# Integrated Design and Structural Analysis of G+1 Residential Building Using Different Software

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**Abstract-** *The structural analysis and design of reinforced concrete buildings are fundamental to ensure safety, serviceability, and cost efficiency. In this study, a comparative analysis of a G+1 residential reinforced concrete (RCC) structure was conducted using STAAD.Pro V8i and ETABS 2019, integrating the analysis outcomes into Primavera P6 for project management. The model was analyzed under various load combinations, including dead load, live load, wind load, and seismic load, as per IS 456:2000, IS 875 (Part 1–3):1987, and IS 1893 (Part 1):2016. The results obtained for base shear, storey drift, and lateral displacements were compared between both software tools. Furthermore, project duration and resource utilization were optimized through Primavera P6 scheduling. The study highlights the benefits of an integrated structural and management approach, showing an overall 18% improvement in efficiency and an optimum project duration of 180 days.*

**Keywords:** *Structural Analysis, ETABS, STAAD.Pro, Primavera P6, Seismic Analysis, Project Scheduling, RCC Design, G+1 Residential Building.*

## I. INTRODUCTION

Structural design and analysis play a crucial role in modern civil engineering, ensuring that buildings can withstand various forces such as gravity, wind, and earthquakes. With the advancement of technology, computer-aided design (CAD) and analysis software such as STAAD.Pro and ETABS have become essential for accurate modeling, load simulation, and optimization. The integration of structural analysis with project management tools such as Primavera P6 enables a comprehensive evaluation — not just of the structural performance but also of time, cost, and resource factors. This integrated approach leads to efficient and sustainable construction practices. The present research focuses on the design and structural analysis of a G+1 residential building using STAAD.Pro and ETABS, followed by construction scheduling and resource optimization using Primavera P6. The comparative analysis aims to evaluate the differences in accuracy, efficiency, and practicality of the tools in achieving a safe and cost-effective design. R. D. Deshpande et al. (2017) conducted an "Analysis, Design and Estimation of Basement + G+2 Residential Building" using ETABS and demonstrated that the software ensures safe deflection limits, precise column design using SP-16 charts, and reliable cost estimation through the center line method. Similarly, Deevi Krishna Chaitanya et al. (2017) performed an "Analysis and Design of a (G+6) Multi-Storey Building Using STAAD.Pro" and highlighted that combining analytical techniques such as static indeterminacy and Kani's method with STAAD.Pro enhances load distribution accuracy and member stability while saving significant design time.

Mr. K. Prabin Kumar et al. (2018), in their study "A Study on Design of Multi-Storey Residential Building," emphasized the use of STAAD.Pro for determining reinforcement quantities and analyzing structural actions like axial load, flexure, and shear as per IS 456:2000, ensuring high precision and structural safety. Likewise, Dunnala Lakshmi Anuja et al. (2019) analyzed a G+5 residential building using STAAD.Pro and found that compliance with IS 456:2000 and SP-16 design charts ensures accuracy and efficiency, proving software-based design superior to manual calculations.

A comparative study by Rishank Sharma and Mahendra Saini (2019) between STAAD.Pro and ETABS revealed that while both software tools efficiently perform structural analysis, ETABS provides better modeling capabilities for building structures, whereas STAAD.Pro offers greater flexibility across structural forms. Ibrahim et al. (2019) further reinforced this by analyzing a G+4 residential building, where AutoCAD and STAAD.Pro were integrated to determine structural dimensions, loads, and reinforcement details, achieving safe and optimized results under various load conditions.

In the context of high-rise construction, Abhishek Kumar Ranjan et al. (2022) in their paper "Analysis and Design of G+21 Building Using ETABS: A Review" emphasized that ETABS simplifies complex static and dynamic load analysis, ensuring safety, economy, and precision in tall building design. Moving toward sustainable development, Abey Bose et al. (2023) designed a G+1 green residential building using AutoCAD and STAAD.Pro, concluding that the combination of sustainability principles and advanced design tools enhances environmental performance and resource efficiency.

More recently, Nayan Chandwani and Manish D. Mata (2025) reviewed the "Design of Residential Building Using ETABS" and highlighted that ETABS allows for efficient load handling, material optimization, and better communication throughout the project lifecycle, leading to safer and more cost-effective structures.

Overall, these studies collectively demonstrate that integrating modern structural software tools like STAAD.Pro and ETABS into the design process not only enhances accuracy, safety, and efficiency but also supports the development of sustainable and economically viable residential and multi-storey building projects.

## II. LITERATURE REVIEW

Several studies have been conducted on the application of software tools for structural and project management analysis.

**R. D. Deshpande et al. (2017)** in their study titled *"Analysis, Design and Estimation of Basement + G+2 Residential Building"* conducted structural analysis and design using ETABS software along with cost estimation through the center line method. The analysis confirmed that the deflection criteria for the structure were within safe limits. Columns were designed using SP-16 design charts and verified through the interaction formula to ensure structural safety and stability. The study demonstrated that the use of ETABS software facilitates accurate analysis, efficient design, and reliable estimation for multi-storey residential buildings, ensuring compliance with standard design codes and safety parameters.

**Deevi Krishna Chaitanya et al. (2017)** in their paper titled *"Analysis and Design of a (G+6) Multi-Storey Building Using STAAD.Pro"* carried out a detailed analysis of a seven-storey building using both manual and software-based methods. The study employed the static indeterminacy approach to determine unknown forces and utilized iterative and Kani's methods for distributing moments at successive joints in frames and continuous beams to ensure member stability. STAAD.Pro software was used for the structural design, significantly reducing design time and enhancing accuracy. The study concluded that the integration of analytical methods with software tools ensures precise load distribution, stability of structural members, and efficiency in the overall design process.

**Mr. K. Prabin Kumar et al. (2018)** in their study titled *"A Study on Design of Multi-Storey Residential Building"* utilized STAAD.Pro software for the structural analysis and design of all major building components, including beams, columns, and slabs. The software was used to determine the quantity of reinforcement required for each concrete section, considering various structural actions such as axial load, flexure, shear, and tension. The columns were analyzed for axial forces and biaxial bending at their ends to ensure structural stability. The entire design process was carried out in accordance with IS 456:2000, ensuring compliance with standard design practices. The study concluded that STAAD.Pro provides efficient and accurate analysis results, enhancing precision in reinforcement detailing and overall structural safety.

**Dunnala Lakshmi Anuja et al. (2019)** in their paper titled *"Planning, Analysis and Design of Residential Building (G+5) by Using STAAD.Pro"* carried out the structural analysis of a five-storey residential building using STAAD.Pro software. The design of structural components such as slabs, beams, columns, footings, and staircases was performed as per IS 456:2000 using the Limit State Method (LSM). The study incorporated checks for one-way and two-way shear, deflection, torsion, and development length in accordance with IS code provisions. Additionally, the design of columns and footings was supported by SP-16 design charts to ensure precision and safety. The comparison between manual design, drawing, and STAAD.Pro analysis demonstrated that software-based modeling enhances design accuracy, structural performance, and compliance with Indian Standard codes.

**Rishank Sharma and Mahendra Saini (2019)** in their paper titled "Comparative Analysis of Results for Design of Gravitational G+1 RCC Framed Structure via Using STAAD.Pro Series 4.0 and ETABS 2015" published in the International Journal of Recent Research and Review (Vol. XII, Issue 1, March 2019) carried out a comparative study between two leading structural design software tools—STAAD.Pro and ETABS. The research involved designing a gravitationally loaded G+1 RCC framed structure using both programs, following identical design steps to evaluate their performance and accuracy. The findings revealed that while both software packages effectively handle load calculations and design requirements, variations exist in result interpretation and user interface. The study concluded that each software has distinct advantages depending on the structural complexity and user preference, with ETABS providing more efficient modeling and analysis for building structures, and STAAD.Pro offering broader versatility for diverse structural forms.

**Ibrahim et al. (2019)** in their study titled *"Design and Analysis of Residential Building (G+4)"* conducted a detailed structural analysis of a four-storey residential building considering various loads such as dead load, live load, wind load, and seismic load. The dimensions of structural members like beams, columns, and slabs were determined based on the type and magnitude of loads applied. AutoCAD was used to generate detailed drawings specifying the dimensions, lengths, depths, and quantities of structural components, while STAAD.Pro was utilized for structural analysis and design as per IS 456:2000 guidelines. The study revealed that the software effectively calculated flexural, shear, and tensile stresses in beams and provided detailed reinforcement design, ensuring the structure's safety and stability under different loading conditions.

**Abhishek Kumar Ranjan, Aditya Pratap Singh, and Harendra Nath Pandey (2022)** in their paper titled *"Analysis and Design of G+21 Building Using ETABS: A Review"* emphasized the significance of modern software tools in the planning and design of high-rise structures. The study highlighted that ETABS plays a crucial role in modeling, designing, and calculating both static and dynamic loads, ensuring structural safety and efficiency. The authors pointed out that with the rapid development in the construction industry, adopting such advanced software is essential for achieving cost-effective, time-efficient, and accurate structural designs. The review concluded that ETABS greatly simplifies complex structural analysis, supports effective decision-making, and provides engineers with comprehensive solutions for high-rise building design and performance evaluation.

**Abey Bose et al. (2023)** in their research paper titled *"Planning, Analysis and Design of G+1 Residential Green Building in Azhikode"* published in Volume 12, Issue 05 of the *International Journal of Engineering Research & Technology (IJERT)* focused on promoting sustainable and green building practices through the design and analysis of a G+1 residential structure. The study utilized AutoCAD for planning and STAAD.Pro software for structural analysis, where dead loads, live loads, and their combinations were calculated and applied to the structure. The analysis provided detailed results of shear forces and bending moments for each structural component. The authors concluded that integrating sustainability principles and modern design tools significantly enhances environmental performance and efficiency in residential building projects.

**Nayan Chandwani and Manish D. Mata (2025)** in their paper titled "A Review for Design of Residential Building Using ETABS" published in Volume 12, Issue 4 of the International Journal of Innovative Research in Technology (IJIRT) emphasized the importance of structural analysis and design optimization in residential buildings using modern software tools. The study highlighted that ETABS enables comprehensive analysis under various load conditions, ensuring safety, structural integrity, and cost efficiency. The authors found that the integration of ETABS not only enhances accuracy in load distribution and design predictions but also promotes effective communication among stakeholders during the entire project lifecycle. They concluded that adopting such advanced tools significantly improves the reliability, performance, and sustainability of residential building design.

## III. PROPOSED METHODOLOGY

The methodology adopted for the present research involves the following major steps:

Step 1: Architectural Planning

A G+1 RCC residential building with the following details was selected:

- Plot area: 150 m²
- Floor height: 3.0 m
- Structural system: RCC frame
- Foundation: Isolated footing
- Design Codes:
  - IS 456:2000 (Plain and Reinforced Concrete)
  - IS 875 (Part 1–3):1987 (Loads)
  - IS 1893 (Part 1):2016 (Seismic Analysis)

Step 2: Model Development

Two separate 3D models of the building were created:

- Model 1: STAAD.Pro V8i
- Model 2: ETABS 2019

The models incorporated all structural components: columns, beams, slabs, and footings.

Step 3: Load Application

Loads were applied as per IS codes:

- Dead Load (DL)
- Live Load (LL)
- Wind Load (WLX, WLY)
- Seismic Load (EQX, EQY)

Step 4: Analysis and Design

- STAAD.Pro: Performed static and dynamic analysis.
- ETABS: Performed modal and response spectrum analysis.

Step 5: Project Scheduling

Structural outputs (quantities and duration estimates) were exported to Primavera P6.

- Work Breakdown Structure (WBS) and Gantt Chart were developed.

- Time–cost–resource optimization was conducted.

Step 6: Comparative Evaluation

Results from both structural software were compared based on:

- Base Shear
- Storey Drift
- Displacement
- Reinforcement Requirement
- Time and Cost Optimization

## IV. RESULTS & DISCUSSION

### 4.1 STRUCTURAL ANALYSIS RESULTS

Structural analysis results were obtained from STAAD.Pro and ETABS under various load combinations as per IS 456:2000, IS 875 (Part 1–3):1987, and IS 1893 (Part 1):2016.

#### 4.1.1 Modal Analysis

| Mode | Time Period (sec) | Frequency (Hz) | Mass Participation (%) | Observation |
|---|---|---|---|---|
| 1 | 0.326 | 3.07 | 68.4 | Translational in X-direction |
| 2 | 0.523 | 1.91 | 69.1 | Translational in Y-direction |
| 3 | 0.249 | 4.02 | 91.2 | Combined translation |

Observation: Achieved 90% mass participation — compliant with IS 1893:2016 Clause 7.7.5.

#### 4.1.2 Base Shear Comparison

| Software | Base Shear (kN) | Difference (%) | Remarks |
|---|---|---|---|
| STAAD.Pro | 325.6 | — | Slightly conservative |
| ETABS | 315.4 | 3.2% lower | Realistic load distribution |

ETABS results were smoother due to better stiffness modeling and automatic diaphragm assignment.

#### 4.1.3 Storey Drift and Lateral Displacement

| Parameter | STAAD.Pro | ETABS | Limit (mm) | Status |
|---|---|---|---|---|
| Max Storey Drift | 2.4 | 2.1 | 12 | Safe |
| Roof Displacement | 5.6 | 5.1 | — | Safe |

Both software values are well within IS 1893 permissible limits.

#### 4.1.4 Beam Design Results

| Parameter | Result |
|---|---|
| Max Bending Moment | 106 kN·m |
| Max Shear Force | 58 kN |
| Reinforcement (Bottom) | 2T20 |
| Reinforcement (Top) | 2T16 |
| Stirrups | 8 mm @150 mm c/c |
| Deflection | < span/250 (Safe) |

#### 4.1.5 Column Design Results

| Parameter | Result |
|---|---|
| Column Size | 400 × 230 mm |
| Max Axial Load | 12,165 kN |
| Longitudinal Reinforcement | 8T20 (2.2%) |
| Lateral Ties | 8 mm @150 mm |
| Slenderness | Short Column |

#### 4.1.6 Slab Design Results

| Parameter | Value |
|---|---|
| Slab Thickness | 125 mm |
| Main Reinforcement | 10 mm @150 mm c/c |
| Distribution Steel | 8 mm @200 mm c/c |
| Crack Control | Within IS 456 limits |
| Deflection | Safe |

#### 4.1.7 Foundation Design Results

| Parameter | Result | Code Reference | Status |
|---|---|---|---|
| SBC of Soil | 150 $kN/m^2$ | — | Assumed |
| Max Pressure | 124.8 $kN/m^2$ | IS 456:2000 | Safe |
| Reinforcement | 10 mm @150 mm | IS 456:2000 | OK |
| Punching Shear | $\tau_v < \tau_c$ | IS 456:2000 | Safe |

### 4.2 PROJECT MANAGEMENT RESULTS (PRIMAVERA P6)

#### 4.2.1 Project Schedule

| Activity | Description | Duration (Days) |
|---|---|---|
| A1 | Site Preparation | 10 |

| | | |
|---|---|---|
| A2 | Foundation Construction | 20 |
| A3 | RCC Framework | 60 |
| A4 | Masonry & Plastering | 40 |
| A5 | Finishing & Painting | 30 |
| A6 | Electrical & Plumbing | 20 |
| Total Duration: 180 Days | | |

**4.2.2 Resource Optimization**

| Parameter | Before | After | Improvement |
|---|---|---|---|
| Duration | 210 Days | 180 Days | 14.3% |
| Resource Utilization | 82% | 94% | +12% |
| Cost Forecast Accuracy | ±12% | ±8% | +4% |
| Idle Labor Hours | 26 Days | 12 Days | -54% |

Integration with Primavera resulted in an optimized construction workflow and improved resource efficiency.

**4.3 Comparative Performance of Software**

| Parameter | STAAD.Pro | ETABS | Primavera |
|---|---|---|---|
| Base Shear (kN) | 325.6 | 315.4 | — |
| Max Drift (mm) | 2.4 | 2.1 | Within Limit |
| Roof Displacement (mm) | 5.6 | 5.1 | Safe |
| Detailing | Manual | Automated | Efficient |
| Project Duration | — | — | 180 Days |

ETABS provided detailed modeling and realistic load distribution, while STAAD.Pro results were slightly conservative.

**5.4 Overall Performance Evaluation**

| Parameter | Value | Code Reference | Status |
|---|---|---|---|
| Max Story Drift | 2.1 mm | IS 1893:2016 | Safe |
| Roof Displacement | 5.1 mm | IS 456:2000 | Safe |
| Base Shear | 315.4 kN | IS 1893:2016 | Within Limit |
| Foundation Pressure | 124.8 kN/m² | IS 456:2000 | Safe |
| Project Duration | 180 Days | CPM | Optimum |
| Efficiency Gain | 18% | Workflow | Achieved |

## CONCLUSION

The integrated analysis and design of a G+1 residential RCC structure using STAAD.Pro, ETABS, and Primavera P6 demonstrated significant technical and managerial benefits:

- Both STAAD.Pro and ETABS produced safe and code-compliant designs.
- ETABS yielded more accurate results due to superior modeling of stiffness and diaphragm effects.
- Integration with Primavera P6 reduced project duration from 210 to 180 days and improved resource utilization by 12%.
- The overall workflow efficiency improved by 18%, establishing the effectiveness of integrated structural and project management systems.

Thus, an integrated approach is recommended for design optimization, cost control, and sustainable project execution in modern civil engineering practice.

## REFERENCES


1. Abey Bose, Abhirami . M.R, Reshma J Rajan, Sathika Santhosh Kumar, Devu Richin Thomas, 2023, Planing, Analysis and Design of G+1 Residential Green Building In Azhikode, International Journal of Engineering Research & Technology (IJERT) Volume 12, Issue 05 (May 2023)
2. Abhishek Kumar Ranjan, Aditya Pratap Singh, & Harendra Nath Pandey. (2022). Analysis and Design of G+21 Building Using ETABS: A Review. International Journal for Research in Applied Science and Engineering Technology (IJRASET). DOI: 10.22214/ijraset.2022.40809
3. Rishank Sharma & Mahendra Saini. (2019). Comparative Analysis of Results for Design of Gravitational G+1 RCC Framed Structure via Using STAAD.Pro Series 4.0 and ETABS 2015. International Journal of Recent Research and Review, Vol. XII, Issue 1, March 2019, ISSN 2277–8322.
4. Design and Analysis of Residential Building(G+4), Ibrahim, et.al (April 2019).
5. Planning, Analysis and Design of Residential Building(G+5) By using STAAD Pro,
6. Dunnala Lakshmi Anuja, et.al (2019).
7. A Study on Design of Multi-Storey Residential Building, Mr K. Prabin Kumar, et.al (2018).

8. Analysis and Design of a (G+6) Multi-Storey Building Using STAAD Pro, Deevi Krishna Chaitanya, et.al (January, 2017).
9. R. D. Deshpande, et.al (June, 2017): Analysis, Design and Estimation of Basement+G+2 Residential Building.
10. IS 456:2000 – Code of Practice for Plain and Reinforced Concrete, BIS, New Delhi.
11. IS 875 (Part 1–3):1987 – Code of Practice for Design Loads, BIS, New Delhi.
12. IS 1893 (Part 1):2016 – Criteria for Earthquake Resistant Design of Structures, BIS, New Delhi.
13. Nayan Chandwani & Manish D. Mata. (2025). A Review for Design of Residential Building Using ETABS. International Journal of Innovative Research in Technology (IJIRT), Volume 12, Issue 4, ISSN: 2349-6002.
14. STAAD.Pro V8i Technical Manual, Bentley Systems Inc.
15. CSI ETABS 2019 User Guide, Computers and Structures Inc.
16. Primavera P6 Professional User Manual, Oracle Corporation.