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**Research Paper**

# Structural Efficiency Evaluation of G+5 Commercial Buildings Using Advanced CAD Techniques

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***Abstract:*** *This study provides a detailed evaluation of the structural efficiency of a G+5 commercial building, using advanced CAD tools to ensure safety, functionality, and aesthetic appeal. The primary goal is to design a structurally sound building that meets Indian Standards and withstands both environmental and operational loads, while preserving its architectural integrity. STAAD Pro software plays a central role in this process, helping to create a 3D model, perform load analysis, and initiate the design of key structural elements. The design follows key Indian Standards, including IS 1893 for seismic forces, IS 875 for wind and live loads, and IS 456 for load combinations. Additionally, advanced concrete design software is used to specify the necessary reinforcement, enhancing the building's strength and safety. One of the challenges tackled in this research is achieving a sleek, flush"architectural look by carefully positioning the columns to align with the building's aesthetic without compromising its structural strength. The paper also provides a step-by-step account of the design process, including structural drawings, layout plans, and an organized breakdown of the construction phases. By demonstrating the successful integration of CAD tools like STAAD Pro with concrete design software, this study sets a standard for balancing safety and efficiency in commercial building design. The results highlight how modern structural engineering can produce durable, visually appealing buildings, offering insights for future projects.*

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## I. Introduction

With the rising demand for urban spaces, there is an increasing need for well-designed, sustainable commercial buildings. This paper presents the design of a G+5 multi-use commercial structure, developed using CAD software. The main objective is to create an efficient, safe, and functional 3D model, ensuring compliance with relevant Indian Standards. The structural analysis and preliminary design of key components have been carried out using STAAD Pro software. The design takes into account several important factors, including seismic loads as per IS 1893 (Part 1) for Bikaner, which falls in Seismic Zone 3, as well as wind loads in accordance with IS 875 (Part 3), considering local wind patterns. Live loads, including floor finishes and other imposed loads, are based on IS 875 (Part 1) guidelines for commercial buildings. As the design evolves, this paper documents each stage with detailed explanations and accompanying images, resulting in comprehensive structural drawings that serve as a blueprint for the construction process.

## II. Literature Review

STAAD Pro, developed by Bentley Systems, is widely used by civil and structural engineers to analyze and design various types of structures, such as towers, buildings, and bridges. The software supports different types of analysis, including dynamic, buckling, and static analysis. Its compatibility with numerous design codes adds to its versatility, making it an essential tool in engineering. Several studies have explored the capabilities of STAAD Pro in structural design. For example, research by Kumar et al. (2018) demonstrated the software's effectiveness in designing multi-story buildings, emphasizing its ability to handle complex geometric modeling and load analysis, resulting in precise and efficient designs. Similarly, Sharma and Gupta (2019) examined the application of STAAD Pro in dynamic and seismic analysis, showcasing how the software ensures structures can withstand seismic forces while adhering to industry standards. Indian Standards (IS) play a crucial role in guiding the construction and design of buildings in India. For the design of a G+5 commercial building, key standards include IS 456:2000, which governs the reinforcement design of concrete structures, IS 875:1987, which is used for load calculations, and IS 1893:2016, which is essential for seismic load design.

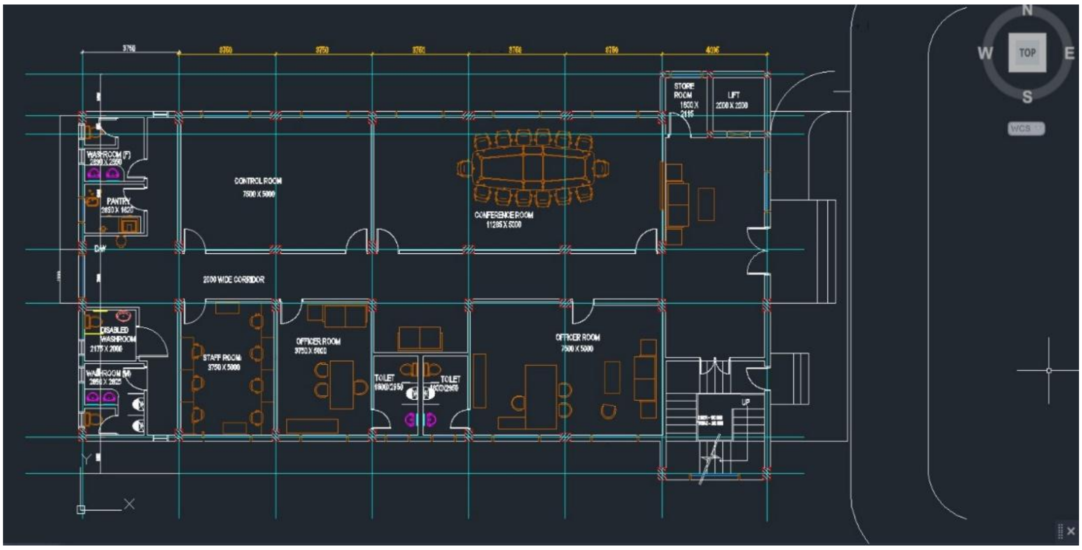

**Fig. 1. AutoCAD plan for the G+5 commercial building**

## III. Methodology

Figure 1 showcases the pre-designed architectural plan for a G+5 commercial building, created using AutoCAD software from Autodesk. The architectural layout was carefully selected to meet both functional and aesthetic requirements. Columns were strategically positioned throughout the building, ensuring that they aligned with the walls to achieve a clean, "flushed out" look. This not only enhanced the visual appeal of the structure but also helped optimize the overall layout, creating a harmonious blend of design and structural integrity.

STAAD Pro software was then utilized to develop a detailed 3D geometric model of the building, as illustrated in the skeletal diagram in Figure 2. The software allowed for accurate modelling of the structure, beginning with the efficient placement of nodes for the columns and beam intersections. The translational repeat function in STAAD Pro was particularly useful for replicating the column positions at regular intervals, ensuring precision and reducing manual input.

Once the nodes were set, beams were created by connecting the respective nodes, forming the basic framework of the structure. The entire floor plan was replicated vertically to create the additional floors, using the completed layout of the ground floor as the base. Each floor was modelled with a height of 3.6 meters, ensuring uniformity and adhering to standard commercial building dimensions.

To model the foundation level, the column nodes were extended downward by an additional 2 meters, accommodating the depth required for the foundation. STAAD Pro's tools were also used to design other key elements, such as the terrace, water tank geometry, and the slabs, ensuring that every aspect of the building was accurately represented in the model. The software's capabilities allowed for seamless integration of these components, resulting in a detailed and comprehensive model ready for further analysis and structural design.

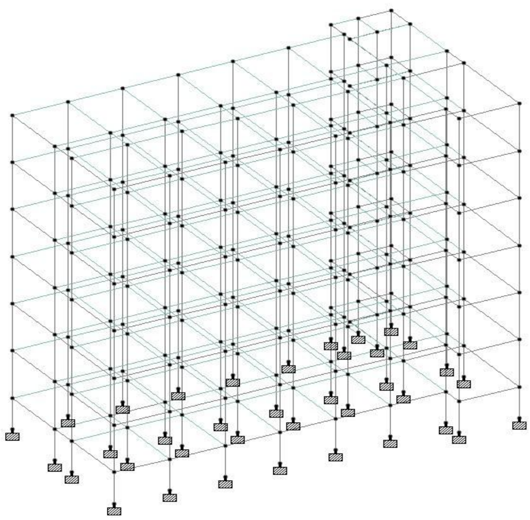

**Fig. 2. Skeletal diagram of G+5 commercial building**

**3.1 Material Properties and Section Assignment:**

The material properties for the beams, columns, and slabs were chosen based on standard industry practices to ensure the structure is both safe and efficient. The beams have a section size of 250mm by 450mm, providing the necessary strength to support the weight from the slabs and distribute the load evenly. For the columns, which play a crucial role in carrying the building's vertical loads and resisting forces like wind and earthquakes, a larger section size of 450mm by 600mm was selected. This ensures they can handle the combined weight of multiple floors above. The slabs were assigned a thickness of 150mm, designed to bear the live and dead loads of each floor, while maintaining stability and durability. These dimensions not only meet safety standards but also contribute to an efficient and cost-effective design for the building.

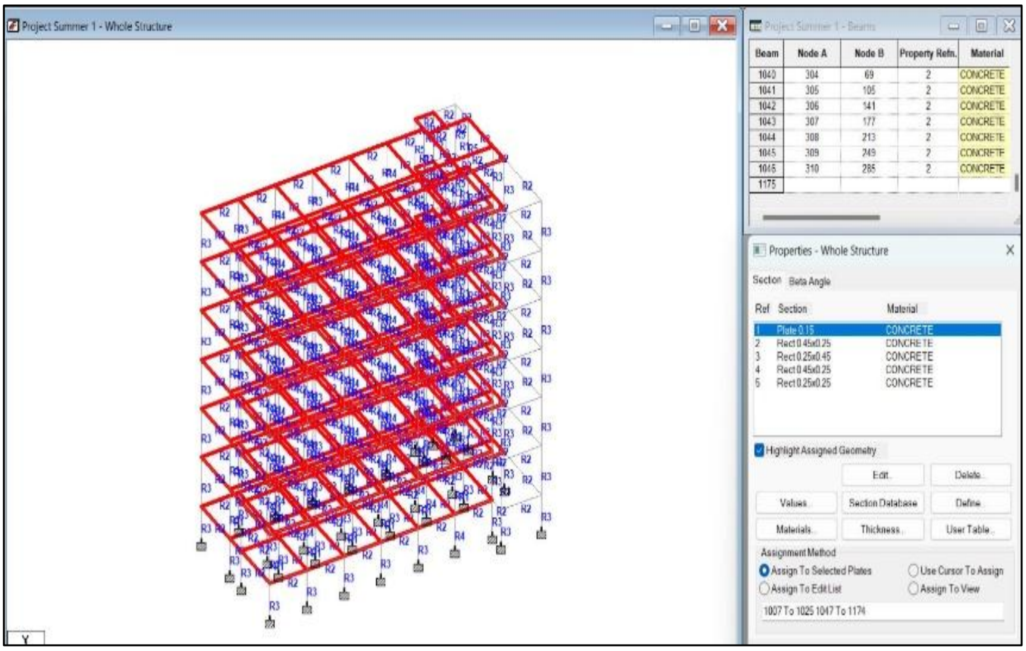


**Fig. 3. Load Cases Creation**

**3.2 Load Definition and Cases:**

a. Seismic Load: The seismic load for the structure was carefully defined in accordance with IS 1893 (Part 1), which provides guidelines for earthquake-resistant design of buildings. Given that the building is located in Lucknow, which falls under Seismic Zone 3, the relevant parameters were incorporated to ensure the structure could withstand potential seismic activity. The design accounts for the possibility of moderate seismic forces, ensuring that the building remains safe and stable during such events. Specific load combinations were also considered to address both vertical and lateral forces that might occur during an earthquake, providing comprehensive protection for the building and its occupants.

b. Wind Load: The wind load for the building was calculated based on IS 875 (Part 3), which governs the design of structures to resist wind forces. Given Lucknow's specific wind patterns, the design was tailored to account for both the average wind speeds in the area and extreme conditions that could arise during storms. The wind load was applied to the building in a way that ensures it remains stable against lateral forces caused by strong winds, minimizing any risk of structural failure or discomfort to the occupants. This includes factoring in pressures on different elevations and ensuring the building's overall stability.

For a visual representation of these load definitions, please refer to Figure 3 for the seismic load distribution and Figure 4 for the wind load analysis.

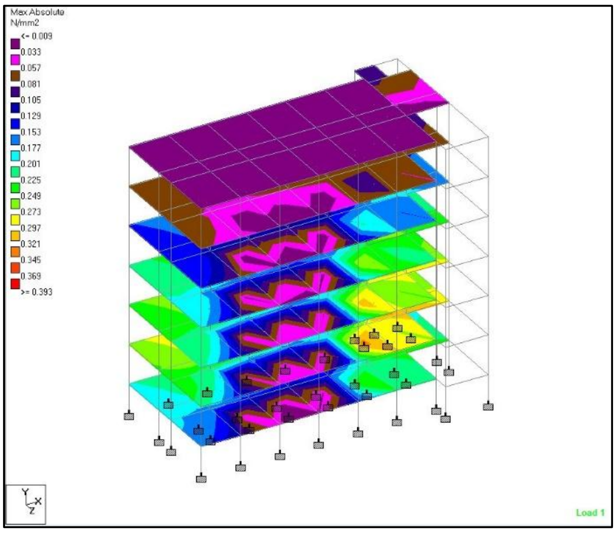


**Fig. 4. Seismic load case**

### 3.3 Wind load cases in X and Z directions:

The dead load case, which represents the self-weight of the structure, was one of the primary considerations in the design process. This load accounts for the weight of all permanent components of the building, including the beams, columns, slabs, walls, and other fixed elements. STAAD.Pro automatically calculates the dead load by factoring in the weight of the materials used in construction, ensuring accurate load distribution throughout the building.

In addition to the dead load, the live load case was also considered. This includes any temporary or movable loads the structure will experience during its lifetime, such as people, furniture, and other items. The floor finish load was set at 0.8 kN/m², taking into account the weight of the floor finishes, which typically include tiles, mortar, and screed layers. The imposed floor load, which represents the live load applied to commercial buildings as specified in IS 875 Part 1, was defined as 4 kN/m². This ensures the building can safely handle the expected weight and traffic in a commercial setting.

For the terrace, an additional DPC (Damp Proof Course) floor load of 0.6 kN/m² was applied. The DPC layer, typically used to prevent water from seeping into the building, adds extra weight that must be accounted for in the overall load calculations.

The live loads were distributed to specific beams, especially those supporting critical walls, including exterior, interior, and parapet walls. These live loads were calculated based on the weight of the walls, which was determined using the densities of the materials involved—such as bricks or concrete blocks—and additional considerations like plaster layers. This ensured that the load was accurately transferred to the beams and that each beam was designed to carry its respective load safely. Finally, the wind load pressure on the building was calculated using the formula outlined in IS 875 (Part 3). The design wind speed was determined by considering the specific wind conditions in the area where the building is located. This includes factors like the local wind pattern, terrain, and the height of the building. The wind load pressure is critical in ensuring that the structure can withstand lateral forces exerted by wind, especially at higher elevations. For a more detailed look at the formula used for calculating the wind load pressure, please refer to Figure 5.

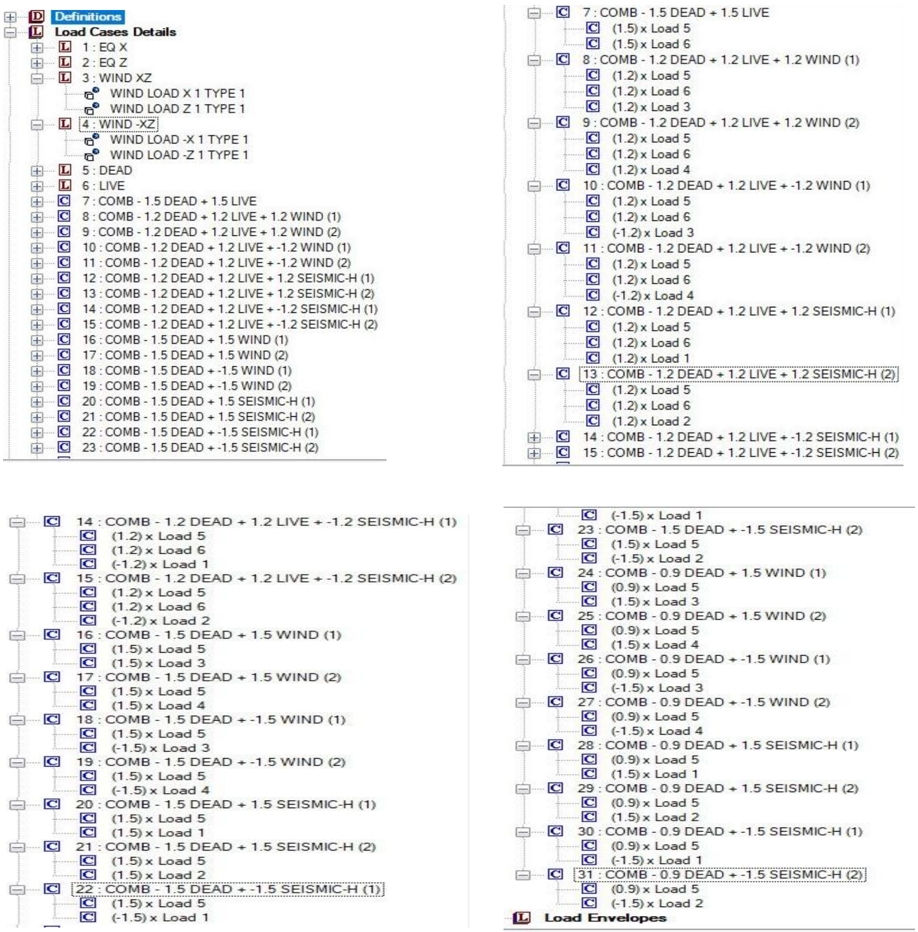


**Fig. 5. Load and definition**

3.4 **Analysis and Design:**

The structural model was thoroughly analyzed using STAAD.Pro to assess the forces and stresses acting on its various members. This analysis incorporated a variety of load combinations to simulate real-world conditions and provide insights into the structural behavior of the building's components under different scenarios.

The design of the beams, columns, and slabs was carried out using STAAD.Pro in combination with Advanced Concrete Design software, ensuring that all elements adhered to relevant Indian Standards, specifically IS 456. The material properties used in the design included a yield strength (Fy) of 500 N/mm² for steel and a characteristic compressive strength (Fck) of 35 N/mm² for concrete, ensuring the structural components met the necessary strength and durability requirements.

Following the initial automated design phase in STAAD.Pro, which produced preliminary designs for the beams, a manual review was conducted to refine the results. This review allowed for more accurate reinforcement specifications, which were then input into the software for further detailing. The Advanced Concrete Design software was also used to perform an in-depth analysis of the columns, particularly focusing on those that did not meet the criteria set during the automated design phase. For improved efficiency, columns with similar reinforcement configurations were grouped together, simplifying the design process while maintaining structural integrity.

Figures 6 and 7 provide different perspectives of the model, showcasing the layout and the detailed structural design. This comprehensive approach ensured that the building was designed not only to meet safety standards but also to optimize material usage and enhance construction efficiency.

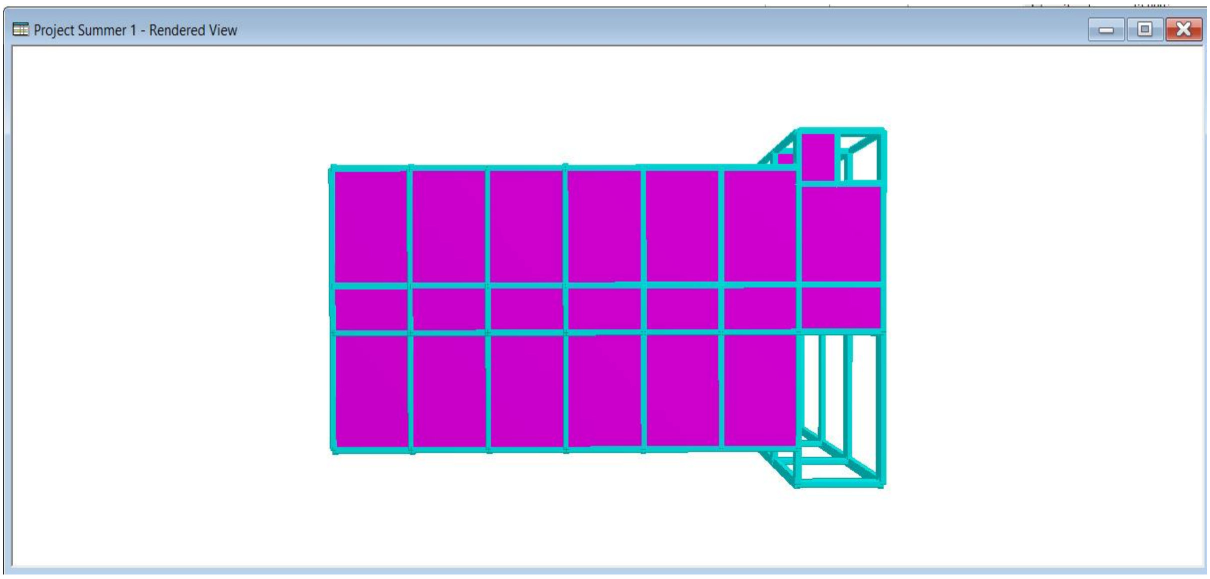


**Fig. 6. Top view**

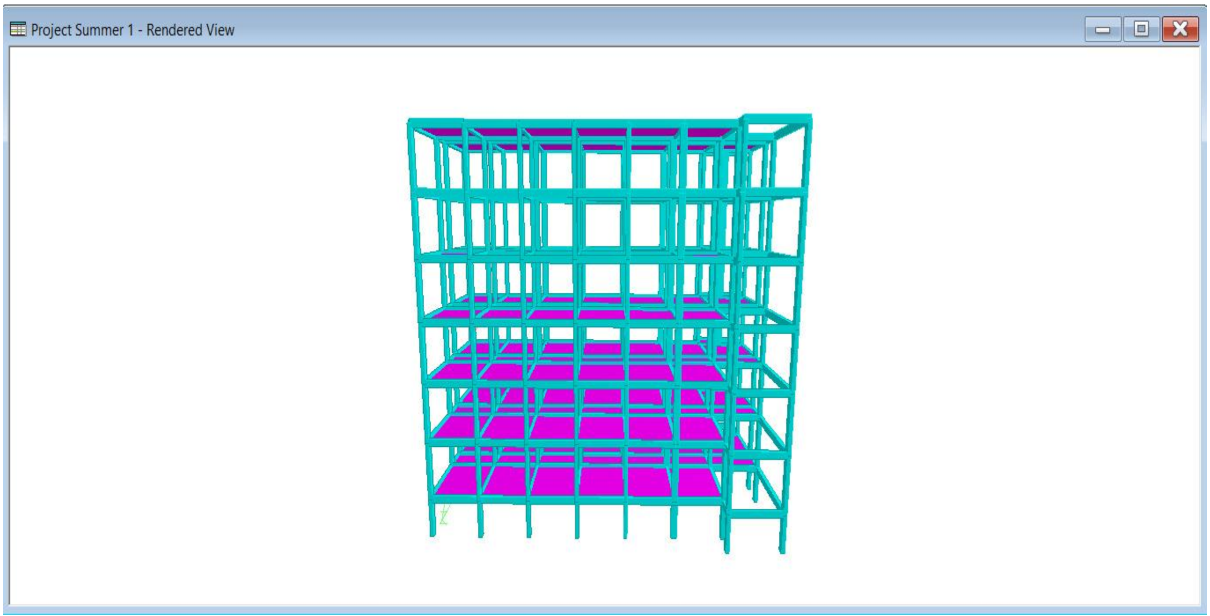


**Fig. 7. Side view**

### 3.5 Design Optimization:

The design procedure involves a meticulous process of selecting appropriate member sizes while implementing advanced analytical techniques to optimize the structure's overall efficiency. The goal is to minimize material usage without compromising the essential aspects of safety, stability, and structural integrity. Throughout the design process, particular attention is given to choosing the correct dimensions for beams, columns, and slabs, ensuring that they can effectively carry the loads they are subjected to, both in normal conditions and in the event of unexpected stresses.

One of the most critical factors considered is the **loading factor**, which plays a key role in determining how the structure responds to various forces. This factor ensures that all load combinations, including dead loads, live loads, wind loads, and seismic forces, are accounted for, ensuring that the building is not only functional but also resilient enough to withstand these forces over time. By carefully evaluating these load factors, the design process prioritizes the long-term durability and safety of the structure.

As shown in Figure 8, the design ensures that the building can endure both environmental stresses and everyday operational loads without compromising its stability. This close attention to load management guarantees that the building remains safe for occupants and continues to perform its intended functions efficiently, even under challenging conditions. The use of modern analytical tools allows for precision in the design, balancing material economy with the highest standards of structural safety.

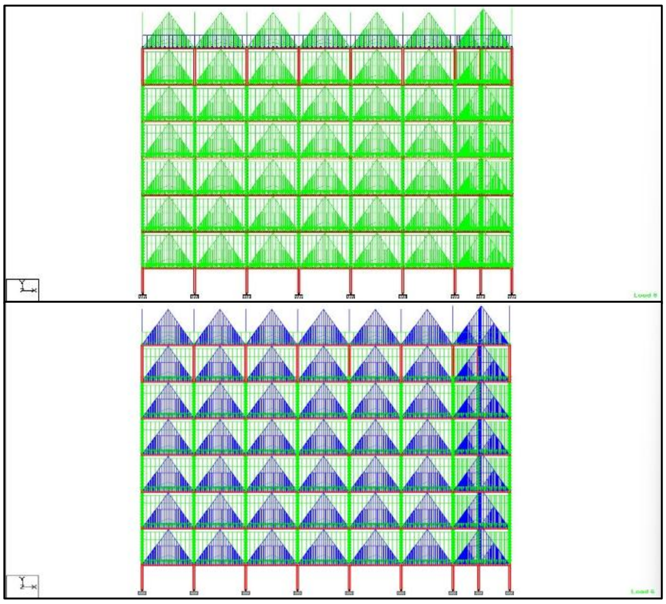

**Fig. 8. Loading**

### 3.6 Reinforcement Detailing:

The comprehensive reinforcement detailing process covers all aspects of the reinforcement design, including the type, dimensions, and precise arrangement of reinforcement bars within the structural components. This step is crucial to ensuring that the reinforcement can adequately resist the loads and forces imposed on the structure, in full compliance with the guidelines set forth in IS 456:2000 standards.

By incorporating reinforcement that is properly sized and strategically placed, the structural components—such as beams, columns, slabs, and footings—are strengthened to handle the stresses they will face throughout the building's lifespan. The detailed drawings and reinforcement schedules generated by the Advanced Concrete Design software play a vital role in the construction process, offering clear guidance to construction teams on how to position and install the reinforcement accurately. This guarantees that the actual construction matches the design specifications, contributing to the overall safety and stability of the building.

Several figures provide a visual representation of the reinforcement detailing. **Figure 9** presents the bent-up bar reinforcement plan, illustrating how these bars are bent and placed to enhance structural resistance. **Figure 10** depicts the detailed layout of the combined footing, essential for distributing loads from multiple columns over a wider area. **Figure 11** outlines the slab scheduling details, ensuring that the slab reinforcement is placed correctly to support imposed loads. **Figure 12** shows the overall reinforcement plan, offering a comprehensive view of how reinforcement is organized within the structure. Lastly, **Figure 13** provides additional reinforcement details, offering deeper insights into specific areas that require extra reinforcement for added strength and durability.
This thorough reinforcement detailing ensures that the building not only meets the required structural standards but also facilitates a smooth and precise construction process.

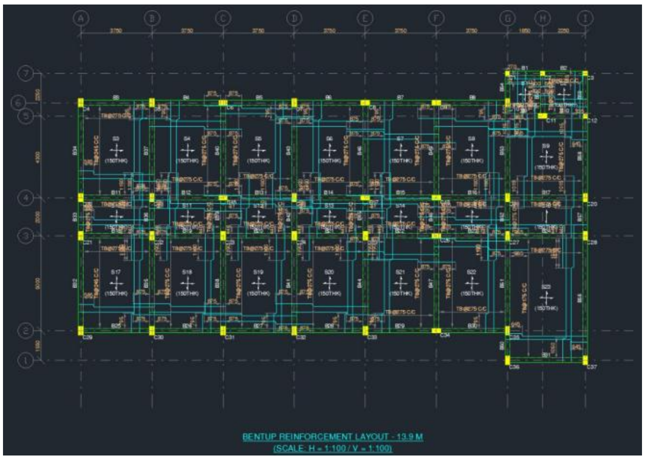


**Fig. 9. Bent-up bar reinforcement plan detail**

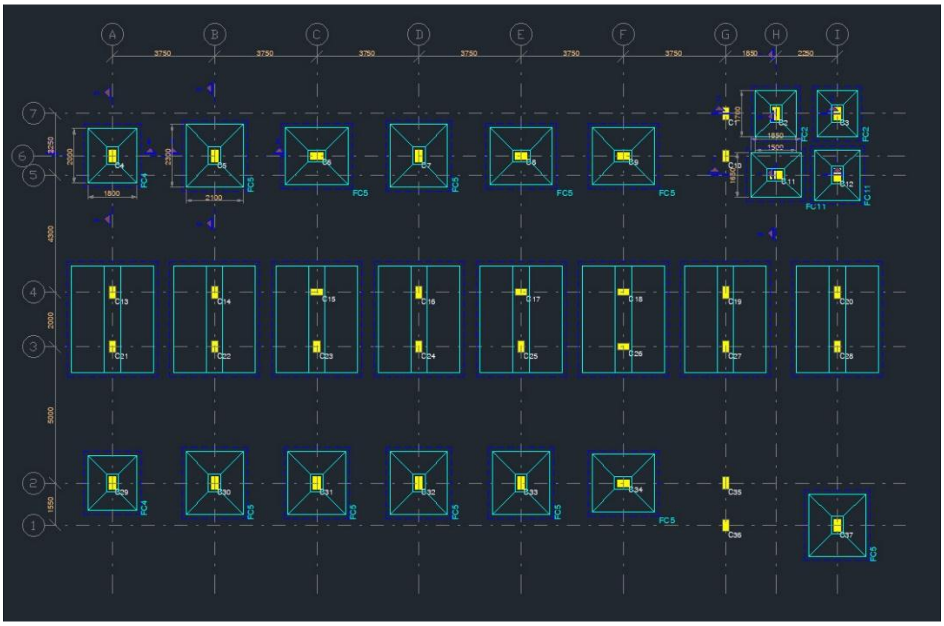

**Fig. 10. Combined footing details**

SLAB SCHEDULE (M35 : FE500) (LEVEL : 13.9 M)

| SLAB NUMBERS | THK | TYPE | BOTTOM REINFORCEMENT | | TOP REINFORCEMENT | | DISTRIBUTION | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | SHORT SPAN (BENT UP) | LONG SPAN (BENT UP) | SS CONT. | LS CONT. | | |
| S1, S2, S4, S5 S6, S7, S8, S10 S11, S12, S13 S14, S15, S18 S19, S20, S21 S22 | 150 | 2-Way | T8 @ 275 | T8 @ 275 | T8 @ 300 | T8 @ 300 | T8 @ 300 | --- |
| S3, S17 | 150 | 2-Way | T8 @ 245 | T8 @ 275 | T8 @ 290 | T8 @ 300 | T8 @ 300 | --- |
| S9 | 150 | 2-Way | T8 @ 275 | T8 @ 275 | T8 @ 300 | T8 @ 300 | T8 @ 300 | --- |
| S16 | 150 | 1-Way | T8 @ 275 | -- | T8 @ 300 | -- | T8 @ 300 | --- |
| S23 | 150 | 2-Way | T8 @ 175 | T8 @ 275 | T8 @ 205 | T8 @ 300 | T8 @ 300 | --- |

**Fig. 11. Details of slab scheduling**

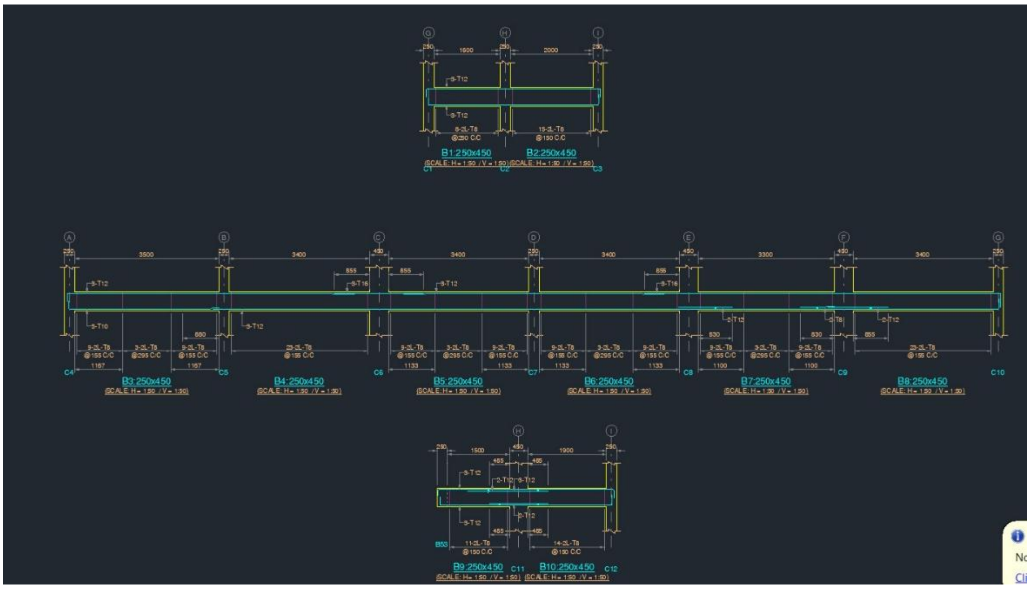

**Fig. 12. Plan of reinforcement**

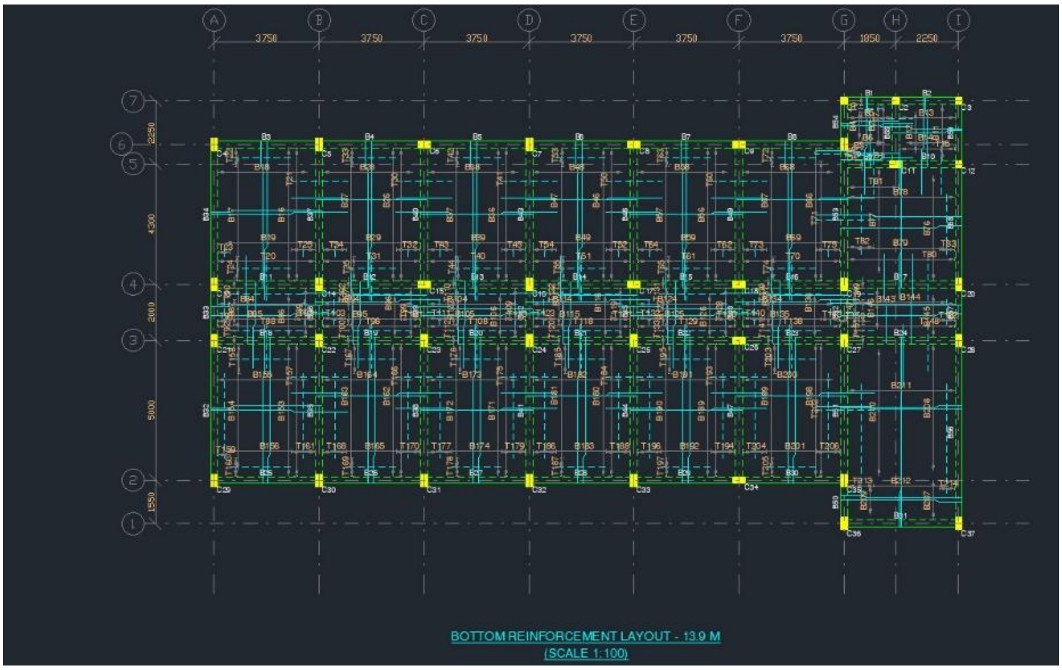


**Fig. 13. Details of reinforcement**

## IV. Results and Discussion

The findings from the structural analysis provide a detailed overview of the internal forces and moments acting on the various components of the building. The results indicate that the structure fully complies with the relevant Indian design standards, including IS 456:2000 for reinforced concrete design, IS 875:1987 for load calculations, and IS 1893:2016 for seismic design. This compliance assures that the building is capable of safely withstanding the applied loads under both typical and extreme conditions.

The analysis highlights the building's ability to bear the **live loads**, as depicted in **Figure 15**, which represents the dynamic loads the building will encounter during its use, such as people, furniture, and equipment. Similarly, the **dead loads**, shown in **Figure 16**, account for the weight of the structure itself, including all permanent elements such as walls, floors, and other materials.

In addition to these loads, the structure's response to **shear forces** is illustrated in **Figure 17**. This shows how the building manages lateral forces that act parallel to the structural elements, ensuring that it can resist sliding or shifting under pressure. The **bending moments**, depicted in **Figure 18**, detail the moments of force that cause the structural elements to bend under load. These figures collectively demonstrate that the structure is well-designed to manage these internal stresses effectively.

Furthermore, the analysis confirms that the building has sufficient stability and resistance to both wind and seismic forces. The design takes into account the wind load and seismic considerations as per the standards, ensuring that the structure can endure environmental pressures, including strong winds and moderate seismic activity. Overall, the results reinforce that the building meets all safety and performance criteria, ensuring durability and reliability throughout its lifespan.

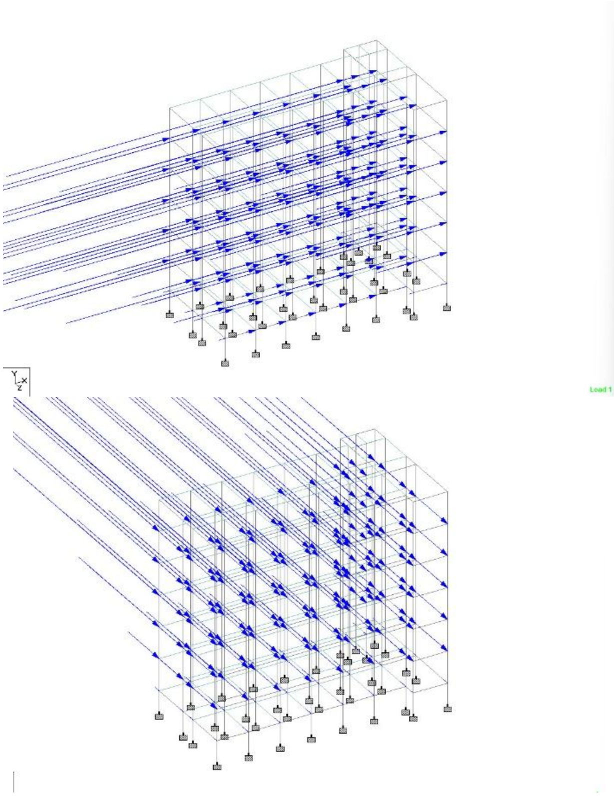

**Fig. 14. Seismic load**

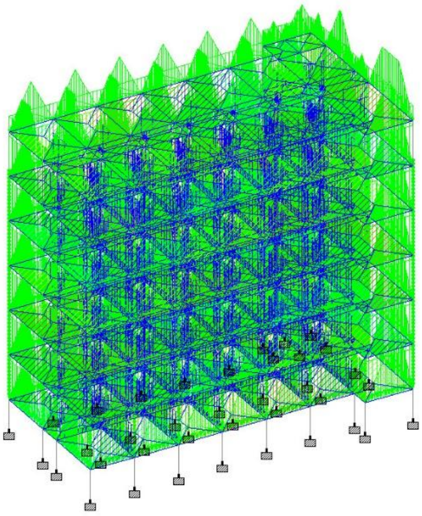

**Fig. 15. Live load**

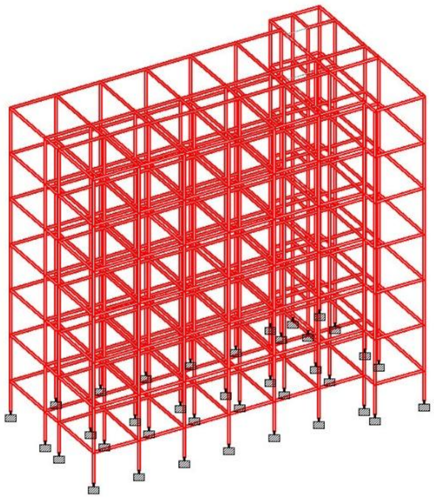

**Fig. 16. Dead load**

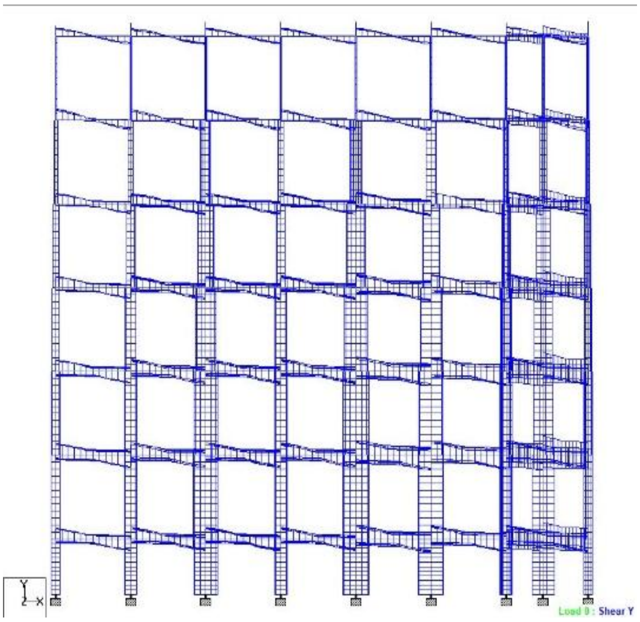

**Fig. 17. Shear force**

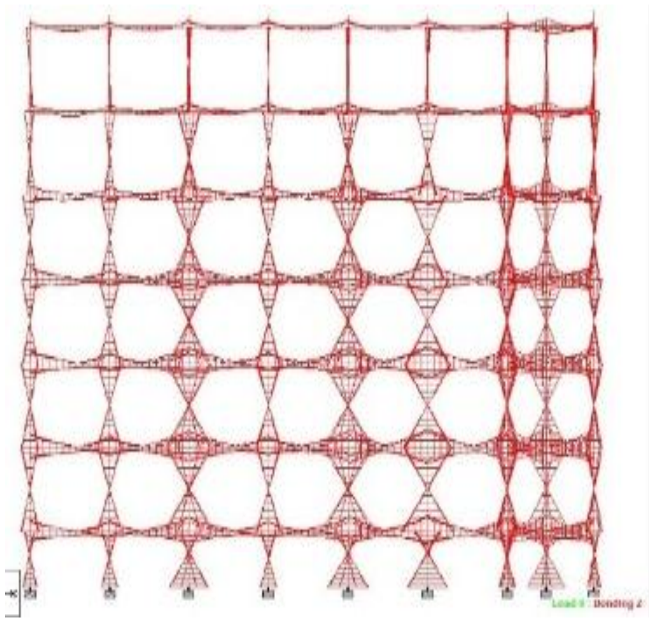

**Fig. 18. Bending force**

## V. Conclusion

In the structural design of a G+5 commercial building, the section titled **"Evaluating Structural Efficiency of the Building"** emphasizes the critical role of computer-aided design (CAD) software in ensuring both the safety and functionality of the structure. The project utilizes **STAAD Pro** for three-dimensional geometric modelling and comprehensive load analysis, alongside **Advanced Concrete Design** software for detailed reinforcement design. These tools significantly enhance the accuracy and efficiency of the modelling, analysis, and design processes, ensuring that the building conforms to the necessary Indian Standards.

Key standards adhered to include **IS 456**, which governs load combinations; **IS 1893**, which addresses seismic load requirements; and **IS 875**, which covers wind and live load considerations. By carefully following these standards, the project guarantees the safety, reliability, and structural integrity of the building. The design process involved thorough planning and execution, incorporating key elements such as load definitions, material properties, geometric modelling, and the precise detailing of structural members.

Throughout the design process, great emphasis was placed on documenting each stage, including photographs and structural drawings, which are crucial for clear communication among stakeholders and to ensure the construction process proceeds smoothly and according to plan.

In conclusion, this paper demonstrates the effective application of modern CAD tools in the creation of a structurally sound, efficient, and sustainable commercial building. The integration of these contemporary design and analysis tools sets a benchmark for future projects, encouraging the adoption of advanced technologies in structural engineering. Future efforts could aim to improve design precision and efficiency by incorporating advanced analytical methods, such as **finite element analysis (FEA)**. Additionally, focusing on the building's environmental performance by introducing **sustainable design principles**—such as eco-friendly materials and energy-efficient technologies—would further enhance its overall value. Moreover, strict adherence to relevant codes and standards remains essential for ensuring the continued safety, stability, and resilience of the structure.

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This paper provides a comprehensive overview of the structural design of a G+5 commercial building using STAAD Pro and AutoCAD, ensuring compliance with relevant Indian Standards. The use of advanced CAD software facilitates the creation of safe, functional, and aesthetically pleasing structures, highlighting the importance of technology in modern structural engineering.