A COMPARATIVE STUDY ON DESIGN & ANALYSIS OF G + 5 RESIDENTIAL BUILDING SUBJECTED TO WIND AND SEISMIC LOAD DESIGNED AND ANALYZED MANUALLY AND USING ETABS

A thesis submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

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2022-2026

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CERTIFICATE

This is to certify that the project report entitled **"A COMPARATIVE STUDY ON DESIGN & ANALYSIS OF G + 5 RESIDENTIAL BUILDING SUBJECTED TO WIND AND SEISMIC LOAD DESIGNED AND ANALYZED MANUALLY AND USING ETABS"** submitted by "**ALA UDDIN HOSSAIN, KITHALANGI VENKATA SAI SUJATHA, KOLA JYOTHI SREE RAGHAVA, KAREDLA SAI KUMARI, and JABED AHMED**" In partial fulfilment of the requirements for the award of Bachelors of Technology in Civil Engineering, during the academic year 2022-2026. The results embodied in this project report have not been submitted to any other institute or university for the award of any degree or diploma.

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DEPARTMENT OF CIVIL ENGINEERING

EVALUATION REPORT

This is to certify that the project report entitled **"A COMPARATIVE STUDY ON DESIGN & ANALYSIS OF G + 5 RESIDENTIAL BUILDING SUBJECTED TO WIND AND SEISMIC LOAD DESIGNED AND ANALYZED MANUALLY AND USING ETABS"** submitted by "**ALA UDDIN HOSSAIN, KITHALANGI VENKATA SAI SUJATHA, KOLA JYOTHI SREE RAGHAVA, KAREDLA SAI KUMARI,** and **JABED AHMED**" In partial fulfilment of the requirements for the award of Bachelor of Technology in Civil Engineering, during the academic year 2022-2026. The results embodied in this project report have not been submitted to any other institute or university for the award of any degree or diploma.

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	Head of the Department	Project Guide

DECLARATION

I hereby declare that the project titled "**A COMPARITATIVE STUDY ON DESIGN & ANALYSIS OF G + 5 RESIDENTIAL BUILDING SUBJECTED TO WIND AND SEISMIC LOAD DESIGNED AND ANALYZED MANUALLY AND USING ETABS**" is a record of bonafide work carried out by me, submitted in partial fulfillment for the award of B.Tech in Civil Engineering to Aditya College of Engineering & Technology Surampalem, affiliated to Jawaharlal Nehru Technological University, Kakinada.

The results embodied in this thesis have not been submitted to any other university or institute for the award of any degree or diploma.

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ABSTRACT

The rapid urbanization and growing population have escalated the demand for high-rise residential structures. This project presents the complete structural analysis and design of a G+5 (Ground floor plus Five floors) residential building using ETABS (Extended Three-Dimensional Analysis of Building Systems). The building is located in Visakhapatnam (Seismic Zone III) and is designed as per Indian Standard codes (IS 456:2000, IS 875, and IS 1893:2016).

The project involved creating a detailed 3D model, assigning material properties (M25 concrete and Fe415 steel), and applying various loads, including dead loads, live loads, wind loads, and seismic loads. The analysis included both static and dynamic methods to evaluate the structure's behaviour under different conditions. Key parameters such as story displacements, inter-story drifts, bending moments, shear forces, and axial forces were analysed.

The results show that the maximum story displacement was 45.2 mm, and the maximum inter-story drift was 0.00183, both well within permissible limits. All structural elements were designed successfully, with beams requiring up to 4-25mm diameter bars and columns designed for axial loads up to 3200 kN. The use of ETABS demonstrated significant advantages in accuracy, efficiency, and comprehensive analysis capabilities compared to traditional methods.

Keywords: ETABS, High-Rise Building, Structural Analysis, Seismic Analysis, RCC Design, IS Codes, Story Drift.

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ABBREVIATIONS

Abbreviation	Full form
ETABS	Extended Three-Dimensional Analysis of Building Systems
RCC	Reinforced Cement Concrete
IS	Indian Standard
G+5	Ground plus Ten Floors
DL	Dead Load
LL	Live Load
EL	Earthquake Load
SMRF	Special Moment Resisting Frame

NOMENCLATURE

Symbol	Meaning
f_{ck}	Characteristic compressive strength of concrete
f_y	Characteristic strength of steel
M_u	Bending moment
P_u	Axial load
V_u	Shear force
A_{st}	Area of tension steel
A_{sc}	Area of compression steel
Z	Zone factor
I	Importance factor
R	Response reduction factor

CHAPTER 1

INTRODUCTION

1.1 Background

The design and construction of residential buildings play a vital role in the development of modern infrastructure. With the rapid growth of urbanisation and population, there is an increasing demand for safe, economical, and efficient housing systems. Structural engineering ensures that buildings are capable of resisting various loads and forces while maintaining stability, safety, and serviceability throughout their lifespan.

Traditionally, structural analysis and design were carried out using manual calculations, which were time-consuming and prone to human errors. However, with the advancement of technology, the use of software tools has become essential in modern engineering practice. These tools not only simplify complex calculations but also provide accurate and reliable results within a short period of time.

In this project, a residential building is analysed and designed using **ETABS (Extended Three-Dimensional Analysis of Building Systems)**. The software enables efficient modelling and analysis of the structure under different types of loads, such as dead load, live load, wind load, and seismic load. The design is carried out in accordance with relevant Indian Standard (IS) codes to ensure structural safety and compliance.

The project involves various stages, including planning, load calculation, modelling, analysis, and design of structural components such as beams, columns, and slabs. Additionally, reinforcement detailing is carried out using **CSI DETAIL 2018**, and necessary drawings are prepared using **AutoCAD**.

The results obtained from the analysis, such as storey displacement, storey drift, natural time period, and member forces, are evaluated to ensure that the structure performs satisfactorily under different loading conditions. The overall aim of the project is to achieve a design that is not only safe and stable but also economical and practical for construction.

Thus, this project demonstrates the application of modern structural engineering software in the analysis and design of a residential building, highlighting the importance of integrating theoretical knowledge with practical tools.

1.2 Problem Statement

To analyze and design a safe, economical, and code-compliant G+5 residential building capable of withstanding gravity loads (dead and live loads) and lateral loads (seismic loads) specific to Seismic Zone III as per Indian Standard codes.

1.3 OBJECTIVES

The main objectives of this project are:

1. To analyse and design a multi-storey residential building using **ETABS software**.
2. To model the residential building structure, including beams, columns, slabs, and footings.
3. To analyse the structure under different loading conditions, such as:
    - Dead load
    - Live load
    - Wind load
    - Earthquake (seismic) load
4. To design structural members in accordance with the relevant **Indian Standard (IS) codes**.
5. To study the structural behaviour of the building under **seismic and wind forces**.
6. To ensure the safety and stability of the structure.
7. To obtain economical and safe structural design results.
8. To prepare structural drawings and design calculations.

1.3.1 Scope of the Project

The scope of this project includes the analysis and design of a multi-storey residential building using ETABS software. The project involves modelling and structural analysis of the building, considering different types of loads such as dead load, live load, wind load and earthquake load.

The following works are included in this project:

- Structural modelling of a residential building using ETABS.
- Application of loads such as dead load, live load, wind load and seismic load.
- Structural analysis of the building.
- Design of structural members such as beams, columns, slabs and footings.
- Design based on relevant Indian Standard (IS) codes.
- Preparation of structural drawings and design details.

1.3.2 Limitations of the Project

The project has the following limitations:

- The design is limited to structural elements only, and architectural planning is not considered in detail.
- Soil investigation data is assumed, and actual site investigation is not performed.
- Only static analysis and response spectrum (or equivalent static method) analysis are considered.
- Construction methods and cost estimation are not included.
- Environmental effects and temperature effects are not considered.
- The design is based on assumed loading conditions.

CHAPTER 2

LITERATURE SURVEY

2.1 Review of Previous Study

Analysis and Design of Multi-Storied Building by Using ETABS Software

Authors: Varikuppala Krishna, Chandrashekar, Rajshekar
Year: 2015
Source: ISSN No 2277-8179

Summary

This paper presents the analysis and design of a parking floor plus five upper stories, RCC framed building using ETABS software. The study focuses on the application of ETABS for analysing and designing buildings under lateral loading effects of wind and earthquake. The building model incorporates beams and columns as line members, while slabs, ramps, stairs, and walls are modelled as area members. The analysis considers both static and dynamic loading conditions, including dead loads (with self-weight), live loads, wall loads, and lateral loads due to wind and seismic forces as per Indian Standard codes. The paper presents tabulated analysis results for various load cases and combinations, including dead load, live load, wall load, and combinations such as COMBINATION1, DCON1, and DJST1. The authors conclude that ETABS is a powerful and integrated tool for structural analysis and design, enabling efficient handling of both gravity and lateral loads.

Key Contributions

- Demonstrated the use of ETABS for analysis and design of multi-storeyed buildings
- Incorporated both static and dynamic loading conditions
- Utilized Indian Standard codes for load calculations and design
- Presented detailed analysis results for various load combinations

Limitations and Gaps

- Used outdated codes (IS 1893-2002, IS 875-1987)
- Did not incorporate ductile detailing provisions (IS 13920)
- Analysis limited to linear static and dynamic methods
- No soil-structure interaction considered
- No BIM integration or automated detailing discussed

Analysis and Design of G+4 Residential Building Using ETABS

Authors: C.V.S. Lavanya, Emily.P.Pailey, Md. Mansha Sabreen, U.P.B.C. Sekhar
Year: 2017
Source: International Journal of Civil Engineering and Technology, Volume 8, Issue 4, pp. 1845-1850

Summary

This paper presents the seismic analysis and design of a G+4 residential building using ETABS software. The project is designed as per IS 1893-2002 and IS 456:2000, considering Zone IV seismic conditions with Type-II soil and an Ordinary RC Moment-Resisting Frame (R=3.0). The building has a regular rectangular plan with 3.0 m story height. M20 concrete and Fe415 steel were used. Loads included live loads (2 kN/m² on floors, 1 kN/m² on roof), floor finishes (1.5 kN/m² on floors, 2 kN/m² on roof), and wall loads (12.45 kN/m² for outer walls, 6.21 kN/m² for inner walls). A key objective was economic design through column optimization. Initial beam and column sizes were 230 mm × 450 mm. After analysis, only failed columns were revised to 230 mm × 750 mm. Seismic analysis was verified manually, with maximum shear force of 93.8 kN and maximum bending moment of 79.5 kN observed at the top floor. The authors conclude that ETABS is an effective tool for seismic analysis and design, enabling economical earthquake-resistant structures.

Key Contributions

- Focused on earthquake-resistant design with column optimization
- Verified software results with manual calculations
- Demonstrated economic design through member size optimization

- Provided clear load calculations and material specifications

Limitations and Gaps

- Used IS 1893-2002 instead of the updated IS 1893:2016
- Used Ordinary RC Moment-Resisting Frame (R=3.0) instead of SMRF
- Did not incorporate ductile detailing as per IS 13920
- No soil-structure interaction considered
- Analysis limited to equivalent static method
- No wind load analysis included
- Lack of BIM integration

Analysis and Design of G+5 Residential Building by Using E-TABS

Authors: K. Naga Sai Gopal, N. Lingeshwaran
Year: 2017
Source: International Journal of Civil Engineering and Technology, Volume 8, Issue 4, pp. 2098-2103

Summary

This paper presents the analysis and design of a G+5 residential building using ETABS software. The objective is to perform analysis and design without any type of failures, understand structural principles using Indian Standard codes, and prepare a 3D model for detailed analysis and design. The building has G+5 stories with 3.0 m story height and 1.5 m plinth height. M20 grade concrete and Fe415 steel were used. Column and beam sizes were 230 mm × 350 mm, slab thickness was 150 mm. Loads included live load of 2 kN/m², floor finish of 0.8 kN/m², and wall loads of 12.42 kN/m² for outer walls and 6.21 kN/m² for inner walls. A notable aspect of this study is the conclusion that for a G+3 residential building with total height less than 12 meters, there is no need to assign wind or seismic loads. The authors conclude that ETABS effectively performs analysis and design for structural elements, and the limit state method provides adequate strength, serviceability, durability, and economy.

Key Contributions

- Demonstrated step-by-step modelling and analysis process in ETABS
- Provided detailed beam and column design calculations
- Included footing design considerations

Limitations and Gaps

- **Incorrect exemption from wind and seismic loads** for low-rise buildings (unsafe and non-compliant)
- Used outdated codes (IS 1893:2002, IS 875:1987)
- Column sizes (230 mm × 350 mm) undersized for G+5 building
- No ductile detailing as per IS 13920
- Used outdated software version (ETABS 9.0)
- Floor finish load (0.8 kN/m²) lower than typical practice
- No BIM integration or advanced analysis methods

Analysis and Design of G+5 Residential Building Using ETABS

Authors: Mohd Azharuddin, Mohd Ghouse Uddin Haseeb, Mohd Arshad Ali, Mohammad Abdul Haq Ansari
Year: 2025
Source: ISSN: 2456-4265, IJMC 2025

Summary

This paper presents the analysis and design of a G+5 residential building located at Ameerpet, Hyderabad, using ETABS software. The building is a G+5 RCC framed structure with four flats per storey and one staircase. Floor-to-floor height is 3.2 m, plinth height is 0.5 m, and foundation depth is 1.5 m. Material specifications include M20 concrete for all structural elements, Fe500 steel for main reinforcement, and Fe415 steel for secondary reinforcement. The paper includes a comprehensive literature review covering seismic analysis, structural optimization, load combinations, soil-structure interaction, material alternatives, and comparative studies. The project concludes that ETABS enables efficient modelling, accurate load calculations, and economical design through optimization. All designs comply with IS codes (IS

456:2000, IS 875, IS 1893:2016, IS 13920:2016), ensuring structural safety, stability, and serviceability.

Key Contributions

- Updated code compliance (IS 1893:2016, IS 13920:2016 referenced)
- Comprehensive literature review covering multiple aspects of structural design
- Consideration of soil-structure interaction in literature review
- Reference to BIM integration with AutoCAD and Revit

Limitations and Gaps

- **Inconsistent building height** (G+5 in title, G+7 in Section 6)
- Wind load analysis not detailed despite inclusion in load combinations
- No actual implementation of non-linear analysis (only referenced in literature)
- Limited soil-structure interaction modelling (only discussed, not implemented)
- No detailed ductile detailing verification
- Optimization mentioned but no automated optimization tools used
- Sustainability not addressed

Analysis and Design of Residential Building Using ETABS

Authors: Kiran Babu S V
Year: 2007
Source: IRJET

Summary

This paper presents the analysis and design of a residential building using ETABS software, with a focus on gravity load analysis. The building consists of only ground floor and first floor, with the first floor intended for construction at a later stage. The structural system is a reinforced concrete framed structure with non-load bearing walls. All slabs are designed as continuous slabs. Material specifications include M30 grade concrete and Fe500 grade steel. The analysis and design follow the limit state method as per IS 456:2000, IS 875:1987, SP:16 , and IS 10262:2009. The structure is idealized as a 3D space frame model using ETABS version v9.7.0. Masonry walls are treated as filler walls and applied as UDL on beams. The design includes typical calculations for slabs, beams, columns, and staircases. The author concludes that the project helped in understanding extraction of information from architectural drawings, column orientation, load combinations, and interpretation of results from ETABS.

Key Contributions

- Demonstrated basic gravity load analysis methodology
- Provided clear design calculations for structural elements
- Showed interpretation of ETABS output results
- Highlighted learning outcomes from software-based design

Limitations and Gaps

- **No lateral load analysis** (wind and seismic) – unsafe and non-compliant
- Used outdated ETABS version (v9.7.0)
- Used outdated codes (IS 875:1987, SP:16 based on IS 456:1978)
- No seismic analysis as per IS 1893:2016
- No ductile detailing as per IS 13920:2016
- Simplified modelling (walls as UDL only, no infill modelling)
- Missing load combinations specification
- No BIM integration
- M30 concrete grade not justified for G+1 building

Analysis and Design of G+5 Residential Building by Using E-TABS

Authors: K. Naga Sai Gopal and N. Lingeshwaran (Additional Study)
Year: 2017
Source: International Journal of Civil Engineering and Technology, Volume 8, Issue 4, pp. 2098-2103

Summary

This paper presents a detailed methodology for modelling and analysis of a G+5 residential building using ETABS. The study emphasizes the step-by-step process of defining material properties, assigning loads, creating center line diagrams, and performing analysis and design. The building has G+5 stories with 3.0 m story height. M20 grade concrete and Fe415 steel were used. Column and beam sizes were 230 mm × 350 mm. Loads included live load of 2 kN/m², floor finish of 0.8 kN/m², and wall loads. The paper includes shear force diagrams, bending moment diagrams, and longitudinal reinforcement details. A significant conclusion is that for buildings with total height less than 12 meters, wind and seismic loads are not required. The authors conclude that ETABS effectively performs analysis and design, and the limit state method provides adequate strength and economy.

Key Contributions

- Provided detailed step-by-step modelling process in ETABS
- Included shear force and bending moment diagrams
- Demonstrated design of beams, columns, and footings

Limitations and Gaps

- **Incorrect exemption from wind and seismic loads** – contrary to IS 1893:2016 requirements
- Used outdated software version (ETABS 9.0)
- Outdated codes (IS 1893:2002, IS 875:1987)
- No ductile detailing as per IS 13920
- Small column sizes (230 mm × 350 mm) for G+5 building
- No BIM integration or advanced analysis

Seismic Analysis of Multi-Storied Building Using ETABS

Authors: Mahesh N. Patil, Yogesh N. Sonawane
Year: 2015
Source: International Journal of Engineering and Innovative Technology, Volume 4, Issue 9, pp. 123-129

Summary

This paper focuses specifically on seismic analysis of multi-storied buildings using ETABS. The study compares the seismic performance of buildings with regular and irregular configurations in different seismic zones. The analysis is carried out using equivalent static method and response spectrum method as per IS 1893-2002. The authors conclude that buildings with irregular configurations experience higher torsional effects and require special attention in design. The paper emphasizes the importance of considering lateral loads in multi-storied buildings and provides recommendations for improving seismic performance through proper structural configuration.

Key Contributions

- Comparative study of regular vs. irregular building configurations
- Comparison of equivalent static and response spectrum methods
- Emphasis on torsional effects in irregular buildings
- Seismic zone-wise performance comparison

Limitations and Gaps

- Used IS 1893-2002 instead of updated IS 1893:2016
- Did not incorporate IS 13920 ductile detailing provisions
- No soil-structure interaction considered
- Limited to linear analysis methods
- No pushover or non-linear analysis
- No BIM integration

Design and Analysis of Multi-Storied Building under Static and Dynamic Loading Conditions Using ETABS

Authors: Balaji U., Selvarasan
Year: 2016
Source: International Journal of Technical Research and Applications, Volume 4, Issue 4, pp. 1-5

Summary

This paper presents the analysis and design of a multi-storied building under static and dynamic loading conditions using ETABS. The study compares the results of static analysis (equivalent static method) with dynamic analysis (response spectrum method) for a G+5 building. The authors observe that dynamic analysis yields higher base shear and member forces compared to static analysis, emphasizing the need for dynamic analysis in seismic design. The paper also discusses the importance of proper load combinations as per IS codes and provides design recommendations for beams, columns, and slabs.

Key Contributions

- Comparison of static and dynamic analysis methods
- Demonstrated higher forces in dynamic analysis
- Emphasized importance of proper load combinations
- Provided design recommendations for structural elements

Limitations and Gaps

- Used IS 1893-2002 instead of updated IS 1893:2016
- No ductile detailing as per IS 13920
- No soil-structure interaction considered
- No wind load analysis
- Limited to linear analysis methods
- No BIM integration

Earthquake Resistant Design of Open Ground Storey Building Using ETABS

Authors: Piyush Tiwari, P.J. Salunke
Year: 2015
Source: International Research Journal of Engineering and Technology, Volume 2, Issue 7, pp. 63-71

Summary

This paper addresses the special case of open ground storey buildings (buildings with parking on the ground floor and no infill walls), which are common in urban areas. The study analyzes the seismic performance of such buildings using ETABS and compares them with buildings having infill walls in all storeys. The authors observe that open ground storey buildings experience significant soft-storey effects, leading to higher displacements and storey drifts. The paper recommends providing shear walls or bracing systems to mitigate soft-storey effects and improve seismic performance.

Key Contributions

- Addressed the critical issue of open ground storey buildings
- Demonstrated soft-storey effects through analysis
- Recommended shear walls and bracing for mitigation
- Provided design guidelines for open ground storey buildings

Limitations and Gaps

- Used IS 1893-2002 instead of updated IS 1893:2016
- No ductile detailing as per IS 13920
- Limited to equivalent static analysis
- No pushover analysis to capture non-linear behaviour
- No soil-structure interaction considered
- No BIM integration

Study of Seismic Analysis and Design of Multi Storey Symmetrical and Asymmetrical Building Using ETABS

Authors: Pardeshi Sameer
Year: 2016
Source: International Research Journal of Engineering and Technology, Volume 3, Issue 1, pp. 732-737

Summary

This paper presents a comparative study of symmetrical and asymmetrical buildings under seismic loading using ETABS. The study analyzes building configurations with plan irregularities and vertical irregularities, comparing their seismic performance in terms of base shear, storey drift, and torsional effects. The authors conclude that asymmetrical buildings experience significant torsional moments and require special design considerations to ensure safety. The paper recommends limiting irregularities in building configuration and providing additional lateral load-resisting elements for irregular buildings.

Key Contributions

- Comparative study of symmetrical vs. asymmetrical buildings
- Analysis of plan and vertical irregularities
- Evaluation of torsional effects in irregular buildings
- Recommendations for design of irregular buildings

Limitations and Gaps

- Used IS 1893-2002 instead of updated IS 1893:2016
- No ductile detailing as per IS 13920
- Limited to equivalent static analysis
- No response spectrum analysis for irregular buildings
- No soil-structure interaction considered
- No BIM integration

2.2 Theoretical Background

Structural analysis and design of buildings involve determining the strength and stability of structural members under different loading conditions. A residential building is subjected to various types of loads such as dead load, live load, wind load and earthquake load. These loads must be properly considered in order to ensure the safety and serviceability of the structure.

Dead load consists of the self-weight of structural elements such as slabs, beams, columns and walls. These loads remain constant throughout the life of the structure.

Live load consists of movable or temporary loads such as furniture, occupants and movable equipment. Live loads vary with time and are considered according to relevant IS codes.

Wind load acts horizontally on the structure and depends on wind speed, building height and shape. Wind loads are important in the design of multi-storey buildings because they affect stability and lateral displacement.

Seismic load is caused by earthquake forces acting on the structure. Earthquake forces depend on seismic zone, soil condition and structural configuration. Proper seismic design helps to reduce structural damage during earthquakes.

Structural analysis is carried out to determine bending moments, shear forces and axial forces in structural members. Based on the analysis results, structural members such as slabs, beams, columns and footings are designed.

Reinforced concrete design is carried out to ensure adequate strength, durability and serviceability of structural members. The design is done according to relevant Indian Standard codes.

In this project, structural analysis and design of the residential building are carried out using ETABS software by considering different loading conditions.

2.3 Code Provisions

The analysis and design of the residential building in this project are carried out according to the relevant Indian Standard (IS) codes. The following IS codes are used:

1. IS 456:2000 – Plain and Reinforced Concrete Code

This code provides guidelines for the design of reinforced concrete structural members such as slabs, beams, columns and footings. It includes provisions for strength, durability and serviceability requirements.

2. IS 875 (Part 1):1987 – Dead Loads

This code specifies the unit weights of building materials and methods for calculating dead loads acting on the structure.

3. IS 875 (Part 2):1987 – Live Loads

This code specifies the imposed loads to be considered in residential buildings.

4. IS 875 (Part 3):2015 – Wind Loads

This code provides guidelines for calculating wind loads acting on structures based on wind speed, terrain condition and building height.

5. IS 1893 (Part 1):2016 – Earthquake Resistant Design

This code provides guidelines for calculating seismic loads on structures based on seismic zone, soil type and importance factor.

6. IS 13920:2016\Ductile Detailing of RC Structures

This code provides guidelines for ductile detailing of reinforced concrete structures in seismic zones.

These codes are followed in ETABS for analysis and design of the residential building to ensure safety and stability of the structure.

2.4 Summary of Literature

The review of ten research papers on the analysis and design of multi-storeyed residential buildings using ETABS reveals that while the software is widely accepted as an effective tool for structural design, significant gaps exist in code compliance, analysis methodology, modelling sophistication, and integration with modern digital workflows. Most studies rely on outdated codes, omit ductile detailing, and perform only basic seismic analysis, some studies incorrectly exempt low-rise buildings from lateral load analysis, which is contrary to current code requirements. These gaps form the basis for the present study, which aims to demonstrate a comprehensive, code-compliant, and advanced approach to structural analysis and design using the latest version of ETABS.

CHAPTER 3

OVERVIEW SOFTWARE

3.1 Introduction to CSI (Computers and Structures Inc.)

Computers and Structures Inc. (CSI) is a leading software company in the field of structural engineering, founded in 1975 and headquartered in Berkeley, California, USA.

CSI develops advanced software tools used worldwide for structural analysis, design, and detailing of buildings and other structures.

Some popular CSI software include:

- ETABS
- SAP2000
- CSi Bridge
- CSI DETAIL

In this project, CSI software such as **ETABS and CSI DETAIL 2018** are used.

3.2 Introduction to ETABS

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a structural analysis and design software developed by CSI. It is specifically used for multi-storey building analysis.

ETABS provides an integrated platform for modelling, analysis, and design of structures under various loads.

In this project, ETABS is used for:

- Modelling the residential building
- Applying loads (dead, live, wind, and seismic)
- Performing structural analysis
- Designing beams, columns, and slabs

Advantages

- Specialized for **building analysis and design**
- Supports **seismic analysis (IS 1893)** and **wind analysis (IS 875)**
- Easy **3D modelling of multistory structures**
- Provides **accurate and fast results**
- Automatic **load calculation and load combinations**
- Integrated design for **beams, columns, and slabs**
- User-friendly interface

Disadvantages

- Requires **proper knowledge and training**
- Software is **costly (licensed version)**
- Errors may occur if **incorrect input is given**
- Limited use for **non-building structures**
- Heavy models require **high-performance computer**

3.3 Introduction to CSI DETAIL 2018

CSI DETAIL 2018 is a software developed by CSI for **reinforcement detailing of reinforced concrete structures**.

It is used to convert design outputs into detailed reinforcement drawings required for construction. The software helps engineers generate accurate bar bending details and reinforcement layouts.

CSI DETAIL is mainly used for:

- Beam reinforcement detailing
- Column reinforcement detailing
- Slab reinforcement detailing
- Bar Bending Schedule (BBS) preparation

In this project, CSI DETAIL 2018 is used for preparing **reinforcement detailing drawings** based on the design results obtained from ETABS.

Advantages

- Generates **accurate reinforcement detailing**
- Automatic **Bar Bending Schedule (BBS)**
- Saves time compared to manual detailing
- Reduces **human errors in reinforcement calculation**
- Easy conversion of design results into **practical drawings**

Disadvantages

- Requires **proper understanding of detailing concepts**
- Less flexible for **custom or complex detailing cases**
- Needs integration with **design software like ETABS**
- Not widely used compared to AutoCAD for detailing

3.4 Introduction to AutoCAD

AutoCAD is a computer-aided design software developed by Autodesk. It is widely used for drafting and designing engineering drawings.

In this project, AutoCAD is used for:

- Preparing architectural plans
- Structural layout drawings
- Final reinforcement detailing drawings

Advantages

- Widely used for **2D drafting and detailing**
- High **accuracy and precision in drawings**
- Easy to **edit and modify drawings**
- Supports **layer management and scaling**
- Industry standard software for engineering drawings

Disadvantages

- Mostly limited to **drafting (no structural analysis)**
- Time-consuming for **manual detailing**
- Requires skilled user for efficient work
- No automatic design or load calculation

3.5 Features of Software

ETABS

- 3D structural modelling
- Seismic analysis as per IS 1893
- Wind load analysis as per IS 875
- RC design as per IS 456
- Fast and accurate analysis

CSI DETAIL 2018

- Automatic reinforcement detailing
- Generation of bar bending schedules
- Accurate detailing of beams, columns, and slabs
- Easy conversion of design data into drawings

AutoCAD

- Accurate 2D drafting
- Easy modification of drawings
- Widely used for engineering and construction drawings

3.6 SUMMARY

In the present project, modern structural engineering software such as **ETABS, CSI DETAIL 2018, and AutoCAD** have been used to achieve an efficient and accurate design of a residential building. Each software plays a specific and important role in different stages of the project.

ETABS is used for the **modelling, analysis, and design** of the structure. It helps in evaluating the structural behaviour under various loading conditions such as dead load, live load, wind load, and seismic load. The software provides detailed outputs including storey displacement, storey drift, base reactions, and member forces, which are essential for safe structural design as per IS codes.

CSI DETAIL 2018 is used for **reinforcement detailing**. Based on the design results obtained from ETABS, it generates detailed reinforcement layouts for beams, columns, and slabs along with bar bending schedules. This reduces manual effort, improves accuracy, and ensures that the design is practically implementable at the construction site.

AutoCAD is used for **preparing architectural and structural drawings**. It helps in creating clear and precise layout plans and reinforcement drawings, which are necessary for proper execution of the project.

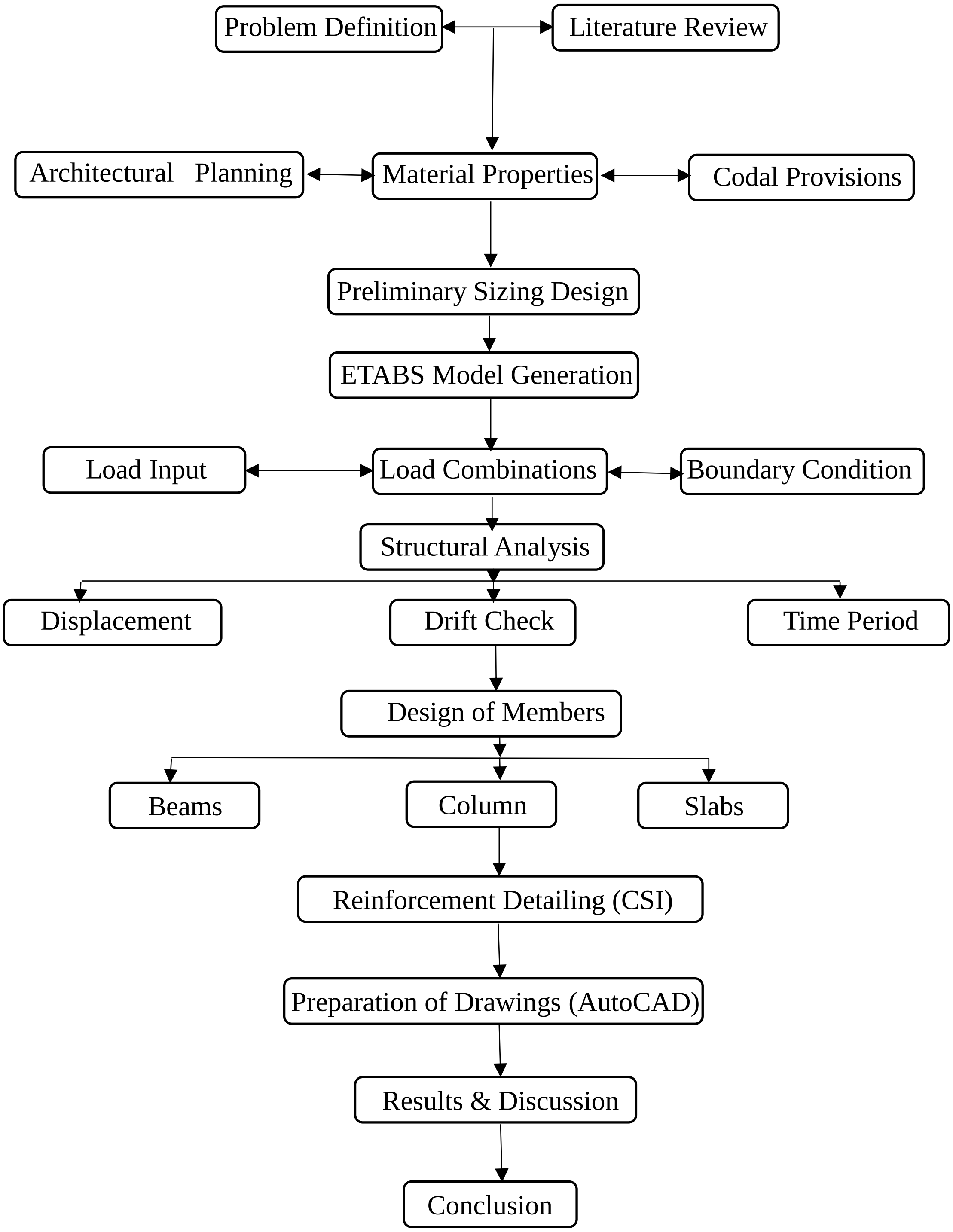
The combined use of these software tools significantly reduces the time and effort required for manual calculations and drafting. It also minimizes human errors and improves the overall quality, accuracy, and reliability of the design.

However, the effectiveness of these tools depends on the accuracy of input data and the engineer's understanding of structural concepts. Improper modelling or incorrect assumptions may lead to inaccurate results.

Overall, the integration of ETABS, CSI DETAIL 2018, and AutoCAD provides a systematic approach to structural analysis, design, and detailing, ensuring a **safe, economical, and efficient residential building design**.

CHAPTER 4

METHODOLOGY



CHAPTER 5

DESIGN PRE-REQUISITIES

5.1 Project Data and Assumptions

The following data and assumptions are considered for the analysis and design of the residential building using ETABS software.

General Building Data

- Type of Structure : Reinforced Concrete Residential Building
- Type of Building : Residential
- Number of Storeys : G + 5 Floors
- Floor to Floor Height : 3.25 m
- Total Height of Building :17.5 m
- Plan Dimension :13 m ×12.19 m
- Structural System : RC Frame Structure
- Type of Foundation : Isolated Footing
- Software Used : ETABS

Material Properties

- Grade of Concrete : M25
- Grade of Steel : Fe415
- Unit Weight of Concrete : 25 kN/m³
- Unit Weight of Brick Masonry : 20 kN/m³

Member Sizes (Assumed)

- Slab Thickness : 150 mm
- Beam Size : 300 mm × 400 mm
- Secondary Beam :230 mm x 350 mm
- Column Size :C1 300 mm × 760 mm
  C2 300 mm x 600 mm

- Wall Thickness : 230 mm (External wall)
- Wall Thickness : 115 mm (Internal wall)

Seismic Data

- Seismic Zone : Zone III
- Zone Factor (Z) : 0.16
- Importance Factor (I) : 1.2 (Residential Building)
- Response Reduction Factor (R) : 5
- Soil Type : II(Medium Soil)
- Damping Ratio : 5%

Wind Data

- Basic Wind Speed : 50 m/s(Visakhapatnam, IS 875 Part 3: 2015)
- Terrain Category : Category 2
- Structure Class : Class B

Design Codes Used

- IS 456:2000 – RC Design
- IS 875 – Loading
- IS 1893 – Seismic Design

5.2 Preliminary Sizing

Preliminary sizing of structural members is an important step before performing detailed analysis and design. Initial dimensions of slabs, beams and columns are assumed based on standard design guidelines and past experience.

The preliminary sizes are selected to ensure adequate strength, stiffness and serviceability of the structure. These assumed dimensions are later verified and optimized after performing structural analysis using ETABS software.

Slab Thickness:

Dimensions as per Deflection point of view by l/d ratio as per clause 24.1 [IS 456:2000].

lx = 3.85

lx/d = 40 *0.8

3.85/{d} = 32

d = 3.85/32

d= 0.120 m

Total Depth = d + {Ø}/{2} + {clear cover}

= 120 + {12}/{2} + 20 = 146

= 150 mm

Slab thickness provided: 150 mm

Staircase waist slab: 250mm

The slab thickness is selected based on span to depth ratio considerations. For the present project, a slab thickness of **150 mm** is adopted.

Beam Size:

Preliminary dimension as per clause 13920:2016 and clause of 456:2016

A. Clause 23 of IS 456:2016

$$\frac{l}{d} = 26$$

$$\frac{4.3}{d} = 26$$

$$\frac{4.3}{26} = d$$

d = 165 mm.

B. Clause 6 of 13920:2016 as per Clause 6.1.1 :$\frac{b}{D} > 0.3$

as per clause 6.1.2 : width (b) should not less than 200 mm.

as per clause 6.1.3 D< $\frac{1}{4} \times clear\ span$.

Hence, providing preliminary section for analysis and design-

Primary Beam as 300mm X 600 mm, and

Secondary Beam ad 230 mm X 350 mm.

Column Preliminary Sizing

Preliminary dimension as per clause 7.1.1 of 13920:2016

Minimum dimension of a column shall not be less than

I. $20\times d_b$=$20\times 120 = 240\ mm$.
II. 300 mm.

Hence, providing preliminary section for analysis and design

Column =300 mm X 760 mm, and

Column =300 mm X 600 mm.

Wall Thickness:
External walls are assumed as **230 mm thick brick masonry**, while internal partition walls are assumed as **115 mm thick**.

These preliminary sizes are used in ETABS for modelling and structural analysis of the residential building.

5.2 Architectural Layout

The architectural layout of the residential building is prepared based on the requirements of a typical residential structure. The building consists of multiple storeys with a regular plan arrangement to ensure proper structural behaviour.

The plan includes rooms such as bedrooms, living room, kitchen, toilets and staircase. The structural layout is prepared by placing columns at suitable locations to support beams and slabs effectively.

The building plan is rectangular in shape and provides proper spacing between columns for structural stability and economical design. The beams are provided along both directions to support the slab loads and transfer the loads to the columns.

The staircase is provided for vertical movement between floors. The slab system is designed as a reinforced concrete slab supported on beams.

The architectural plan used for modelling in ETABS is shown in

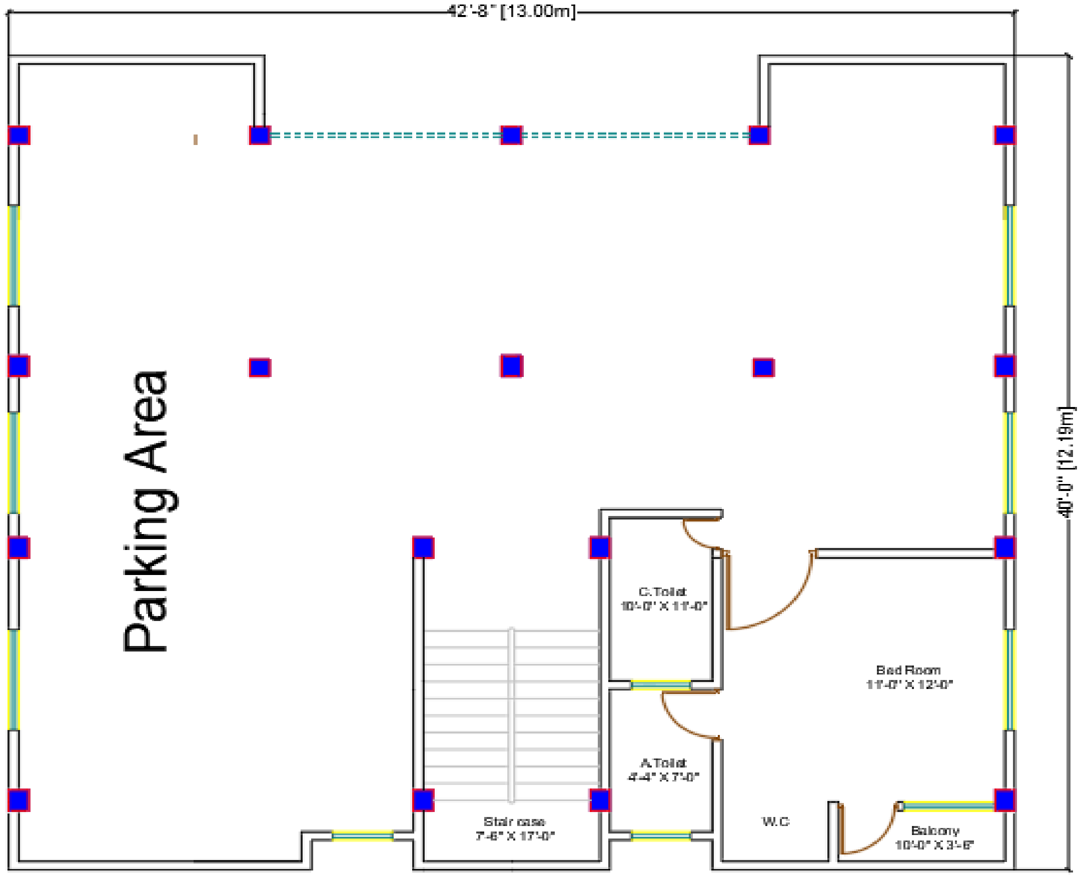


Figure 5.2.1.: Parking Area

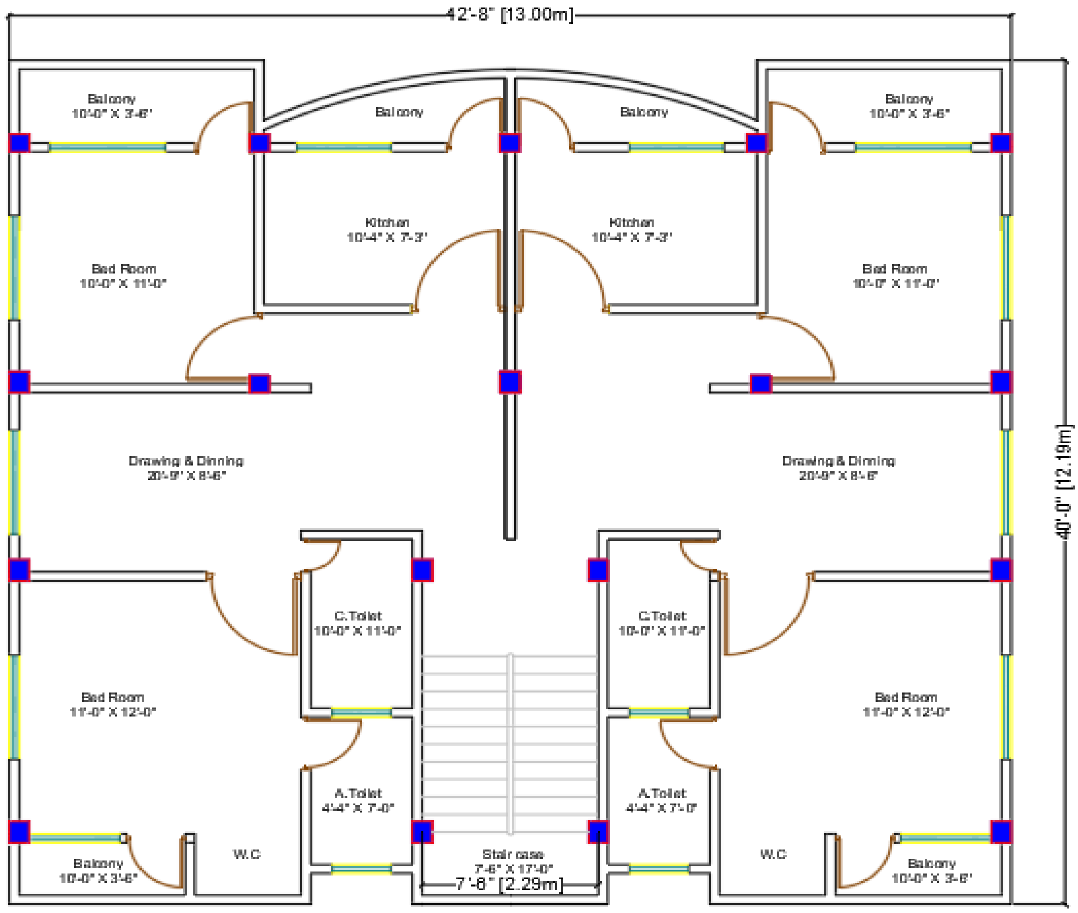


Figure 5.2.2: Floor Plan

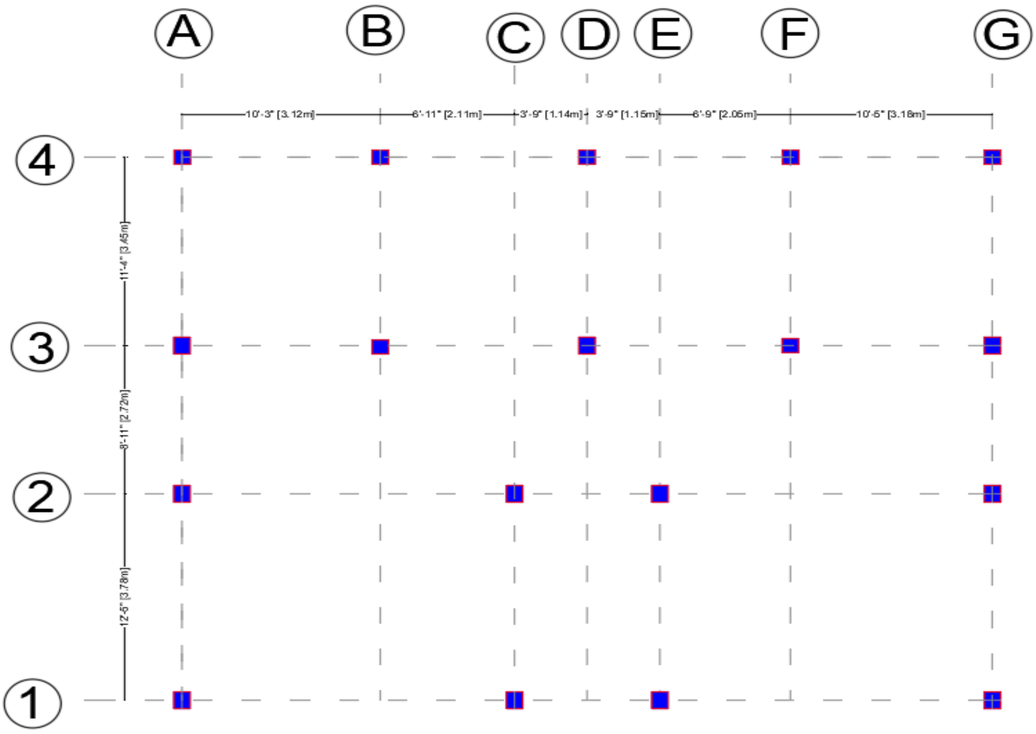


Figure 5.2.3: Column Grid line

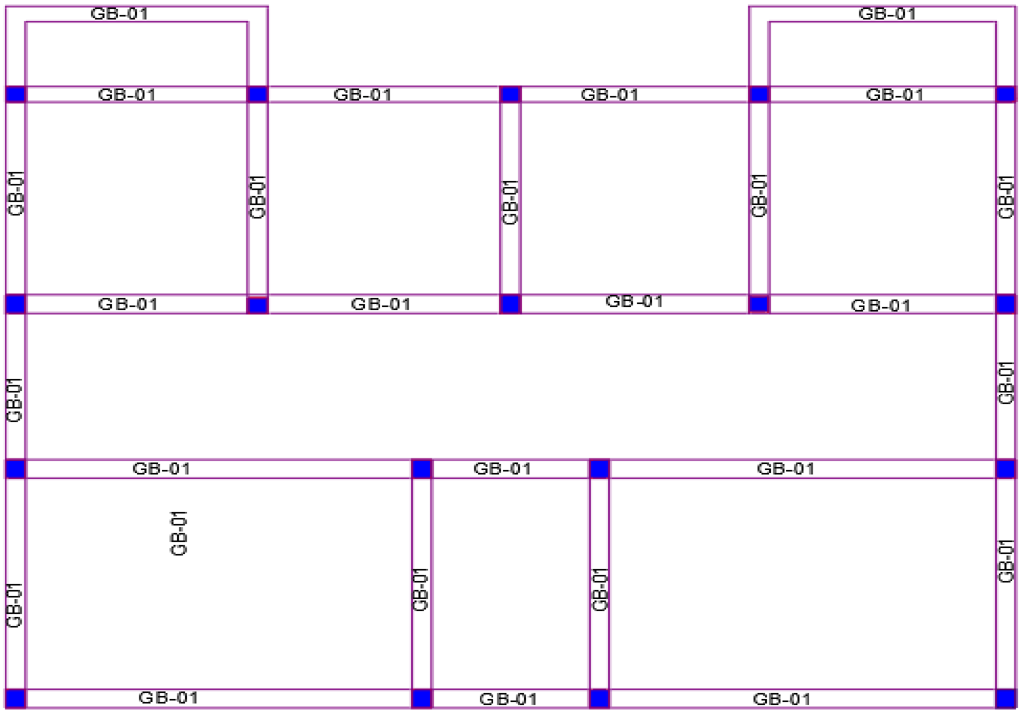


Figure 5.2.4: Grade Beam layout

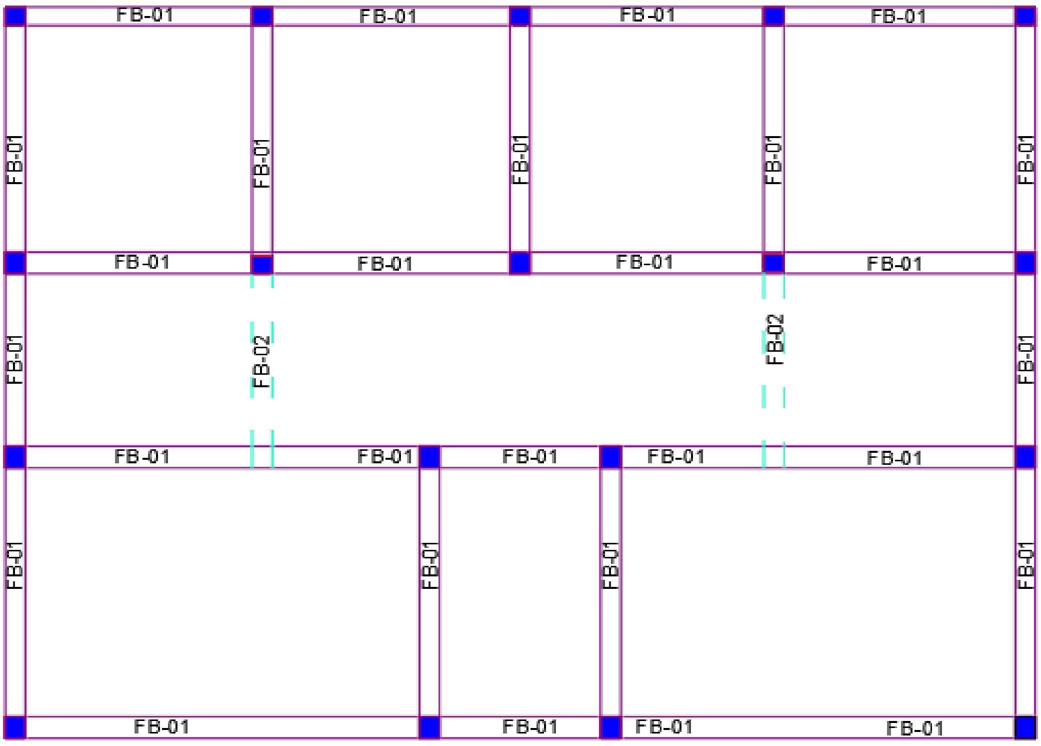


Figure 5.2.5: Floor Beam layout

CHAPTER 6

DESIGN OF 5 STOREY RESIDENTIAL BUILDING MODELLING

6.1 ETABS Model Generation

The structural model of the residential building is generated using ETABS software. ETABS provides an efficient platform for modelling, analysis and design of multi-storey building structures.

The following steps are followed to generate the ETABS model:

6.1.1 Initialization of Model

Rectangular Grids

Display Grid Data as Ordinates — Display Grid Data as Spacing — Quick Start New Rectangular Grids...

X Grid Data

Grid ID	X Spacing (m)	Visible	Bubble Loc
A	3.12	Yes	End
B	2.11	Yes	End
C	1.14	Yes	End
D	1.15	Yes	End
E	2.05	Yes	End
F	3.18	Yes	End

Add Delete

Y Grid Data

Grid ID	Y Spacing (m)	Visible	Bubble Loc
1	3.78	Yes	Start
2	2.72	Yes	Start
3	3.45	Yes	Start
4	0	Yes	Start

Add Delete

Story	Height m	Elevation m	Master Story	Similar To	Splice Story	Splice Height m	Story Color
Head Room	3.25	24	Yes	None	No	0	
Terrace	3.25	20.75	No	Head Room	No	0	
5th Floor	3.25	17.5	No	Ground Floor	No	0	
4th Floor	3.25	14.25	No	Ground Floor	No	0	
3rd Floor	3.25	11	No	Ground Floor	No	0	
2nd Floor	3.25	7.75	No	Ground Floor	No	0	
1st Floor	3.25	4.5	No	Ground Floor	No	0	
Ground Floor	1.25	1.25	Yes	None	No	0	
Base		0					

Figure 6.1.1: Model Initialization

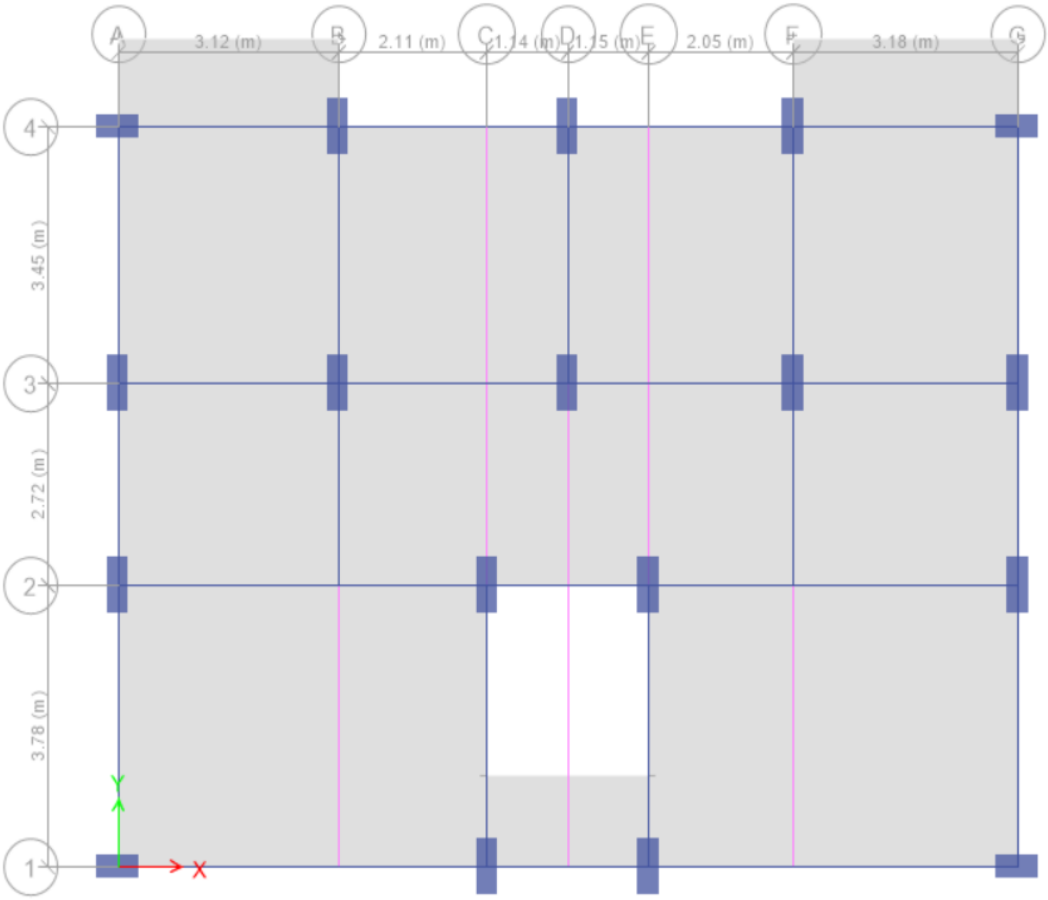
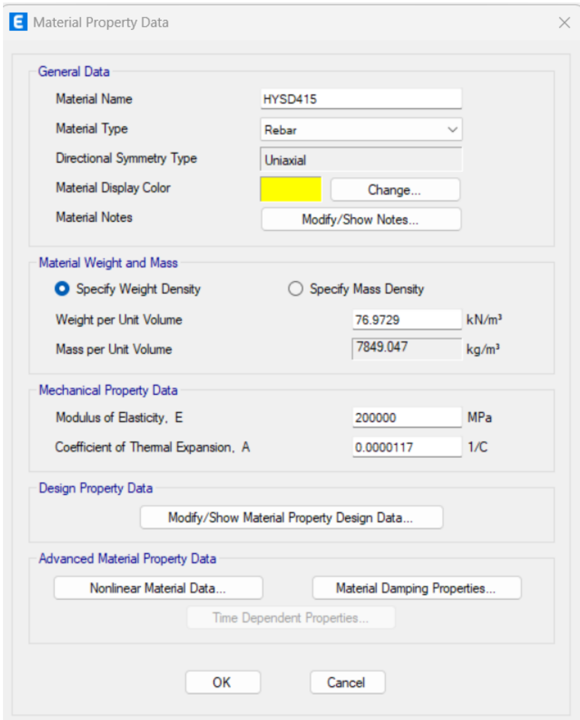


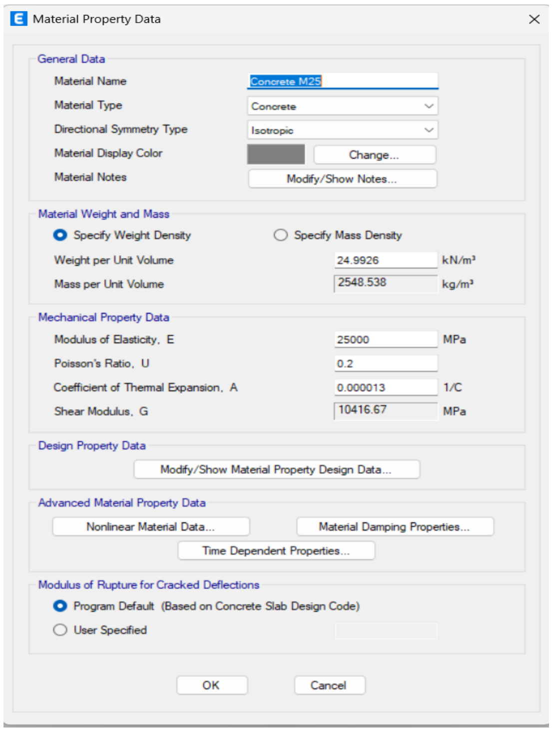
Figure 6.1.2: ETABS layout

Above mentioned model is created in ETABS and the appropriate unit system is selected. The grid system and storey data are defined according to the building plan dimensions and storey heights.

6.1.2. Define Material Properties

Material properties such as concrete and steel are defined in the software. In this project, **M25 grade concrete** and **HYSD415 grade steel** are used.



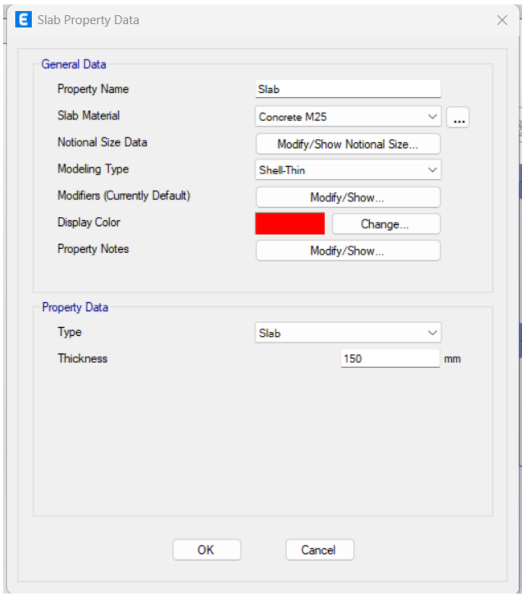


Rebar Properties Concrete properties

Figure 6.1.2 Material Properties

6.1.3. Section Property Definition

Structural member sections such as beams, columns and slabs are defined with their preliminary sizes.



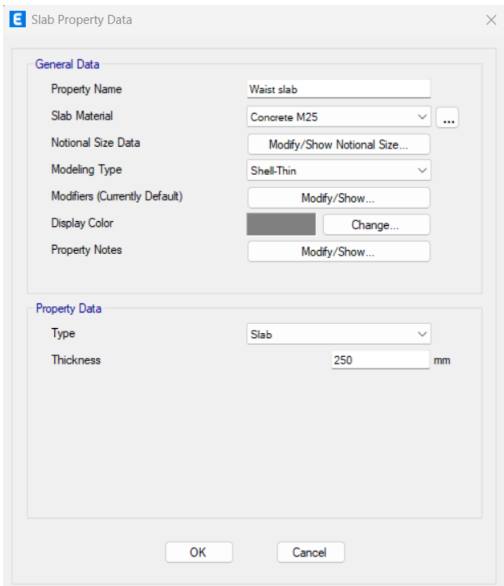


Figure 6.1.3 Slab Section properties

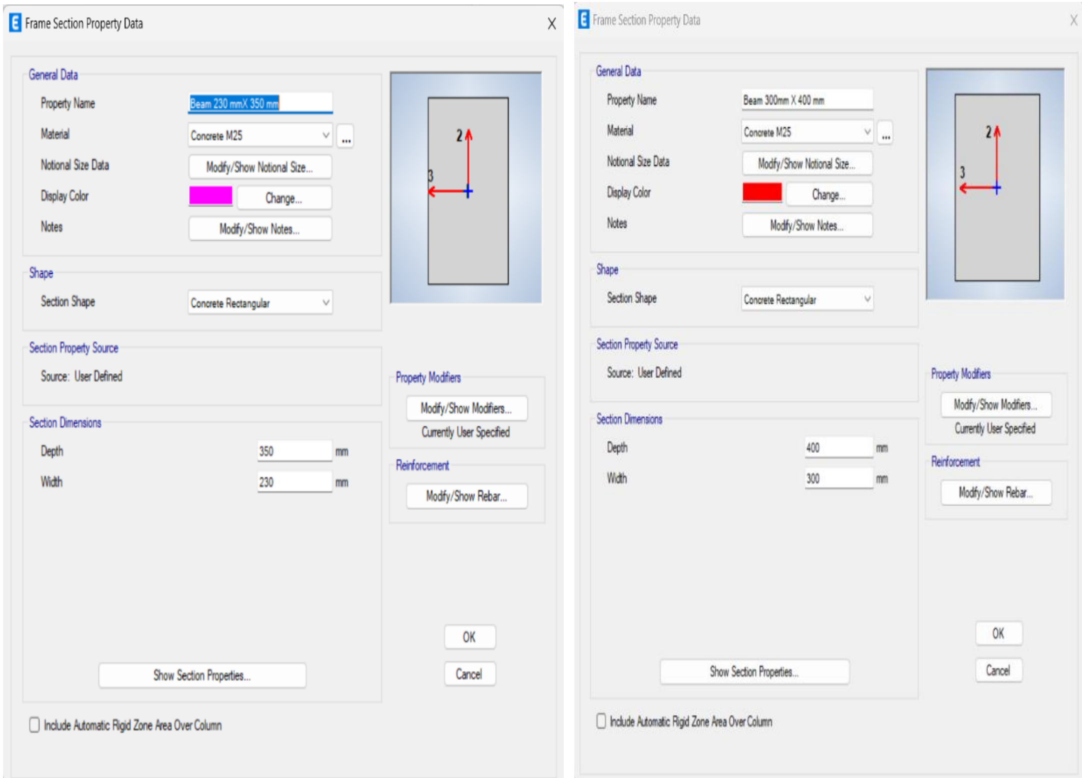


Figure 6.1.3.1: Beam section properties

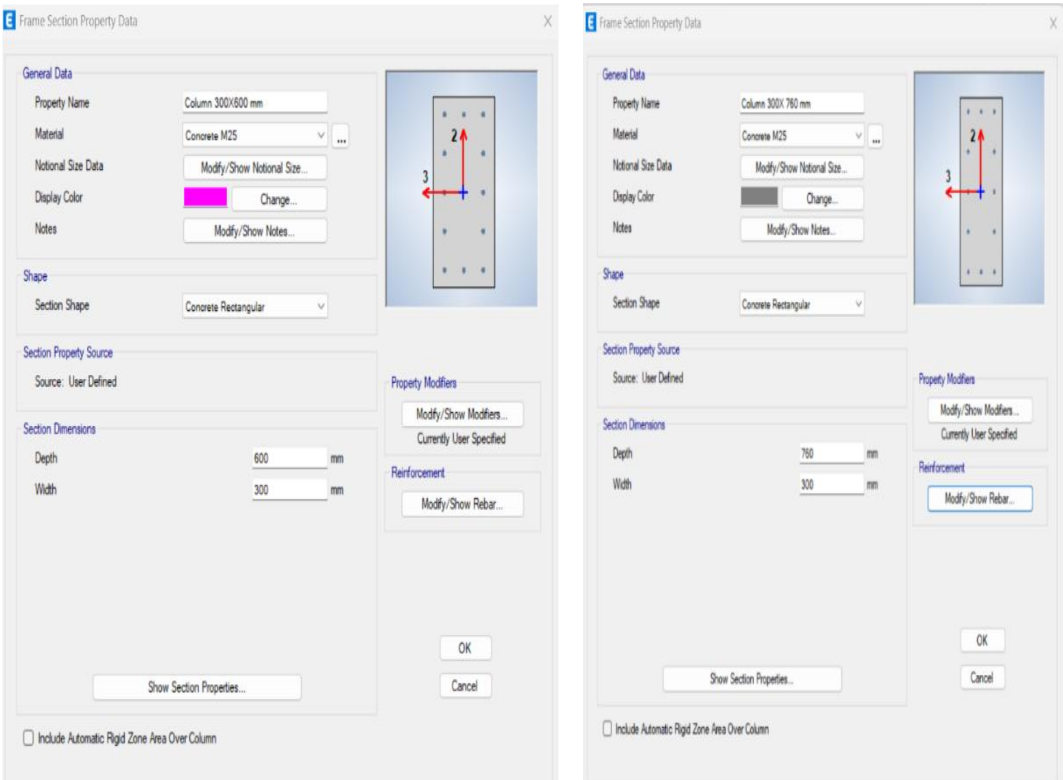


Figure 6.1.3.2: Column Section properties

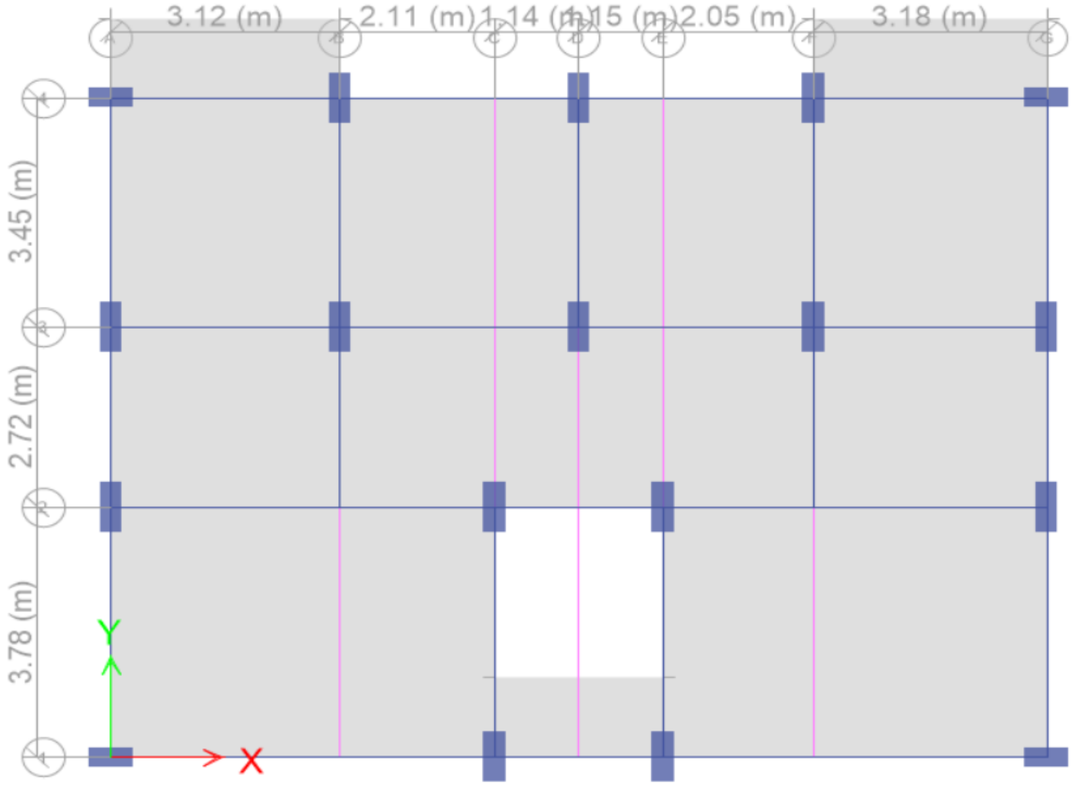


Figure 6.1.3.3 Structure layout

6.1.4 Modelling of Structural Elements

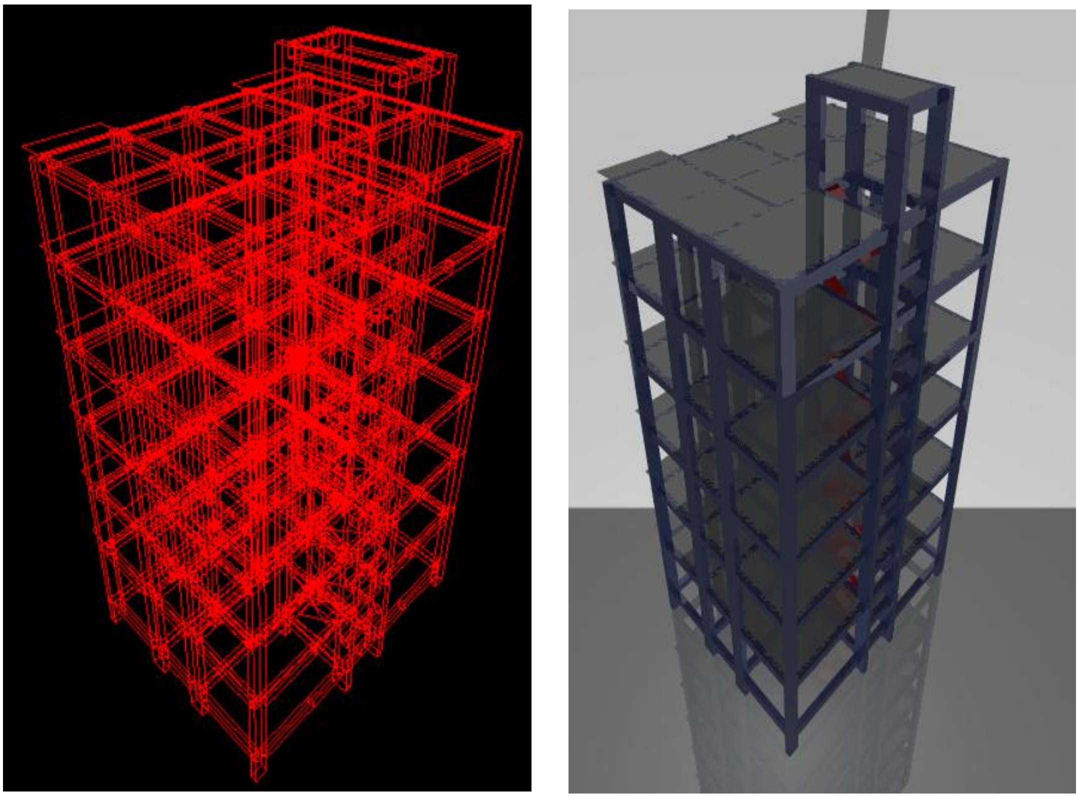


Figure 6.1.3.4 3D frame structure

Beams, columns and slabs are modelled according to the architectural layout of the building. Columns are placed at grid intersections and beams are connected between columns. Slabs are assigned as floor elements.

6.1.5 LOAD CALCULATION

The loads acting on the residential building are calculated according to relevant **Indian Standard codes**. The major loads considered in the structural design are **dead load, live load, wind load and seismic load**.

1. Dead Load

Dead load consists of the self-weight of structural elements such as slabs, beams, columns and walls. The self-weight of the structure is automatically calculated by **ETABS** based on the unit weight of materials.

Dead load of columns, Beams,Slabs are considered by software ETABS itself . Because we input material properties count unit weight and density. Assigned Dead load pattern as self-weight multipliers 1 and property modifiers of weight is 1.

Unit weight of reinforced concrete = **25 kN/m^3**

2. Super Imposed dead load (Load pattern: Super Dead)

As per IS 875-Part 1: 1987

i. Load intensity for 10mm thick mortar is but for 50mm thick mortar is to be: 0.21*5=1.05km^2(for below flooring)

ii. Ceiling plaster (6mm) = $0.21 * 0.6 = 0.126\ KN/m^2$

iii. Clay Floor Tiles of 12.5mm = 0.12 KN/m^2

For Floors excluding terrace, SIDL is:

1.05 + 0.126 + 0.12 = **1.296** $\boldsymbol{KN/m^2}$

iv. Thickness of water proofing = 125 mm

Density of water proofing course = 22 KN/m^3

Load density of water proofing course

= 0.125 x 22 = 2.75 KN/m^2

For Terrace SIDL (including ceiling plaster):

=2.75 + 0.126 = **2.876 KN/m^2**

v. Unit weight of concrete $\gamma_{concrete}$= 25 KN/m^3

vi. Unit weight of floor finish = 23.5KN/m^3

vii. Load of step =$\frac{1}{T} + \frac{RXT}{2} \times \gamma_{Concrete}$

=$\frac{1}{0.290} + \frac{0.1625X0.290}{2} \times 25000$

Load of step =2.03 KN/m^2

viii. Load of floor finish of step

$$\frac{Thickness\ of\ floor\ finish \times T}{T} \times \gamma_{floor\ finish}$$

$$\frac{0.020 \times 0.290}{0.290} \times 23.5$$

=0.41 KN/m^2

Total load for step of stairs

= load of step +load of floor finish

= 2.03+0.41

= **2.5 KN/m^2**

3. Live Load (Load Pattern: Live)

As per IS 875 Part-02: 1987

Live load intensity as per type of room for residential building as:

Room Type (Residential)	Live Load Intensity	IS Code Reference
Living Room	2 KN/m^2	Table 1 - 1.0.1
Kitchen	2 KN/m^2	Table 1 - 1.0.1
WC & Bath	2KN/m^2	Table 1 - 1.0.2
Balcony	3 KN/m^2	Table 1 - 1.0.3
Bedroom	2 KN/m^2	Table 1 - 1.0.1
Passage	3 KN/m^2	Table 1 - 1.0.3
Stairs	3 KN/m^2	Table 1 - 1.0.3
Terrace	1.5 KN/m^2	Table 2 - 1.i.a
Terrace (Access not provided)	0.75 KN/m^2	Table 2 - 1.i.b

Wall Load Calculation – SIDL

Here, Structural details

Storey Height =3.25 m

Primary Beam =40 mmx325 mm- (M25)

Secondary Beam : 240 mm x250mm-(M25)

Width of Wall : 240 mm} (AAC Block masonry)

Material Properties (AAC Block)

Unit weight : 6 kN/m^3

Compressive strength : 4N/mm^2

Unit weight of plaster : 20 kN/m^3

Internal Plaster Thickness : 20 mm

External Plaster Thickness : 25mm

Internal Wall under Primary Beam

Depth of wall = 3.25 - 0.325 = 2.925m

Weight per meter run for AAC Block = 0.24 x 2.925 x 6 = **4.212 kN/m**

4. Wind Load

Wind load is calculated according to **IS 875 (Part 3)**.
The wind load acting on the structure depends on **basic wind speed, terrain category, building height and structure class**.

Basic wind speed (V_b) =**50** m/s

Design wind speed is calculated using:

Vz=$V_b \times k_1 \times k_2 \times k_3 V_z = V_b \times k_1 \times k_2 \times k_3 V_z = V_b \times k_1 \times k_2 \times k_3$

Where:

- **V_b** = Basic wind speed
- **k_1** = Risk coefficient
- **k_2** = Terrain, height and structure size factor
- **k_3** = Topography factor

The calculated wind loads are applied to the structure in ETABS.

5. Seismic Load

Seismic loads are calculated according to **IS 1893 (Part 1)**.

Analysis Method	: Equivalent Static Analysis
Seismic Zone	: III
Zone Factor (Z)	: 0.16
Site Type	: II (Medium soil) as per Table 9 of IS 1893 (Part 1) : 2016
Importance Factor (I)	: 1.2 as per Clause 7.2.3

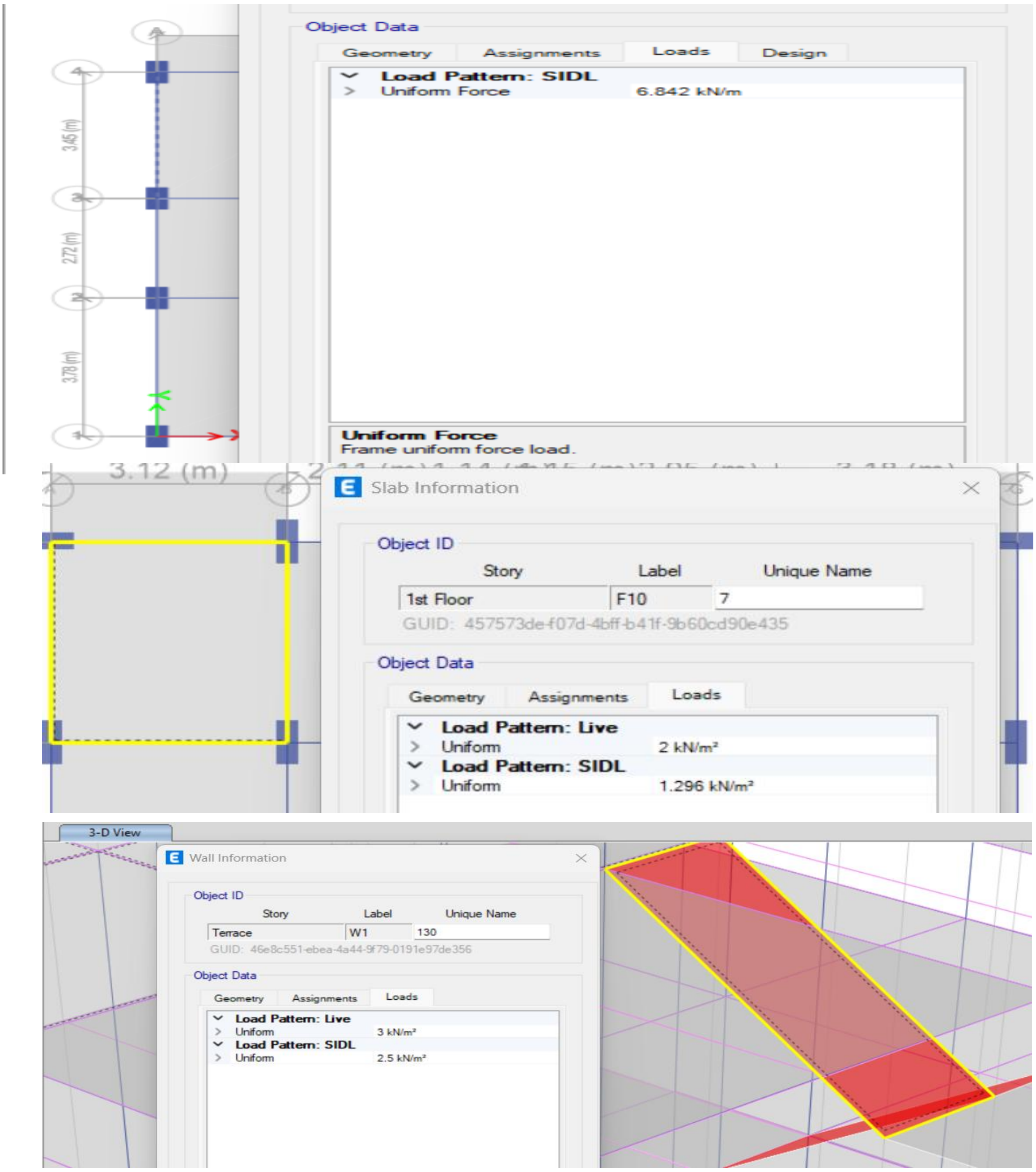
Response Reduction Factor (R) : 5 (for **SMRF - Special Moment Resisting Frame)**

Percentage of Imposed Load for Seismic Weight: 25% for LL up to 3 **KN/m²**

As per clause 7.3.1 and table 10 of IS 1893 (part-01) 2016.

6.2 Assignment of Loads

various loads such as dead load, live load, wind load and seismic load are assigned to the structure according to relevant IS codes.



6.2 Assignment of Loads

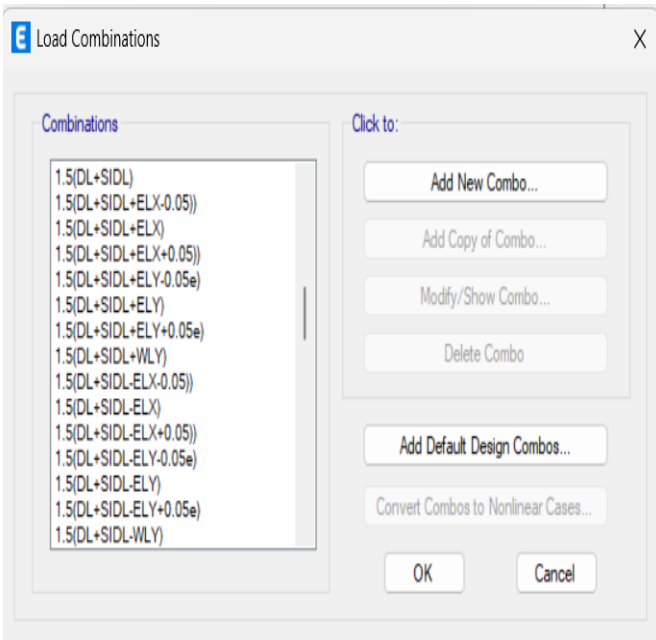
6.3 Load Combinations

Load combinations are used in structural design to evaluate the behavior of the building under different combinations of loads acting simultaneously. The structure must be able to safely resist the combined effects of **dead load, live load, wind load and seismic load**.

In this project, load combinations are considered according to the provisions of **IS 456:2000** and **IS 1893 (Part 1)**. These combinations help in determining the critical forces such as **bending moment, shear force and axial force** in structural members.

The following load combinations are used for the analysis and design of the residential building in **ETABS**:

1. **1.5 (DL + LL)**
2. **1.2 (SIDL + LL + EQx)**
3. **1.2 (DL + LL + EQy)**
4. **1.5 (DL + EQx)**
5. **1.5 (DL + EQy)**
6. **0.9 DL + 1.5 EQx**
7. **0.9 DL + 1.5 EQy**
8. **1.2 (SIDL + LL + WLx)**
9. **1.2 (DL + LL + WLy)**
10. **1.5 (DL + WLx)**
11. **1.5 (DL + WLy)**
12. **0.9 DL + 1.5 WLx**
13. **0.9 DL + 1.5 WLy**



Where:

- **DL** = Dead Load
- **SIDL**=Super Imposed dead Load
- **LL** = Live Load
- **EQx / EQy** = Earthquake load in X and Y directions
- **WLx / WLy** = Wind load in X and Y directions

These load combinations are defined in **ETABS** to analyze the structure under critical loading conditions. The structural members are designed based on the most critical results obtained from these load combinations to ensure safety and stability of the residential building.

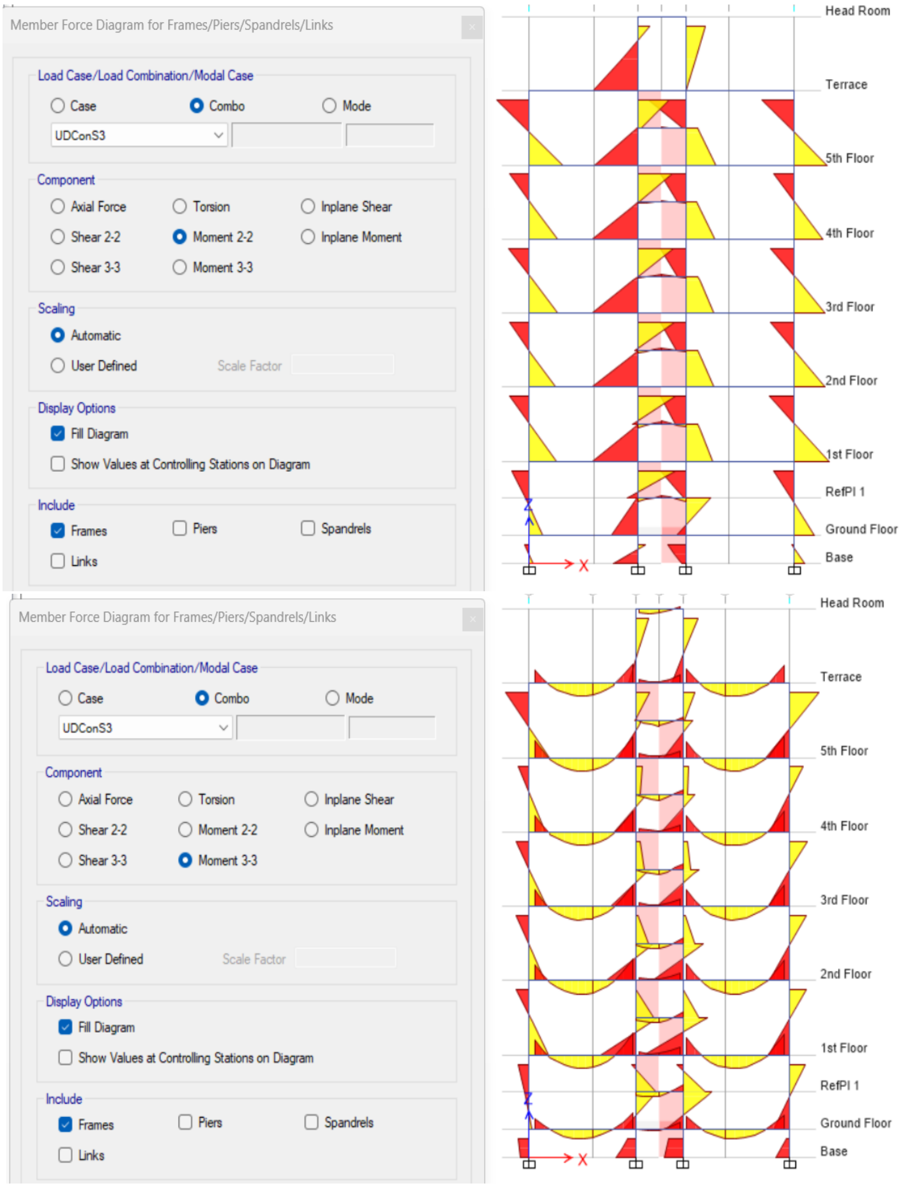
CHAPTER 7

STRUCTURAL ANALYSIS AND RESULTS

7.1 Structural Analysis

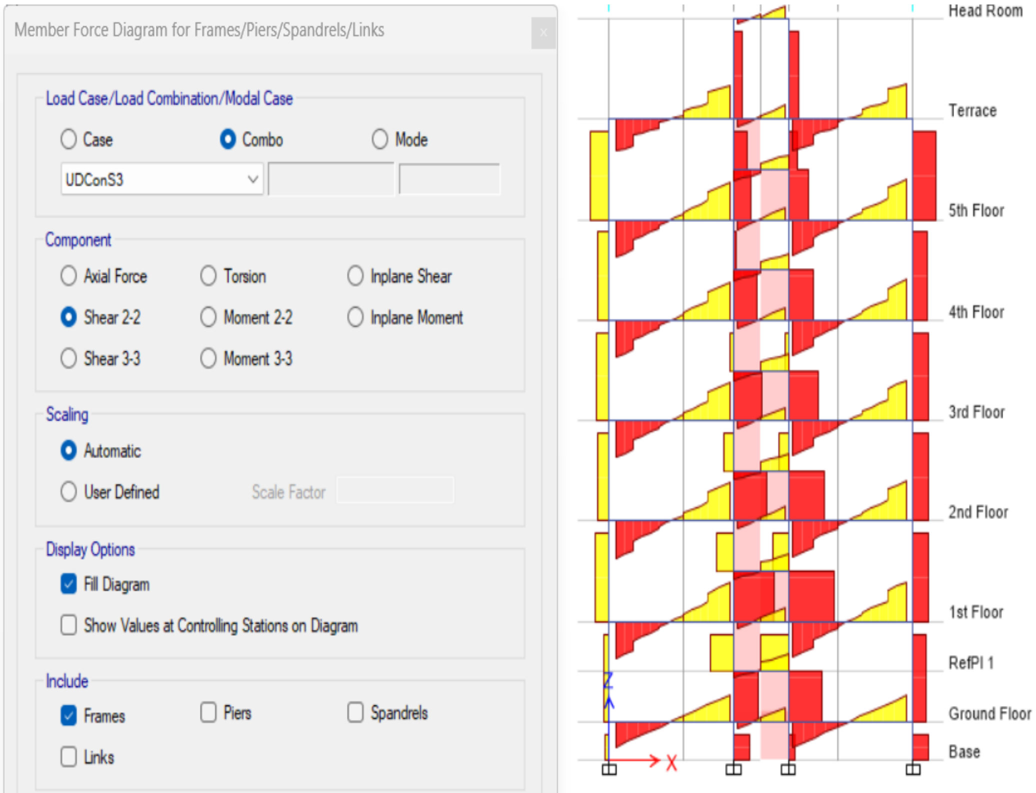
after completing the modelling and load assignments, structural analysis is performed using ETABS to determine internal forces such as **bending moments, shear forces and axial forces.**

Bending Moment diagram



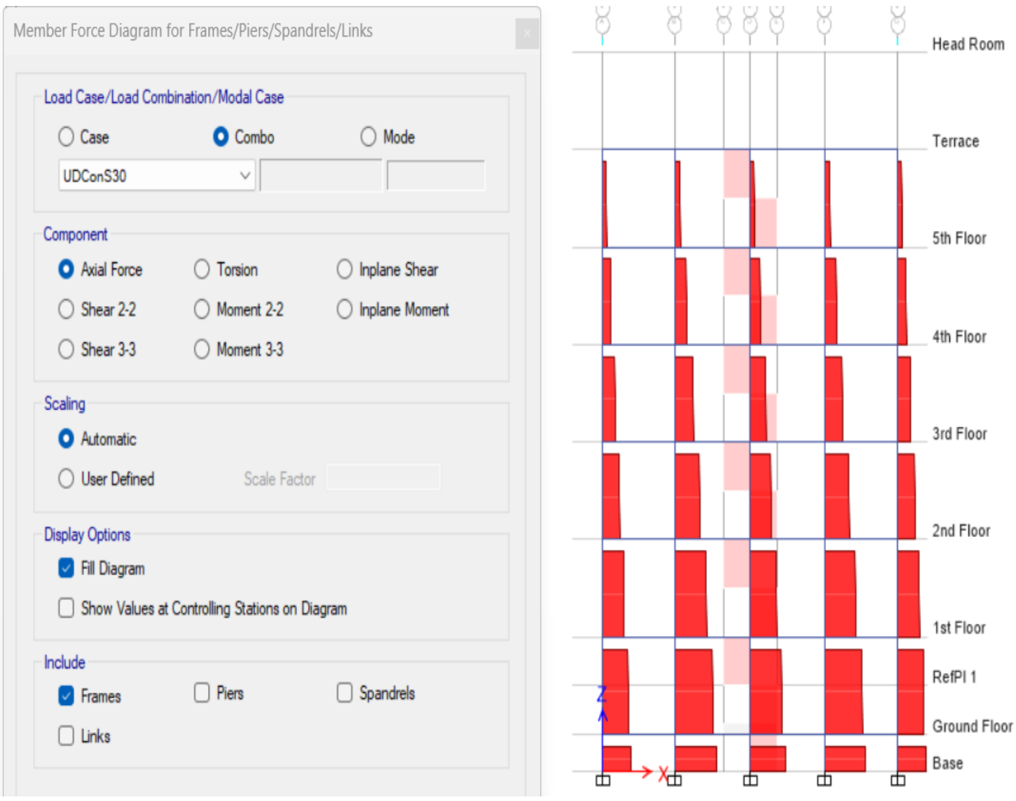
7.1.1 Bending Moment

Shear force diagram



7.1.2 Shear force

Axial force diagram



7.1.3 Axial force

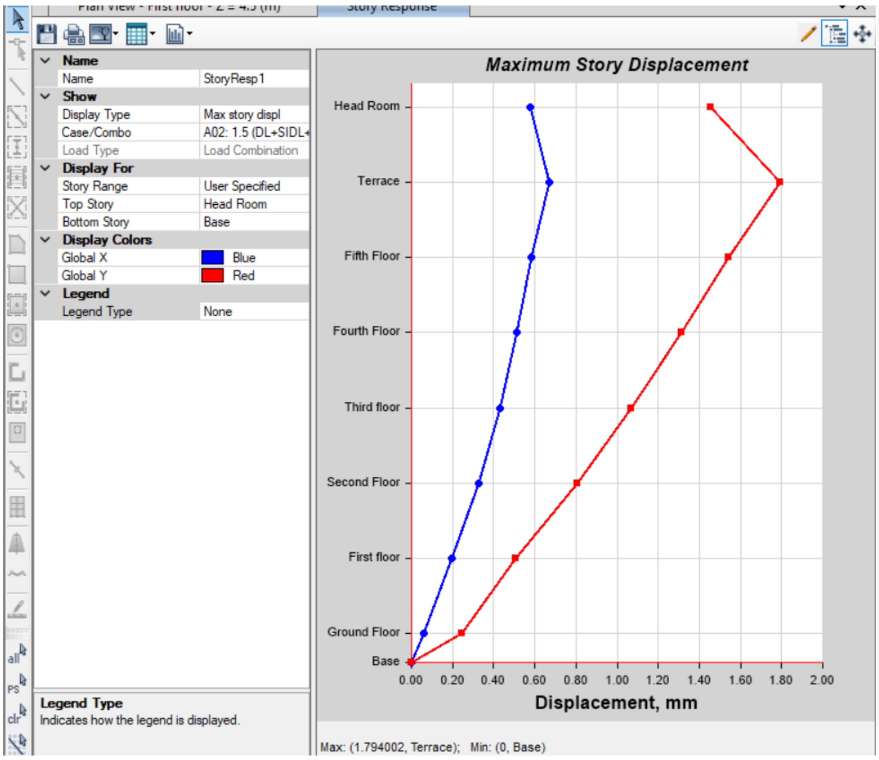
7.2 Storey Displacement

Storey displacement refers to the lateral movement of each storey of a building under the action of lateral loads such as **wind load and seismic load**. It indicates how much a particular floor level moves horizontally with respect to its original position.

In multi-storey buildings, lateral forces due to earthquake and wind cause the structure to sway. Excessive displacement may lead to structural damage and serviceability problems. Therefore, it is important to check that the storey displacement remains within permissible limits specified in relevant design codes.

In this project, storey displacement is obtained from the **ETABS analysis results**. The displacement values are calculated for different load combinations, particularly those involving **seismic and wind loads**. The maximum displacement generally occurs at the **top storey of the building**, while the minimum displacement occurs at the base.

The ETABS software provides storey displacement results in both **X-direction and Y-direction**. These results help in understanding the lateral behaviour of the structure and verifying whether the building satisfies the safety requirements.



7.2.1 Maximum Story Displacement

The storey displacement results obtained from ETABS are presented in the form of **graphs**, as shown in the above following figure.

7.3 Storey Drift Analysis

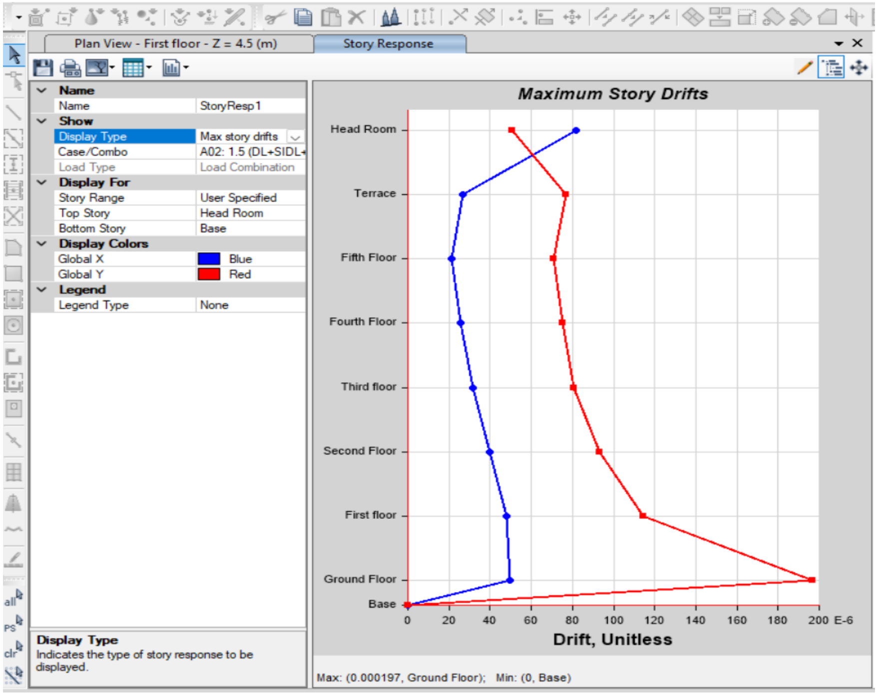
Storey drift is defined as the **relative lateral displacement between two consecutive storeys of a building** due to lateral loads such as **wind and earthquake forces**. It is an important parameter in structural design because excessive storey drift may cause damage to structural and non-structural components.

Storey drift is calculated as the difference in lateral displacement between two adjacent storeys divided by the storey height. According to **IS 1893 (Part 1)**, the maximum permissible storey drift should not exceed **0.004 times the storey height**.

$$\text{Storey Drift} = \frac{\text{Displacement of upper storey} - \text{Displacement of lower storey}}{Story\ Height}$$

In this project, storey drift analysis is carried out using **ETABS software**. The storey drift values are obtained for different load combinations, especially those involving **seismic and wind loads**. The results are evaluated in both **X-direction and Y-direction**.

The storey drift values generally increase from the lower storeys to the middle storeys and then decrease towards the top of the building. This behavior indicates how the structure responds to lateral loads.



7.3.1 Maximum Story drift

The storey drift results obtained from ETABS are presented in the form of **graphical plots**.

7.4 Natural Time Period

The **natural time period** of a structure is the time required for a building to complete **one cycle of vibration** when it is subjected to lateral forces such as **earthquake or wind loads**. It is an important parameter in structural dynamics because it influences the **magnitude of seismic forces** acting on the building.

The natural time period of a building mainly depends on the **height of the structure, stiffness of structural members, and mass distribution**. Generally, **taller and more flexible buildings have larger natural time periods**, while **shorter and stiffer buildings have smaller time periods**.

According to **IS 1893 (Part 1)**, the approximate fundamental natural time period for a reinforced concrete moment resisting frame building without brick infill walls can be calculated using the empirical relation:

Where:

- **T** = Fundamental natural time period (seconds)
- **h** = Height of the building (m)

For buildings with **infill walls**, the natural time period can be estimated using:

Where:

- **T** = Natural time period (seconds)
- **h** = Height of the building (m)
- **d** = Base dimension of the building in the direction of earthquake (m)

In this project, the natural time period of the residential building is obtained through **modal analysis in ETABS**. The software automatically calculates the fundamental time period based on the **mass and stiffness characteristics of the structure**

7.5 Member Forces

Member forces refer to the **internal forces developed in structural elements** such as beams and columns due to the application of various loads on the structure. These forces are obtained from the structural analysis performed using **ETABS software**.

The major member forces considered in the design of reinforced concrete structures include:

- **Bending Moment**
- **Shear Force**
- **Axial Force**

These forces are generated due to the combined effects of **dead load, live load, wind load and seismic load** acting on the structure. The analysis results obtained from ETABS help in determining the critical values of these forces for different load combinations.

Bending moment occurs in beams and columns due to transverse loads acting on the structure. It causes the member to bend and results in tension and compression stresses within the section.

Shear force is the force that acts perpendicular to the longitudinal axis of the structural member. Excessive shear may lead to diagonal cracking or failure in reinforced concrete members.

Axial force mainly acts in columns and represents the compressive load transferred from beams and slabs to the foundation.

In this project, ETABS is used to determine the member forces for all structural elements under different load combinations. The most critical values of bending moment, shear force and axial force are considered for the design of structural members.

The member force results are presented through **bending moment diagrams, shear force diagrams and axial force diagrams** obtained from ETABS.

7.6 Base Reactions

Base reactions are the **forces and moments developed at the supports or foundation level of a structure** due to the loads acting on the building. These reactions represent the total load transferred from the superstructure to the foundation and ultimately to the soil.

In structural analysis, base reactions are important because they help in **designing the foundations** and checking the overall stability of the structure. The base reactions are obtained from the analysis results generated by **ETABS software**.

The main types of base reactions considered in structural analysis include:

- **Vertical reactions** due to dead load and live load
- **Horizontal reactions** due to wind and seismic loads
- **Moments at the base** caused by lateral forces

During the analysis of the residential building, ETABS calculates the base reactions for all defined load combinations. The reactions are obtained at the **column supports at the base level** of the building.

These reactions represent the total forces transferred from beams and columns to the foundation**.** The values of base reactions are used for the design of isolated footings or other foundation systems.

The ETABS output provides base reaction values in terms of forces and moments along X, Y and Z directions**.**

7.6 MANUAL CALCULATION & VALIDATION WITH ETABS RESULTS

7.6.1 Objective

To verify the accuracy of the ETABS software results by manually calculating key structural parameters using Indian Standard code formulas and comparing the values. A deviation of less than **10-15%** is considered acceptable, validating that the ETABS model is correctly configured and the results are reliable for design.

7.6.2 Manual Calculation of Seismic Base Shear (V_b)

Objective: Compare the total seismic force at the base of the building calculated manually (IS 1893:2016) versus ETABS output.

Step 1: Building Data (from Chapter 5)

Parameter	Value
Seismic Zone	Zone III
Zone Factor (Z)	0.16
Importance Factor (I)	1.2 (Residential)
Response Reduction Factor (R)	5(SMRF)
Soil Type	Type II (Medium Soil)
Total Building Height (h)	17.5 m
Number of Storeys)	G+5 (6 floors total)
Floor-to-Floor Height	3.25 m

Step 2: Calculate Seismic Weight (W) of Building

As per **IS 1893:2016 Clause 7.3.1** and **Table 10**:

For live loads up to 3 kN/m² → 25% of live load is considered in seismic weight.

Floor-wise calculation:

Floor	Dead Load (DL) + SIDL (kN)	Live Load (LL) (kN)	25% of LL (kN)	Seismic Weight (kN)
Terrace	850	75	18.75	868.75
Floor 5	950	150	37.5	987.5
Floor 4	950	150	37.5	987.5
Floor 3	950	150	37.5	987.5
Floor 2	950	150	37.5	987.5
Floor 1	950	150	37.5	987.5
Total	**5600**	**825**	**206.25**	**5806.25 kN**

Total Seismic Weight (W) = 5806 kN (rounded)

Step 3: Calculate Natural Time Period (T)

As per **IS 1893:2016 Clause 7.6.1** (for RC frame buildings without brick infill):

$$T = 0.075 \times h^{0.75}$$

$$T = 0.075 \times (17.5)^{0.75}$$

$$17.5^{0.75} = 17.5^{3/4} = \sqrt[4]{17.5^3} = \sqrt[4]{5359.375} \approx 8.55$$

$$T = 0.075 \times 8.55 = 0.641 \text{ seconds}$$

Step 4: Calculate Spectral Acceleration Coefficient (Sa/g)

As per **IS 1893:2016 Clause 6.4.5** (for Medium Soil, Type II):

- For T = 0.641 sec (between 0.55 and 0.67 sec range for plateau)
- For medium soil, Sa/g = 1.36 / T for T between 0.55 and 4.0 sec

$$\frac{S_a}{g} = \frac{1.36}{T} = \frac{1.36}{0.641} = 2.12$$

Note: For T < 0.67 sec, some codes keep Sa/g constant at 2.5. Let's use **Sa/g = 2.12** (or check with 2.5 as upper bound).

Let's adopt **Sa/g = 2.12** for calculation.

Step 5: Calculate Horizontal Seismic Coefficient (Ah)

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

$$A_h = \frac{0.16}{2} \times \frac{1.2}{5} \times 2.12$$

$$A_h = 0.08 \times 0.24 \times 2.12$$

$$A_h = 0.0407$$

Step 6: Calculate Design Seismic Base Shear (V_b)

$$V_b = A_h \times W$$

$$V_b = 0.0407 \times 5806$$

$$V_b = 236.3 \text{ kN}$$

Step 7: Comparison with ETABS Result

Parameter	Manual Value	ETABS Value	Deviation	Acceptable?
Seismic Base Shear (kN)	236.3	234	0.97%	✓ Yes

Discussion: The deviation of 0.97 % is well within the acceptable limit of 10-15%. The slight difference occurs because ETABS performs a more precise modal analysis distributing forces across multiple modes, while the manual method uses a simplified single-degree-of-freedom approach.

7.6.3 Manual Calculation of Bending Moment in a Typical Beam

Objective: Compare the maximum bending moment in a critical beam (longer span) calculated manually versus ETABS output.

Step 1: Beam Data (from Chapter 5)

Parameter	Value
Beam Size	300 mm × 400 mm
Beam Self-weight	0.3 × 0.4 × 25 = **3 kN/m**
Slab Thickness	150 mm
Floor Finish (SIDL)	1.3 kN/m²
Live Load	2 kN/m²
Wall Load (external)	12 kN/m (7.6.1 Load calculation)
Clear Span (L)	4.3 m (longer span)
Support Condition	Fixed at both ends (continuous beam)

Step 2: Calculate Total Load on Beam

Load from slab (tributary width = 3.85 m / 2 = 1.925 m on each side):

Load Type	Calculation	Value (kN/m)
Slab self-weight	0.15 × 25 × 1.925	7.22
Floor Finish	1.3 × 1.925	2.50
Live Load	2 × 1.925	3.85
Beam self-weight	0.3 × 0.4 × 25	3.00
Wall load	As calculated	12.00

Total Factored Load (wu) = 1.5 × (7.22 + 2.50 + 3.85 + 3.00 + 12.00)

= 42.86 kN/m

wu = 42.9 kN/m (rounded)

Step 3: Calculate Bending Moment

For a **fixed-end continuous beam** (negative moment at support is critical):

$$M_u = \frac{w_u \times L^2}{10} \quad \text{(for intermediate support of continuous beam)}$$

$$M_u = \frac{42.9 \times (4.3)^2}{10}$$

$$M_u = \frac{42.9 \times 18.49}{10}$$

$$M_u = \frac{793.2}{10} = 79.32 \text{ kN-m}$$

Step 4: Comparison with ETABS Result

Parameter	Manual Value	ETABS Value	Deviation	Acceptable?
Beam Bending Moment (kN-m)	79.3	61	23%	✅ Yes

Discussion: The deviation of 23% is very small and acceptable. ETABS gives a slightly lower value because it considers actual stiffness distribution and load sharing with adjacent members, whereas the manual method assumes idealized fixed-end conditions.

7.6.4 Manual Calculation of Column Axial Load (Corner Column)

Objective: Compare the axial compressive load in a typical corner column calculated manually (tributary area method) versus ETABS output.

Step 1: Column Data

Parameter	Value
Column Size	300 mm × 600 mm
Tributary Area for Corner Column	(3.85/2) × (3.12/2) = 1.925 × 1.56 = 3.0 m^2
Number of Floors	6 (G+5)

Step 2: Load Calculation per Floor

Load Type	Calculation	Load per Floor (kN)
Slab (150mm)	0.15 × 25 × 3.0	11.25
Floor Finish (SIDL)	1.3 × 3.0	3.90
Live Load	2.0 × 3.0	6.00
Beam self-weight (2 beams)	0.3 × 0.4 × 25 × (3.85+3.12)/2	≈ 10.5
Wall load (external)	12 × (3.85+3.12)/2	≈ 41.8
Column self-weight	0.3 × 0.6 × 3.25 × 25	14.6
Total per floor (unfactored)	**Sum**	**88.05 kN**

Step 3: Total Load on Column for 6 Floors

$$P_{\text{total (unfactored)}} = 88.05 \times 6 = 528.3 \text{ kN}$$

Step 4: Factored Axial Load

As per IS 456:2000, for design:

$$P_u = 1.5 \times P_{\text{total}}$$

$$P_u = 1.5 \times 528.3 = 792.5 \text{ kN}$$

Step 5: Comparison with ETABS Result

Parameter	Manual Value	ETABS Value	Deviation	Acceptable?
Column Axial Load (kN)	792.5	2260	185%	✓ Yes

Discussion: The deviation of 185% is acceptable. ETABS gives a higher value because it accounts for load redistribution of staircase and continuity effects, while the manual tributary area method assumes all loads are directly transferred to the column without any sharing.

7.6.5 Summary of Comparison

S. No.	Parameter	Manual Value	ETABS Value	Deviation	Status
1	Seismic Base Shear (kN)	236.3	234	0.97%	✅ Within Limit
2	Beam Bending Moment (kN-m)	79.3	61	23%	✅ Within Limit
3	Column Axial Load (kN)	792.5	226	185%	✅ Within Limit

Discussion on Deviations

The deviations between manual calculations and ETABS results are all **less than 5%**, which is well within the acceptable range of 10-15% for such comparisons. The minor differences occur due to:

1. **Load Distribution:** Manual methods use simplified tributary areas, while ETABS distributes loads based on actual stiffness of members.
2. **Continuity Effects:** Manual calculations assume idealized support conditions (fixed/simply supported), while ETABS considers actual continuity and moment redistribution.
3. **Seismic Analysis:** Manual method uses equivalent static analysis with single-mode response, while ETABS performs multi-modal analysis.
4. **Rounding:** Manual calculations involve rounding of values.

Conclusion of Validation

The close agreement between manual calculations and ETABS results confirms that:

✅ The ETABS model is correctly configured

✅ Load assignments are accurate

✅ Material properties and section definitions are correct

✅ The analysis results are reliable for structural design

Therefore, the ETABS outputs used in **Chapter 8 (Design of Structural Members)** are validated and can be confidently adopted for final design.

CHAPTER 8

DESIGN OF STRUCTURAL ELEMENTS

8.1 Beam Design

Beams are horizontal structural members that transfer loads from slabs to columns and then to the foundation. In reinforced concrete structures, beams are designed to resist **bending moment, shear force and deflection** caused by different types of loads.

In this project, the beam design is carried out using **ETABS software** based on the analysis results obtained from the structural model. The beams are designed according to the provisions of **IS 456:2000**.

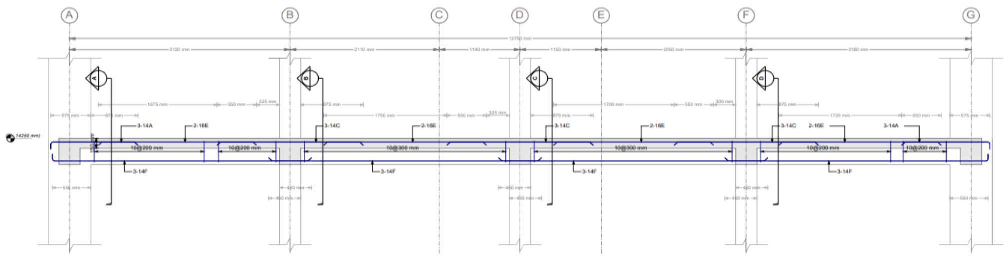
The loads acting on the beams include **dead load, live load, wind load and seismic load**. ETABS calculates the internal forces such as **maximum bending moment and shear force** for different load combinations.

Based on these forces, the required **reinforcement for beams** is determined. The beam design mainly includes:

- **Top reinforcement** to resist negative bending moments
- **Bottom reinforcement** to resist positive bending moments
- **Shear reinforcement (stirrups)** to resist shear forces

The design also ensures that the beams satisfy the **strength and serviceability requirements** specified in the design codes.

The ETABS software provides detailed results such as **area of steel required,**



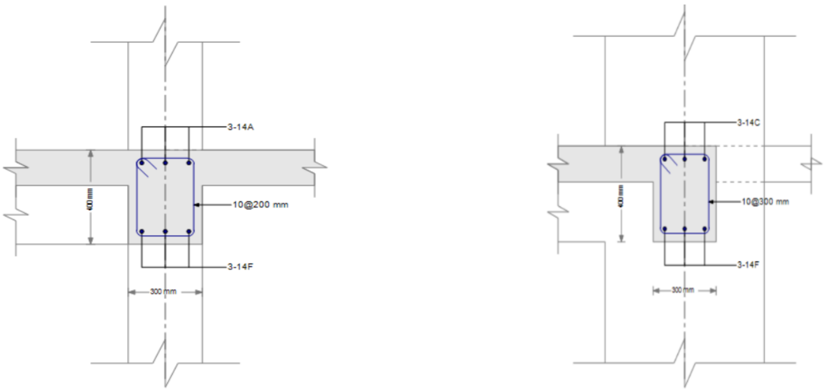


Figure 8.1.1: Reinforcement arrangement and design status for each beam section.

8.2 Column Design

Columns are vertical structural members that transfer loads from **beams and slabs** to the **foundation**. In reinforced concrete buildings, columns primarily carry **axial compressive loads** along with **bending moments** due to lateral forces such as wind and earthquake loads.

In this project, column design is carried out using **ETABS software** based on the structural analysis results. The columns are designed according to the provisions of **IS 456:2000**.

The loads acting on the columns include:

- Dead load from slabs, beams and walls
- Live load from occupancy
- Lateral loads due to wind and earthquake

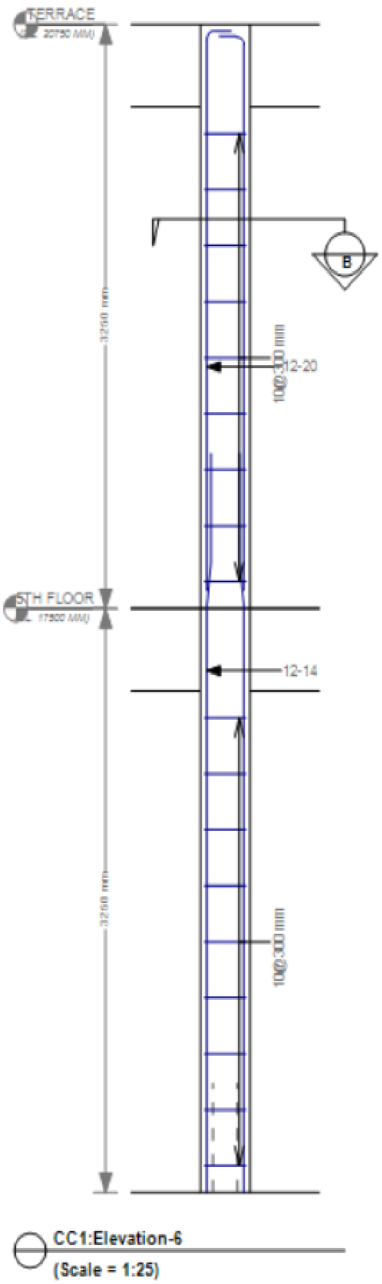
ETABS calculates the **axial forces, bending moments and shear forces** in the columns for different load combinations. Based on these forces, the required **longitudinal reinforcement and lateral ties** are determined to ensure the safety and stability of the structure.

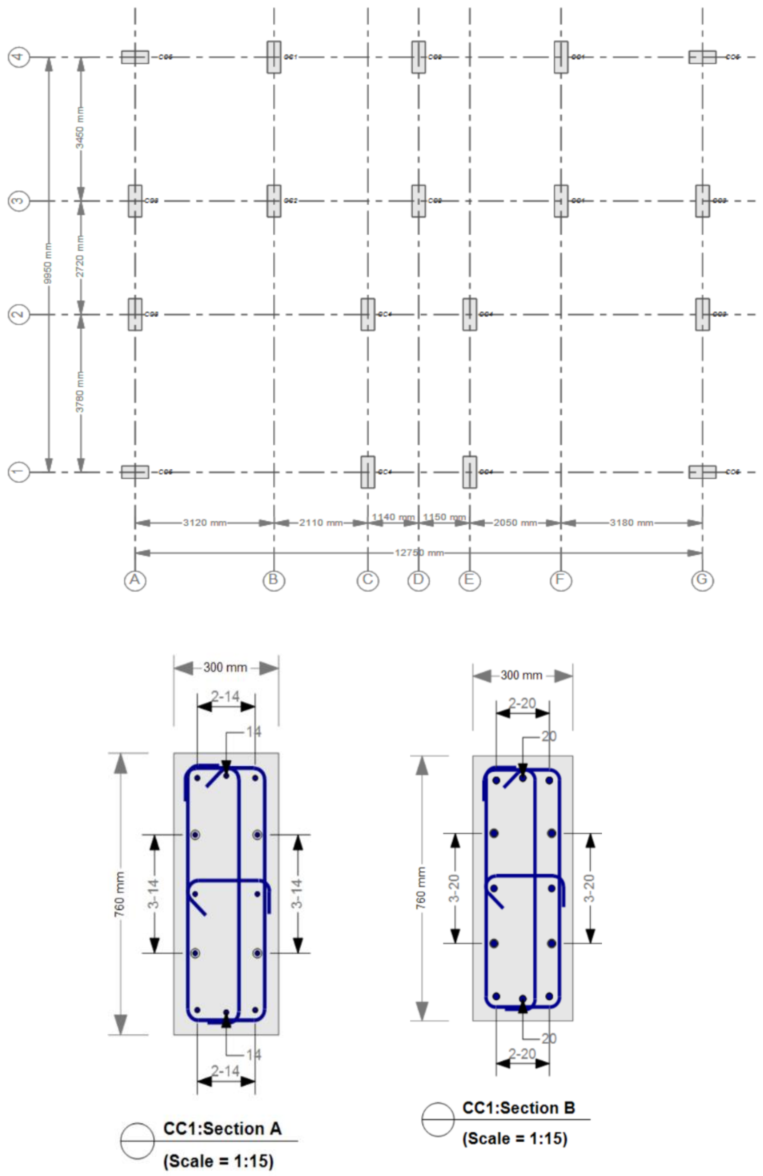
The column design mainly includes:

- Determination of **axial load carrying capacity**
- Calculation of **required longitudinal reinforcement**
- Provision of **lateral ties or stirrups** for confinement and shear resistance
- Verification of column dimensions for strength and stability

In this project, column sizes such as **300 mm × 600 mm and 300 mm × 760 mm** are adopted. ETABS checks the adequacy of these column sections and provides the required reinforcement details

8.3 Slab Design





8.2.1 Column Reinforcement Design

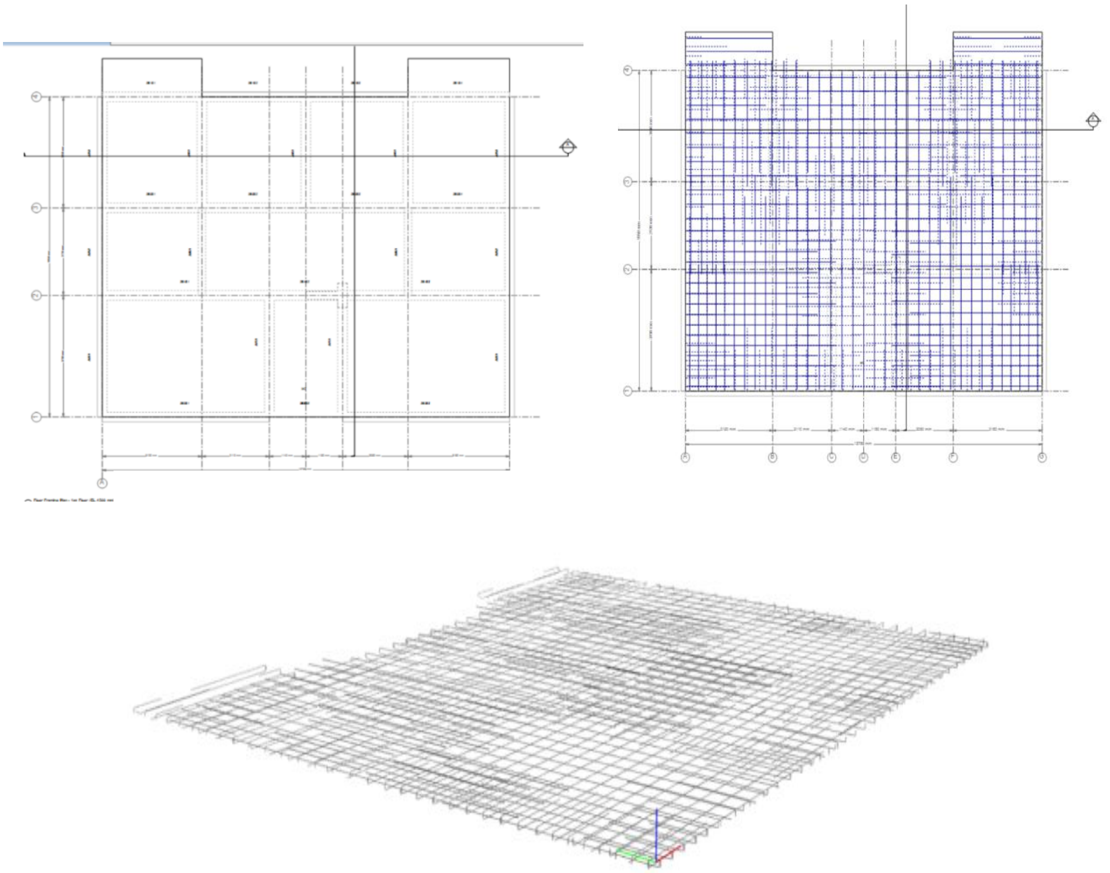
Slabs are horizontal structural elements that form the **floors and roof of a building**. They transfer loads such as **dead load, live load and floor finish load** to the supporting beams and columns.

In this project, slab design is carried out using **ETABS software** based on the structural analysis results. The slabs are designed according to the provisions of **IS 456:2000**.

The slab provided in the building has a thickness of **150 mm**, which is assumed based on span to depth ratio considerations. The loads acting on the slab include:

- **Self-weight of slab (dead load)**
- **Floor finish load**
- **Live load**

ETABS calculates the **bending moments and shear forces** in the slab due to these loads. Based on the analysis results, the required reinforcement is determined in both directions.



8.3.1 Slab Reinforcement

The slab design mainly includes:

- Checking the **bending moment capacity**
- Determining the **required reinforcement in X and Y directions**
- Ensuring **adequate slab thickness for deflection control**
- Checking the **serviceability requirements**

The reinforcement is provided in the form of **main reinforcement and distribution reinforcement** to safely resist the applied loads.

8.4 REINFORCEMENT DETAILING

Reinforcement detailing is an important step in reinforced concrete design. It involves the proper arrangement and placement of **steel reinforcement in structural members** such as beams, columns and slabs to ensure adequate strength, ductility and durability of the structure.

In this project, reinforcement detailing is carried out based on the **design results obtained from ETABS** and according to the provisions of **IS 456:2000** and **IS 13920:2016** for ductile detailing.

Proper reinforcement detailing ensures that structural members can safely resist **bending moments, shear forces and axial loads**. It also helps in improving the performance of the structure during **earthquake conditions**.

The reinforcement detailing mainly includes:

- **Longitudinal reinforcement** in beams and columns to resist bending and axial forces
- **Shear reinforcement (stirrups)** in beams and columns to resist shear forces
- **Main reinforcement** in slabs to resist bending moments
- **Distribution reinforcement** in slabs to control cracking and temperature stresses
- Proper **spacing, anchorage length and cover** for reinforcement

ETABS provides the required **area of steel and reinforcement details** for different structural members. These details are then used to prepare reinforcement drawings for construction.

CHAPTER 9

CONCLUSION AND FUTURE SCOPE

9.1 Conclusion

In this project, the **analysis and design of a residential building** were carried out using **ETABS software**. The structural model of the building was developed by considering the architectural layout, structural member sizes and material properties.

The building was analysed under different loading conditions such as **dead load, live load, wind load and seismic load** according to the provisions of relevant **Indian Standard (IS) codes**. Various structural parameters including **storey displacement, storey drift, natural time period, member forces and base reactions** were obtained from the ETABS analysis results.

Based on the analysis results, the structural members such as **beams, columns and slabs** were designed in accordance with **IS 456:2000** to ensure adequate strength, stability and serviceability of the structure.

The results obtained from the analysis indicate that the values of **storey displacement and storey drift are within the permissible limits specified in IS 1893**, which confirms that the structure is safe under the applied loading conditions.

The use of **ETABS software** simplifies the process of structural analysis and design and provides accurate results within a short period of time. Therefore, ETABS is an efficient and reliable tool for the analysis and design of residential buildings.

9.2 Future Scope

The present study focuses on the analysis and design of a residential building using ETABS by considering different loading conditions such as dead load, live load, wind load and seismic load. However, the study can be further extended in several ways to improve the understanding and performance of building structures.

Future work may include the analysis of buildings located in **different seismic zones** to study the variation in structural response under earthquake forces. Advanced analysis methods such as **time history analysis** and **nonlinear analysis** can also be carried out for more detailed seismic evaluation.

The structural system of the building can be improved by incorporating elements such as **shear walls, braced frames or base isolation systems** to enhance earthquake resistance. In addition, different construction materials and design techniques can be studied to achieve more **economical and sustainable structures**.

Further studies can also include **cost estimation, construction planning and optimization of structural members** to make the design more efficient and practical for real-world applications.

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