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Structural Analysis and Design of a Multi-Storey Residential Building Incorporating Wind Load Using STAAD Pro

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ABSTRACT: Structural planning is a combination of artistic and scientific principles used to design structures that are creating cost-effective, functional, and long-lasting structures. In today's highly competitive world, efficiency is key, and various software programs are employed to aid in completing tasks more intelligently. This particular project involves the analysis and design of a multistorey residential building with ten floors above ground (G+10) using STAAD Pro software, specifically considering wind load and following the guidelines outlined in the IS Codal provisions. The analysis of the entire structure is conducted using STAAD Pro software, while the design of individual structural elements including columns, beams, slabs, staircase, and shear walls is done manually, incorporating relevant outputs from STAAD Pro. The foundation design is accomplished using STAAD Foundation software and AutoCAD is employed for drafting and detailing. The loads acting on the members are considered by IS 875:1987 (Part 1, Part 2, Part 3).

KEYWORDS: Analysis, Design, STAAD Pro, Wind Load, Residential Building

I. INTRODUCTION

Efficient structures are essential for meeting the basic need for shelter in human civilization. Civil engineering, specifically through the analysis of structures, plays a crucial role in achieving this goal. To address the challenges of urban population growth and high land costs. This project aims to design a multi-storey G+10 residential building with four residential flats on each floor. Each flat consists of four 2 BHK units, with a floor-to-floor distance of 3 meters. STAAD Pro, a widely used software, is employed for the analysis and design of the structure based on the analyzed report. Wind load expressed as pressure or force per unit area, is a critical factor that needs to be considered. Structural engineers refer to building codes and standards specific to their region to determine the wind load on different parts of the structure. Incorporating the wind load into the design process ensures that the building can withstand the forces imposed by the wind.

II. LITERATURE SURVEY

The research papers from various journals provide valuable insights into the significance and necessity of the project involving the analysis and design of a multistorey (G+10) residential building using STAAD Pro. Here is a summary of the literature presented

Several studies have been conducted to analyze and design multi-storey buildings using STAAD Pro software and compare the results with manual calculations. Rashmi Agashe [1] found that while the analysis remained consistent, the design differed slightly. STAAD Pro facilitated a quicker and easier analysis and design process compared to manual calculations, particularly for elements such as slabs, beams, columns, rectangular footings, and staircases designed according to the IS 456-2000 limit state method. Similarly, Mahesh Pawar [2] concluded that the structural components of a G+7 residential building designed with STAAD PRO were safe in shear and flexure, with economical steel quantities and short-term deflection within acceptable limits. Sreeshna K.S. [3] used STAAD Pro.V8i for the analysis

and manual detailing of an apartment building's structural components, including slabs, columns, beams, and pile caps, adhering to standard specifications. Mrs. Rakhi Shelke [4] studied wind analysis on residential buildings using STAAD-Pro, observing that wind loads increase with height, emphasizing the need to design structures for wind loads independently in both directions. These studies collectively showcase the efficiency and reliability of STAAD Pro in analyzing and designing multi-storey buildings, optimizing their performance and structural integrity.

III. METHODOLOGY

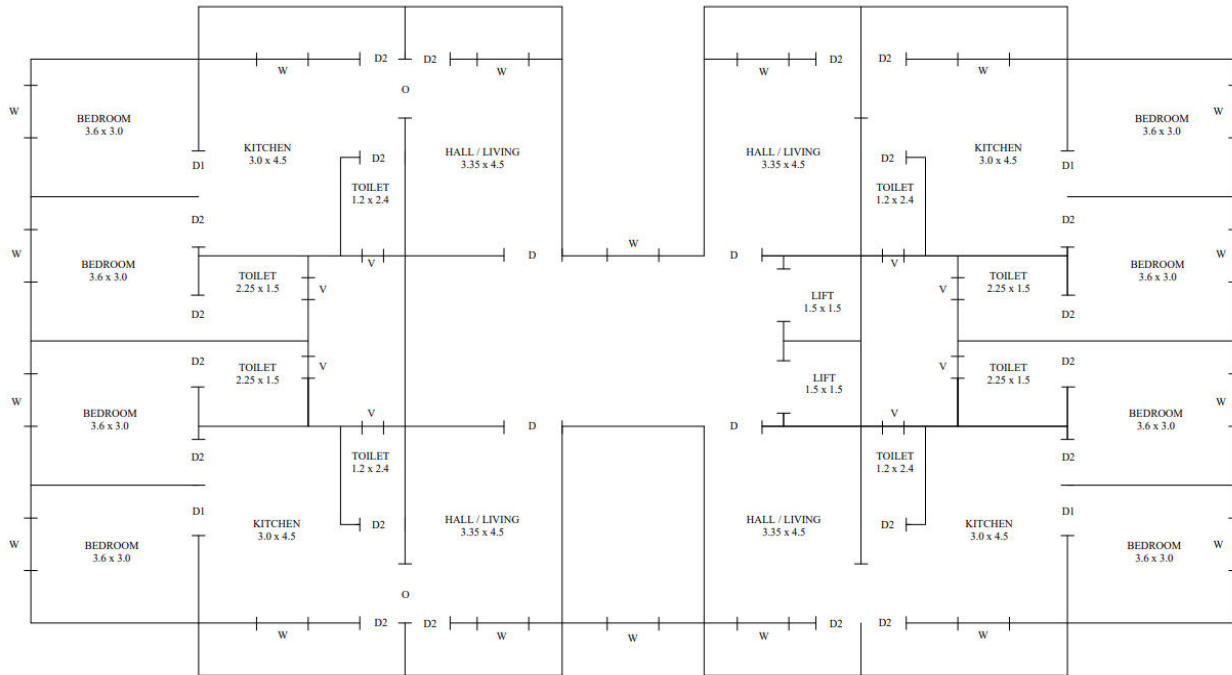


Fig 1: Project work plan

To ensure a well-designed structure Initially, the layout of columns, beams, slabs, and shear walls is determined based on specific requirements. Then, the software is configured with the appropriate design codes and standards. Nodes are created by specifying column distances, and material properties like the sizes of columns, beams, slabs, and shear walls are defined. After defining the properties, they are assigned to the corresponding structural elements. Supports, usually fixed supports for columns, are assigned at the base of the structure. Loads are defined, considering factors such as dead loads (e.g., the weight of walls), live loads (e.g., occupants, floor finishing), and wind loads (based on location, building height, and exposure). Load combinations are established to account for simultaneous load occurrences. The analysis is performed using STAAD Pro to assess how the structure responds to the applied loads. The analysis results are carefully reviewed for any errors or warnings. Based on the analysis and design code requirements, the structural elements (columns, beams, slabs, shear walls) undergo design. This involves determining the necessary reinforcement and dimensions to ensure structural adequacy and safety. Throughout the process, it is crucial to maintain simplicity and clarity in instructions and calculations to obtain accurate results and achieve a well-designed structure.

IV. MODELLING AND ANALYSIS

1. Project Details

This paper presents the design details of a residential building featuring a reinforced concrete (RCC) framed structure with cement concrete block walls. The building is a 2 BHK apartment complex, situated on a plot measuring 28.3 m x 15.9 m. It consists of 11 stories (ground floor plus 10 upper floors) and incorporates a dog-legged staircase for vertical circulation. Shear walls with a thickness of 300mm are strategically placed to enhance structural integrity. The floor-to-floor height is 3 meters, and the construction materials include M25-grade concrete and Fe-500 grade steel.

2. Generation of Structure

In the process of generating the structure, nodes representing key structural elements were placed at the specified center-to-center distances as per the plan. These nodes were interconnected with beams to establish the skeletal framework of the building. The entire structure was subjected to loadings to facilitate the subsequent analysis. Additionally, slabs were created using the plate command, while surfaces for the shear walls were drawn using the surface command.

3. Defining and assigning the member properties

The member properties for the structural elements were defined and assigned based on preliminary calculations. The assigned member properties are as follows: columns with dimensions of 450 mm x 600 mm, beams with dimensions of 450 mm x 450 mm, slabs with a thickness of 150 mm, and shear walls with a thickness of 300 mm. These properties were established to ensure structural integrity and to meet the design requirements of the residential building.

4. Assigning Supports

The base supports of the structure were designated as fixed. These supports were generated utilizing the STAAD Pro software, which facilitated the determination and allocation of the fixed supports for the structural system.

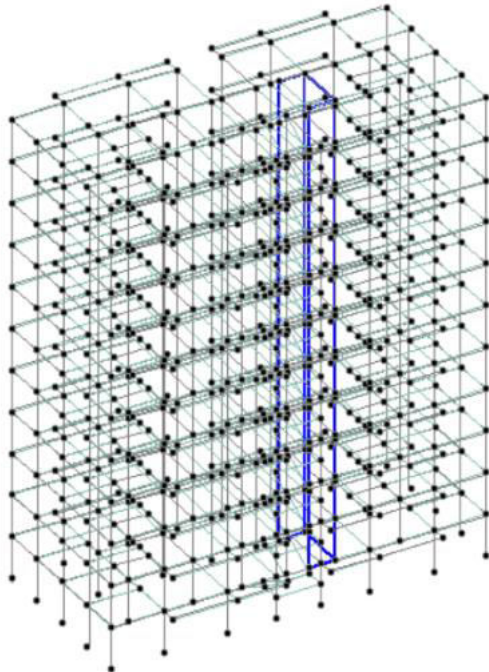


Fig 2: Skeletal Structure

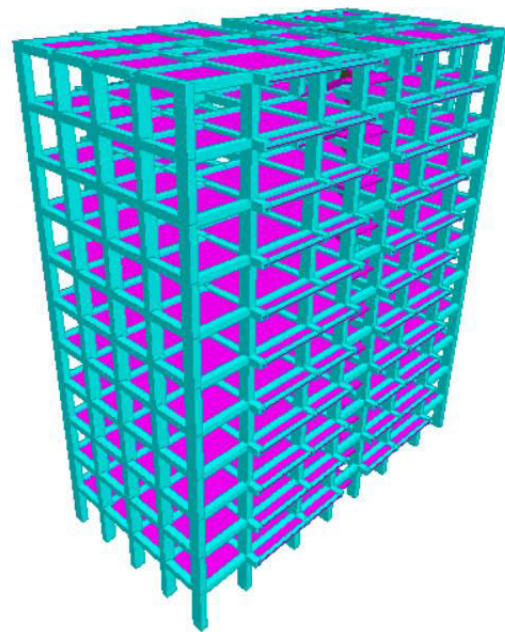


Fig 3: Rendered view of the Structure

5. Assigning Loads

i) Dead Loads

The dead loads assigned to the structure include the self-weight, which was generated by STAAD Pro using the self-weight command applied to the entire structure. Additionally, the wall load was manually calculated considering concrete block walls with a density of 20 kN/m³ as per 875(Part 1). The wall load assigned to the structure was 15.3 kN/m and a floor finish load of 2 kN/m² was assigned to the structure.

ii) Live Loads

The live loads assigned to the structure, according to IS 875 (Part 2), varied according to different occupancies. For residential areas, rooms, kitchens, toilets, and bathrooms were assigned a load of 2 kN/m², while staircases, corridors, and balconies were assigned a load of 3 kN/m².



iii) Wind Loads

The wind data collected for Guwahati suggests that the region falls under wind zone 2, with a basic wind speed (V_b) of 50 m/s. To determine the appropriate terrain category, various factors specified in IS 875: Part 3 are taken into consideration. Additionally, the design factors including the risk coefficient factor (K_1), terrain and height factor (K_2), and topography factor (K_3) are accounted for in the analysis. The design wind speed (V) is then calculated using the formula $V = V_b \times K_1 \times K_2 \times K_3 \times K_4$, with V_b being 50 m/s. The values of K_1 , K_2 , and K_3 are obtained from IS 875: Part 3, as well as other relevant tables provided by the applicable standards.

Height from ground	Wind Pressure P_z (kN/m ²)
10m	0.672
15m	0.672
20m	0.672
30m	0.988
33m	1.028
For 33m Wind Pressure = 1.028 kN/m²	

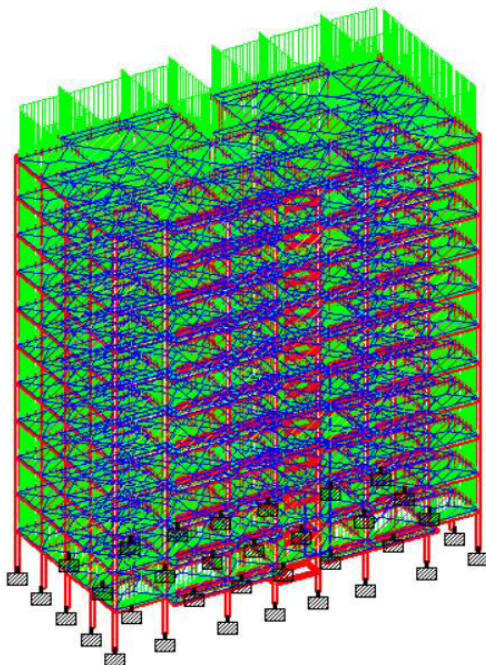


Fig 4: Dead Load assigned on the structure

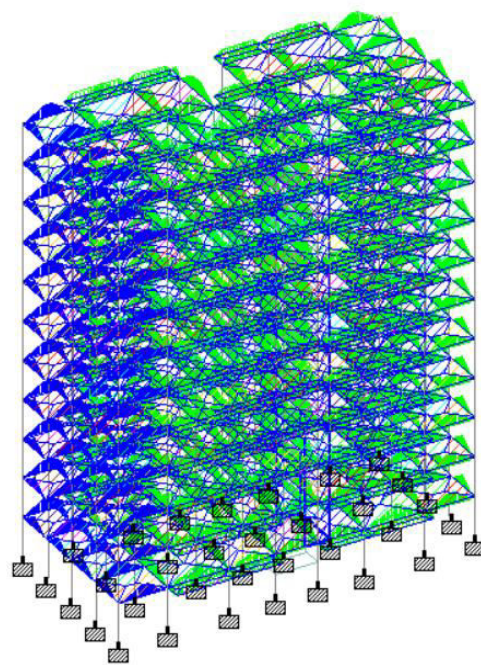


Fig 5: Live Load assigned on the structure

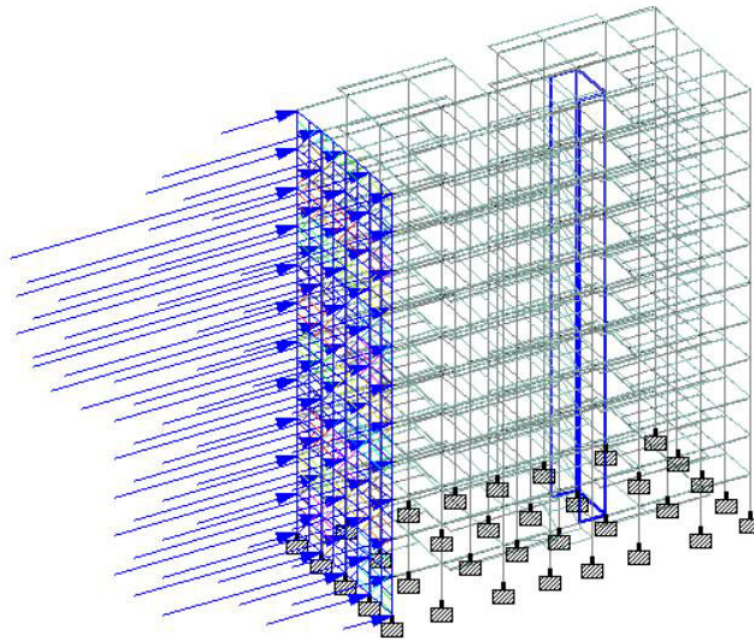


Fig 6: Wind Load assigned on the structure

6. Load Combinations

Load combinations are taken as per IS 456:2000. In our case the building is designed for wind loads. Therefore, only wind loads are considered. The structure is analyzed by taking all the below combinations

- | | |
|-------------------|------------------------|
| 1. 1.5 (DL + LL) | 6. 1.2 (DL + LL + WLx) |
| 2. 1.5 (DL + WLx) | 7. 1.2 (DL + LL - WLx) |
| 3. 1.5 (DL - WLx) | 8. 1.2 (DL + LL + WLz) |
| 4. 1.5 (DL + WLz) | 9. 1.2 (DL + LL - WLz) |
| 5. 1.5 (DL - WLz) | |

7. Analysis and Design

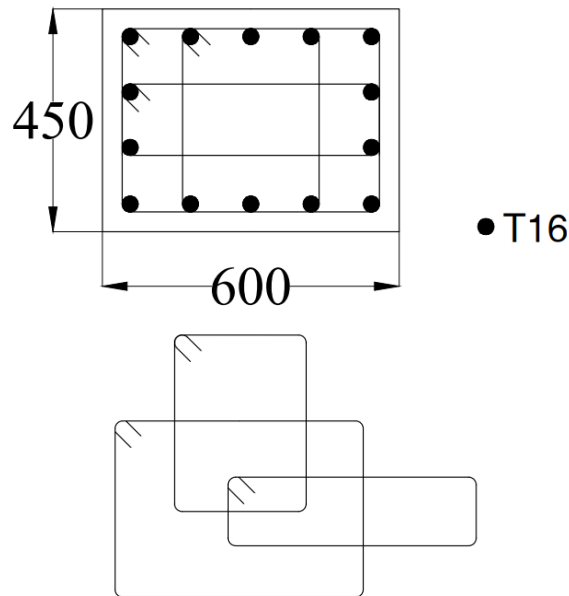
The structure was thoroughly analyzed after assigning material properties and loads. No errors were detected, indicating accurate modelling. It complies with the IS 456:2000 code for concrete structures. Parameters like the clear cover, yield strength (f_y), characteristic strength of concrete (f_{ck}), and minimum and maximum reinforcement diameters were specified correctly. The design clearly identified beams and columns, ensuring a comprehensive understanding. With zero errors, we can confidently say that the structure is safe and meets the high standards of structural engineering.

8. Design Results

The output file generated by STAAD Pro, which includes the design commands, provides essential data for the comprehensive design of all structural elements in the buildings.

9. Design of structural elements

Because STAAD Pro software did not provide enough information for the structural detailing, so we did it manually for all the structural elements. To assess the accuracy of the reinforcement area calculated by STAAD Pro, we compared it with our own calculations. We observed that the two sets of data had a slight similarity, but were not identical. Consequently, we utilized AutoCAD software to carefully and accurately design the columns and beams. This example highlights the careful attention to detail and precision we employed during the detailing process.



Provide links @ 175mm C/C

Fig 7: Detailing of column

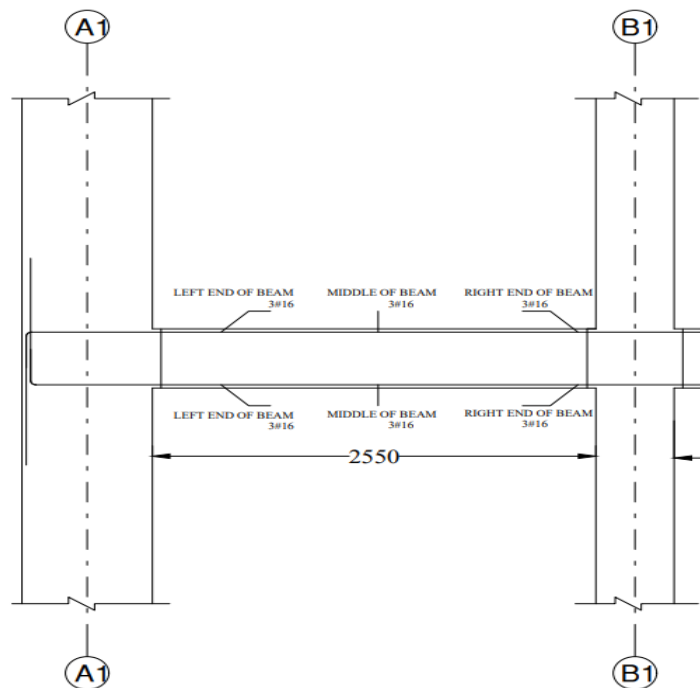


Fig 8: Detailing of beam

We designed the slabs and staircase of the structure by using IS 456 method. Similarly, we manually designed the shear wall, taking into account the bending moments and shear forces we obtained from STAAD Pro, following the IS 13920 - 2016 code provisions. The footings were designed as isolated footing. For the footing design, we used Staad Foundation Software to ensure stability and strength.

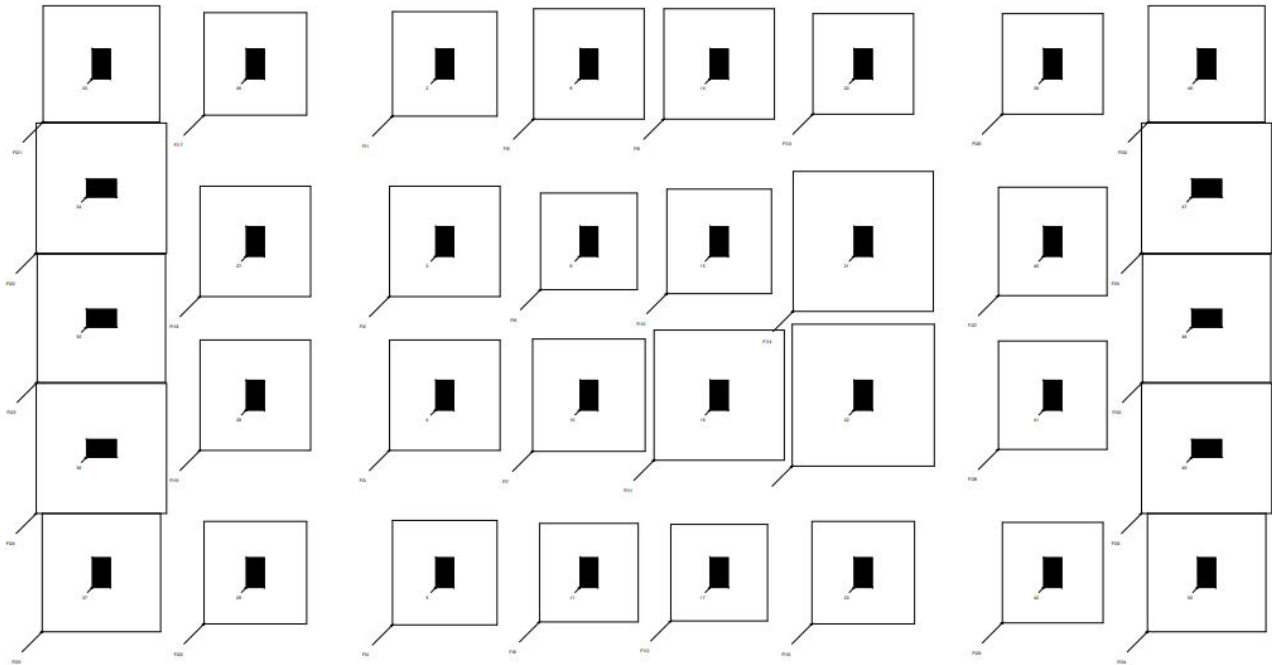


Fig 8: Foundation Plan

V. CONCLUSION

After the analysis and design of the structure using STAAD Pro, the following conclusions were drawn:

1. The analysis conducted with STAAD Pro software confirms that the structural components of the G+10 storey residential building are safe and capable of withstanding the expected loads.
2. However, when considering the detailing process, manual detailing of columns and beams was found to be more precise and practical for on-site construction.
3. The proposed sizes of the structural elements were found to be appropriate, effectively supporting the intended loads and ensuring the necessary strength and stability for the building.
4. With a total concrete volume requirement of 663 cubic meters, proper planning and procurement can be carried out to ensure the construction progresses smoothly.
5. Overall, the combination of software analysis and manual detailing provides a comprehensive understanding of the building's structural integrity and paves the way for a successful construction process.
6. The same procedure can be applied to analyze the structure in different locations across India, considering varying wind speeds. By using the established analysis methodology and accounting for specific regional wind conditions, the structural performance can be evaluated and compared, ensuring the design meets the required safety standards for each specific location.

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