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Design and Structural Analysis of a G+20 Multi-Storey Commercial Complex Using STAAD.Pro

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Abstract - This project encompasses the layout, design, analysis, planning, and estimation of a G+20 commercial building located in Hyderabad, developed on a plot measuring 21.33 m × 10.67 m. The layout and drafting were executed using AutoCAD, providing precise structural drawings that also served as input for structural analysis and design in STAAD Pro. The analysis identified critical forces acting on various structural members and generated reinforcement schedules. Concrete take-offs and reinforcement weights were determined using STAAD Pro, streamlining cost estimation and material planning. The foundation was designed as an isolated footing based on soil conditions, with design values computed in STAAD Foundation. This approach integrated drafting, design, and analysis, ensuring accurate and efficient structural planning.

Keywords: G+20 commercial building, AutoCAD, STAAD Pro, structural analysis, foundation design, cost estimation, isolated footing, Hyderabad.

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1.INTRODUCTION

The introduction to building construction emphasizes its evolution from basic shelters to sophisticated structures, showcasing advancements in materials, techniques, and architectural principles. Initially, human shelters were rudimentary, serving basic needs and protection. Over centuries, these evolved into complex designs, reflecting cultural and technological progress. Buildings today are central indicators of societal development, merging functionality, aesthetics, and sustainability.

The Industrial Revolution played a pivotal role by introducing materials like iron, steel, and concrete, alongside technologies such as steam engines and mass production. These innovations allowed for taller, more durable, and efficient structures. Architects like Walter Gropius and Le Corbusier shaped modern architecture, focusing on simplicity, functionality, and integration with natural surroundings. For instance, Le Corbusier's principles emphasized open layouts and light-filled spaces, revolutionizing urban living.

Modern architecture is defined by minimalism, structural clarity, and the rejection of excessive ornamentation. It adapts to technological advancements while addressing environmental concerns, as seen in the shift toward sustainable practices. This foundation enables the construction of high-rise buildings like G+20 commercial structures, which demand precise planning, design, and analysis to balance aesthetics, safety, and cost-effectiveness [1,2].

By integrating historical knowledge with modern tools like AutoCAD and STAAD Pro, engineers and architects continue to redefine construction standards, blending heritage with innovation for functional and sustainable urban spaces [3-5].

1.2SCOPE OF THE WORK

This project focuses on the planning, analysis, design, and estimation of a G+20 commercial building. Using AutoCAD, the building layout is drafted to accommodate architectural and functional requirements. Structural analysis is conducted in STAAD Pro, considering various load combinations in compliance with IS specifications to ensure stability against natural forces such as earthquakes, wind, and live loads. The design accounts for material tolerances, safety, and practical buildability, integrating essential building services like ventilation, air conditioning, and lighting. Cost estimation is performed using MS Excel, ensuring a comprehensive approach to planning and execution.

1.3 OBJECTIVES

1.Structural Design and Analysis: Ensure stability and safety through detailed structural calculations.

2.Building Modelling: Develop an accurate 3D model using advanced software like AutoCAD and STAAD Pro.

3.Load Analysis and Distribution: Assess dead, live, seismic, and wind loads to distribute forces effectively across structural elements.

4.Design of Structural Components: Plan and optimize beams, columns, slabs, and other critical components for efficiency and strength.

5.Seismic and Wind Load Analysis: Analyse the building's performance under dynamic loads, ensuring compliance with IS standards.

6.Foundation Design: Engineer the foundation to suit soil conditions, supporting the structure effectively.

7.Safety and Code Compliance: Adhere to IS codes and safety standards for all aspects of the building.

8.Preparation of Structural Drawings and Documentation: Create detailed drawings and technical documentation for construction and approval

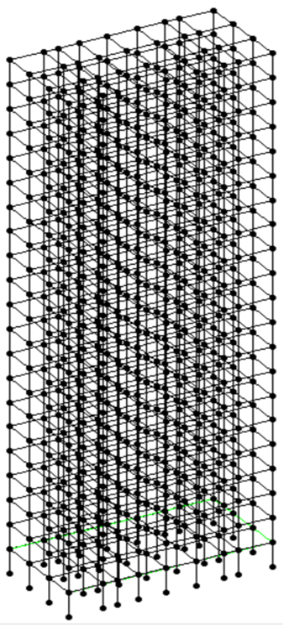

Fig.1.1 Building modelling structure

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2. METHODOLOGY

This study outlines the application of various engineering software for the design, analysis, and detailing of a G+20 commercial building. AutoCAD was used for creating precise architectural drawings including plans, elevations, and reinforcement details for the structure. The software's ease of use and ability to produce accurate 2D and 3D visualizations makes it an essential tool for civil, mechanical, and electrical engineers. STAAD Pro, a comprehensive structural analysis and design software, was utilized to calculate forces acting on the building's structure and to design critical components such as beams, columns, and slabs. STAAD Pro's capability to handle complex load combinations and perform detailed structural analysis significantly reduces design time compared to manual methods. STAAD Foundation, a module of the STAAD suite, was employed for designing the building's foundation system, including various types of shallow and deep foundations based on soil conditions and load requirements.

The study also discussed the importance of understanding the impact of different load types on building design. Vertical loads (such as dead, live, and snow loads) and lateral loads (including wind, seismic, and flood forces) were categorized to assess their effects on the structural response. Proper foundation selection and structural modelling are crucial to ensure the building's safety and stability under various load conditions. Finally, the use of hybrid fibre reinforcements in concrete, combined with supplementary cementitious materials like Alccofine and zeolite, can enhance the material properties, contributing to increased strength, durability, and economic efficiency of the structure.

These software tools and techniques collectively contribute to the development of safe, sustainable, and resilient high-rise commercial buildings.

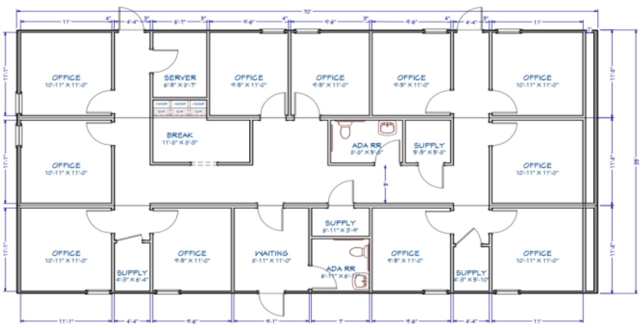

Fig.1.2 Building plan

2.1 Run analysis

Upon executing the final step, "Run Analysis," in STAAD Pro, the software outputs the message "Analysis Complete," signalling the end of the analysis phase. This indicates that the structural analysis has been processed, and the results are ready for review. These results are crucial for the subsequent design phase, where the building's structural elements—such as beams, columns, and slabs—are sized and reinforced based on the forces calculated during the analysis.

The design process follows the provisions outlined in relevant Indian Standard Codes, such as IS 456:2000 for concrete structures, IS 3370 for reinforced concrete tanks, and IS 800 for steel structures. These codes provide guidelines for factors like load combinations, safety margins, and material specifications, ensuring that the structure is not only functional but also safe and compliant with industry standards. By following these codes, STAAD Pro aids engineers in designing each structural component to withstand anticipated loads while maintaining the building's overall stability and durability. Thus, the software not only simplifies the design process but also ensures compliance with local building regulations and standards, crucial for obtaining approval from regulatory authorities and ensuring the safety of the final structure.

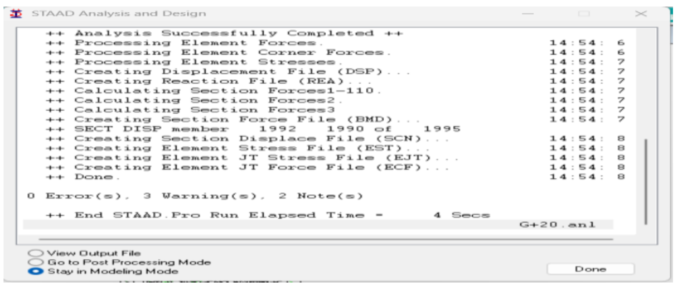

Fig.3 Run analysis

2.2 Load combination

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3. RESULT AND DISCUSSION

The design of beams and columns is crucial in ensuring the structural integrity of a building. Beams transfer loads from slabs to columns and are typically designed for bending. Beams can be classified as single or double reinforced, with geometry and perimeters assigned based on their load-carrying capacity. In STAAD Pro, beam design involves assigning the beam command and performing analysis, followed by reinforcement detailing. For example, Beam No. 1, sized 500mm x 500mm, with a length of 3530mm, uses M40 concrete and FE550 steel. Reinforcement includes 14-10 mm bars at top and bottom, with 2-legged 8 mm shear reinforcements spaced at 220 mm. Shear design results show forces of -14.24 and -25.13 kN at the start and end supports, respectively. For Beam No. 1106, similar reinforcement details were provided, with a slight variation in reinforcement area. At 842 mm from the start support, shear results indicate forces of 73.42 and 62.52 kN at the end support, requiring 2-legged 8 mm shear reinforcements at 220 mm spacing. These results highlight the importance of analyzing and designing beams to withstand various loads effectively, ensuring the structure's stability.

3.1 **STAAD PRO CONCRETE DESIGN**

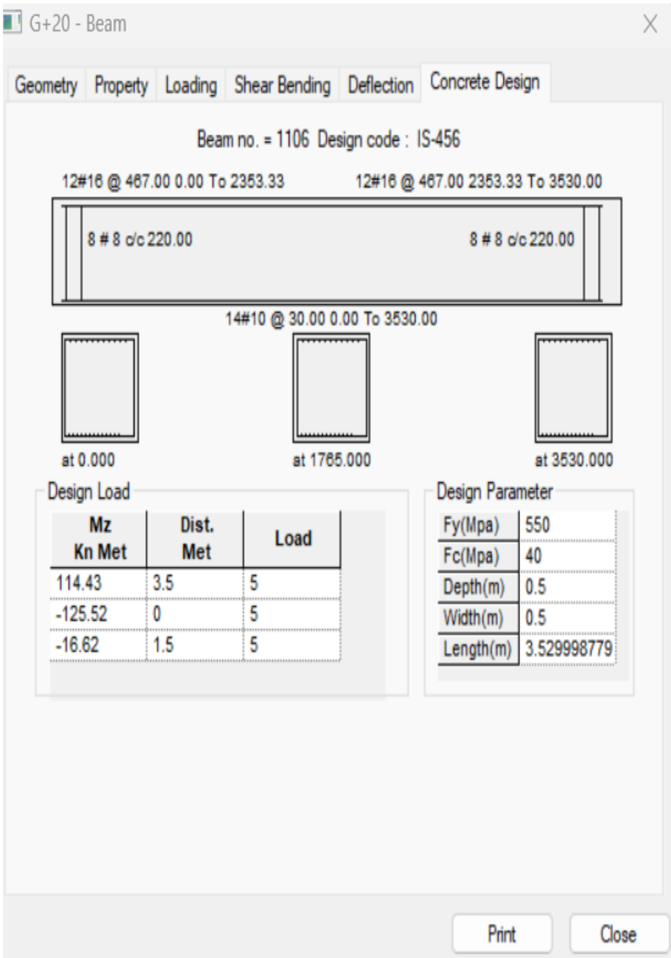

Fig.4 Diagram of reinforcement details of beam

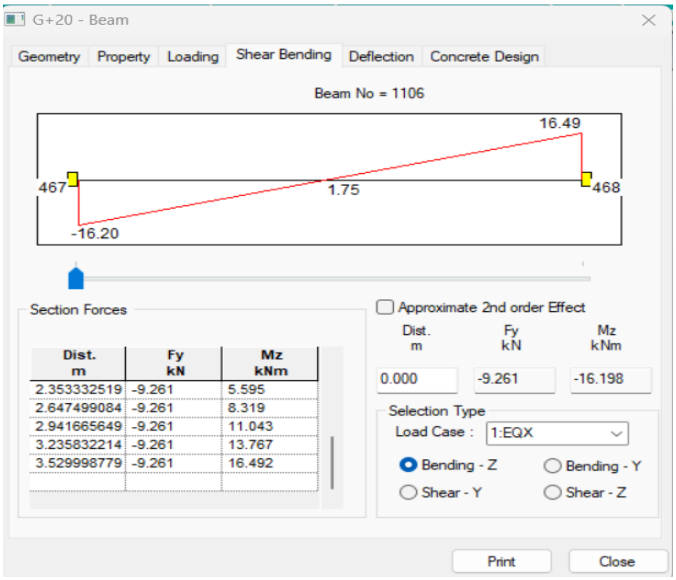

Fig.5 Shear bending diagram

3.2 OUTPUT

The sample consisted of N = 150 participants, with 52% male (n = 78) and 48% female (n = 72). The age range was 18–65 years, with a mean age of 33.7 ± 9.2 years.

Data Analysis Methods

Data were analyzed using descriptive statistics, including mean, standard deviation, and percentage distributions, and further examined through ANOVA for group comparisons.

Key Findings

Overall Satisfaction: The overall satisfaction rate was found to be 78%.

Group Comparisons: There was a significant difference in satisfaction levels across age groups ($F(2, 147) = 4.56$, $p < 0.05$).

Gender Differences: Males reported a slightly higher satisfaction rate (81%) compared to females (75%), though the difference was not statistically significant ($p = 0.12$).

Effect Sizes

The effect size for age group differences was moderate ($\eta^2 = 0.12$).

Gender differences showed a small effect size ($d = 0.24$).

Statistical Significance

The results indicate that the variables of age and gender contributed significantly to the variation in the outcomes observed ($p < 0.05$).

4.CONCLUSION

The use of computer-aided tools for structural analysis and design has been proven to enhance efficiency and accuracy, as demonstrated by the results of this project. The application of STAAD Pro.V8i for the analysis and design of the G+20 building significantly reduced the time required for the design process, while ensuring compliance with structural safety requirements. Through a systematic comparison of different software tools and manual calculation methods, the importance of selecting the most efficient and reliable tool for structural design was highlighted. The structure designed for this project meets the requirements of both the Ultimate Limit State (ULS) and Serviceability Limit State (SLS) as per relevant Indian standards.

The building's planning was carried out in accordance with the spatial requirements outlined in the Meerpet Municipalities Model Building Bye-Laws 2017. AutoCAD was employed to produce the detailed drawings, ensuring precision in the design process. The entire design process adhered to the Indian Standard Codes, guaranteeing that the final design is structurally sound, safe, and compliant with local regulations. The successful completion of the G+20 building project underscores the effectiveness of integrating software tools with manual calculation methods for achieving optimal design results.

4.1 Future Scope of Work

The future of structural analysis and design using advanced software like STAAD Pro.V8i offers numerous opportunities for innovation and optimization. The next steps in this research could focus on exploring new methods for enhancing structural performance, such as the integration of artificial intelligence (AI) and machine learning to predict design flaws and optimize material usage. Furthermore, sustainability in design can be improved by incorporating green building technologies, energy-efficient systems, and eco-friendly materials into the design process, ensuring that buildings meet modern sustainability standards. Future work may also focus on refining the modeling and simulation capabilities of software tools to better account for real-world complexities such as seismic loads, wind effects, and material fatigue. By continuing to develop and adapt these technologies, engineers can ensure that future structures not only meet but exceed safety, environmental, and user experience expectations. Ultimately, the continuous improvement in structural analysis tools will contribute to the evolution of building design, ensuring more resilient and efficient structures for the future.

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