigned, and suitable boundary conditions are applied before running the analysis. The study observes Total deformation, Stresses distribution and Natural frequency overall building structure. By using simulation, it becomes easier to identify critical areas and evaluate safety without physical testing. The results help in understanding the performance of the building and support better design decisions for safe and efficient construction. This work also highlights the importance of numerical simulation in modern structural engineering practice. Instead of depending only on manual calculations, ANSYS Workbench allows detailed visualization of how forces travel through beams, columns and slabs. The response of the structure is studied through stress patterns and displacement results, which helps in understanding whether the building satisfies basic safety and serviceability requirements, the simulation stresses are within the allowable permissible limit's as per standard IS 456-2000 code for the concrete [M25] material.*

Keywords: Commercial Office Building G+8, Static Structural Analysis, Equivalent von misses Stresses, Modal Analysis Natural Frequency,

1. Introduction

This project report presents the planning, design, and construction of a G+8 commercial office building made with M25 grade concrete. The building is designed to meet modern standards of safety, functionality, and aesthetics, while ensuring durability and cost- effectiveness. The structure consists of a ground floor and eight upper floors, which will be used for commercial and office purposes. Each floor is planned to provide flexible working spaces, conference rooms, and service areas to support the daily operations of businesses. The main goal of this project is to create a safe and sustainable building that meets the growing demand for office spaces in urban areas. The design focuses on proper space utilization, structural stability, and efficient use of materials. Special attention has been given to providing adequate natural light, ventilation, and accessibility features to create a comfortable environment for users. The building is constructed using reinforced cement concrete (RCC) with M25 grade concrete, which offers good strength and durability for multi-story structures. M25 concrete, with a characteristic compressive strength of 25 N/mm^2, is suitable for heavy load-bearing components such as columns, beams, and slabs. The reinforcement used in the structure helps resist tension and improves the overall performance of the building under various loads. Modern construction techniques and equipment have been used to maintain quality and ensure timely completion of the project. The design also follows relevant **Indian Standards (IS codes)** for structural design, earthquake resistance, and safety provisions. Environmental aspects, such as waste management, water conservation, and energy efficiency, have been considered to make the building eco-friendly.

2. Materials Selected

Concrete [M25]: M25 grade concrete is widely used in RCC buildings because it provides good strength and durability for structural members. It is designed to achieve a compressive strength of 25 MPa after 28 days of proper curing. This grade is suitable for beams, columns, slabs, and footings in multi-story structures. M25 concrete offers a good balance between strength and workability, making it easy to place and compact at the construction site. With proper mixing and curing, it ensures safety, stability, and long-term performance of the building.

Table 1: Materials Properties based of Concrete [M25]

Property's	Units	Concrete [M25]
Young's Modulus	MPa	25000
Density	Kg/mm^3	2.5e^{-06}

Poisson's Ratio	-	0.18
Compressive Ultimate Strength	MPa	41
Compressive Yield Strength	MPa	25
Tensile Ultimate Strength	MPa	5
Tensile Yield Strength	MPa	2.2

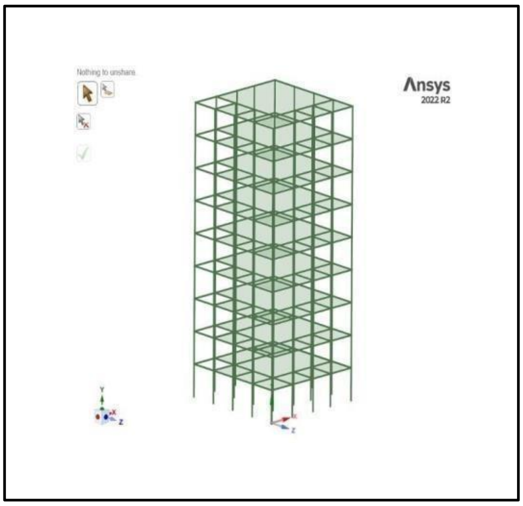


Fig 1: CAD Model in Ansys space claim

Table 2: G+8 Commercial building Dimensions

Plan dimension	18592x13716 (mm)
Total Height of the building	27000 (mm)
Height of Each Story	3000 (mm)
Size of The Beam	450x450 (mm)
Size of The Column	600x600 (mm)
Slab Thickness	150 (mm)
Wind Speed	30 M/S
Wall Thickness	230 (mm)
Floor Finish	1 KN/m^2
Risk Coefficient Factor (K1)	1
Terrain Height and Structural Size Factor (Category 3) K2	As Per Different Floor's
Topography Factor (K3)	1

The **Fig**:1 The G+8 RCC building modelled in Ansys Space claim. The elevation helps in understanding the total height, story arrangement and structural configuration used for the study. It gives a clear idea of how the building is positioned before applying loads such as dead load, live load, and wind or seismic effects during the analysis stage of the model properly.

All the required dimensions for the RCC commercial building as shown in **Table:2** including column sizes, beam sizes, slab thickness and overall building height, have been clearly defined before starting the analysis. These details help in creating an accurate structural model. Proper dimensional data ensures correct load calculation, safe design, and realistic results during analysis.

Table 3: Live Loads as per IS875 Part -2

Building Area's	KN/m^2	MPa
Conference Hall	3	0.003
Pantry	2	0.002
Toilet's	2	0.002
Store Area	5	0.005
Waiting Area	4	0.004
Kitchen	3	0.003
Varanda	3	0.003
Chamber	2	0.002
President Room	3	0.003
Generator Room	7	0.007
Reception Area	3	0.003
Lift Area	5	0.005

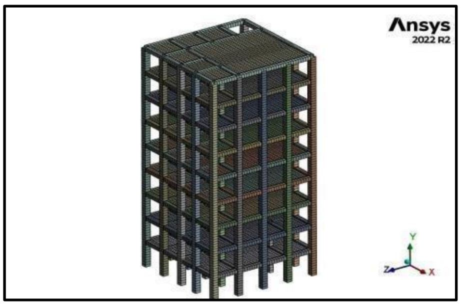


Fig 2: Meshed Model

The **Fig 2** shows a meshed model in Ansys workbench software. In Ansys workbench the mesh quality will be smooth it can mesh complex object without any error, also using washers where there is a hole present to get best elements without any other mixing elements, the **Table:4** shows below the meshing details in Ansys workbench with node as 20651 and element 18010.This meshed model is used in Ansys workbench to analyze the natural frequency, stresses, strain, deformation and

Table 4: Meshed details

Nodes	Elements
20651	18010

3. Methodology

First, a literature survey on the RCC commercial building was done to understand the basic concepts and previous studies. Then, materials were selected based on their mechanical properties. After that, wall load and wind loads were calculated. Next, the building model was created in ANSYS Workbench 2022. The model was then meshed and imported into the software for analysis. Suitable boundary conditions were applied to represent real support conditions. Structural analysis was carried out to find the equivalent von Mises stress, equivalent strain, and total deformation of the structure. Modal analysis was also performed to determine the natural frequency of the building. Finally, the conclusions were made based on the results obtained from the analysis.

4. Results & Discussion

a. Calculation Of Wind Load

1.1 WIND LOAD CALCULATION AS PER IS 875 PART-3

- Wind Pressure:

$P = 0.6 \times Vz^2$ (01)

- Design wind speed:

Vz = V b x K1 x K2 x K3 x K4 (02)

Here K2 is Terrain height & Structural size Factor Table 2 Page 24 Terrain Category (3) Structural size (B) Normal size Building
Here (V_b) is Basic wind speed (m/s) For Bangalore is 33 m/s Page 23 Here (K1) is Risk Coefficient Factor.
Here (K3) is Topography Factor.

Here (K4) is Important Factor For the cyclonic region Vz = 33 x 1 x 0.88 x 1 x 1 = 28.02 m/s
$P = 0.6 \times (28.02)^2$ = **439 N/m^2 OR 0.000439 MPa**

But I want in (Newton) to apply Because of we have beams not a solid body so pressure Can't be applied on beams so we have to convert pressure in to wind force so the wind force can be applied on beams & column.

A = H X W

A = 3000 X 18592 A = 55.7 M^2

Force = P*A

F = 439 x 55.7 = 2447202 N G L Force (03)

1st FLOOR CALCULATION (WIND FORCE) (04)

Vz = 33 x 1 x 0.94 x 1 x 1 = 31.02 m/s

$P = 0.6 \times (31.02)^2$ = 484.6 N/M^2 or 0.000484 MPa F = 484 x 55.7 **= 27002 N**

2nd FLOOR CALCULATION

Vz = 33 x 1 x 0.97 x 1 x1 = 32.02 m/s

P = 0.6 x $(32.02)^2$ = 518 N/M^2 OR 0.000518 MPa

F= 518 x 55.7 **= 28852 N** **(05)**

3nd FLOOR CALCULATION

Vz = 33 x 1 x 0.94 x 1 x1 = 31.02 m/s

P = 0.6 x $(31.02)^2$ = 0.000517 MPa

F = 517 x 55.7 **= 29000 N** **(06)**

4th FLOOR CALCULATION

Vz = 33 x 1 x 1.02 x 1 x 1 = 33.66 m/s P = 0.6 x $(33.66)^2$ = 0.000580 MPa
F = 580 x 55.7 **= 32193 N** **(07)**

5th FLOOR CALCULATION

V z = 33 x 1x 1.03 x 1 x 1 = 34 m/s P= 0.6 x $(34)^2$ = 0.000605 MPa
F = 605 x 55.7 **= 33639 N** **(08)**

6th FLOOR CALCULATION

V z = 33 x 1 x1.06 x 1 x 1 = 34.98 m/s P = 0.6 x $(34.98)^2$ = 0.000626 MPa
F = 626 x 55.7 **= 34925 N** **(09)**

7th FLOOR CALCULATION

V z = 33 x 1 x 1.08 x 1 x 1 = 36 m/s P= 0.6 x $(36)^2$ = 0.000642 MPa
F= 642 x 55.7 **= 35818 N** **(10)**

8th FLOOR CALCULATION

V z = 33 x 1.09 x 1 x 1 = 36.5 m/s P = 0.6 x $(36.5)^2$ = 0.000655 MPa
F= 655 x 55.7 = **36431 N** **(11)**

1.2 WALL LOAD'S CALCULATION:

Wall Thickness x Height x Density of Brick Masonry

0.230 x 3 x 20

13.8 KN/m **(12)**
Plaster load (both sides) 20 mm Thickness.

0.02 + 0.02 = 0.04 m

0.04 x 3 x20 = 2.4 KN/m

Total wall loads on Beam's:

13.8 + 2.4 **= 16.2 KN/m OR N/mm** **(13)**

1.3 Force Reaction:

- **Slab dead load** = Thickness x Density of RCC

  = 0.15 x 25

  = 3.75 KN/m^2

- **Floor Finish** = 1KN/m^2

  Total Dead load of Slab = 3.75 + 1= 4.75 KN/M^2

- **Beam Dead Load** = Area x Density

  = 0.45 x 0.45 x 25

  = 5.06 KN/m

- **Column Dead Load** = Area x Height x Density

  = 0.60 x 0.60 x 27 x 25

  = 243 KN/m

- **Wall Dead Load** = Thickness x Height x Density

  = 0.230 x 27 x 20

  = 124.30 KN/m

- **Total Live Load** = including all Live load

  = 41 KN/m^2

FORCE REACTION = 40800000 N

REFFERANCE: IS 875 PART -1 (Clause 3.1)

It is saying that Dead load shall be calculated based on unit weight of material& assumed dimension.

In my case 36523305.42 N
Only 9% Difference (5 – 10% is Variation is Allowed)

1.4 EQUIVALENT VON- MISES STRESS:

(AS PER IS 456-2000 Clause 36.4.2 Design Compressive Stress in Concrete)

$F_{cd} = F_{ck} / \gamma m$

= 25 / 1.5

= 6.50 MPa < 16.67 MPa (It is with in it's Permissible Limit's)

Von – Mises stress is mainly used for Ductile material like steel Concrete is brittle material but Ansys show's Von- mises stress to understand overall stress Behavior's.

1.5 MAXIMUM PRINCIPAL STRESS:

AS PER IS 456-2000 CLAUSE 6.2.2 The Tensile Strength of Concrete is 3.5 MPa

0.7 x √fck = 0.7 x √25 = 3.5 MPa

3.5 < 7.23 MPa

- It Is Practically Acceptable
- RCC member transfer tension to steel reinforcement
- Principal Stress Point Ansys Shows Stress in Overall Material Model.

1.6 MINIMUM PRINCIPAL STRESS:

AS PER IS CODE 456-2000 (Clause 38.1)

= 0.45 x Fck

= 0.45 x 25

= - 7.09 MPa < - 11.25 MPa (Hence the structure is safe under applied loading condition).

1.7 MAXIMUM SHEAR STRESS:

AS PER IS 456- 2000 (Clause 40.2.3) & Table 20

M25 ⟶ 3.1 MPa

In my case 3.6 MPa > 3.1 MPa (only 0.5 % Difference it is acceptable)

- Solution: Grade of concrete we need to increase
- Providing Additional Shear Reinforcement Increase Section Size

1.8 EQUIVALENT ELASTIC STRAIN:

AS PER IS CODE 456-2000 (Clause 38.1 (b))

It Is Calculated Based on Hooke's Law

Strain = σ / E

It is up to 0.0003 to 0.0035 Before Cracking Starts In my case 0.00026 < 0.0035 (it is with in its Limit).

- The Structure is working in safe Elastic Range
- No Excessive Deformation
- It Is with In Its Permissible Limit's.

b. ANSYS RESULT'S:

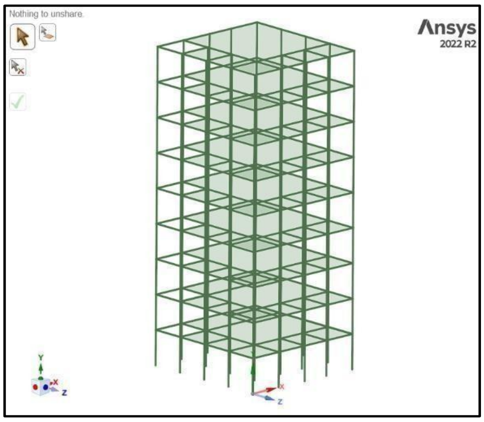


Fig: 3 Side view of the building

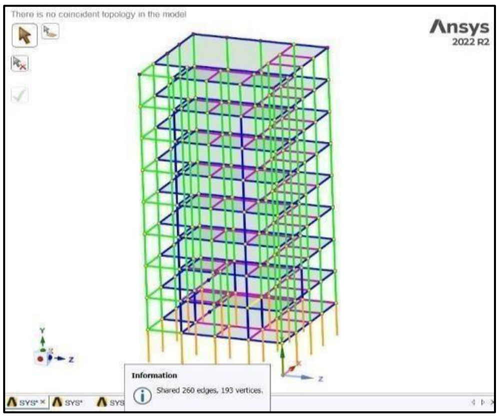


Fig: 4 Shear check

This **fig:3** presents the side view of the G+8 RCC building modelled in ANSYS Workbench. The elevation helps in understanding the total height, storey arrangement, and structural configuration used for the study. It gives a clear idea of how the building is positioned before applying loads such as dead load, live load, and wind or seismic effects during the analysis stage of the model properly.

The **Fig:4** shows that first, in ANSYS Space Claim, I have modelled the structure. Once that's done, I have selected the entire building. After that, I have selected the each joint individually. Then, when all joints are selected, the red color should be shown. Once they're highlighted in red, there is a green tick option at left side after ticking that the checkbox for the shear check. After doing that, notification will come saying that "There is no shear. Means the structure is in bonded connection between column, beam & slab.
Before applying any external loads, the RCC G+8 building model was checked in ANSYS Workbench. At this stage, no shear effect was observed in the structure, confirming that the model is stable and free from initial shear stresses before loading.

Fig: 5 Fixed Support of G+8 Building.

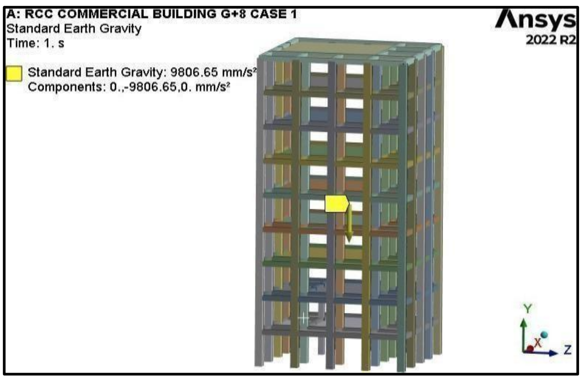


Fig:6 Standard Earth Gravity.

The **Fig:5,** shows the Fixed Support are provided at the base of the G+8 building to represent the actual foundation condition. These supports restrict movement and rotation of the structure at ground level, ensuring stability and realistic load transfer to the foundation. **Fig:6** shows the gravity load acting on the structure in downward direction & it is taken as 9806.65 mm/s^2, which represent the natural gravitational acceleration of the earth.

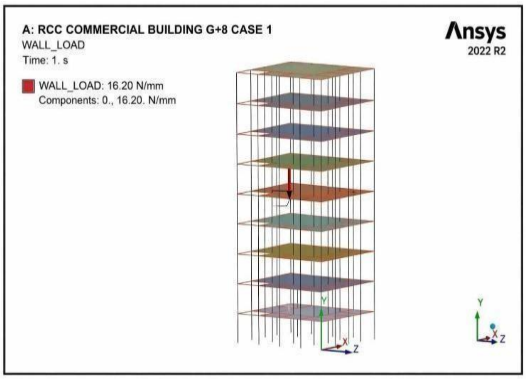
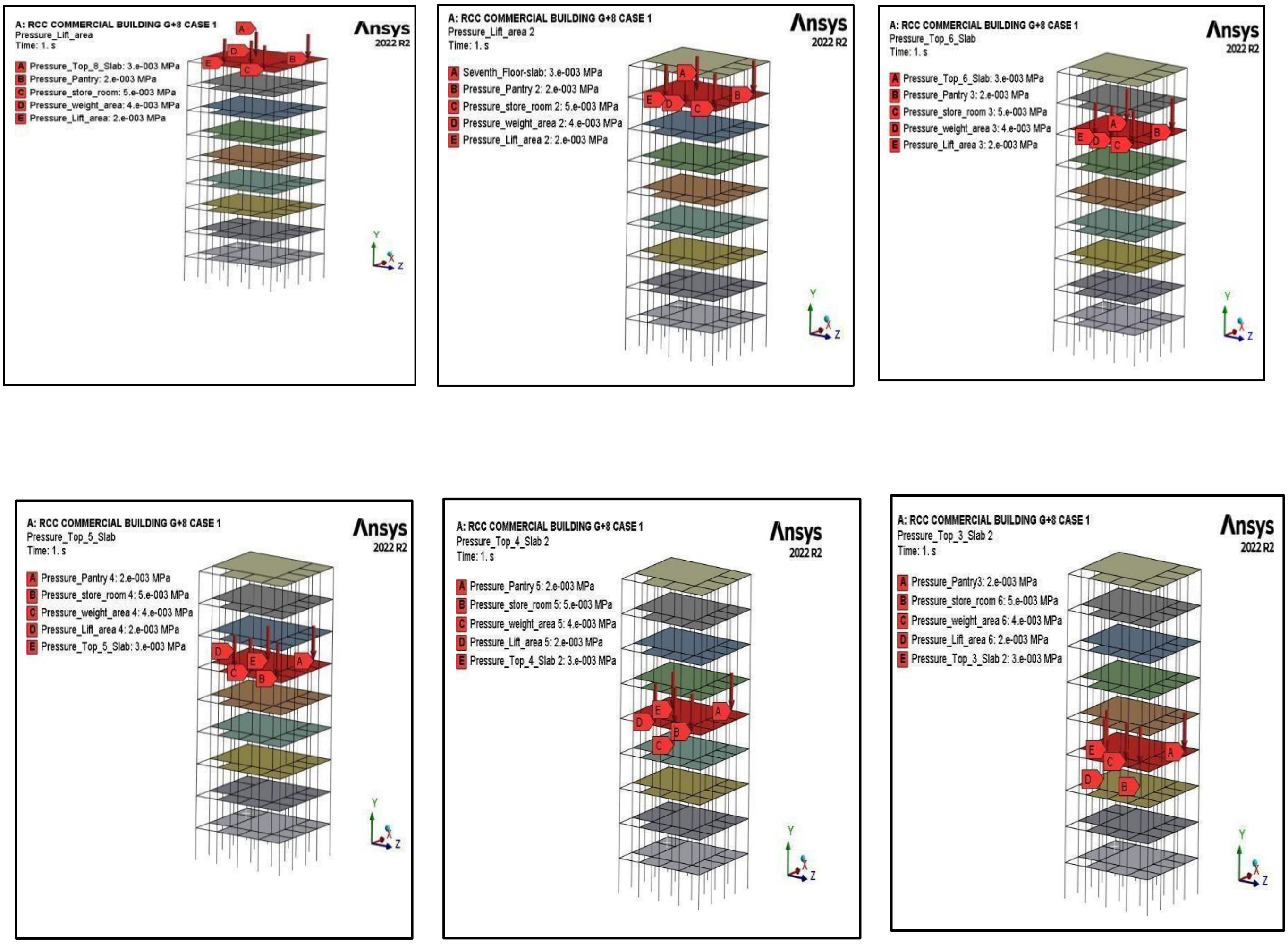


Fig:7 Wall Load Acting on structure.

The self-weight of brick walls and finishing layers creates wall load in the structure. This load acts continuously along the supporting beams and is transferred to columns and foundations. For this RCC G+8 commercial building model, wall load is considered as uniformly distributed load to simulate real site conditions. And its valve is taken as 16.2 N/mm.



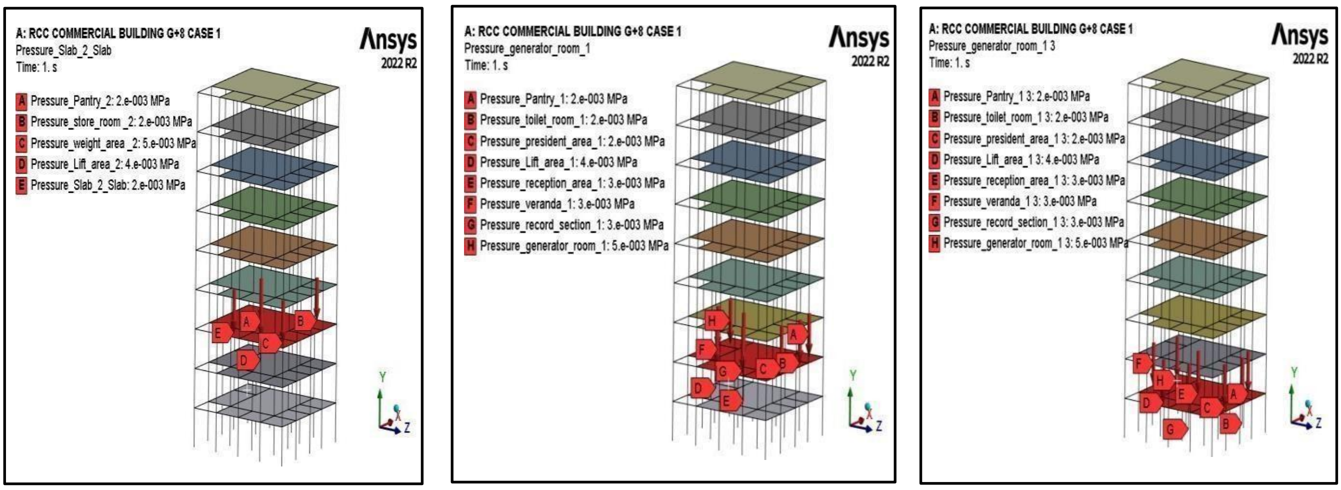


Fig: 8 Live load's acting on each & every floor.

the live load is applied and distributed on every floor of the G+8 commercial building. It helps in understanding how load transfer takes place through different structural members.

CASE 1: RESULT'S WHENSTRUCTURE CARRYS DEAD & LIVE LOAD'S:

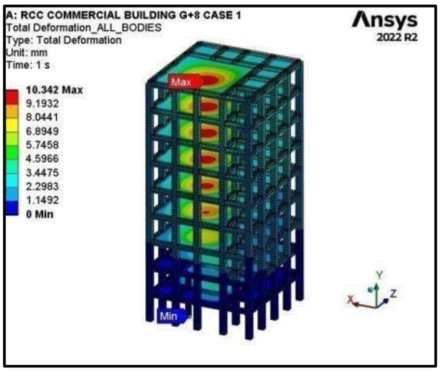


Fig:9 Total Deformation.

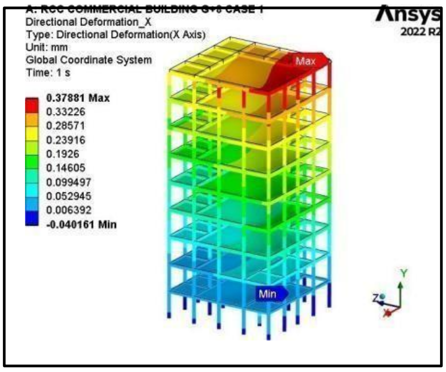


Fig: 10 Deformation (X-Axis)

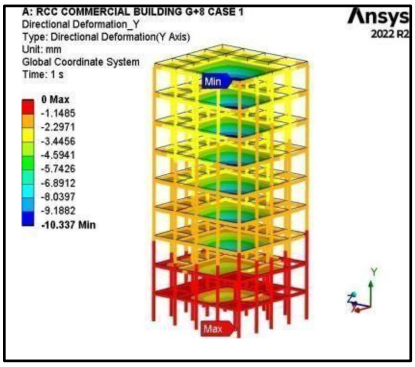


Fig:11 Deformation in (Y)

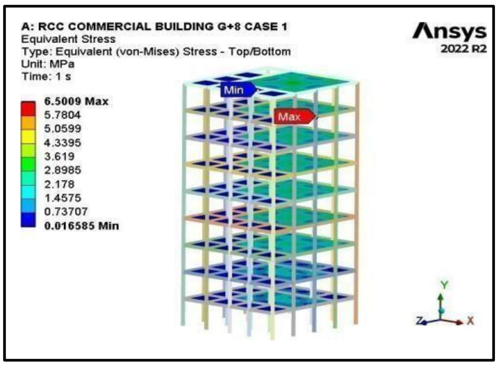


Fig: 12 Equivalent (Von – Mises) Stress.

Fig: 13 Minimum Principal Stress.

The **Fig:9** The deformation is minimum at the base around **0 mm** because of fixed support and maximum at the top floor due to load effects & it is around **10.34 mm**. **Fig:10** This result shows Directional Deformation in the X direction. The base portion has minimum deformation because it is fixed, and it is around **- 0.040161 mm** deformation increases towards the top floors. Is around **0.37881 mm Fig: 11** The analysis results indicate that the displacement of the structure in the Y-direction is **zero** at certain locations **Fig: 12**. The maximum stress is mainly observed near beam-column joints and load transfer areas is around **6.5009 MPa** & Minimum stress is mainly observed slab-beam is around **0.016585 MPa. Fig: 13** higher compression is obtained near beam and column joint areas because these regions carry more load. Is around **-7.0989 MPa**

CASE 2: RESULT'S WHEN STRUCTURE CARRYS DEAD, LIVE LOADS & WIND LOAD'S:

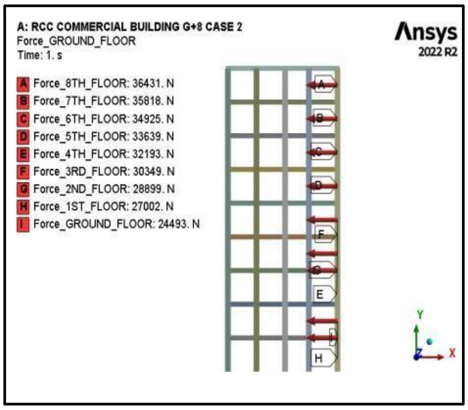


Fig: 14 Wind Load's acting on structure.

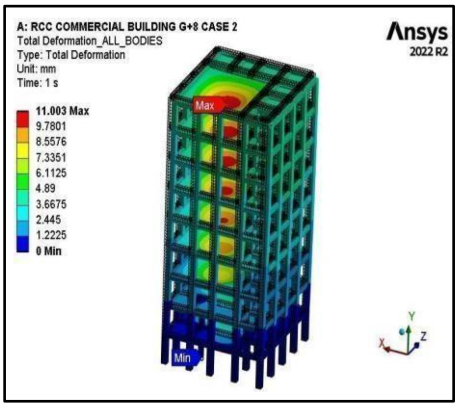


Fig: 15 Total deformation

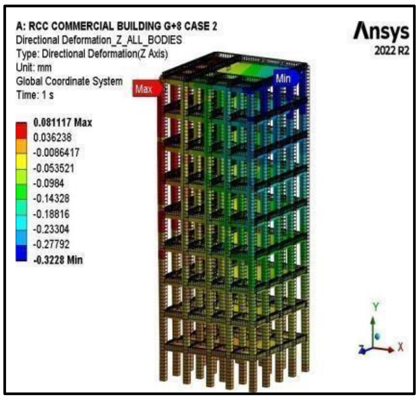
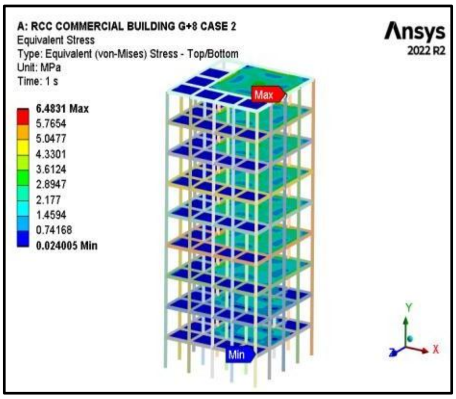


Fig:16 Directional deformation- Z



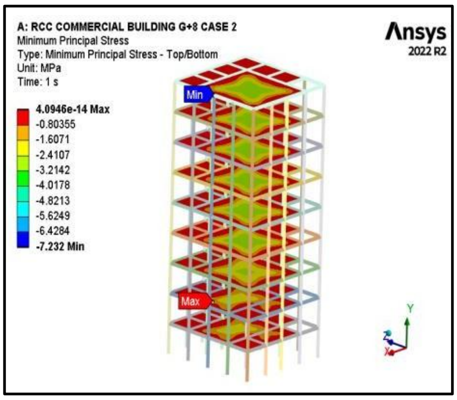


Fig: 17 Equivalent (Von – Mises) Stress. Fig: 18 Minimum Principal Stress Fig: 19 Maximum shear Stress

Fig:14 Wind load is acting on the building in the X- direction, so lateral forces are developed at every floor level. From the result, it can be understood that the upper floors are more affected because they are directly exposed to wind pressure. Due to this load, the structure shows a small side movement, and the frame resists this action to maintain overall stability and safety of the building. **Fig: 15** The deformation is minimum at the base around **0 mm** because of fixed support and maximum at the top floor due to load effects & it is around **11.003 mm**. **Fig: 16** The result shows that the maximum Z-direction deformation is about **0.081117 mm**, and the minimum value is **0.3228 mm**. **Fig: 17** The maximum stress is mainly observed near beam-column joints and load transfer areas is around **6.4831 MPa** & Minimum stress is mainly observed slab-beam is around **0.024005 MPa Fig: 18** higher compression is obtained near beam and column joint areas because these regions carry more load. Is around **- 7.2320 MPa Fig: 19** The Maximum shear stress is mainly observed near beam and column connection areas is around **3.616 MPa** and lower floors because these parts carry more load. The upper floors show less shear stress is around **0.013855 MPa**

Table:5 Static structural Analysis Results of G+8 Commercial Building

G+8 RCC mmercial building	Total Deformation in (mm)	Equivalent von-mises Stress	ximum Shear Stress	uivalent Elastic Strain	Maximum Principal Stress	Minimum Principal Stress
Case 1	10.32	6.509	3.6141	0.00026	7.2282	7.098
Case 2	11.003	6.4831	3.616	0.00026	7.128	7.232

Table:6 Allowable Permissible Limit's AS PER IS 456-2000 For M25 Grade Concrete.

G+8 RCC ommercia l Building	Equivalent Von-mises stress (MPa)	aximum Principal Stress (MPa)	Minimum Principal Stress (MPa)	Maximum Shear Stress (MPa)	Equivalent Elastic Strain
Allowable Permissible Limit's	11.67	3.50	-11.25	3.1	0.0035

C. MODEL ANALYSIS RESULT:

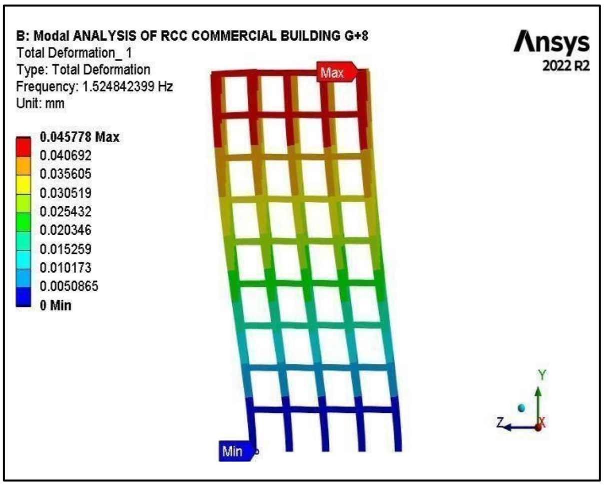


Fig:20 .1st Mode Frequency.

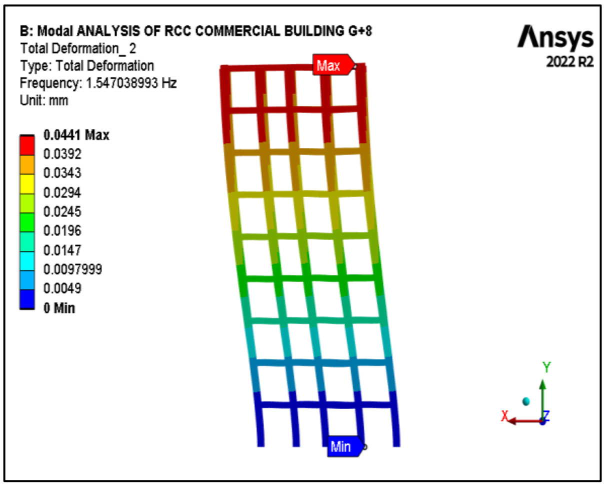


Fig: 21. 2nd Mode Frequency.

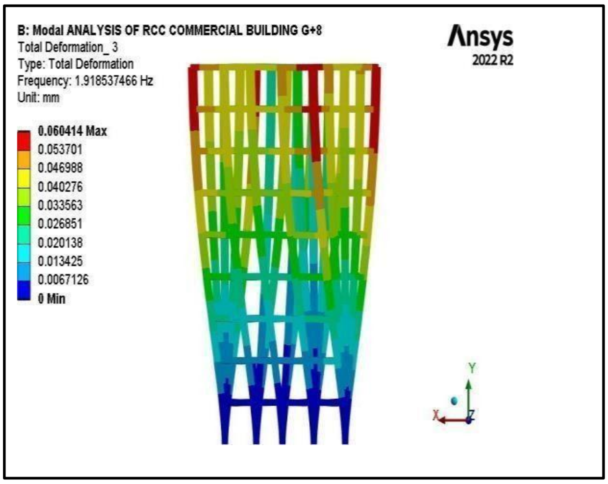


Fig: 22. 3rd Mode Frequency

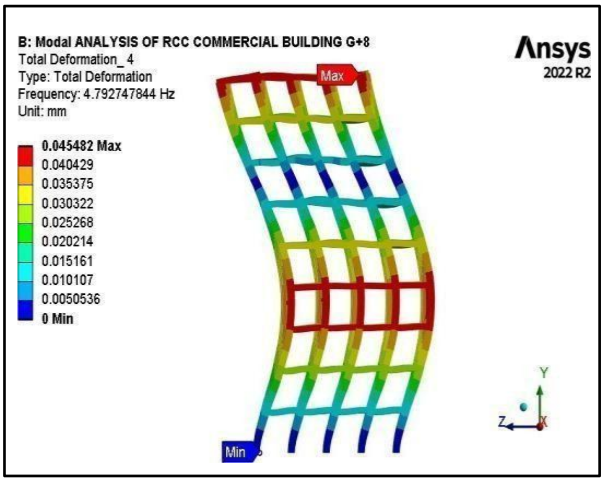


Fig: 23 .4th Mode Frequency

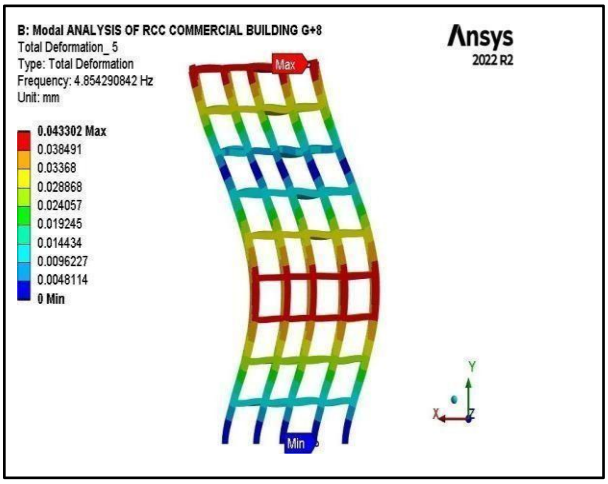


Fig:24. 5th Mode Frequency

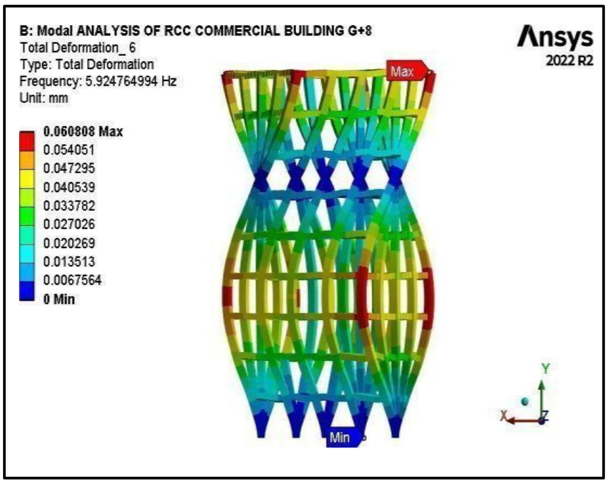


Fig:25. 6th Mode Frequency.

The **Fig:20 to 25** Six modes of the natural frequency of the G+8 RCC Commercial Building material, the frequency increases low too high in different modes and location. It can be observed that the frequency is increasing up to **5.924764 Hz** from initial mode to final mode as per results.

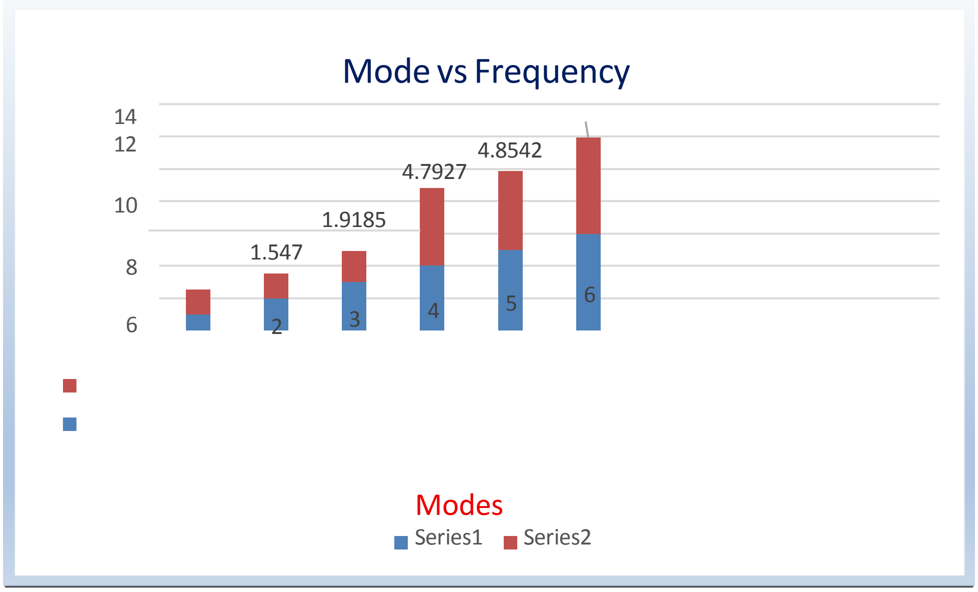


Chart: 1 Shows the Frequency vs. Modes of the G+8 RCC Commercial Building.

Table 7: Natural Frequency of the G+8 Commercial Building

Modes	Natural Frequency's (Hz)
1	1.5248
2	1.547
3	1.9185
4	4.7927
5	4.8542
6	5.9247

5 CONCLUSIONS:

5.1 Static Structural Analysis:

From the analysis results, it is observed that all the stresses developed in the structure are within the permissible limits as specified in IS 456:2000. This indicates that the RCC commercial building is structurally safe under the applied loads and boundary conditions. The deformation and strain values are also within acceptable limits, showing that the design is stable, reliable, and suitable for practical construction.

5.2 Modal Analysis:

In every mode the maximum deformations are observed at the Top floors of the building.

In modal analysis are performed for 6 modes, in starting three modes are very flexible & remaining 4,5& 6 modes are stiff. We see that natural frequency increasing consistently for all six modes.

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