# IP1302 - DESIGN PROJECT

# ANALYSIS AND DESIGN OF RESIDENTIAL BUILDING (APARTMENT)

A project report submitted in partial fulfillment of the requirements for the award of the degree of

**Bachelor of Technology**

in

**Department of Civil Engineering**

by

**MUTHUKUMARAN B(CE22B1022)**
**SIVABALAJI S (CE22B1034)**
**VIJAY NITHISHWAR S (CE22B1038)**

**Under the guidance of:**
**Dr. Sathish kumar**
**Assistant professor**
**Department of civil Engineering**

**Faculty in charge: Dr. Senthil Kumar V**

**Assistant Professor**

**DEPARTMENT OF CIVIL ENGINEERING**
**NATIONAL INSTITUTE OF TECHNOLOGY PUDUCHERRY**
**KARAIKAL – 609 609**

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# ABSTRACT

This project focuses on the structural design of a Ground plus Five (G+5) residential apartment building located in Karaikal. The primary goal is to develop a safe, durable, and efficient multi-storey building that meets the growing housing demands in urban areas with limited land availability. The design follows relevant Indian Standard codes to ensure compliance with safety, serviceability, and sustainability requirements.

The building is modeled and analyzed using ETABS software to assess the effects of various loads including dead load, live load, wind load, and seismic load. Load combinations are applied as per IS codes to simulate real-life conditions. The structure employs a moment-resisting reinforced concrete frame system to provide adequate resistance against lateral forces, minimizing structural damage during earthquakes and strong winds.

Detailed design calculations and reinforcement detailing are carried out based on the Limit State Design method. The project also addresses practical aspects such as optimal space utilization and construction feasibility in the Karaikal region. This study aims to deliver a comprehensive design solution that balances structural integrity, cost efficiency, and occupant safety for modern residential construction.

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# 1. INTRODUCTION

This project presents the structural modeling, analysis, and design of a G+5 residential apartment located in Karaikal, Puducherry, a coastal region characterized by moderate seismic activity and exposure to significant wind forces. The structural system is designed to safely withstand gravity loads and lateral forces, adhering to the guidelines specified in IS 456:2000 for reinforced concrete design, IS 875 (Parts 1–3) for loading standards, and IS 1893 (Part 1): 2016 for seismic analysis.

A comprehensive finite element model of the structure is developed using ETABS software to accurately capture the behavior of structural components under various load combinations. Detailed structural drawings, including framing plans and reinforcement layouts, are prepared using AutoCAD to ensure clarity and precision in the design documentation. The design process involves rigorous evaluation of serviceability criteria, strength requirements, ductility demands, and performance under seismic loading.

Special consideration is given to the selection and detailing of lateral load-resisting elements, structural irregularities, and foundation systems appropriate for site-specific geotechnical conditions. This project aims to bridge theoretical knowledge and practical application by leveraging advanced computational tools to deliver a structurally sound, code-compliant, and efficient apartment building design.

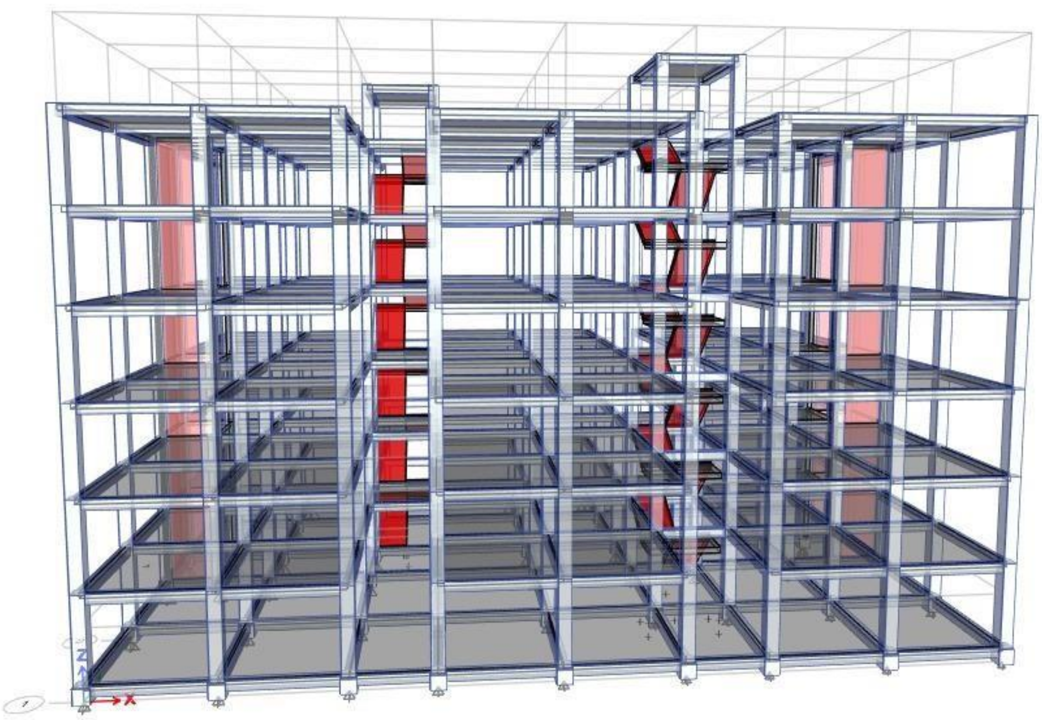


**Figure : 1**

## 1.2 Problem statement:

The rapid urbanization and increasing population in the Karaikal region of Puducherry have led to a growing demand for multi-storey residential buildings that are structurally safe, space-efficient, and economically viable. However, the design and construction of such buildings pose several challenges, including compliance with seismic safety standards (as Karaikal falls under Seismic Zone II), efficient load distribution, optimization of structural materials, and adherence to relevant IS codes.

This project aims to address these challenges by designing a G+5 apartment building using standard engineering practices, ensuring safety under dead, live, wind, and seismic loads. The project involves the use of modern software tools like ETABS and AutoCAD for structural modeling, analysis, and detailing. The goal is to develop a structurally efficient, code-compliant, and constructible apartment design suitable for the local site conditions and urban housing needs.

## 1.3 Objectives:

The objective of this project is to design a safe, economical, and structurally efficient G+5 apartment building in the Karaikal region, using advanced structural analysis tools like ETABS while adhering to relevant IS codes. The project aims to meet the urban housing needs with considerations for wind and seismic loads to ensure long-term durability and safety.

## 1.4 Summary:

This project focuses on the structural design of a G+5 residential apartment building located in the Karaikal region, addressing the growing demand for safe and efficient urban housing. The building is designed to comply with relevant Indian Standards (IS codes) and the National Building Code (NBC 2016), considering factors such as dead, live, wind, and seismic loads, as Karaikal falls under Seismic Zone II. Key structural components—including slabs, beams, columns, footings, and shear walls—are analyzed and designed using ETABS, with detailed drawings prepared in AutoCAD. The project aims to deliver a cost-effective, durable, and practical building solution while enhancing technical knowledge in multi-Storey design, load analysis, and structural detailing. Through this work, the project bridges academic learning with real-world civil engineering applications.

# 2. METHODOLOGY

## 2.1 Overview:

To carry out the structural design of a G+5 apartment building in Karaikal, I followed a systematic process that covered every key stage from planning to final design. The steps are explained below:

1. **Defining the Objective**
   The first step was to clearly define the goal of the project, which was to design a structurally sound G+5 apartment that is safe, economical, and compliant with relevant IS codes.

2. **Site and Regional Data Collection**
   I gathered important data about the Karaikal region, such as wind speed, seismic zone classification, and basic environmental conditions. This information was essential for applying correct load values in the design.

3. **Architectural Planning**
   A functional floor plan was developed considering space utilization, ventilation, and access. This included designing typical floor layouts with proper arrangement of rooms, staircase, and utility spaces.

4. **Preliminary Structural Layout**
   Based on the architectural plan, I decided the positions of columns and beams. Initial assumptions for member sizes were made to ensure the structure could carry the expected loads.

5. **ETABS Modeling**
   The building was modeled using ETABS software. I created a 3D structural model by defining all elements like columns, beams, and slabs with suitable material and cross-sectional properties.

6. **Load Application**
   After modeling, I applied all necessary loads—dead load, live load, wind load (as per IS 875 Part 3), and seismic load (as per IS 1893 Part 1). ETABS was used to generate appropriate load combinations based on IS 875 Part 5.

7. **Structural Analysis and Design**
   The model was analyzed to determine internal forces. Based on these results, I designed the structural elements (beams, slabs, and columns) using IS 456:2000. For seismic detailing, IS 13920:2016 was referred where required.

8. **Preparation of Structural Drawings**
   Once the design was completed; I prepared detailed structural drawings that included reinforcement details for beams, slabs, and columns. These drawings are essential for actual construction.

9. **Report Compilation**

Finally, all the data-planning, analysis results, design calculations, and drawingswere compiled into a complete project report, presenting a clear record of the design process and conclusions.

**FLOW CHART:**

START

⇓

REVIEW & IS CODE STUDY

⇓

DATA COLLECTION AND PRELIMINARY PLANNING

⇓

LOAD CALCULATIONS ( design , live ,seismic, wind)

⇓

ETABS MODELING

(G+5 APARTMENT STRUCTURE)

⇒ Analysis of structure

⇒ Design of structure

⇒ Result & Safety check

⇒ Rebar Detailing

⇒ DOCUMENTATION AND REPORT

## 2.2 Data collection:

### 2.2.1 Description of Building

Description of building based upon the collected as built information is as follows.

| | |
|---|---|
| Building Type | Residential Apartment building |
| Location | Karaikal |
| Total Area | 936.28 sq.m |
| Number of Flats | 30 each floor has 6 dwelling units |
| Structural System | Special Moment Resisting RCC Frame |
| No. of Stories | 5 Storey RCC |
| Storey Height | All story of the building is with height 3.2m<br>And head room height is 2.9m |
| Area | a. Ground floor<br>b. First floor<br>c. Second floor<br>d. Third floor<br>e. Fourth floor<br>f. Fifth floor<br>g. Terrace<br>h. Head room |
| Floor Thickness | 200mm |
| Parapet wall height | 1m |
| Earthquake Zone | II |
| Importance factor,I | 1 |
| Wind Speed | 50m/s |
| Structure Class | A |
| Risk coefficient(k1) | 1 |
| Topography(k3) | 1 |
| Terrain Category | 2 |
| Lateral load resistant elements | Column 500 X 500mm |
| | Main Beams 350mm×350mm and Secondary beams 350 x 350mm including slab in all floors by 200mm Thickness. |
| Concrete Grade | M35 |
| Steel type | HYSD Bar Fe550 |
| Site type | II Medium Soil |
| Response Reduction, R | 5 |

| | |
|---|---|
| **Dead load:**<br>Beam<br>Slab<br>Staircase | 12.88 kN/m<br>1.296 kN/m<br>2.345 kN/m |
| **Live load:**<br>Slab and Staircase | 2 kN/m and 3kN/m |

### 2.2.2 Loads

This chapter presents the design loads considered in the structural design, including gravity loads and seismic loads.

| S.N | Descriptions | Unit weight | Reference |
|---|---|---|---|
| 1 | Concrete | 25 KN/m³ | IS-875(part 1) - 1987 |
| 2 | Masonry wall | 19.2 KN/m³ | IS-875(part-1)-1987(Table-1) |
| 3 | Cement Concrete, plain | 12.55 KN/m³ | IS-875(part-1)-1987(Table-1) |
| 4 | Plaster Punning | 20.4 KN/m³ | IS-875(part-1)-1987(Table-2) |

### Gravity Load:

Self-weight of the structure is considered as dead load and finishes and partitions are considered as superimposed dead load. Live load is determined in accordance with occupancy or use. The following loads are in addition to the self-weight of the structure. The minimum loading requirements shall be taken from IS 875 (Part 2)-1987 or equivalent.

**Live Load and Superimposed Dead Load**

| Occupancy or Use | Live Load |
|---|---|
| Rooms | 2.0 KN/m$^2$ |
| Corridors, passages, balconies and staircase | 3.0 KN/m$^2$ |

### Dead Load calculations A.

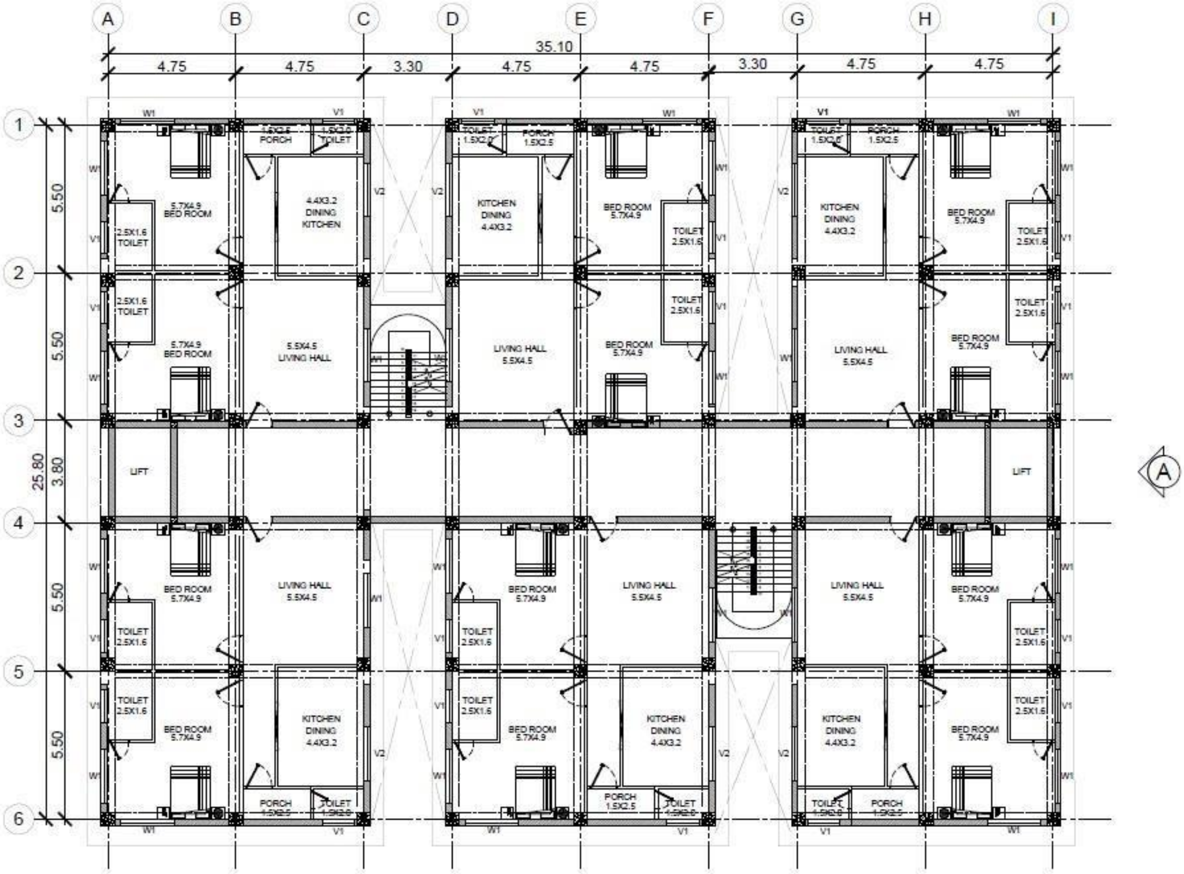
**Slab Load:**

| | | | | |
|---|---|---|---|---|
| **Slab Thickness** | **200** | **mm** | **1.296** | **KN/m$^3$** |
| **Stair Slab Thickness** | **250** | **mm** | **2.345** | **KN/m$^3$** |

**B. Beam Load:**

| | | | | |
|---|---|---|---|---|
| **Beam dimension** | **350 x 350** | **mm** | **12.88** | **KN/m$^3$** |

## 2.3 Floor plan design




1st to 5th FLOOR

**Figure: 2: Plan view 1 to 5 floor**

The given architectural drawing represents the floor plan for the 1st to 5th floors of a G+5 residential apartment building. The design features two symmetrical blocks separated by a central corridor that accommodates two staircases and two lifts, ensuring smooth vertical circulation. Each floor contains a total of eight identical residential units-four in each block-arranged in a mirrored layout for structural and spatial efficiency.

The building follows a systematic grid layout labeled horizontally from A to I and vertically from 1 to 6. Horizontally, the grid spans 35.10 meters in total, with equal bay widths of 4.75 meters between columns A–B, B–C, D–E, E–F, G–H, and H–I, and a narrower spacing of 3.30 meters between C–D and F–G. Vertically, the structure extends 25.80 meters, with 5.50-meter spans between rows 1–2, 2–3, 4–5, and 5–6, and a central segment of 3.80 meters between rows 3–4, where the lift and staircases are located.

Each apartment unit comprises a spacious living hall measuring 5.5 meters by 4.5 meters, a kitchen-cum-dining area sized 4.4 meters by 3.2 meters, and two bedrooms, each measuring 5.7 meters by 4.9 meters. Each bedroom has access to an attached toilet, typically measuring 2.5 meters by 1.6 meters. The entry to each unit includes a small porch or entrance area, averaging about 1.5 by 2.5 meters, ensuring a welcoming and private transition into the home.

Windows (marked W1) and ventilators (marked V1) are appropriately positioned to provide adequate natural lighting and ventilation throughout each unit. The overall floor plan exhibits a high degree of repetition and symmetry, which is beneficial for costeffective construction and structural balance. This layout ensures functional living spaces with efficient use of floor area and convenient access to all essential amenities through a well-organized circulation core.

### 2.3.1 Ground floor plan design

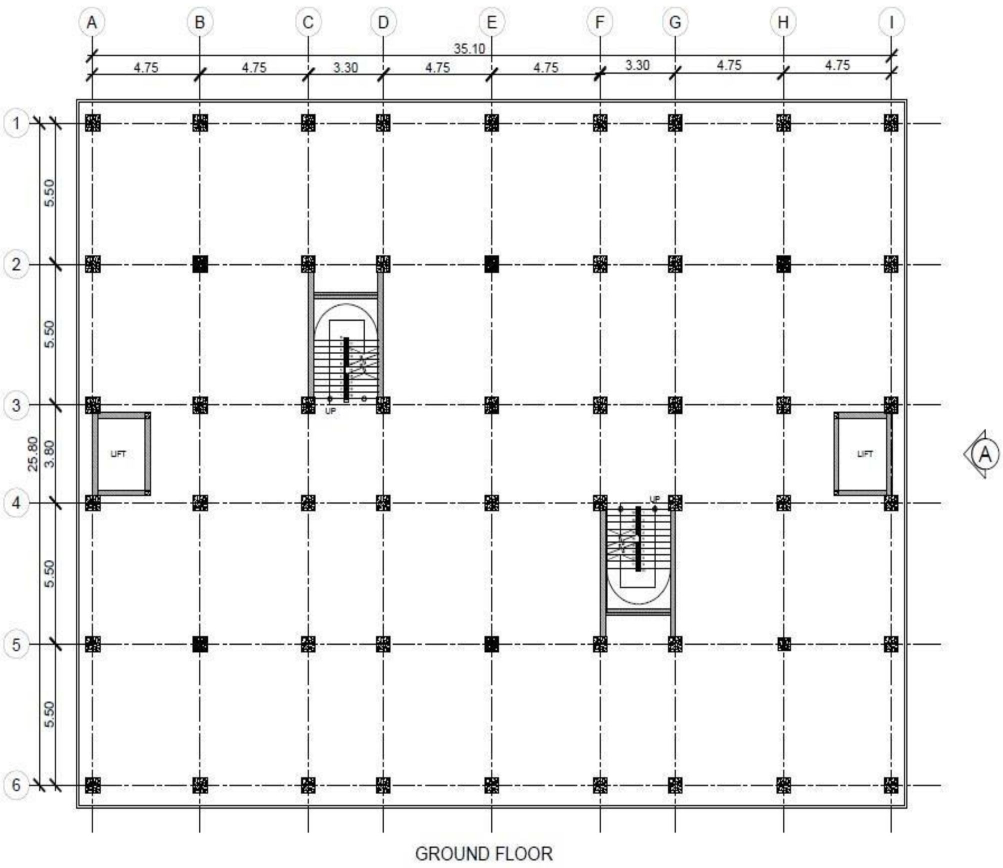



**Figure:3: ground floor plan**

The Ground Floor Plan of the G+5 apartment building is designed mostly as an open space, likely used for **parking or common areas**. The layout follows the same grid as the upper floors, with columns arranged in a regular pattern. The total size of the building is **35.10 meters wide** and **25.80 meters deep**. Most of the grid spaces are **4.75 meters**, with a few central bays being **3.30 meters** wide.

There are **two staircases** in the middle of the building, each with a **lift** next to it. These are placed in the same location as on the upper floors for easy access between floors. Additionally, there are **two more lifts**, one on the left side and one on the right side of the building, providing more convenience.

The ground floor has **no rooms or walls**, just columns and open space. This makes it suitable for **vehicle parking or movement**. The design is simple, practical, and ensures the structure supports the upper floors while keeping the ground floor clear and functional.

### 2.3.2 Elevation of the Apartment

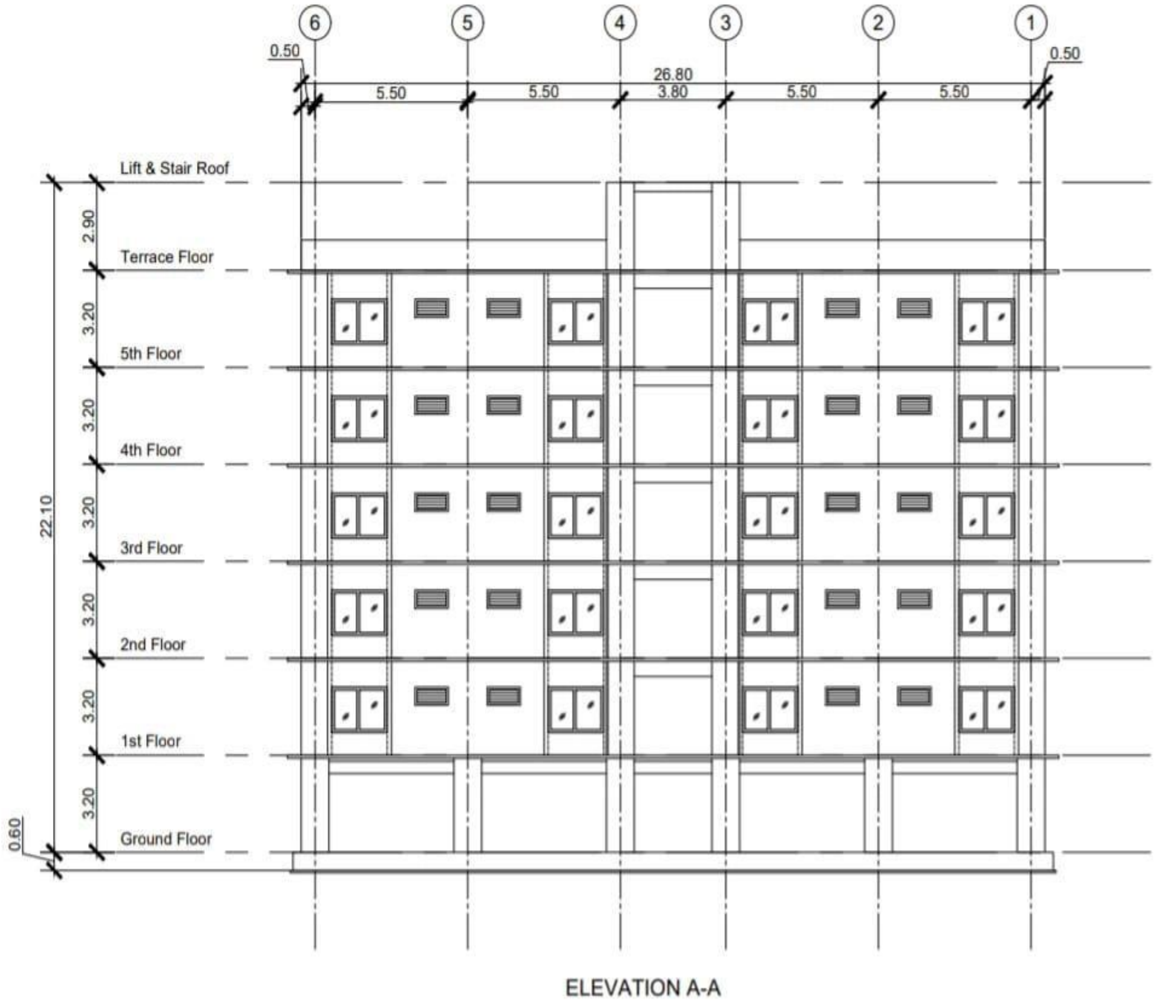



**Figure: 4: Elevation of the Apartment**

## 2.4 ETABS 3D Modelling

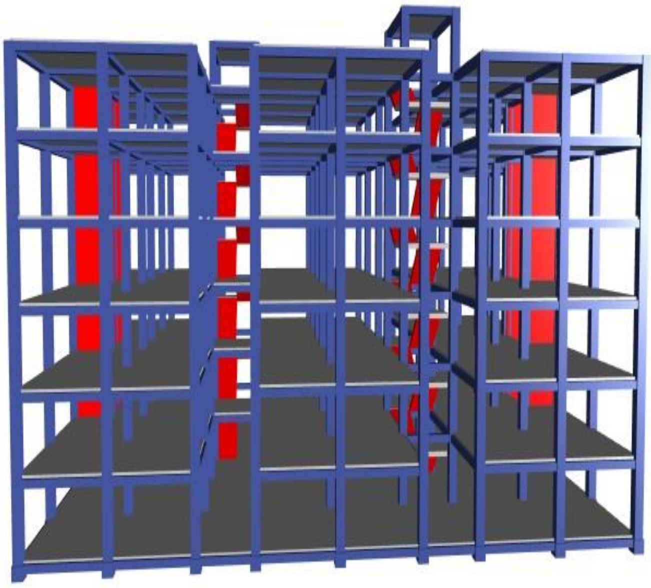


**Figure : 5: Etabs 3D Apartment Model**

The ETABS 3D model shows the full G+5 apartment building with all floors. It includes **columns, beams, and slabs** based on the plan. Each floor looks the same, which makes the structure easy to understand.

There are **two staircases** and **four lift spaces** in the model. The **ground floor** is open with only columns, used for parking. The upper floors have rooms as shown in the plan.

The model has different loads like **dead load, live load, wind, and earthquake**. ETABS checks how the building handles these loads and shows results like **story movement, base forces, and bending**.

### 2.4.1 Plan view in ETABS:

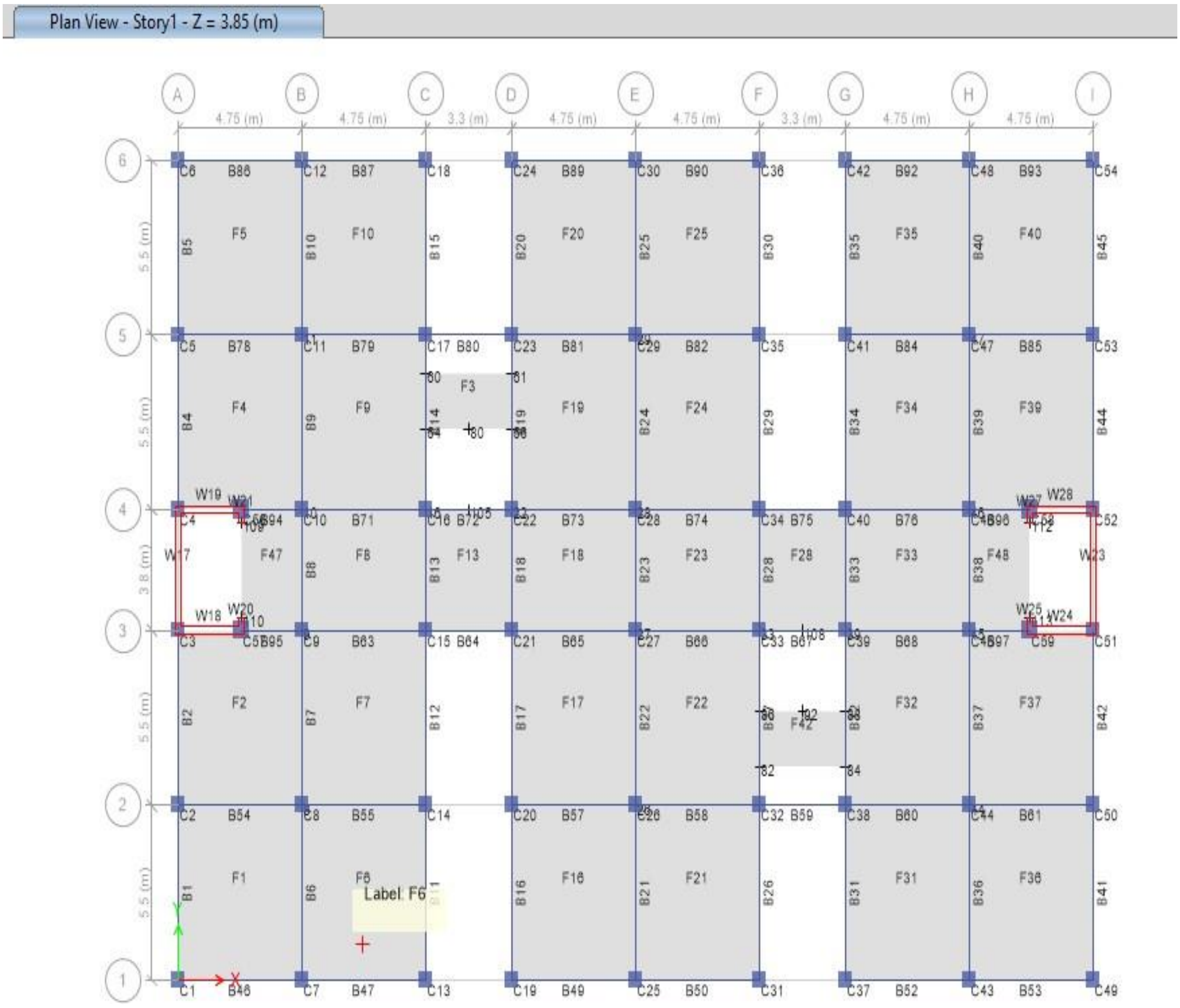



**Fig 6: Some two-dimensional view of the building in ETABS**

In ETABS, the **plan view** shows the building from the top. In this view:

- **Columns** are named like **C1, C2, C3** – these are vertical members.
- **Beams** are named like **B1, B2, B3** – these connect the columns.
- **Slabs or floors** are named like **F1, F2, F3** – these are the floor parts of each level.

These names (C1, B2, F1, etc.) help you easily find and check each part of the structure. The plan view shows where all the parts are placed, and it makes designing and analyzing the building much easier.

## 2.4.2 Elevation in etabs

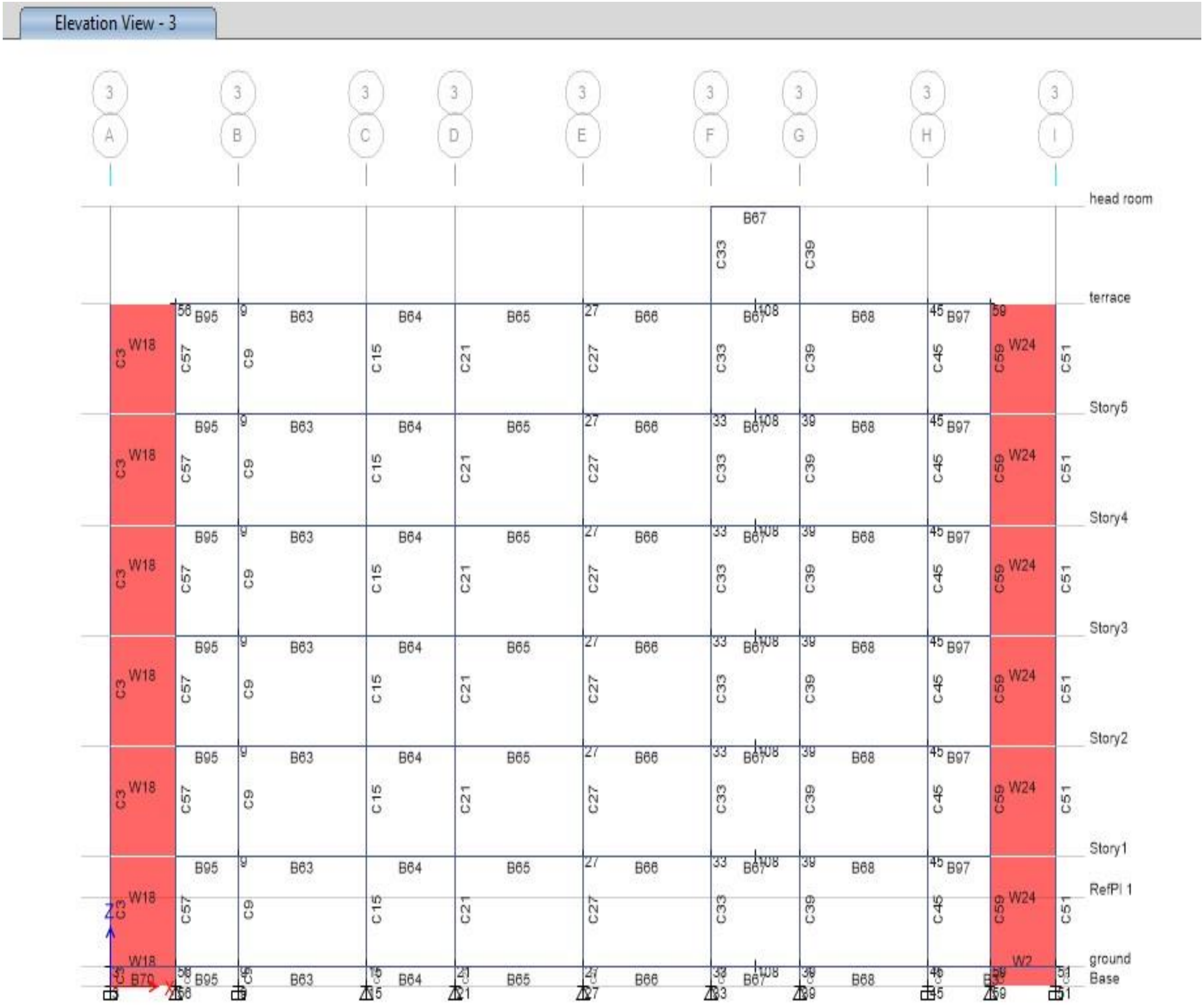
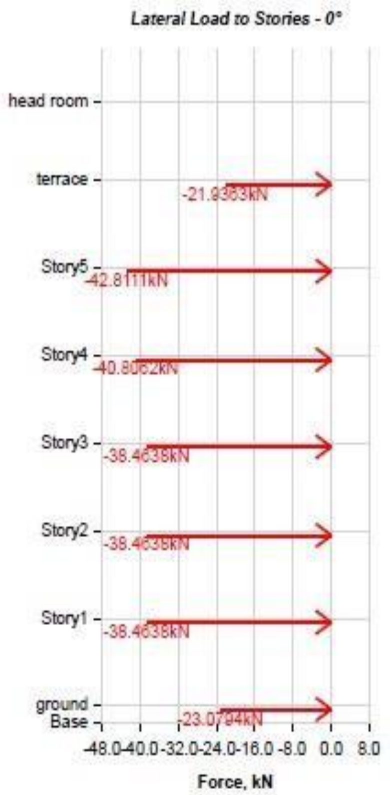



**Figure 7: Assigned Columns, Beams and Slab section used in mode**

## 2.5 Lateral force in wind y-direction:

Indian IS875:1987 Auto Wind Load Calculation
This calculation presents the automatically generated lateral wind loads for load pattern windx according to
Indian IS875:1987, as calculated by ETABS.
Exposure Parameters
Exposure From = Shell Objects
Structure Class = Class A
Terrain Category = Category 2
Top Story = head room
Bottom Story = ground
Include Parapet = No
Factors and Coefficients
Risk Coefficient, k 1 [IS 5.3.1] k1 = 1
Topography Factor, k3 [IS 5.3.3] k3 = 1
Lateral Loading
Design Wind Speed, V z [IS 5.3] Vz = Vb k1 k2 k3 Vz = 54.1
Design Wind Pressure, p z [IS 5.4] pz = 0.6 V2 z

**Applied Story Forces**




| Story | Elevation | X-Dir | Y-Dir |
|---|---|---|---|
| | m | kN | kN |
| head room | 23 | 0 | 0 |
| terrace | 20.1 | 0 | -21.9363 |
| Story5 | 16.85 | 0 | -42.8111 |
| Story4 | 13.6 | 0 | -40.8062 |
| Story3 | 10.35 | 0 | -38.4638 |
| Story2 | 7.1 | 0 | -38.4638 |
| Story1 | 3.85 | 0 | -38.4638 |
| ground | 0.6 | 0 | -23.0794 |
| Base | 0 | 0 | 0 |

## 2.5.1 Lateral force in wind x-direction:

**Indian IS875:1987 Auto Wind Load Calculation**

This calculation presents the automatically generated lateral wind loads for load pattern windy according to

Indian IS875:1987, as calculated by ETABS.

Exposure Parameters

Exposure From = Shell Objects

Structure Class = Class A

Terrain Category = Category 2

Top Story = head room

Bottom Story = ground

Include Parapet = No

Factors and Coefficients

Risk Coefficient, k 1 [IS 5.3.1] k1 = 1

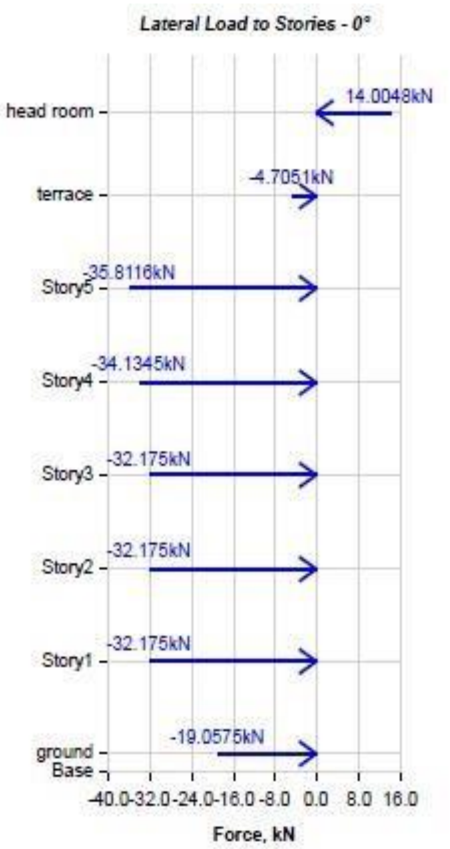
Topography Factor, k3 [IS 5.3.3] k3 = 1

Lateral Loading

Design Wind Speed, V z [IS 5.3] Vz = Vb k1 k2 k3 Vz = 54.1

Design Wind Pressure, p z [IS 5.4] pz = 0.6 V2 z

**Applied Story Forces**




| Story | Elevation | X-Dir | Y-Dir |
|---|---|---|---|
| | m | kN | kN |
| head room | 23 | 14.0048 | 0 |
| terrace | 20.1 | -4.7051 | 0 |
| Story5 | 16.85 | -35.8116 | 0 |
| Story4 | 13.6 | -34.1345 | 0 |
| Story3 | 10.35 | -32.175 | 0 |
| Story2 | 7.1 | -32.175 | 0 |
| Story1 | 3.85 | -32.175 | 0 |
| ground | 0.6 | -19.0575 | 0 |
| Base | 0 | 0 | 0 |

## 2.5.2 Lateral force in EQx direction:

### IS 1893:2016 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern seismic x according to IS 1893:2016, as calculated by ETABS.

**Direction and Eccentricity**

Direction = X

**Structural Period**

Period Calculation Method = Program Calculated

**Factors and Coefficients**

Seismic Zone Factor, Z [IS Table 3] $Z = 0.1$

Response Reduction Factor, R [IS Table 9] $R = 5$

Importance Factor, I [IS Table 8] $I = 1$

Site Type [IS Table 1] = II

**Seismic Response**

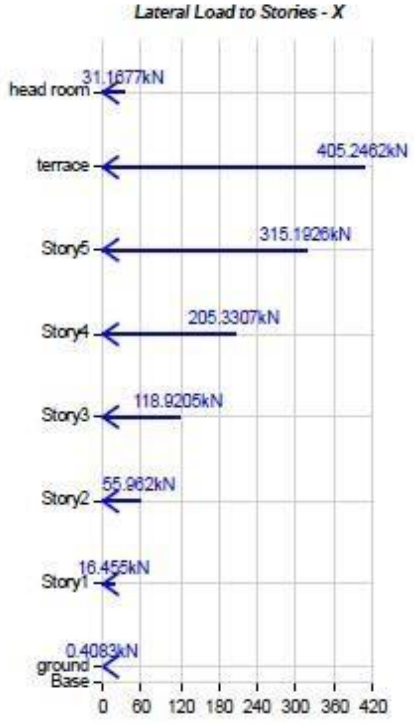
Spectral Acceleration Coefficient, $S_a/g$ [IS 6.4.2] $\frac{S_a}{g} = 2.5$ $\frac{S_a}{g} = 2.5$

**Equivalent Lateral Forces**

Seismic Coefficient, $A_h$ [IS 6.4.2] $A_h = \frac{Z\, I \frac{S_a}{g}}{2\, R}$

**Calculated Base Shear**

| Direction | Period Used (sec) | W (kN) | $V_b$ (kN) |
|---|---|---|---|
| X | 0.507 | 45947.3209 | 1148.683 |




| Story | Elevation | X-Dir | Y-Dir |
|---|---|---|---|
| | m | kN | kN |
| head room | 23 | 31.1677 | 0 |
| terrace | 20.1 | 405.2462 | 0 |
| Story5 | 16.85 | 315.1926 | 0 |
| Story4 | 13.6 | 205.3307 | 0 |
| Story3 | 10.35 | 118.9205 | 0 |
| Story2 | 7.1 | 55.962 | 0 |
| Story1 | 3.85 | 16.455 | 0 |
| ground | 0.6 | 0.4083 | 0 |
| Base | 0 | 0 | 0 |

## 2.5.3 Lateral force in EQY direction:

### IS 1893:2016 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern seismic y according to IS 1893:2016, as calculated by ETABS.

**Direction and Eccentricity**

Direction = Y

**Structural Period**

Period Calculation Method = Program Calculated

**Factors and Coefficients**

Seismic Zone Factor, Z [IS Table 3] $Z = 0.1$

Response Reduction Factor, R [IS Table 9] $R = 5$

Importance Factor, I [IS Table 8] $I = 1$

Site Type [IS Table 1] = II

**Seismic Response**

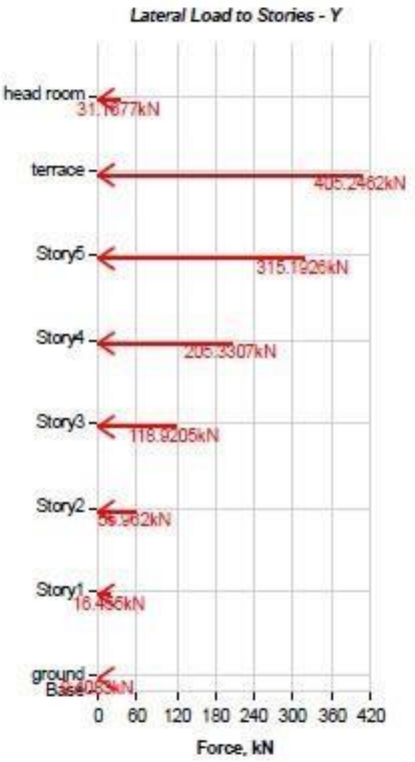
Spectral Acceleration Coefficient, $S_a/g$ [IS 6.4.2] $\frac{S_a}{g} = 2.5$ $\frac{S_a}{g} = 2.5$

**Equivalent Lateral Forces**

Seismic Coefficient, $A_h$ [IS 6.4.2] $A_h = \frac{Z\, I \frac{S_a}{g}}{2\, R}$

**Calculated Base Shear**

| Direction | Period Used (sec) | W (kN) | $V_b$ (kN) |
|---|---|---|---|
| Y | 0.479 | 45947.3209 | 1148.683 |




| Story | Elevation | X-Dir | Y-Dir |
|---|---|---|---|
| | m | kN | kN |
| head room | 23 | 0 | 31.1677 |
| terrace | 20.1 | 0 | 405.2462 |
| Story5 | 16.85 | 0 | 315.1926 |
| Story4 | 13.6 | 0 | 205.3307 |
| Story3 | 10.35 | 0 | 118.9205 |
| Story2 | 7.1 | 0 | 55.962 |
| Story1 | 3.85 | 0 | 16.456 |
| ground | 0.6 | 0 | 0.4083 |
| Base | 0 | 0 | 0 |

# 3. RESULTS AND DISCUSSION

## 3.1 Analysis and design results

The loads calculated are applied in the modeled building. Besides from the dead and live loads, the probable seismic loads are also taken care of as karaikal(Puducherry) is categorized amongst seismically active zones. Moreover, the building itself carries high importance and the seismic force consideration is of topmost priority. The Building is storied and hence, the static analysis is enough to ensure its safety against. Through consideration is given in analysis of the building following standard theories of structures and relevant codes of practice.

A three dimensional linear static analysis has been carried out using the standard software ETAB 2019. V1.1. The Structure is assumed to be fixed at the Plinth level. The brick wall is considered as the filler wall only. The beams are modeled as rectangular beams. The flange effect of the beams has been neglected. Center to center dimension of the structure has been considered in the analysis. The rigid end effect has also been considered in the analysis.

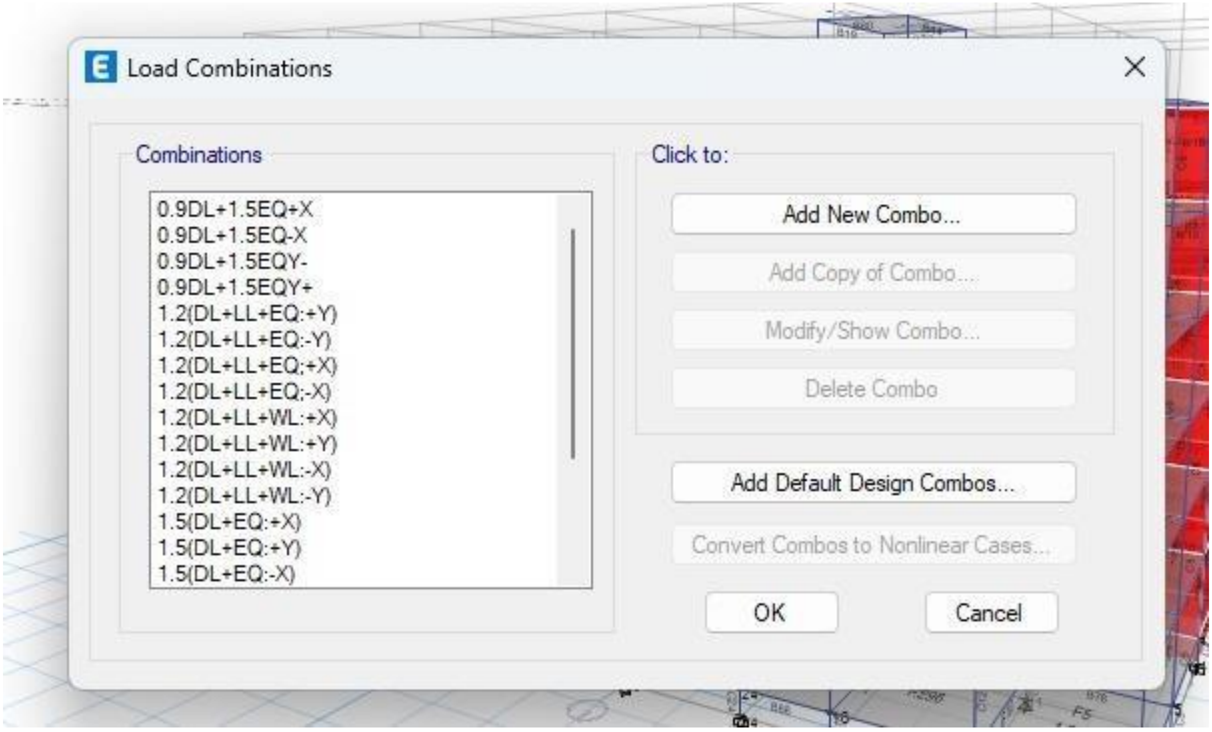
Following load cases and combinations were used for the analysis of the structural components of the building.

**Load Cases**

Following loads have been considered in the analysis of the building as per IS 456- 2000 and IS1893-2016.

- Dead Load (DL)
- Live load (LL)
- Earthquake load in +ve X-direction ($EQ_{PX}$)
- Earthquake load in –ve X-direction ($EQ_{NX}$)
- Earthquake load in +ve Y-direction ($EQ_{PY}$)
- Earthquake load in –ve Y-direction ($EQ_{NY}$)

## Load combination



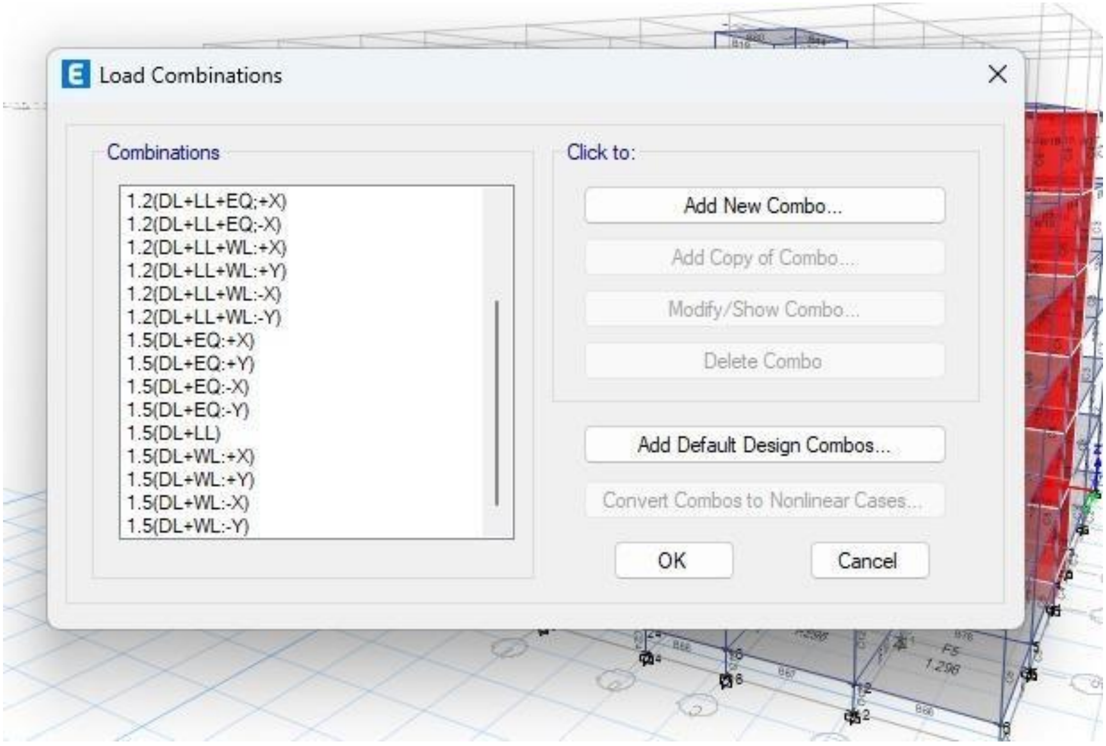




**Fig 8: load combination**

**Lateral Load Calculation**

The characteristic (intensity, duration, etc.) of seismic ground vibration expected at any location depends upon the magnitude of earthquake, its depth of focus, distance from the epicenter, characteristic of the path through which the seismic waves travel, and the soil strata on which the structure stands. The random earthquake ground motion, which causes the structure to vibrate, can be resolved in any three mutually perpendicular directions. The predominant direction of ground vibration is usually horizontal. Earthquake is not likely to occur simultaneously with wind.

## Seismic Loads for Ultimate Limit State (ULS)

Seismic coefficient Method was adopted to analyze the building for Earthquake loads

Design Base Shear $V_B = C_d * W$ *105-2000)*

Where,

$C_d$ = Design horizontal seismic coefficient as per NBC 105-2000

$= \frac{Cd\ (T1)}{R\mu * \Omega u} = \frac{0.75}{4*1.5} = 0.125$

**Z= Zone Factor = 0.10(Karaikal)**

**I= Importance Factor = 1.0 Table 8.1 NBC105**

**$C_d (T_1) = C_h (T)$X ZX I =2.5x0.3x1=0.75**

**$C_h$ (T)= Basic Seismic coefficient on the basis of time period, T of the structure [Fig.4.1 NBC 105-2000] = 2.5**

**T. = $0.075*h^{0.75}$ (7.3, NBC105-2000]. For Concrete frames = 0.507 sec**

**h=Height of building (m) above ground level =12.8 m**

W = Seismic Weight of Building, that includes total Dead load plus appropriate amount of live load. [Table 5.2, NBC105-2000].

- The live load on roof need not be considered for calculating the seismic weight of the building. [Table 5.2, NBC 105-2000].

For the purpose of analysis, seismic forces are applied in the model of the building in ETABS. Hence, the manual calculations of seismic weight, base shear and the seismic forces have not been shown. However, the ETABS output for the Seismic Weight, Base Shear and Seismic Forces in each storey diaphragm are as follows.

## 3.2 Shear force ,bending moment and Axial force


**Figure 9; Bending moment against seismic x- direction**

The **Bending Moment Diagram (BMD)** shows how bending moments change along a structure when forces, like seismic loads, act on it. In the seismic X-direction, the BMD helps engineers see how bending moments vary as the building sways during an earthquake. Typically, bending moments are higher at the base of the structure and decrease as you go up. The diagram helps engineers design parts of the building, like beams and columns, to resist bending and stay safe during an earthquake. The highest bending moments usually happen where the force changes direction, often near the base or middle of the structure.


**Figure 10 ; Shear force diagram**

Shear force in the seismic X-direction refers to the internal forces generated in a structure due to lateral loads caused by ground motion during an earthquake, typically in the horizontal Xdirection. This force is a result of the seismic activity, which pushes or pulls the building in a specific direction, causing it to sway laterally. The shear force in this direction affects structural elements such as shear walls, frames, and columns, which must be designed to resist these forces without failing. The magnitude of the shear force varies across the height of the building, generally being larger at lower floors and decreasing as the height increases. Several factors influence the shear force, including the seismic zone, the building's dynamic characteristics, and the seismic force coefficient, which is based on the location and the building's structural properties. During seismic analysis, software tools like ETABS calculate the internal shear force based on these factors, helping engineers design the structure to withstand seismic loads effectively. Understanding and accounting for shear forces in the Xdirection is crucial for ensuring the safety and stability of the structure during an earthquake.


**Figure 11: Axial force**

Axial force refers to the internal force acting along the longitudinal axis of a structural member, either as **compression** or **tension**. In the context of seismic loading in the **X-direction**, these forces are primarily induced in **columns and braces** as the building sways due to horizontal ground motion.

During an earthquake, the structure experiences lateral forces that cause horizontal movement. This movement generates additional axial forces in vertical elements like columns, especially those aligned in the seismic X direction. These forces are critical in **moment-resisting frames (MRF)**, where columns must carry both bending moments and increased axial loads due to overturning effects and floor inertia.

## 3.3 Seismic Weight and Base Shear from Seismic Coefficient method

| TABLE: Load Pattern Definitions - Auto Seismic - User Coefficient | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Ecc Ratio | Top Story | Bottom Story | C | K | Weight Used | Base Shear |
| | | | | | | kN | kN |
| EQx | 0.05 | HEAD ROOM | Base | 0.125 | 1 | 3750.8442 | 468.8555 |
| EQy | 0.05 | HEAD ROOM | Base | 0.125 | 1 | 3750.8442 | 468.8555 |

**TABLE: Auto Lateral Loads to Stories**

| TABLE: Story Response | | | | |
|---|---|---|---|---|
| Story | Elevation | Location | X-Dir | Y-Dir |
| | m | | kN | kN |
| HEAD ROOM | 23.1 | Top | 31.1677 | 31.1677 |
| TERRACE | 20.2 | Top | 405.246 | 405.246 |
| FIFTH FLOOR | 17 | Top | 315.192 | 315.192 |
| FOURTH FLOOR | 13.8 | Top | 205.3307 | 205.3307 |
| THIRD FLOOR | 10.6 | Top | 118.9205 | 118.9205 |
| SECOND FLOOR | 7.4 | Top | 55.962 | 55.962 |
| FIRST FLOOR | 4.2 | Top | 16.455 | 16.455 |
| GROUND FLOOR | 1.0 | Top | 0.4083 | 0.4083 |
| BASE | 0 | Top | 0 | 0 |

**TABLE: Story Shears**

| TABLE: Story Response | | | | |
|---|---|---|---|---|
| Story | Elevation | Location | X-Dir | Y-Dir |
| | m | | kN | kN |
| HEAD ROOM | 12.816 | Top | -23.2745 | -23.2745 |
| | | Bottom | -23.2745 | -23.2745 |
| THIRD FLOOR | 9.6012 | Top | -189.6691 | -189.6691 |
| | | Bottom | -189.6691 | -189.6691 |
| SECOND FLOOR | 6.4008 | Top | -375.7934 | -375.7934 |
| | | Bottom | -375.7934 | -375.7934 |
| FIRST FLOOR | 3.2004 | Top | -468.8555 | -468.8555 |
| | | Bottom | -468.8555 | -468.8555 |
| BASE | 0 | Top | 0 | 0 |
| | | | | |

### 3.3.1 Story Response Plot

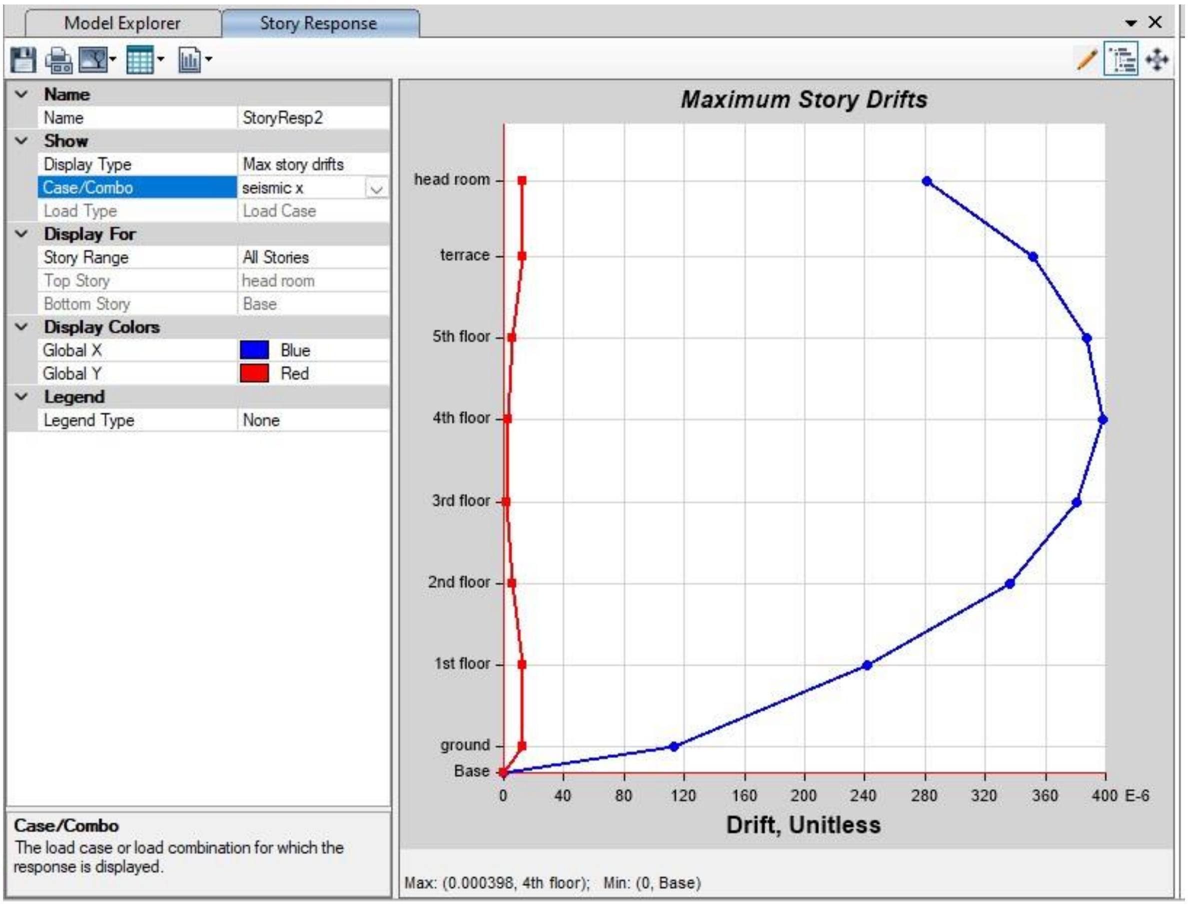



**Figure 12 : Story drift X**

**Storey drift** is the relative horizontal displacement between two consecutive floors of a building under lateral loads such as **earthquake** or **wind** forces. It is a critical parameter in structural design as it indicates how much the structure "sways" during such events.

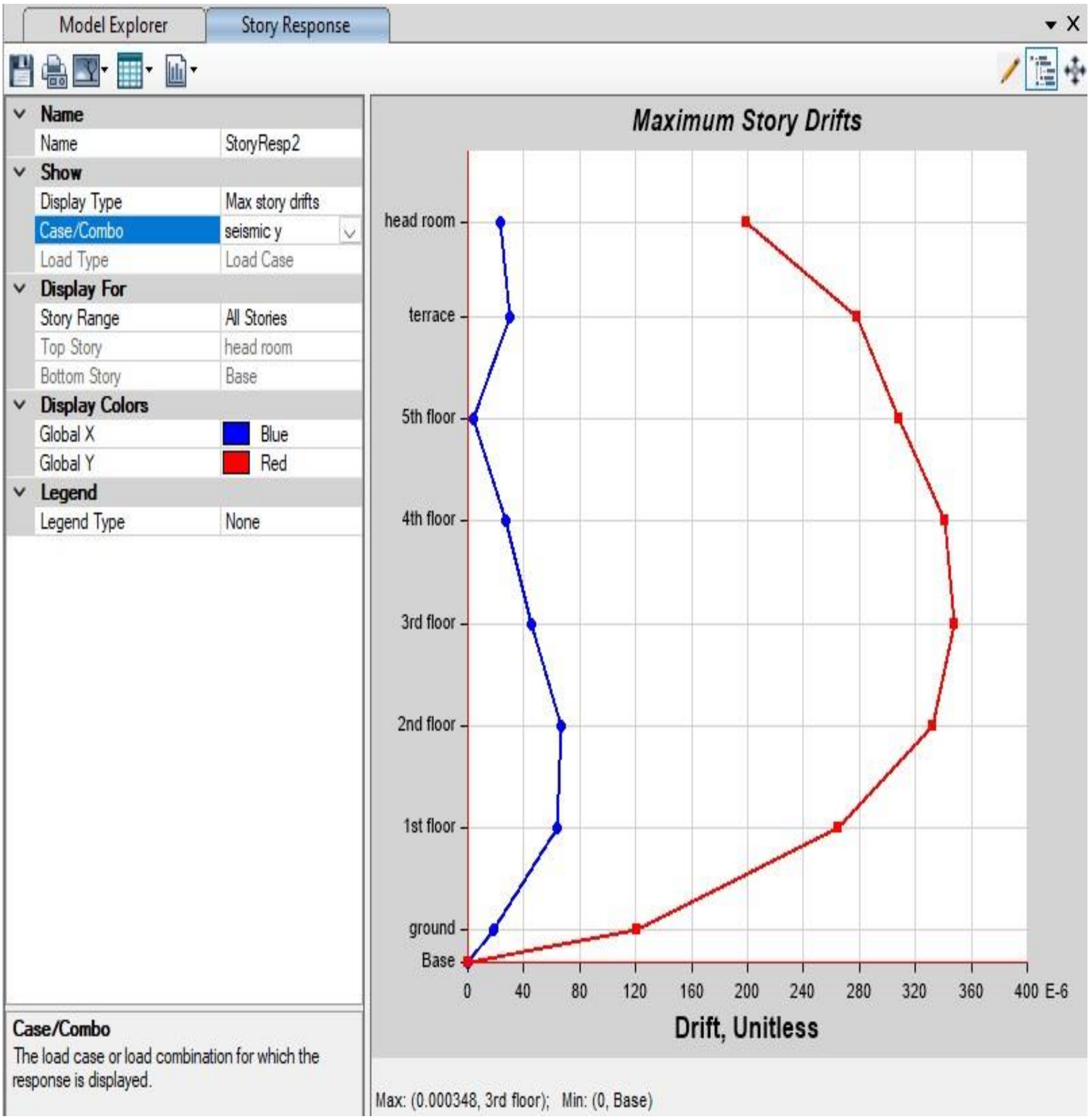
In this project, the **maximum storey drift** is calculated as part of the seismic analysis using ETABS software. The building is located in **Seismic Zone II (as per IS 1893:2016)**, so drift control is essential to prevent structural and non-structural damage during earthquakes.

According to **IS 1893 (Part 1): 2016, Clause 7.11.1**, the permissible storey drift is:

**0.004 times the storey height**
For example, if the storey height is 3.2 meters, the maximum allowable drift is: 0.004 × 3200 mm = **12.8 mm**

The **maximum drift** usually occurs between the **first and second floor** or between **middle storeys**, depending on stiffness distribution. Excessive drift may indicate the need for design adjustments, such as increasing member sizes, adding shear walls, or modifying the lateral loadresisting system.

In this G+5 design, drift values were checked for each floor level. The building satisfies the code requirements, ensuring both **occupant safety** and **structural integrity** during seismic events.


Model Explorer
Story Response
Name
Name
StoryResp2
Show
Display Type
Max story drifts
Case/Combo
seismic y
Load Type
Load Case
Display For
Story Range
All Stories
Top Story
head room
Bottom Story
Base
Display Colors
Global X
Blue
Global Y
Red
Legend
Legend Type
None
Case/Combo
The load case or load combination for which the response is displayed.
Maximum Story Drifts
head room
terrace
5th floor
4th floor
3rd floor
2nd floor
1st floor
ground
Base
0
40
80
120
160
200
240
280
320
360
400 E-6
Drift, Unitless
Max: (0.000348, 3rd floor); Min: (0, Base)

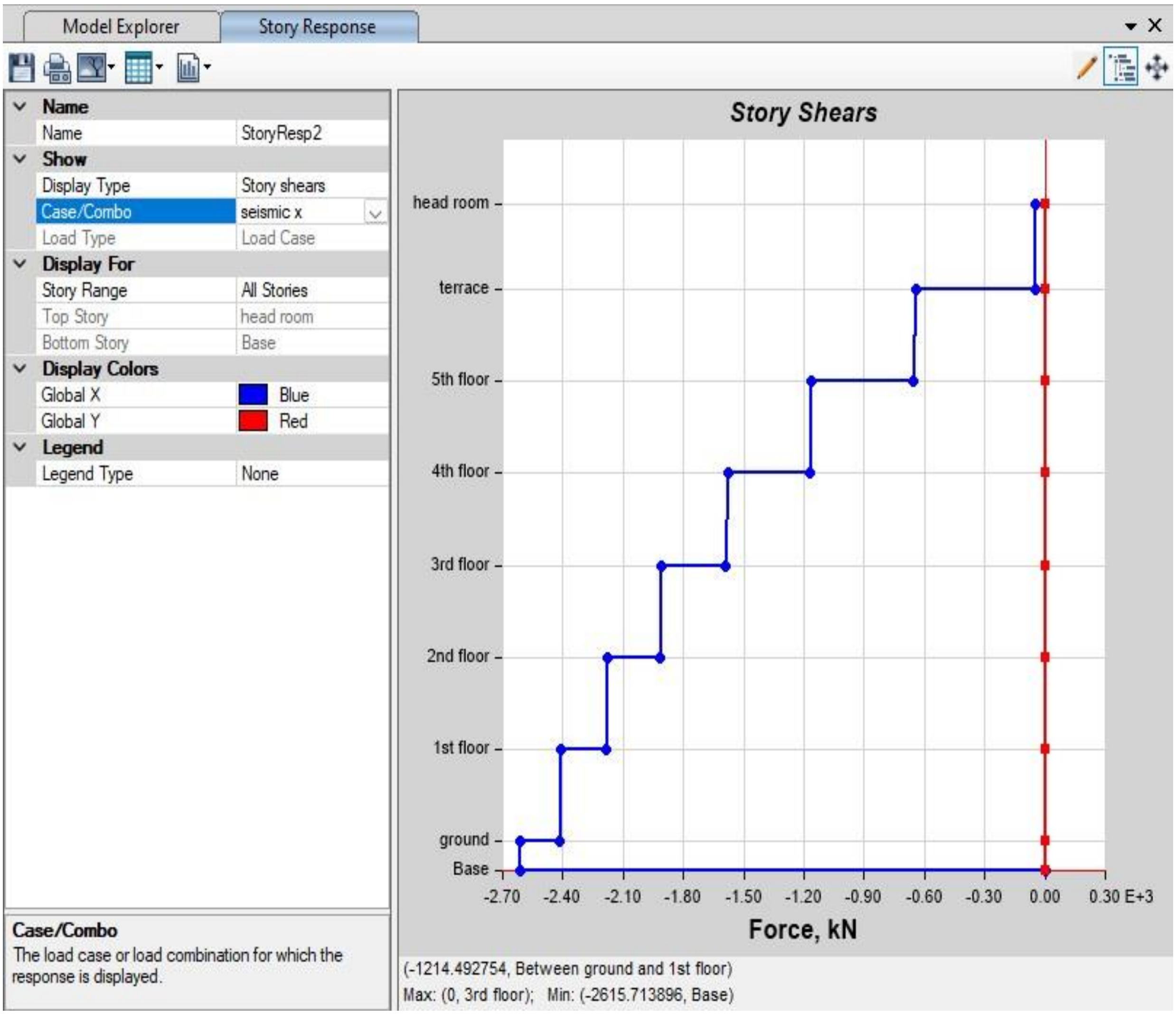



**Figure 13: story shear EQ X**

**Storey shear** is defined as the **total horizontal force** experienced by each storey of a building due to lateral loads such as **earthquake** or **wind** forces. It represents the sum of all the lateral forces above and including that floor, transmitted to the structural elements (columns, shear walls, and beams) at that level.

In this project, seismic analysis was performed using ETABS software as per **IS 1893 (Part 1): 2016**, considering the building located in **Seismic Zone II**. The storey shear values were calculated under the applied seismic loads in both X and Y directions.

The storey shear is **maximum at the base** and gradually **decreases towards the top**, as upper floors carry less cumulative lateral load. These values are crucial for designing lateral loadresisting elements and for ensuring the safe distribution of earthquake forces through the structural system.

By analyzing storey shear at each level, the structure is validated to safely transfer seismic loads from the superstructure to the foundation without failure or excessive deformation. This contributes significantly to the **overall seismic performance** and **stability** of the building.

## 3.4 Rebar percentage

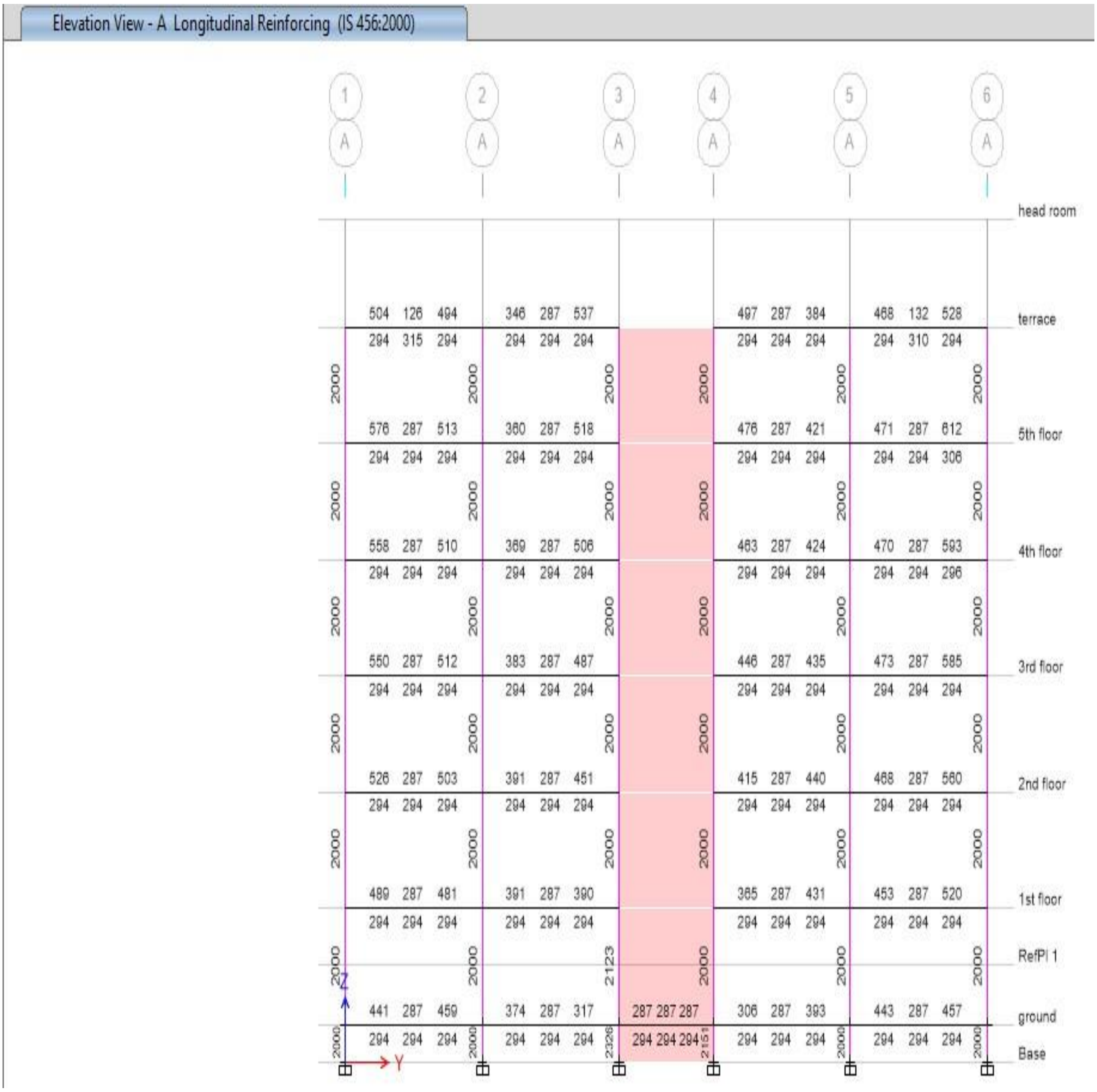



**Figure 14: Area of steel**

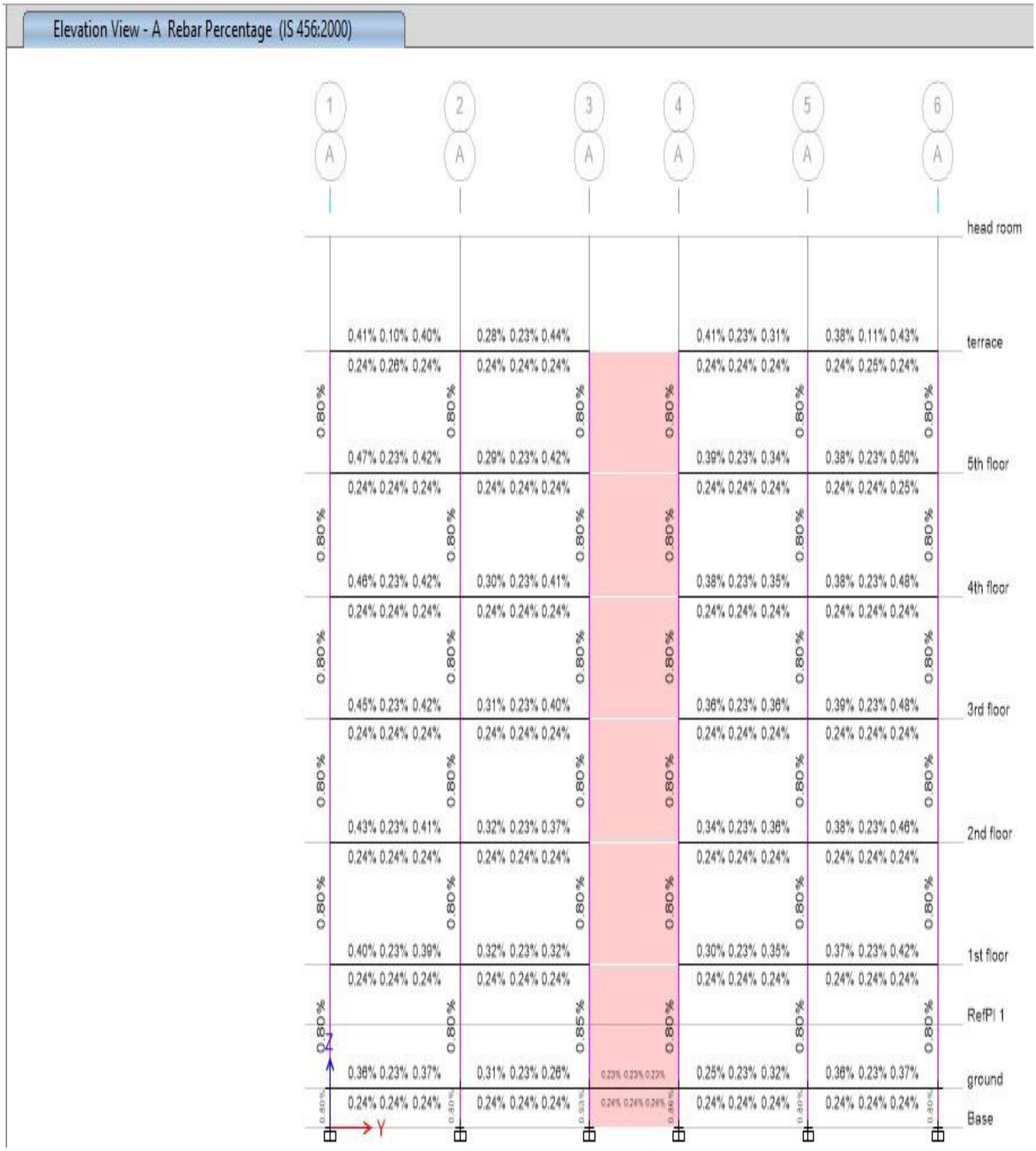



**Figure 15: Rebar Percentage**

**Rebar percentage** (also called **reinforcement ratio**) is the ratio of the **area of steel reinforcement** (rebars) to the **total cross-sectional area** of a concrete element (like a beam, column, or slab). It tells us how much steel is used in a concrete section to resist loads.

It is calculated using the formula:

$$\text{Rebar Percentage} = \left( \frac{\text{Area of steel (Ast)}}{\text{Area of concrete (Ac)}} \right) \times 100$$

## 3.5 Building Deflection

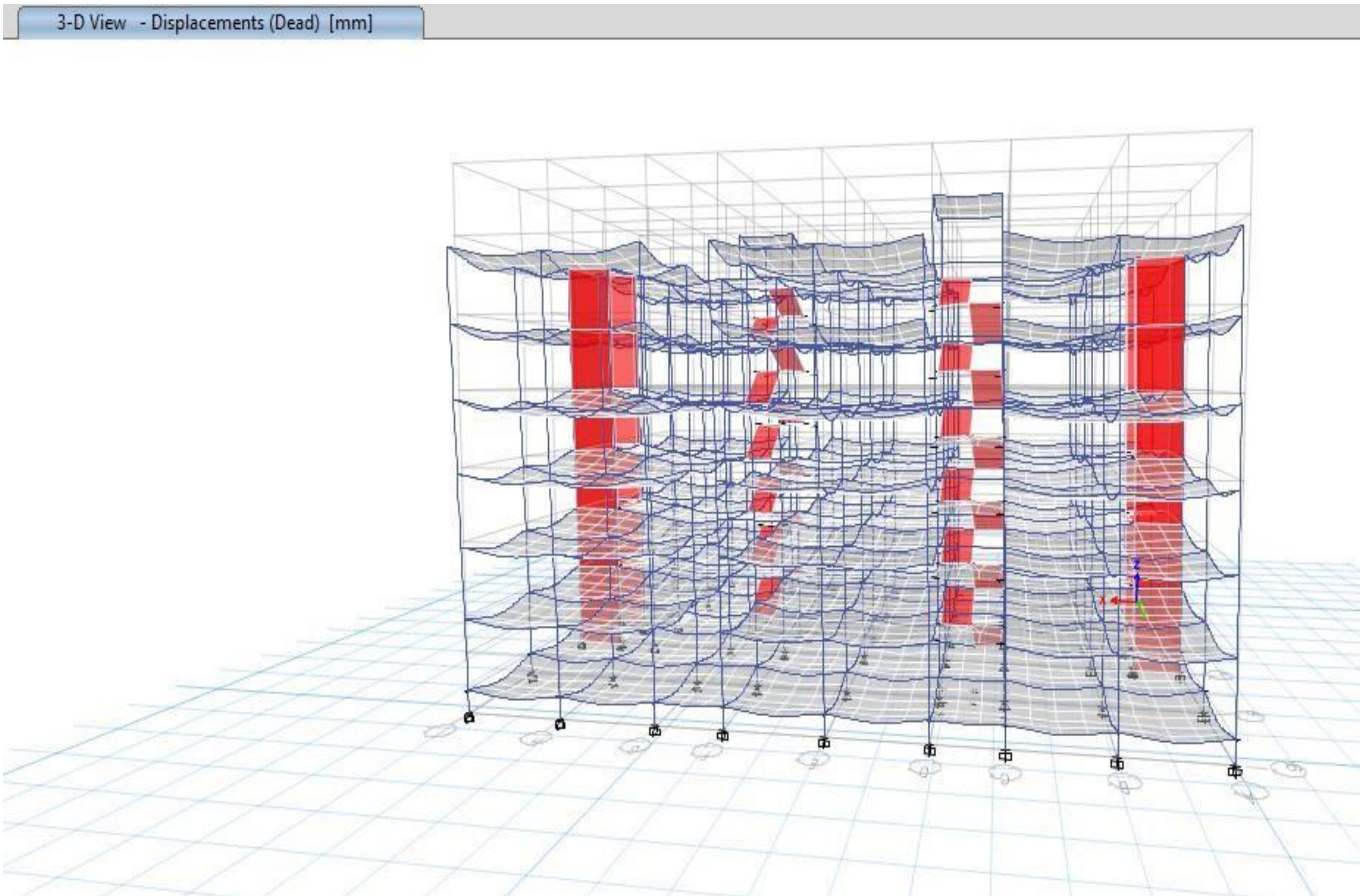



**Figure 16: Deflection of Building during dead loading condition**

## 3.6 Rebar Detailing for beam

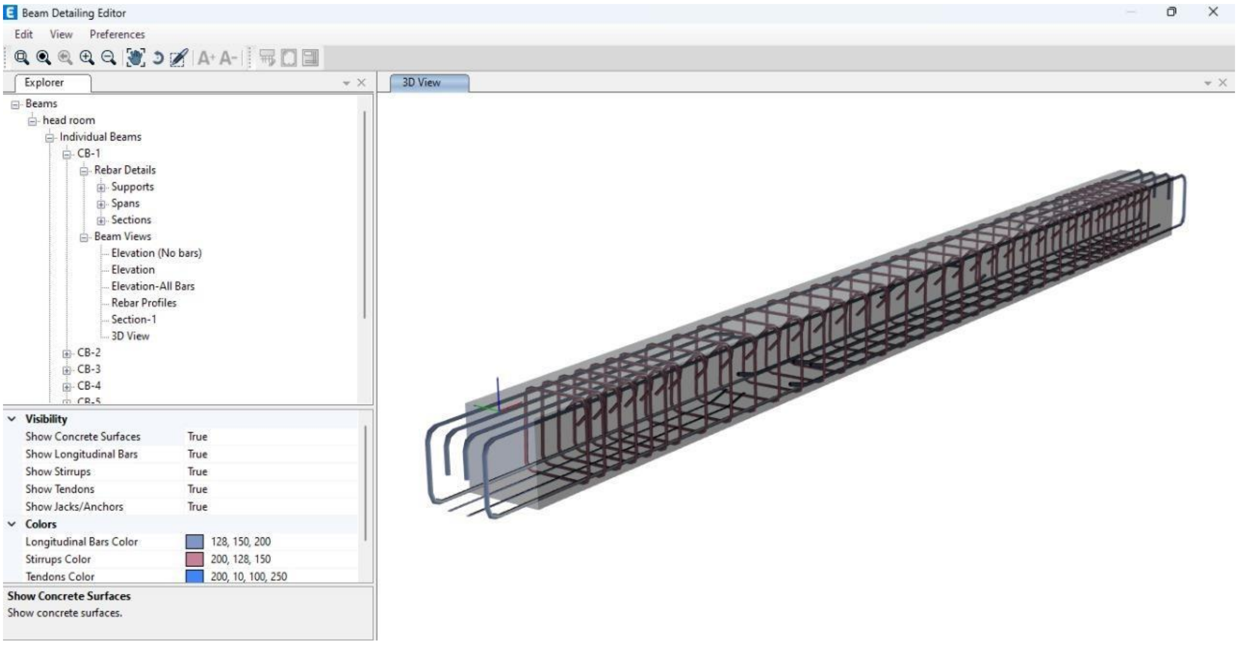



**Figure 17: Beam Rebar 3D view**

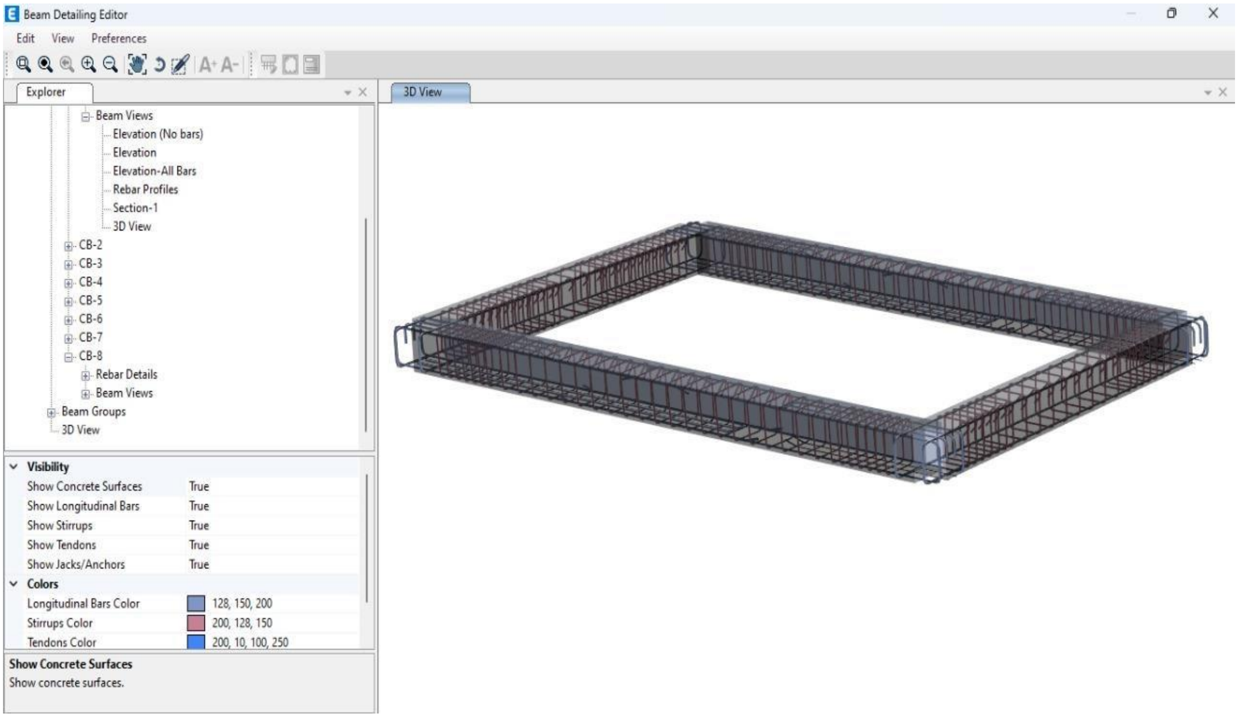



**Figure 18: Group of Beam Rebar 3D view**

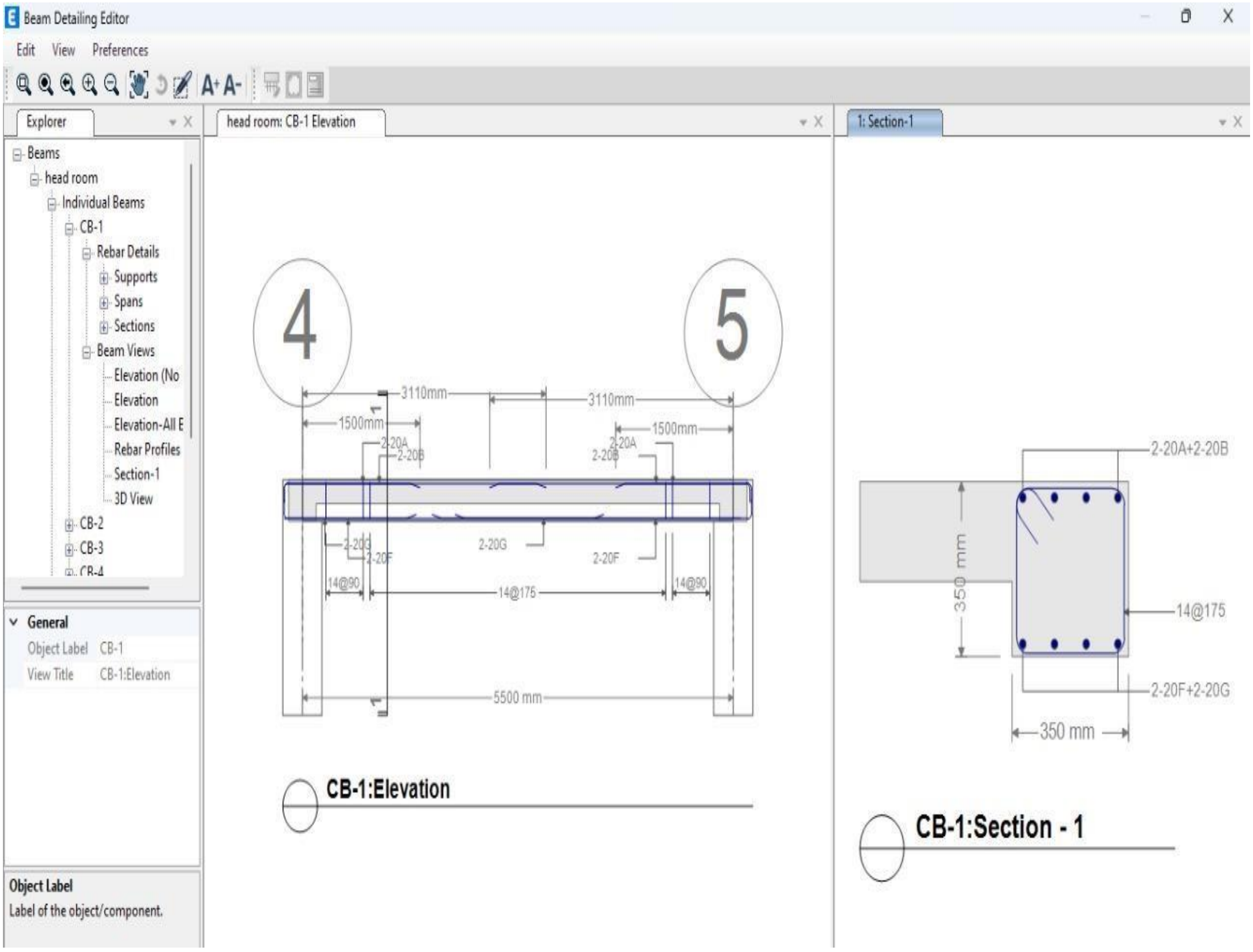



Figure 19: Beam Rebar Detailing

## 3.7 Rebar Detailing for column

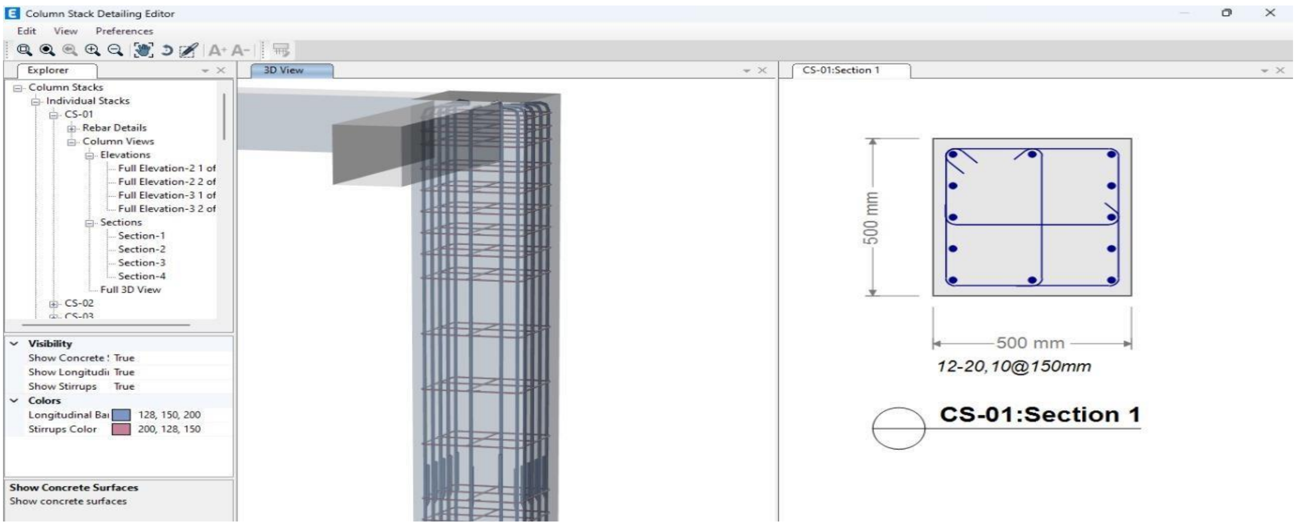



Figure 20: headroom column detailing

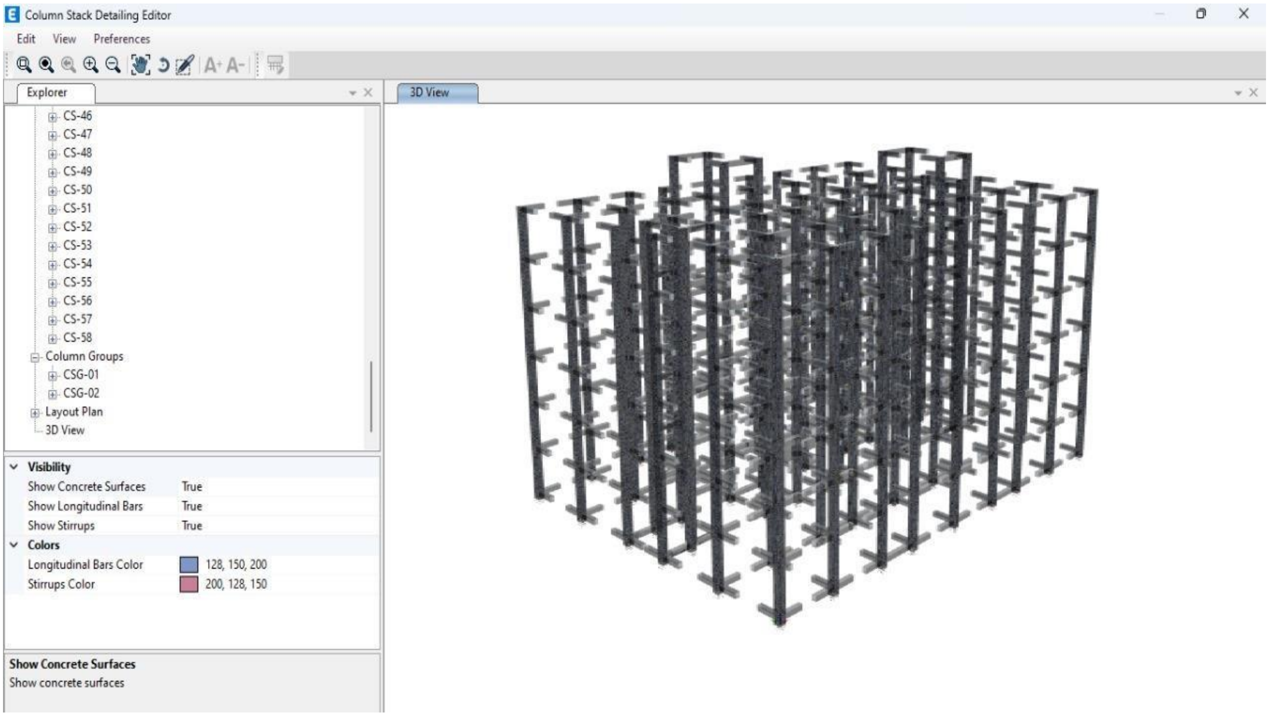



**Figure 21: Group of column rebar 3D view**

## 3.8 Parameters to be checked after static coefficient analysis of structure

### Story Drift

In order to control deflection of structural elements, the criteria given in clause 23.2 of IS: 456:2000 is proposed to be used.

To control overall deformation due to earthquake load, the criteria given in clause 5.6.3 of NBC 105:2020 is applied. The story drift in any story due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.025 at ultimate limit state.

Due to EQx

| **Floors** | **Displacement mm** | Drift mm | Drift Ratio | Check Drift |
|---|---|---|---|---|
| STAIR COVER | 26.869 | 2.96 | 0.000925 | ok<0.025 |
| THIRD FLOOR | 23.914 | 5.655 | 0.001767 | ok<0.025 |
| SECOND FLOOR | 18.272 | 9.679 | 0.003024 | ok<0.025 |
| FIRST FLOOR | 8.599 | 8.601 | 0.002688 | ok<0.025 |

Due to EQy

| **Floors** | **Displacement mm** | Drift mm | Drift Ratio | Check Drift |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| STAIR COVER | 25.841 | 2.716 | 0.000849 | ok<0.025 |
| THIRD FLOOR | 23.13 | 5.573 | 0.001741 | ok<0.025 |
| SECOND FLOOR | 17.666 | 9.363 | 0.002926 | ok<0.025 |
| FIRST FLOOR | 8.423 | 8.422 | 0.002631 | ok<0.025 |

| TABLE: Story Max Over Avg Displacements | | | | | |
|---|---|---|---|---|---|
| **Story** | **Output Case** | **Direction** | **Maximum** | **Average** | **Ratio** |
| | | | mm | mm | |
| STAIR COVER | EQx | X | 26.869 | 26.313 | 1.021 |
| THIRD FLOOR | EQx | X | 23.914 | 22.548 | 1.061 |
| SECOND FLOOR | EQx | X | 18.272 | 17.346 | 1.053 |
| FIRST FLOOR | EQx | X | 8.599 | 8.188 | 1.05 |
| STAIR COVER | EQy | Y | 25.841 | 25.042 | 1.032 |
| THIRD FLOOR | EQy | Y | 23.13 | 20.91 | 1.106 |
| SECOND FLOOR | EQy | Y | 17.666 | 16.187 | 1.091 |
| FIRST FLOOR | EQy | Y | 8.423 | 7.776 | 1.083 |

**Here, maximum displacement/average displacement is <1.2.**
**Therefore, building has no irregularity.**

# 4. SUMMARY

## 4.1 Summary of the Main Findings of the Project

The project focuses on the structural analysis and design of a **G+5 apartment building** using a **Moment Resisting Frame (MRF)** system, following the **Limit State Method** as per IS 456:2000. The building is located in **Karaikal**, a region that falls under **Seismic Zone II**, requiring careful consideration of **lateral loads** such as wind and earthquake forces. Using **ETABS software**, the entire structure was modeled and analyzed under various load combinations. Key parameters like **storey shear**, **storey drift**, **base reactions**, and **bending moments** were studied in detail. Structural components such as **beams**, **columns**, and **slabs** were designed with appropriate reinforcement percentages, ensuring they remain within the code limits.

The analysis confirms that the building is **structurally safe and serviceable**, with all critical values within the permissible limits. The moment-resisting frame system proved effective in resisting lateral loads, making the building suitable for urban residential use with enhanced seismic performance.

## 4.2 Conclusions Drawn from the present study

From the present study, it is concluded that the structural design and analysis of a **G+5 apartment building** using a **Moment Resisting Frame (MRF)** system is effective in ensuring **safety**, **stability**, and **serviceability** under both gravity and lateral loads. The use of the **Limit State Method** and modeling in **ETABS software** allowed for precise analysis of critical parameters such as **storey drift**, **storey shear**, and **base reactions**.

The results showed that:

- **Storey drifts** were within the permissible limits, ensuring lateral stability.
- **Storey shear** and **bending moments** were effectively resisted by the frame system.
- **Reinforcement percentages** were within IS code limits, avoiding over- or under-reinforcement.

Thus, the building meets all relevant design criteria according to IS 456:2000 and IS 1893:2016. The project enhances practical knowledge of earthquake-resistant design and demonstrates the importance of accurate modeling and structural detailing in multistorey construction.

## 4.3 Recommendations for Future Research or Practical Application

**Use of Advanced Materials**: Future studies can explore the use of high-performance concrete, fiberreinforced concrete, or corrosion-resistant rebars to enhance durability and seismic performance of multistorey buildings.

1. **Nonlinear Analysis**: A more detailed dynamic or nonlinear time-history analysis can be conducted to study the true behavior of the structure under real earthquake records, especially for critical zones.
2. **Sustainable Design Practices**: Integrating green building concepts such as rainwater harvesting, solar panels, and energy-efficient materials can make the structure more environmentally friendly.
3. **Retrofitting Techniques**: Research can focus on retrofitting strategies for existing buildings using moment-resisting frames to improve earthquake resistance in older urban structures.
4. **Cost Optimization**: Optimization techniques and software tools can be applied to balance structural performance with construction cost, making high-rise housing more affordable.
5. **BIM Integration**: Incorporating Building Information Modeling (BIM) can improve coordination, reduce errors, and streamline the construction process for practical site implementation.

# 5. CONCLUSIONS

- The present project focused on the structural analysis and design of a G+5 residential apartment building using a Moment Resisting Frame (MRF) system. The design was carried out using the Limit State Method as per IS 456:2000 for structural design and IS 1893:2016 for seismic considerations. The project aimed to ensure the structural safety, serviceability, and stability of the building under gravity and lateral loads, especially in a seismic-prone region like Karaikal (Zone III).

- The building was modeled and analyzed using ETABS software. Various structural parameters such as storey drift, storey shear, base reaction, bending moment, and reinforcement requirements were evaluated under different load combinations including dead, live, seismic, and wind loads. The lateral load behavior of the MRF system was critically assessed, ensuring that the structure responds effectively to earthquake forces while remaining within permissible limits.

- The results of the analysis confirmed that the building's structural members, including beams and columns, have been efficiently designed with reinforcement percentages that follow codal guidelines. Storey drift values were well within the limits, which validates the lateral stiffness and seismic performance of the structure. The base shear distribution and story displacements showed a balanced structural response under dynamic loading.

- In conclusion, the G+5 apartment building designed in this study is structurally safe, code-compliant, and suitable for residential use in moderate seismic zones. The project not only highlights the effectiveness of the Moment Resisting Frame system in multistorey construction but also reinforces the importance of accurate modeling, load analysis, and reinforcement detailing in achieving a reliable and safe structure.

## 6. REFRENCES

**1.National Building Code (NBC) 2016**

**Reference for planning norms, fire safety, and structural safety:**

**NBC 2016 Volumes (BIS website) (Login may be required)**

**2. IS 456:2000 - Code for RCC Design**

**For reinforced concrete design practices: IS 456:2000 on BIS Website (Free archive copy)**

**3. IS 875 (Part 1 to 5) - Loads on Buildings**

**For calculating dead, live, wind, and seismic loads:**

**IS 875 Series**

**4. ETABS Software Official Page (CSI)**

**For structural analysis using ETABS:**

**ETABS - Computers and Structures, Inc.**

**Seismic Zone Map of India (IS 1893: Part 1)**

**Use Karaikal's seismic zone info in design:**

**IS 1893 (Part 1): 2016**