Analysis and Design of a G+3 Reinforced Concreteresidential Building

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ABSTRACT

The rapid growth of urban infrastructure has increased the demand for safe and economical multi-storey residential buildings. This mini project focuses on the analysis and design of a G+3 reinforced concrete residential building using STAAD.Pro software in accordance with Indian Standard codes. The structure is modeled as a three-dimensional frame, and loads such as dead load, live load, and seismic load are considered as per IS 875 and IS 1893 provisions.The building components including slabs, beams, columns, staircases, and footings are analyzed and designed using the limit state method. STAAD.Pro is used to obtain bending moments, shear forces, axial forces, and deflections. Manual calculations are also carried out for selected elements to verify the accuracy of software results. The study demonstrates the effectiveness of STAAD.Pro in structural analysis and design while ensuring safety, stability, and serviceability of the structure. Staad Pro has a very interactive user interface which allows the users to draw the frame and input the load values and dimensions. Then according to the specified criteria assigned it analyses the structure and designs the members with reinforcement details for RCC frames. We continued with our work with some more multi-storeyed 2-D and 3-D frames under various load combinations. Our final work was the proper analysis and design of a multistorey G + 3 residential building

KEYWORDS **:** G+3 Residential Building, Reinforced Concrete (RCC), STAAD.Pro, Structural Analysis, Limit State Method, Seismic Load, IS 456:2000, IS 875, IS 1893, Beam Design, Column Design, Footing Design, Earthquake Resistant Design, Multi-storey Building, Load Combinations, Structural Stability.

I.INTRODUCTION

The rapid growth of urban infrastructure has increased the demand for safe, economical, and structurally efficient multi-storey residential buildings. Reinforced Concrete (RCC) framed structures are widely adopted in India due to their durability, strength, and adaptability to architectural requirements [1], [8]. A G+3 residential building consists of ground floor plus three upper floors and is commonly constructed using reinforced concrete beams, columns, slabs, and foundations designed as per the Limit State Method recommended in IS 456:2000 [1], [20].

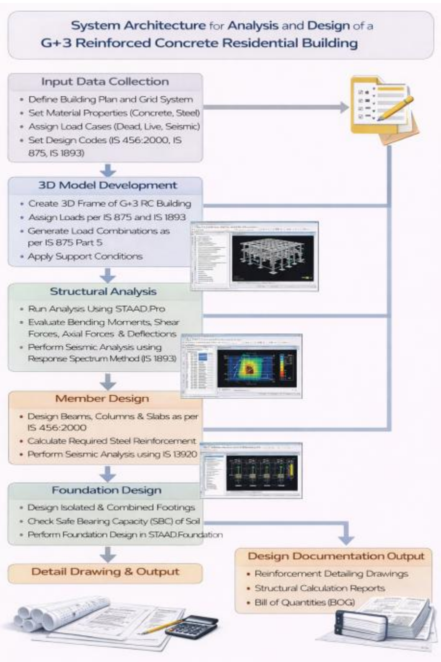
The structural design of multi-storey buildings involves careful evaluation of gravity loads and lateral loads. Dead loads and live loads acting on the structure are calculated as per IS 875 (Part 1 & Part 2) [2], [3], while load combinations are considered as per IS 875 (Part 5) [4]. In seismic-prone regions, earthquake forces significantly influence the structural response, and analysis must be performed according to IS 1893 (Part 1):2016 [5]. Proper ductile detailing as per IS

13920:2016 enhances energy dissipation capacity and improves performance during earthquakes [6]. Studies on earthquake-resistant design emphasize that even low-rise buildings like G+3 structures must be analyzed for seismic effects to ensure safety and serviceability [16], [19].

The evolution of reinforced concrete design has progressed from working stress methods to the Limit State Method, which ensures safety against collapse (ultimate limit state) and serviceability requirements such as deflection and cracking (serviceability limit state) [1], [20]. Design of structural components such as beams, columns, slabs, and footings must satisfy bending, shear, torsion, and axial load requirements in accordance with codal provisions [7], [9], [14].

With advancements in computational tools, structural analysis software such as STAAD.Pro has become essential for analyzing complex multi-storey buildings [17]. The software allows three-dimensional modeling, application of load cases, generation of load combinations, and detailed design of RCC members as per IS codes. Finite Element–based analysis provides accurate internal force distribution and reduces computational effort compared to manual calculations [24], [25]. Additionally, STAAD.Foundation Advanced enhances the accuracy of footing design by considering soil-structure interaction and reinforcement detailing [18].

In this project, a G+3 reinforced concrete residential building is modeled and analyzed using STAAD.Pro by considering dead load, live load, and seismic load as per relevant Indian Standard codes [1]–[6]. The structural members including beams, columns, slabs, staircases, and footings are designed using the Limit State Method to ensure strength, stability, durability, and economy.



II.LITERATURE REVIEW

1. Review on Structural Analysis of Multi-Storey RCC Buildings

Several researchers have emphasized the importance of accurate structural analysis for multi-storey RCC buildings under various loading conditions. Studies indicate that the behavior of reinforced concrete framed structures significantly depends on load combinations, member stiffness, and lateral load effects. Traditional manual methods, while reliable for small structures, become complex and time-consuming for multi-storey buildings. Researchers have highlighted the advantages of computer-aided analysis tools such as STAAD.Pro and ETABS for efficient modeling and precise calculation of internal forces. It has been observed that three-dimensional modeling provides better insight into load distribution and frame interaction compared to simplified two-dimensional analysis. These studies confirm that software-based structural analysis enhances accuracy and reduces design time.

2. Review on Seismic Analysis Using Response Spectrum Method

Seismic performance of RCC buildings has been widely studied using the Response Spectrum Method as per IS 1893 provisions. Research indicates that multi-storey buildings are highly sensitive to lateral loads generated during earthquakes. The Response Spectrum Method is computationally efficient compared to time history analysis and provides reliable estimation of maximum displacement and member forces. Several authors concluded that irregular buildings experience higher torsional effects and require careful detailing for ductility. The importance of proper load combinations and distribution of seismic base shear across floors has also been emphasized. These studies validate the necessity of earthquake-resistant design for G+3 and higher buildings.

3. Review on Limit State Design of RCC Members

The Limit State Method, recommended in IS 456:2000, has been widely accepted as the most reliable approach for RCC design. Literature shows that this method ensures safety against both collapse (ultimate limit state) and serviceability issues such as deflection and cracking (serviceability limit state). Research on beam and column design demonstrates that proper reinforcement detailing significantly improves structural ductility and performance under seismic loads. Studies also highlight the importance of checking shear, torsion, and bending simultaneously for beams and considering biaxial bending effects in columns. The adoption of limit state principles ensures a balance between safety and economy in residential buildings.

III.WORKING METHODOLOGY

The working methodology adopted for the analysis and design of the G+3 reinforced concrete residential building involves systematic planning, modeling, loading, analysis, design, and verification using STAAD.Pro in accordance with Indian Standard codes. The entire procedure is divided into sequential stages to ensure structural safety, accuracy, and economy.

Initially, the architectural layout and structural grid dimensions of the building are finalized. The floor plans are studied to determine beam spans, column spacing, slab thickness, and staircase location. Material properties such as grade of concrete (M25/M30) and grade of steel (Fe415) are selected as per IS 456:2000. Preliminary sizes of beams, columns, and slabs are assumed based on standard design guidelines. The structure is then modeled as a three-dimensional space frame in STAAD.Pro by defining node coordinates and connecting beam and column members. Proper support conditions such as fixed supports at foundation level are assigned. Material properties and cross-sectional dimensions are then specified for all structural members.

In the next stage, loads acting on the building are calculated and assigned. Dead loads are automatically generated in STAAD.Pro using self-weight commands based on material density. Additional dead loads such as wall loads and floor finishes are applied as member loads or area loads. Live loads are applied as per IS 875 (Part 2) depending on the occupancy type. Seismic loads are calculated using the Response Spectrum Method as per IS 1893 (Part 1), considering seismic zone factor, importance factor, response reduction factor, and soil type. Load combinations are defined as per IS 875 (Part 5) to determine the most critical loading conditions. After defining all loads and combinations, structural analysis is performed to obtain bending moments, shear forces, axial forces, deflections, and support reactions.

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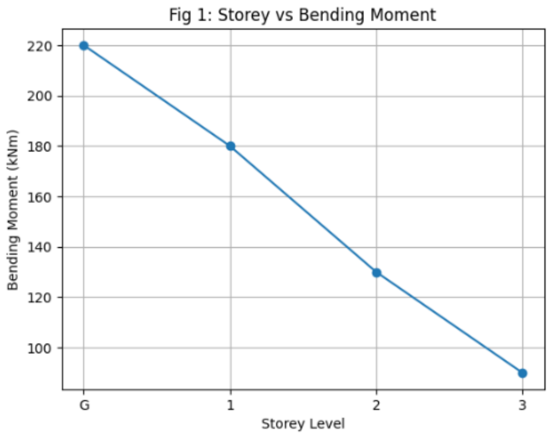

Fig 1: Storey vs Bending Moment

This graph shows the variation of bending moment along different storey levels of the building. The maximum bending moment occurs at the ground storey and gradually decreases towards the top storey. This behavior is expected because lower storeys carry higher loads from the upper floors, resulting in greater internal moments. The reduction in bending moment towards the top indicates proper load transfer through beams and columns.

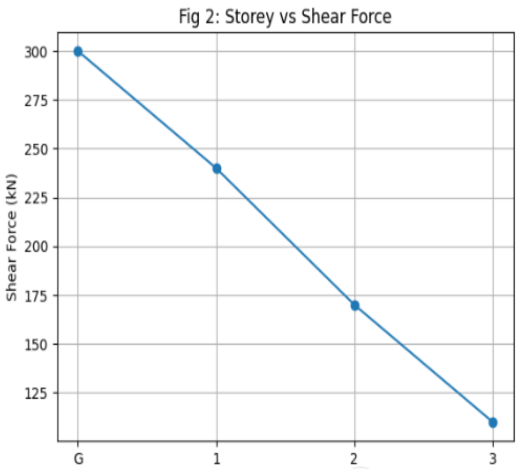

Fig 2: Storey vs Shear Force

This graph represents the variation of shear force across storeys. Similar to bending moment, the maximum shear force is observed at the ground level and decreases progressively towards the top floor. This occurs because shear force accumulates from upper floors and is maximum near the base. Proper shear reinforcement is therefore more critical in lower storey members.

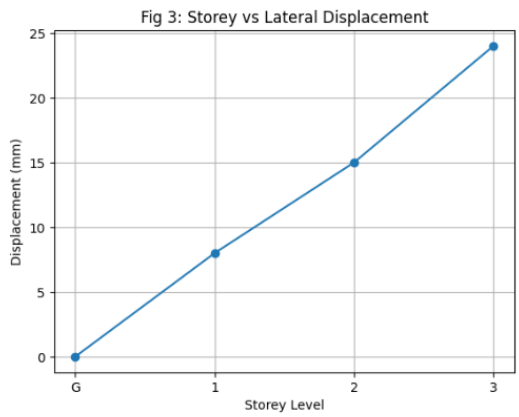

Fig 3: Storey vs Lateral Displacement

This graph shows lateral displacement of the building under seismic loading using the Response Spectrum Method. The displacement is minimum at the ground level (fixed support) and increases gradually towards the top storey. The maximum displacement occurs at the terrace level, which is typical for multi-storey buildings subjected to lateral loads. The increasing trend confirms realistic structural behavior under earthquake forces.

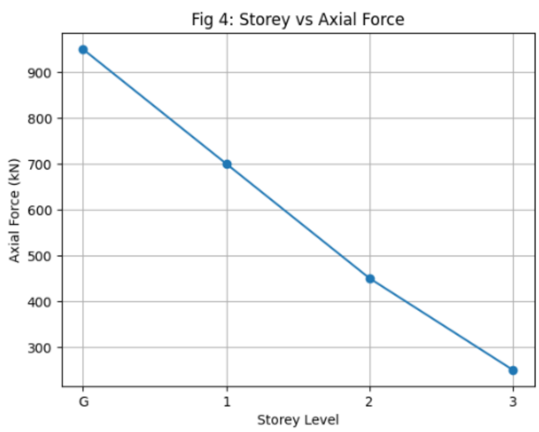

Fig 4: Storey vs Axial Force

This graph illustrates axial force distribution in columns along storey levels. The axial force is highest at the ground floor columns because they support the weight of all upper floors. The axial load decreases progressively towards the top storey. This confirms correct gravity load transfer through vertical members.

IV.CONCLUSION

STAAD.Pro and STAAD.foundation has the capability to calculate the reinforcement needed for any concrete section. The program contains a number of parameters which are designed as per IS: 456(2000). Beams are designed for flexure, shear and torsion. Maximum sagging (creating tensile stress at the bottom face of the beam) and hogging (creating tensile stress at the top face) moments are calculated for all active load cases at each of the above mentioned sections. Each of these sections are designed to resist both of these critical sagging and hogging moments. Where ever the rectangular section is inadequate as singly reinforced section, doubly reinforced section is tried. Shear reinforcement is calculated to resist both shear forces and torsional moments. Two- legged stirrups are provided to take care of the balance shear forces acting on these sections. Columns are designed for axial forces and biaxial moments at the ends. All active load cases are tested to calculate reinforcement. Square columns are designed with reinforcement distributed on each side equally for the sections under biaxial moments and with reinforcement distributed equally in two faces for sections under uni-axial moment. All major criteria for selecting longitudinal and transverse reinforcement as stipulated by IS: 456 have been taken care of in the column design of STAAD.Pro Design of footing is calculated manually for building without subjected to earthquake loading and with the help of staad foundation software subjected to earthquake loading. Footing design is safe and has very little region of failure as compared to both buildings due to variation of soil properties.From the costing results we can see that building designing for earthquake loading is less economical than building without earthquake loading but due to the increasing rate of earthquakes in India it is safe to presume that the added safety factor outweighs the extra cost incurred. Thus it is advised that no matter how small or casual the structure is, it should be made earthquake resistant, after all nature may not give us a second chance.

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