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Structural Load Evaluation of a Low-Rise Residential Building (G+4) Using STAAD.Pro: A Review

Ashwini P. Meshram[1,*], Nikhil K. Borkar[1], Omprakash G. Bhalavi[1], Shubham P. Kawale[2]

Abstract

The structural analysis and design of multi-story residential buildings have become more complex because cities continue to grow, while safety requirements become more demanding, and building codes establish stricter requirements. The traditional methods of structural analysis worked through manual execution, which required extended periods to complete and suffered from computational errors that primarily affected indeterminate structures and lateral loading conditions. This review paper provides a detailed evaluation of previous works related to the analysis and design of G+4 and similar multi-story residential buildings that have relied on computer-aided structural analysis software, with a special emphasis on STAAD.Pro. The studies subjected to review have centered on determining the behavior of structures under gravity, wind, and earthquake forces according to Indian Standard Codes IS 456:2000, IS 875, and IS 1893. The study evaluates programming parameters through the measurement of bending moments, shear forces, axial forces, story displacements, and deflections. Software analysis produces accurate results that ensure code compliance and decrease design time while optimizing material usage according to the literature review. The review demonstrates that STAAD.Pro provides capabilities for reinforcement detailing and serviceability checks. The paper demonstrates that STAAD.Pro provides reliable and efficient design capabilities for creating safe, economical, and sustainable low- to mid-rise residential buildings.

Keywords: Bending moment, G+4 building, RCC frame, seismic load, STAAD.Pro, structural analysis, wind load

INTRODUCTION

The increasing demand for residential construction, driven by rapid urban growth, has led to the development of multi-story buildings that combine safety features with economical construction methods and durable building materials. The design and structural analysis processes establish two essential functions that maintain building safety under all operational load conditions. Residential buildings must support multiple load types, including dead loads and live loads, as well as wind and earthquake forces, which impact both building stability and performance. Proper load monitoring combined with load impact assessment on structural components protects against structural failures, which create dangerous accidents and result in fatalities while maintaining code compliance.

Structural analysis relied on manual methods, including moment distribution and slope-deflection, and Kani's methods for its execution. These

***Author for Correspondence**
Ashwini P. Meshram
E-mail: meshramashwini940@gmail.com

[1]Student, Department of Civil Engineering, Kavikulguru Institute of Technology and Science, Ramtek, RTM Nagpur University, Maharashtra, India
[2]Assistant Professor, Department of Civil Engineering, Kavikulguru Institute of Technology and Science, Ramtek, RTM Nagpur University, Maharashtra, India

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techniques provide theoretical correctness; however, they become impractical for high-rise building operations because of their extensive computational requirements, which increase the likelihood of calculation errors. In modern structural engineering, engineers depend on structural analysis software, such as STAAD.Pro, ETABS, and SAP2000, because computer technology enables these tools to function as essential engineering resources. Engineers utilize these software programs to create complex structural models that enable them to test various load scenarios and achieve accurate results faster than traditional methods [1].

STAAD.Pro is one of the leading structural analysis and design tools for engineers working with reinforced concrete and steel building systems. The program includes multiple features that enable users to create 3D models and analyze systems that experience both static and dynamic loading conditions. Researchers have successfully used STAAD.Pro to evaluate and design various residential and commercial building types, ranging in height from low to high. The analysis of G+4 and G+5 residential buildings demonstrated that the software could measure bending moments, shear forces, axial forces, and deflections with utmost precision, while still following Indian Standard (IS) 456:2000 and other related codes [2, 3].

The design process for multi-story buildings relies heavily on the analysis of lateral loads, including wind and earthquake forces, and even low-rise buildings must undergo this assessment. The design process for columns and shear-resisting elements must consider the substantial lateral forces produced by seismic forces, along with the resulting internal forces. Researchers who used STAAD.Pro in the analysis of G+19 and other high-rise buildings concluded that the software delivers accurate predictions of lateral deflections and guarding under seismic loading according to IS 1893 [4, 5]. The same results appeared in mid-rise residential buildings, showing that the serviceability criteria for story drift and deflection limits remained within acceptable boundaries [6].

Studies have established that manual calculation must be performed to validate software accuracy through a comparison between hand-produced results and automated software outputs. The researchers confirmed that the manual design results matched those of STAAD.Pro. Thus, the software is a dependable design tool. Computer-aided design enables building projects to use fewer reinforcement materials. The same level of safety will be accomplished at reduced construction expenses.

Recent studies have investigated the benefits of STAAD.Pro in the reinforcement design of beams and slabs, as well as columns and footings, using limit state methods. The IS code provisions can be verified through fast checks, which include one-way shear, two-way shear deflection, torsion, and development length assessments. The combination of architectural design with structural analysis improves both the building process and the operational performance of residential structures while enhancing their visual appeal.

The present review paper gathers and evaluates previous research on G+4 residential building design through the application of STAAD.Pro. The main objective of this study is to assess the effectiveness of software-based structural analysis in handling various loading conditions, improving design accuracy, and supporting overall structural safety. The review results provide valuable information to engineers and researchers who design multi-story residential buildings.

LITERATURE REVIEW

Literature Survey

Prajakta Hepat et al. (2024) documented the methodology for modeling a G+4 residential frame in STAAD.Pro, covering geometry definition, load application (dead, live, wind, and seismic loads per IS codes), load combinations, and member design checks. The authors compared STAAD.Pro outputs with manual calculations to validate bending moments, shear, and deflections. The paper highlights STAAD.Pro's strengths: 3-D modeling, automated load generation, and integrated design checks that speed up iterations and optimization of reinforcement. The limitations discussed include the need for experienced interpretation of software results, mesh/simplification effects on accuracy, and code-specific input nuances. Practical recommendations stress cross-verification with hand calculations for critical members and sensitivity checks for load patterns [1].

Parmar et al. (2023) analyzed a G+5 reinforced concrete frame under seismic codal provisions (IS 1893), comparing base shear, story displacement, and member forces across different seismic zones. Time history and response spectrum analyses were used to capture the dynamic effects. The study found that ductile detailing and the provision of concentric bracings significantly improved the seismic performance: the base shear redistributed to braced frames, and story drifts fell within the allowable limits when bracing was provided. The authors recommended designing columns for biaxial bending and using capacity design principles for beams and shear walls. They also underscored the need to model P–δ effects for tall frames and verify that the automatic mass distribution in STAAD.Pro matched the intended diaphragm behavior [2].

Mohamed Hamud Mohamed et al. (2021) synthesized multiple small-scale studies on mid-rise buildings analyzed using STAAD.Pro. Common themes include validation of software results with hand calculations, the effect of load combinations on member sizing, and the importance of appropriate boundary conditions. The critique points out that STAAD.Pro is capable of executing both static and dynamic analyses with great success while simultaneously using ETABS and STAAD.Pro are producing the same member forces whenever modeling assumptions coincide. The author refers to literature that suggests some actions, such as checking by hand calculations, carrying out sensitivity analysis for different seismic zones, and precise modeling of diaphragms and continuities. Practical gaps are mentioned, such as a lack of research on the long-term effects (creep/shrinkage) and performance of structures under multi-hazard loading [3].

Bandipati Anup et al. (2019) demonstrated the stepwise application of limit state design in STAAD.Pro for a G+4 framed building. It compares 2D frame checks with full 3D modeling and finds that 3D effects (torsion, out-of-plane stiffness) noticeably change member forces versus planar assumptions. The authors report that the short-term deflections of slabs and beams remained within 20 mm for their models and that shear and flexural checks conformed to IS 456:2000. They recommend full 3D modeling for the final design, iterative refinement of member sizes, and use of STAAD.Pro's design modules to obtain economical reinforcement while following codal detailing for ductility and development length.

Y. Ahmad et al. (2023) analysis focused on a four-story RC building by comparing unbraced and braced configurations under seismic loads. The results show that X-type concentric steel bracing on peripheral frames markedly increases lateral stiffness and reduces interstory drift and maximum displacement. The study quantified the improvements: braced models exhibited up to a 40%–60% reduction in lateral displacement depending on the bracing location. The research shows that bracing systems help redistribute internal forces while decreasing column requirements, which enables designers to size vertical structural elements more efficiently. The study shows that strategic bracing enables ductile detailing to enhance building resilience while decreasing the need for retrofitting in moderate seismic zones [6].

Malarande et al. (2020) in the comparative study examined the effect of seismic zoning on base shear and reinforcement quantities for the same structural layout across different zones. It finds that base shear increases with seismic zone severity, necessitating larger lateral-force resisting elements and more reinforcement. The study demonstrates that different construction methods will require different amounts of steel, although the total concrete volume will remain unchanged. The authors propose zone-specific optimization through shear wall and bracing systems, which will manage seismic drift in high-risk areas while using ductile design to stop brittle material breakdown. The researchers demonstrate that STAAD.Pro software can automatically produce design load cases needed for zone studies in an efficient manner [3].

Abdiaziz Yasin Isse et al. (2021) review collated classroom and project-level research using STAAD.Pro to handle different seismic zones and architectural layouts. Key observations include variability introduced by diaphragm assumptions (rigid vs. semi-rigid), the significance of tributary area definitions for gravity loads, and the need for mesh refinement in shell elements for slabs. The review also points out that STAAD.Pro's automated design modules expedite preliminary sizing, but that final detailing (lap lengths, hooks) must be confirmed per IS provisions and SP-16 charts. The authors call for more research into non-linear/pushover analyses within STAAD.Pro for performance-based design applications [5].

Kewlan et al. (2022) demonstrated the STAAD.Pro workflow for a G+4 commercial building, including load assignment for heavier live loads, serviceability checks for deflection under larger spans, and interaction checks for column design under combined axial and bending actions. The findings highlight that serviceability, especially V-notching of slabs for large spans and vibration considerations for long cantilevers, must be evaluated in commercial structures. Using STAAD.Pro, the authors performed load combination studies and concluded that commercial loading often governs beam depth and slab thickness more than seismic demands for low-rise structures, whereas columns remain controlled by combined axial–bending in multi-story frames [7].

Adhiraj A. Wadekar et al. (2022) aggregated review synthesizes multiple project papers showing consistent workflows: architectural plan → material properties → load calculations (IS 875) → STAAD.Pro modeling → static/dynamic analysis → member design per IS 456 and SP-16. The study established three main findings, which state that.

1. 3D modeling captures critical interactions that 2D frames fail to detect.
2. The lateral response of the structure is mostly affected by its torsional irregularity and diaphragm flexibility, and
3. Bracing systems, together with shear walls, provide effective solutions to control building drift.

The authors advocate for software validation to verify both mass assignment and load patterns, which requires peer-reviewed studies that compare STAAD.Pro results with advanced non-linear analyses [8].

Kundan Kulbhushan et al. (2019), although primarily ETABS-focused, this study includes comparisons with STAAD.Pro results and highlights consistency when modeling assumptions match. Outcomes: modal analysis and time history procedures captured higher-mode effects better in ETABS's building-oriented environment, while STAAD.Pro offered broader element types and flexibility for irregular geometries. The authors recommend ETABS for regular building blocks and STAAD.Pro for complex 3-D frames with nonstandard support. Both packages produce reliable member forces for design if diaphragm modeling, mass distribution, and load patterns are handled carefully. The paper endorses cross-tool validation for critical projects [9].

Viswanath et al. (2023) synthesized multiple studies indicates that concentric bracing retrofits improve stiffness and reduce the demands on primary vertical members. Quantitatively, braced frames experience a decrease in lateral drift and a shift in shear forces; nevertheless, stress concentration at the connections of the braces and columns must be considered in the design. The review emphasizes that bracing can reduce displacements and base shear when used in certain layouts but may also increase shear concentration in the stories, thus calling for the proper design of beams to ensure ductility and avoid brittle failure. Practical considerations include the use of ductile connections and the assessment of bracing regarding the compatibility of architectural openings.

Aquib Zafar Ansari et al. (2024) reviewed seismic analysis strategies for tall buildings modeled in STAAD.Pro, including dynamic analysis methods (response spectrum, time history) and soil-structure interaction considerations. It emphasizes the need for higher-mode effects, P-Delta checks, and torsional irregularity assessment as height increases. For tall RC buildings, recommended practices include modeling separate substructures for mat foundations, using appropriate mass distribution for higher modes, and employing staged construction analysis where relevant. The review highlights STAAD.Pro's capability for extensive modeling, but notes limitations for advanced non-linear soil-structure interaction where specialized finite element tools may be preferable [10–12].

Research Gap

The existing literature shows that researchers have extensively studied multi-storey residential building designs and analyses using STAAD.Pro and ETABS structural analysis software. Researchers conduct their studies to examine how bending moments, shear forces, deflections, and reinforcement designs perform under both gravity and seismic loads. Most current research focuses on software outputs that have not been verified through a direct comparison of load impacts and serviceability assessment methods. Wind loads tend to receive insufficient attention in studies that impact low- to mid-rise residential buildings based on their research methodologies.

The existing documentation fails to establish proper record-keeping for detailed modeling assumptions, load calculation methods, and structural response interpretation. This research project requires a complete study that will produce accurate load models, response evaluation techniques, and performance assessment methods for G+4 residential buildings that use STAAD.Pro (Table 1).

Summary of Literature Reviews

The literature reviewed reveals a wide-ranging application of STAAD.Pro in the analysis and design of low-to-mid-rise reinforced concrete buildings, especially G+4 and G+5 structures.

Table 1. Comparative analysis.

S.N.	Authors and year	Building type/height	Type of analysis	Key observations
1	Prajakta Hepat et al., 2024	G+4 Residential	Static and Seismic (IS Codes)	Software results matched manual analysis; expert validation remains essential.
2	J.S. Parmar et al., 2023	G+5 RC Building	Response Spectrum and Time History	Bracing and ductile detailing significantly reduced drift and seismic demand.
3	Mohamed Hamud Mohamed et al., 2021	Mid-rise RC Buildings	Static and Dynamic	STAAD and ETABS yield similar results with consistent modeling.
4	Bandipati Anup et al., 2019	G+4 RC Frame	Static Analysis	3-D modeling captures torsion ignored in 2-D frames.
5	Y. Ahmad et al., 2023	4-Storey RC Building	Seismic with Bracing	X-bracing reduced lateral displacement and column demand.
6	Malarande et al., 2020	Multi-storey RC Building	Seismic Zone Comparison	Higher seismic zones increase base shear and steel requirements.
7	Abdiaziz Yasin Isse et al., 2021	Multi-storey Buildings	Static and Seismic	Diaphragm assumptions and slab meshing strongly influence results.
8	Rahul Kewlan et al., 2022	G+4 Commercial Building	Static and Serviceability	Live load and deflection govern design in commercial buildings.
9	Adhiraj A. Wadekar et al., 2022	Multi-storey Buildings	Static and Dynamic	Torsional irregularity and diaphragm flexibility affect lateral response.
10	Kundan Kulbhushan et al., 2019	Multi-storey RC Building	Dynamic (ETABS versus STAAD)	Both software reliable when modeling assumptions are consistent.
11	Viswanath et al., 2023	RC Buildings with Bracing	Seismic Retrofit	Bracing improves stiffness but requires careful connection detailing.
12	Aquib Zafar Ansari et al., 2024	Tall RC Buildings	Dynamic and SSI	Higher-mode effects and P-Delta are crucial for tall buildings.

Most scientific investigations affirm that STAAD.Pro is reliable with respect to the calculation of bending moments, shear forces, deflections, and member forces, provided that the modeling conditions and load combinations are in accordance with the Indian Standard Codes. Comparative studies indicate that there is a close relationship between software-based and manual calculations, which underscores the need to verify the loading on critical members. The three-dimensional representation is a useful tool whereby the silhouette of the structure, which is made up in a two-dimensional analysis, becomes a significant problem. Specific studies reveal that with the help of ductile detailing and the adoption of bracing or shear walls, one can attain a substantial reduction in lateral displacement and story drift. In addition, STAAD.Pro to ETABS comparisons show equal precision among the software when consistent modeling parameters are applied. In conclusion, the literature repeatedly asserts that the application of software in structural analysis not only increases the precision and speed of the process but also leads to a reduction in the overall cost, while professional consideration remains the major factor in the design to ensure safety and compliance with the building code.

CONCLUSION

The analysis of various research studies on multi-story residential and commercial building analysis and design shows that STAAD.Pro and structural analysis and ETABS software tools provide the most accurate structural modeling and analysis, and design capabilities. The same calculation and Indian Standard compliance were the methods of reporting researchers for these tools, as they calculated shear forces, bending moments, deflections, and reinforcement requirements with great diligence. The mid-rise buildings G+4 and G+5 and the high-rise building G+19 underwent analysis, which included dead and live, and wind and seismic loads, to demonstrate that the structural components met the safety and operational requirements. Several studies mentioned the beneficial integration of software analysis and manual calculations, which improved accuracy, reduced human error, and saved time; however, architects and engineers were tied to building codes and functional planning. The research evidence showed that software-assisted design validation for multi-story building projects functioned as both an effective method and a speedier solution.

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