Full Length Article

A Study On 3d Bim Modelling And Structural Analysis Of A G+4 Residential Building Using Revit And Etabs.

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Abstract: *This project presents the* ***Analysis, Design, and BIM-based Modelling*** *of a multi-storey* ***G+4 reinforced cement concrete (RCC) residential building*** *using advanced structural engineering and modelling software tools, including CSI ETABS, CSI SAFE, CSI Detail, and Autodesk Revit. The primary objective of this study is to develop an efficient and accurate structural system by integrating conventional design practices with modern Building Information Modeling (BIM) techniques.*

The structural analysis of the building is carried out using ETABS, where the complete 3D model is developed by defining grid systems, material properties, and structural components such as beams, columns, and slabs. The structure is analysed under various loading conditions including dead load, live load, wind load, and seismic load in accordance with relevant Indian Standard codes such as IS 456:2000, IS 875, and IS 1893:2016. The software provides critical outputs such as bending moments, shear forces, axial forces, storey drift, and base shear, which are used for the safe and economical design of structural elements. The design of beams, columns, and slabs is performed using limit state design principles to ensure structural safety, serviceability, and durability. Foundation design is carried out using SAFE, where soil-structure interaction, bearing capacity, and settlement considerations are incorporated to design safe and stable footing systems. Reinforcement detailing is further developed using CSI Detail, which generates accurate bar bending schedules (BBS) and detailed reinforcement drawings, reducing manual errors and improving construction efficiency. The integration of ETABS, SAFE, CSI Detail, and Revit ensures a streamlined workflow from analysis and design to detailing and modelling. This approach significantly improves accuracy, reduces design conflicts, and enhances project efficiency. The study highlights the importance of BIM in modern construction practices by demonstrating its role in improving visualization, coordination, cost-effectiveness, and decision-making throughout the project lifecycle. Overall, this project emphasizes the adoption of integrated software tools and BIM technology for the development of safe, economical, and sustainable multi-storey residential buildings, marking a significant advancement in structural engineering and construction management practices.

KEYWORDS: *Reinforced Cement Concrete (RCC), G+4 Residential Building, Structural Analysis, Structural Design, Building Information Modelling(BIM), CSI ETABS, CSI SAFE, CSI Detail, Autodesk Revit, Seismic Analysis, Load Calculation.*

1. INTRODUCTION

The field of civil engineering, and specifically structural engineering, has witnessed a paradigm shift over the past two decades with the advent of advanced computer-aided tools and digital technologies. The traditional approach of designing buildings using manual calculations and 2D drafting has been progressively replaced by sophisticated software-based methodologies that offer superior accuracy, efficiency, and collaboration.

Residential buildings form the backbone of urban infrastructure, and their structural integrity is of paramount importance for the safety of occupants and the durability of construction.

One of the most significant advancements in the Architecture, Engineering, and Construction.

A G+4 residential building (Ground floor plus four upper floors) represents a typical mid-rise structure commonly found in urban environments. Such buildings must be designed to safely withstand all applied loads, including gravity loads (self-weight, dead loads, and live loads) and lateral loads (wind and earthquake forces), while also meeting serviceability criteria such as deflection limits and crack control. The structural system generally consists of reinforced concrete columns, beams, slabs, and foundations, designed in accordance with the guidelines of the Bureau of Indian Standards, including IS 456:2000, IS 875, and IS 1893:2016.

Fig1.1:BIM MEP Model

The integration of analysis, design, detailing, and BIM modelling within a single workflow ensures improved accuracy, reduced errors, and better coordination among project participants. This project demonstrates how the combined use of ETABS, SAFE, CSI Detail, and Revit can lead to an efficient, economical, and well-coordinated structural design process

1.2 BACKGROUND OF STUDY

The construction industry has undergone a remarkable evolution with the integration of digital technologies into planning, analysis, and execution processes. Traditionally, structural design of buildings relied on manual calculations and two-dimensional drafting techniques, which were time-consuming, prone to human error, and limited in visualization capabilities. With the rapid advancement of computational tools, the industry has shifted towards software-based analysis and design methods that provide higher accuracy, efficiency, and reliability.

Urban centres such as Hyderabad are experiencing rapid population growth and urbanization, leading to a surge in the construction of multi-storey residential buildings. This growth necessitates the adoption of efficient structural systems and modern design tools to ensure safety, durability, and cost-effectiveness.

Fig 1.2: Advance Structural Tools

NEED FOR THE PROJECT

In real-world construction projects, errors in design, lack of coordination between teams, and miscommunication can lead to serious consequences such as structural failures, increased project costs, and delays in construction. Traditional methods, which rely heavily on manual calculations and 2D drafting, often fail to provide the required level of accuracy and integration between different stages of the project.

This project aims to overcome these challenges by adopting an integrated approach using modern engineering software tools.

Issues Addressed by the Project

a) **Lack of coordination between design and modeling:**
In conventional workflows, design and drafting are often carried out separately, leading to inconsistencies. This project integrates analysis, detailing, and modeling into a unified process to ensure better coordination.

b) **Errors in manual calculations:**
Manual calculations are prone to human errors, which can affect the safety and performance of the structure. By using advanced software tools, accurate and reliable results can be obtained.

c) **Difficulty in visualizing complex structures:**
2D drawings make it difficult to understand the spatial arrangement of structural elements. The use of 3D BIM modeling improves clarity and understanding.

d) **Inefficiency in traditional drafting methods:**
Traditional drafting is time-consuming and requires frequent revisions. Modern software allows automatic updates, saving time and effort.

BENEFITS OF THE PROJECT

a) **Improved accuracy:**
The use of software tools ensures precise analysis, design, and detailing, reducing the chances of errors.

b) **Better visualization:**
3D modeling helps in clearly understanding the

structure and its components.

c) Reduced construction errors:
Early detection of issues and proper coordination minimize errors during construction.

d) Time and cost savings:
Automation and integration reduce project time and overall cost by avoiding rework and delays.

1.2 Building Information Modeling (BIM)

Building Information Modeling (BIM) is a digital representation of the physical and functional characteristics of a facility. BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle, from inception onward. It enables:

a) **3D Visualization:** Comprehensive three-dimensional visual representation of the building structure, enabling better communication among stakeholders.
b) **Data Integration:** All structural data including member sizes, material properties, loads, and analysis results are embedded within the model.
c) **Clash Detection:** Identification of spatial conflicts between structural members and other building systems (MEP, architectural elements) before construction.
d) **Quantity Take-off:** Automated extraction of material quantities directly from the model for cost estimation.
e) **Construction Documentation:** Generation of accurate construction drawings, sections, elevations, and schedules directly from the model.
f) **Lifecycle Management:** Utilization of the model throughout the building's lifecycle including construction, operation, maintenance, and renovation.

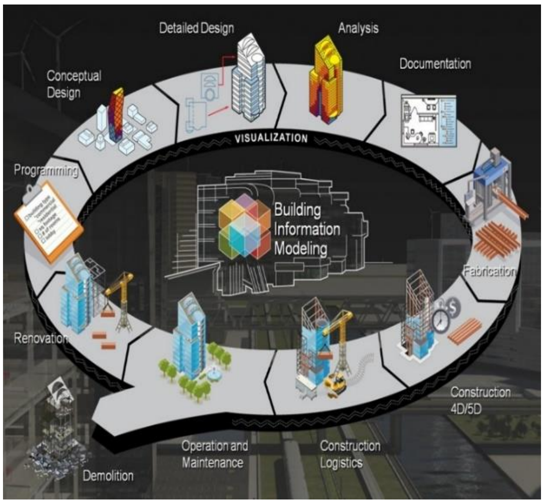

Fig 1.3: Building Information Modeling

1.3 Importance of Structural Modeling

a) Structural modeling is the process of creating a mathematical representation of a building structure to analyze its response to various loads and design its members accordingly. The importance of accurate structural modeling cannot be overstated:
b) **Safety:** Accurate structural models ensure that all members are adequately designed to withstand applied loads without failure, protecting the lives of building occupants.
c) **Economy:** Optimized structural design through computer analysis reduces material wastage and construction costs while meeting safety requirements.
d) **Seismic Resistance:** India is highly seismically active, with Hyderabad falling in **Seismic Zone II** as per IS 1893:2016. Proper seismic analysis is essential for building safety in earthquake-prone regions.
e) **Code Compliance:** Structural models facilitate compliance with Indian Standards such as IS 456:2000 (Plain and Reinforced Concrete), IS 875 (Code of Practice for Design Loads), and IS 1893:2016 (Criteria for Earthquake Resistant Design).
f) **Documentation:** Structural models generate comprehensive documentation including design reports, reinforcement details, and construction drawings essential for the construction process.
g) **Quality Control:** Computer-based structural analysis provides systematic checks and validations that enhance the overall quality of the structural design.

<u>OBJECTIVES</u>

1.4 Objectives of the Project

The specific objectives of this project are:

a) To create a detailed **3D BIM structural model** of a G+4 residential building using Autodesk Revit, incorporating all major structural elements including columns, beams, slabs, and foundations.
b) To develop a comprehensive **structural analysis model** in ETABS 2015 for the G+4 building, defining all material properties, section properties, boundary conditions, and loads.
c) To perform **structural analysis** of the building for dead loads, live loads, and seismic loads as per relevant Indian Standard codes.
d) To carry out **structural design** of all RC members (columns, beams, slabs, and foundations) as per IS 456:2000 using ETABS.
e) To generate **structural drawings and detailing** including plan views, sectional views, elevation views, and reinforcement details using ETABS and Revit.
f) To demonstrate the **integration between ETABS and Revit** in a BIM workflow, enhancing design accuracy, visualization, and documentation quality.
g) To compare the **BIM-based approach** with traditional 2D drafting methods and highlight the advantages of adopting BIM in structural engineering practice.
h) To improve **accuracy in visualization, documentation, and understanding** of the structural system for better project coordination.

SCOPE OF THE PROJECT

- **a)** Analysis of a G+4 RCC residential building using CSI ETABS under DL, LL, WL, and EQ loads.
- **b)** Design of structural elements (beams, columns, slabs) as per IS codes (IS 456, IS 875, IS 1893).
- **c)** Foundation design using CSI SAFE considering soil and load conditions.
- **d)** Reinforcement detailing and Bar Bending Schedule (BBS) using CSI Detail.
- **e)** Development of a 3D BIM model using Autodesk Revit.
- **f)** Integration of analysis, design, and BIM workflow for better coordination.
- **g)** Use of BIM for clash detection, visualization, and quantity take-off.
- **h)** Focus on achieving a safe, economical, and efficient structural design.

Overall Scope

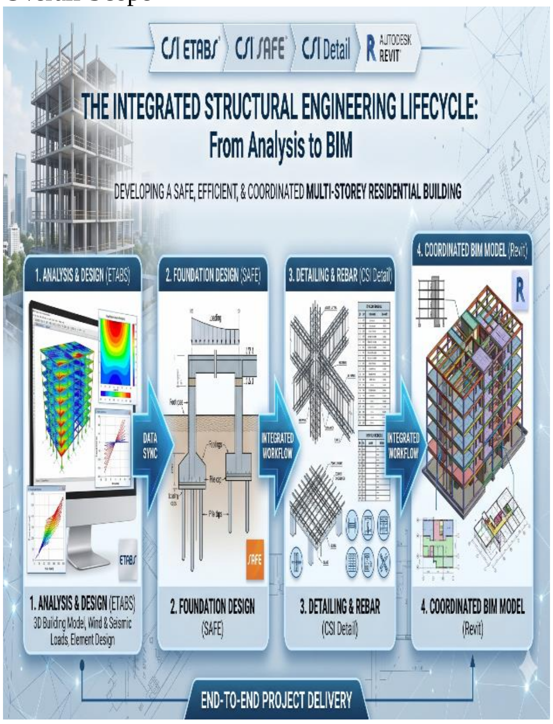

Fig 1.4: Overall Project Scope

This project covers the complete structural lifecycle from analysis and design to detailing and BIM modelling, demonstrating the effective use of ETABS, SAFE, CSI Detail, and Revit in developing a safe, efficient, and coordinated multi-storey residential building.

2. LITERATURE REVIEW

2.1 REVIEW OF PREVIOUS STUDIES

M. Lava Ram Kumar Nayak, K. Roshitha, D. Phanindra Babu, D. Umadevi4, A. Nagraju, Eera.Srinivas (03, March 2024)

Building construction is the engineering deals with the construction of building such as residential houses. In a simple building can be define as an enclose space by walls with roof, food, cloth and the basic needs of human beings. In the early ancient times humans lived in caves, over trees or under trees, to protect themselves from wild animals, rain, sun, etc. as the times passed as humans being started living in huts made of timber branches. The shelters of those old have been developed nowadays into beautiful houses. Rich people live in sophisticated condition houses. In order to compete in the ever-growing competent market, it is very important for a structural engineer to save time. as a sequel to this an attempt is made to analyse and design a Multi-storied building by using a software package Revit and staad pro. The Revit software used for the 3D modelling of the building Key Words: Design, Analysis, Residential Building, Auto Cad, Autodesk Revit, Staad Pro

Janmejay More (06, June-2021)

The principal objective of this project is to analyses, design and make building estimation of a multistoried building [G + 4] using STAAD Pro and MS EXCEL. The design methods used in STAAD-Pro analysis are Limit State Design conforming to Indian Standard Code of Practice. The structure was subjected to self-weight, dead load, live load and seismic loads under the load case details of STAAD Pro. The supports at the base of the structure were also specified as fixed. Then STAAD Pro was used to analyses the structure and design the members. In the postprocessing mode, after completion of the design, we can work on the structure and study the bending moment and shear force values with the generated diagrams. The design of the building is dependent upon the minimum requirements as prescribed in the Indian Standard Codes. Strict conformity to loading standards recommended in this code, it is hoped, will ensure the structural safety of the buildings which are being designed

3. PROJECT DESCRIPTION

The project involves the structural design and BIM modeling of a **G+4 Residential Building** (Ground Floor + 4 upper floors, total 5 floors). The building is intended for residential use in an urban setting, consistent with typical apartment construction in Hyderabad, Telangana, India.

The building is a Reinforced Concrete (RC) framed structure with flat slabs supported on RC beams and columns, founded on isolated/combined footings bearing on natural ground. The structural system is designed as a Special Moment Resisting Frame (SMRF) to provide adequate earthquake resistance per IS 1893:2016.

Project Location: Hyderabad, Telangana, India

Seismic Zone: Zone II (per IS 1893:2016 – Annexure E)

Building Type: Residential – Group Housing

Number of Stories: Ground Floor + 4 Upper Floors = G+4 (5 Stories total)

Total Height: 15.0 m (5 stories × 3.0 m floor-to-floor height)

REINFORCEMENT MODELING

Reinforcement detailing is a crucial step in structural engineering, as it ensures that all structural elements have adequate strength and durability to resist applied loads. In this project, reinforcement (rebar) is modeled using Autodesk Revit 2026, which allows accurate 3D placement of reinforcement in columns, beams, slabs, and footings.

Unlike traditional 2D drawings, Revit enables realistic 3D visualization of reinforcement, improving understanding and reducing construction errors.

3.1. General Reinforcement Guidelines

While modeling reinforcement, the following important factors are maintained:

a) Proper Cover:
Adequate concrete cover is provided to protect reinforcement from corrosion and environmental effects.

b) Correct Spacing:
Reinforcement bars are spaced uniformly to ensure proper load distribution and avoid congestion.

c) Accurate Placement:
All rebars are placed precisely as per design requirements to maintain structural integrity.

3.2. Column Reinforcement

Columns are reinforced with longitudinal bars and lateral ties to resist axial loads and bending.

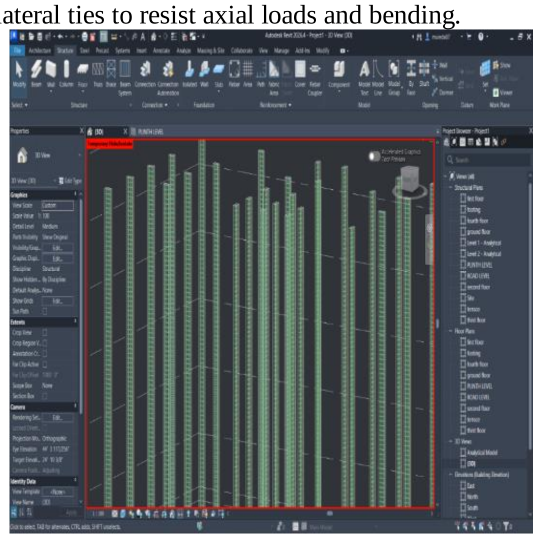

Fig 3.1:Column Reinforcement

Column Details

a) C1 (9” × 15”)
6 bars of 12 mm diameter
Ties: 8 mm dia @ 8” c/c

b) C2 (9” × 15”)
8 bars of 12 mm diameter
Ties: 8 mm dia @ 8” c/c

c) C3 to C6 (9” × 18”)
8 bars of 12 mm diameter
Ties: 8 mm dia @ 8” c/c

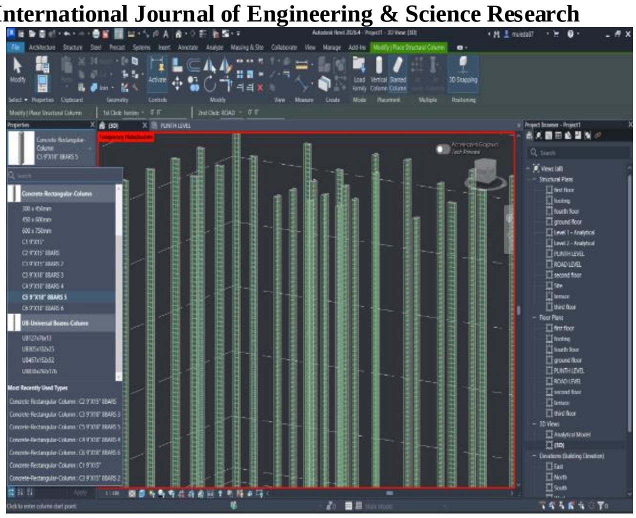

Fig 3.2: Type of Column

Modeling

a) Vertical bars are placed along the column height
b) Ties are provided at regular spacing for confinement
c) Alignment is maintained with grid and levels

3.3. Beam Reinforcement

Beams are designed to resist bending and shear forces.

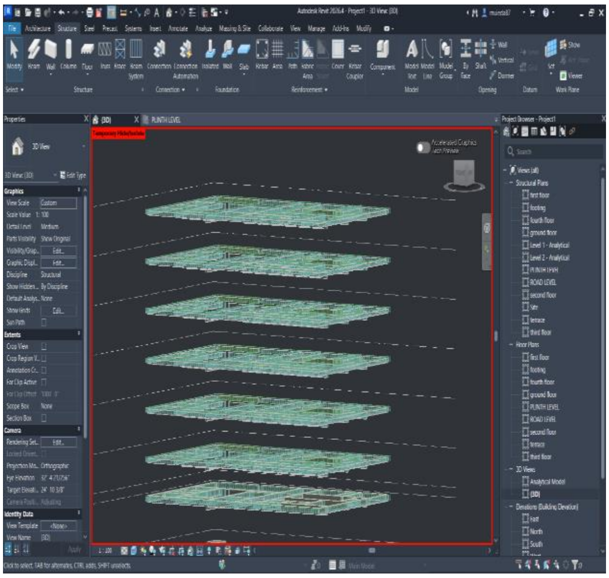

Fig 3.3:Beam Reinforcement

Beam Details

a) B1 (9” × 16”)
Top: 3 bars of 12 mm
Bottom: 3 bars of 16 mm
Stirrups: 8 mm @ 8” c/c

b) B2 (9” × 21”)
Top: 3 bars of 12 mm
Bottom: 3 bars of 16 mm
Stirrups: 8 mm @ 8” c/c

c) B3 (9” × 24”)
Top: 3 bars of 12 mm
Bottom: 3 bars of 16 mm
Stirrups: 8 mm @ 8” c/c

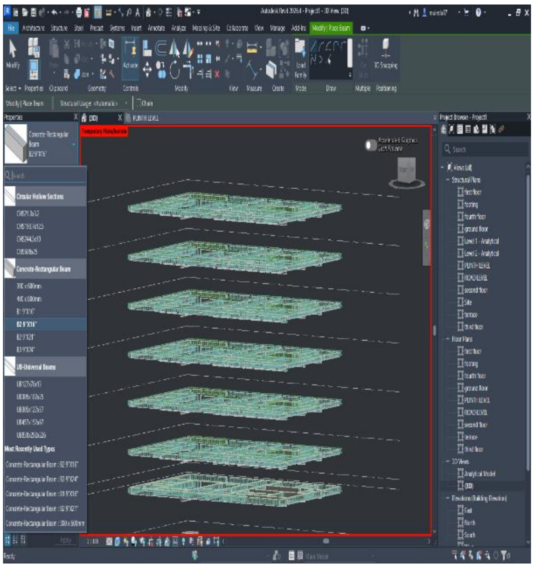

Fig 3.4:Beam Reinforcement

Modeling

a) Top and bottom bars are placed along beam length
b) Stirrups are added for shear resistance
c) Proper anchorage and spacing are maintained

3.4. Slab Reinforcement

Slabs are horizontal structural elements that distribute loads to beams.

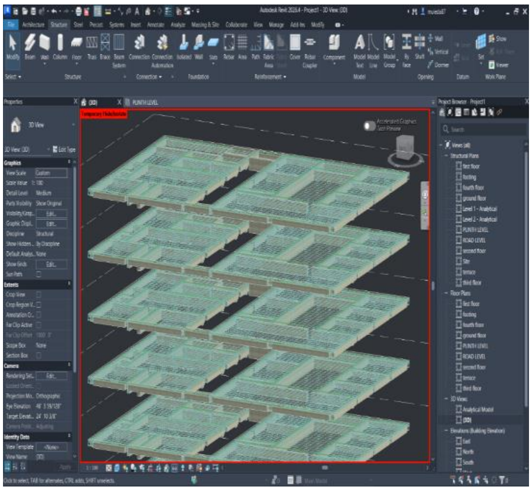

Fig 3.5:Slab Reinforcement

Slab Details

a) Thickness: 150 mm
b) Bottom reinforcement: 16 mm straight bars
c) Top reinforcement: 16 mm cranked bars
d) Modeling
e) Main bars are placed in one direction
f) Distribution bars are placed perpendicular
g) Cranked bars are provided at supports for additional strength

3.5. Footing Reinforcement

From your provided footing schedule (image), isolated footings are used with reinforcement provided in both directions.

Key Features

a) Reinforcement is provided along both directions (L and B)
b) Bottom reinforcement resists bending due to soil pressure
c) Proper depth and spacing are maintained

Modeling in Revit

a) Bottom mesh reinforcement is created
b) Bars are placed orthogonally
c) Cover is maintained from all sides

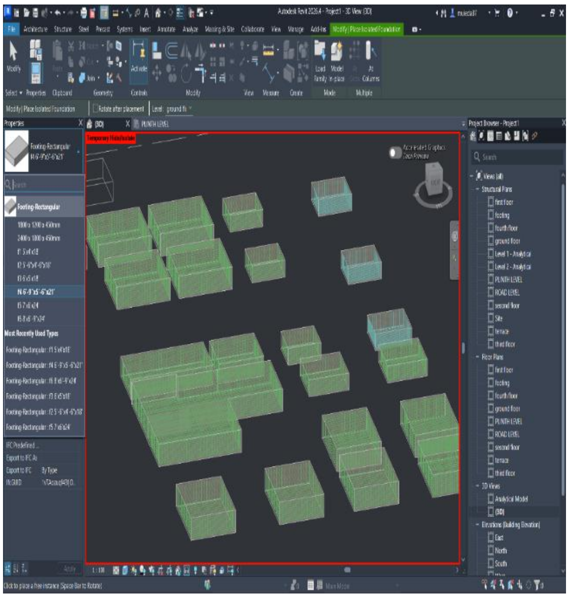

Fig 3.6:Footing Reinforcement

3.6. Advantages of Reinforcement Modeling in Revit

a) Accurate 3D representation of rebars
b) Automatic bar bending schedules (BBS)
c) Easy modifications and updates
d) Improved coordination between elements
e) Reduction in construction errors

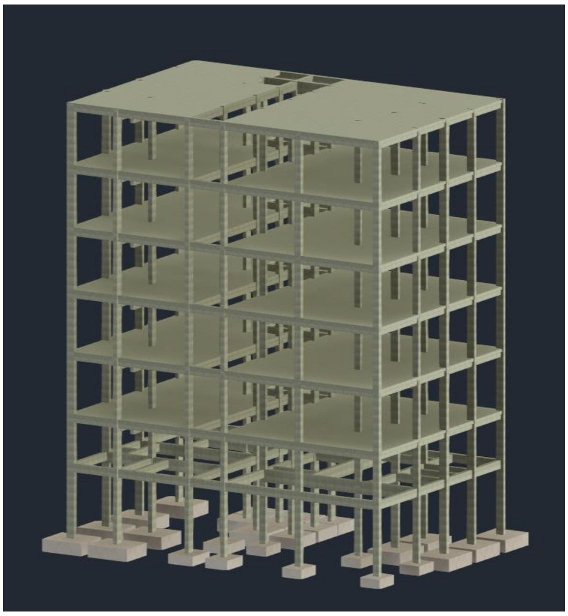

Fig 3.7:3D structural View of Building

CONCLUSIONS

The present project successfully illustrates a comprehensive approach to the analysis, design, detailing, and BIM-based modeling of a G+4 reinforced cement concrete residential building by integrating advanced structural engineering tools and modern methodologies. The use of industry-standard software such as ETABS, SAFE, CSI Detail, and Autodesk Revit has enabled a seamless workflow from conceptual planning to final modeling and documentation. This integration reflects current industry practices and demonstrates the importance of digital transformation in structural engineering.

The structural analysis carried out using ETABS ensured that the building performs safely under various types of loads, including dead loads, live loads, wind loads, and seismic forces, as per relevant Indian Standard (IS) codes. The analysis results confirmed that the structure is stable, efficient, and capable of resisting all applied loads without exceeding permissible limits. The design phase focused on achieving both strength and serviceability requirements, ensuring that structural elements such as beams, columns, slabs, and foundations are not only safe but also economical and durable. Proper selection of member sizes and reinforcement contributed to an optimized structural system.

The application of SAFE for foundation design provided a deeper understanding of load transfer mechanisms and soil-structure interaction. It helped in designing safe and cost-effective footing systems that can adequately support the superstructure. Additionally, the use of CSI Detail for reinforcement detailing significantly improved the accuracy and clarity of structural drawings. Automated generation of bar bending schedules reduced human errors, improved efficiency, and ensured better coordination during construction.

A key highlight of this project is the implementation of Building Information Modeling (BIM) using Autodesk Revit. The development of a detailed 3D structural model enhanced visualization and allowed for better interpretation of the design. BIM also facilitated clash detection, coordination among different disciplines, and improved project planning. The ability to integrate analysis results from ETABS into Revit minimized discrepancies between design and modeling, thereby ensuring consistency and reliability throughout the project lifecycle.

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