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Reinforcement Design and Seismic Response Analysis: A Comparison of STAAD Pro and ETABS

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Abstract:- This study looked at the design and seismic performance of a G+6 multistory residential building using STAAD Pro and ETABS software. The design and analysis followed the Indian Standard Codes and Practices for a building measuring 40×60 ft, divided into 20 segments. The analysis included dead, live, wind, and seismic loads, and the structure was tested under each condition. Key modeling assumptions for this study included using standard concrete and steel material properties, such as M25 grade concrete and Fe415 grade steel, fixed boundary conditions at the base, and load combinations according to Indian Standard provisions IS 456:2000 and IS 1893:2016. The results showed that ETABS usually indicated a larger reinforcement area for the columns than STAAD Pro, but the required reinforcement area was smaller for ETABS. For beams, ETABS provided more cost-effective options due to its flexibility in bar size and quantity. The study also noted that STAAD Pro could not automatically design slab reinforcements according to Indian standards. Seismic response analyses were carried out, including base shear, story drift, and displacement. These findings reveal the differences in precision between the software and the need for accuracy and efficiency. A detailed review of the design and seismic performance of multi-story buildings uncovered several strategies and factors that are important for improving resilience in earthquake-prone areas.
Keywords: *Design Process, ETABS, Load Applications, Seismic Response, STAAD Pro, Structural Analysis*

1. Introduction

A critical review of the design and seismic performance of multistory buildings explores the methods and frameworks used in seismic design, particularly focusing on performance-based design approaches. Performance-based seismic design (PBD) has emerged as a crucial method for assessing and enhancing the structural integrity and resilience of multistory buildings against seismic events. This allows for a rationalized analysis of how buildings respond to seismic forces, moving beyond traditional prescriptive codes [1]. Studies emphasize the importance of integrating multiple seismic performance measures, including expected annual loss and collapse safety, into the design process to ensure not only life safety but also economic considerations [2]. Recent advancements suggest a shift towards more comprehensive methodologies that incorporate probabilistic approaches to evaluate the seismic fragility of multi-story structures. For example, cross-laminated timber coupled wall systems have been assessed using probabilistic seismic fragility assessments, highlighting the variability in seismic performance owing to design parameters [3]. Lessons learned from past earthquakes, such as the Wenchuan Earthquake, have underscored the importance of strictly adhering to seismic design codes and principles to meet performance objectives under different seismic intensities [4]. Additionally, post-earthquake decision-making frameworks are critical for assessing and planning the reoccupancy of buildings by evaluating their performance using instrumented data and probabilistic risk assessments [5]. Incorporating such comprehensive evaluations into the seismic design of multi-story buildings is pivotal for improving resilience, ensuring safety, and optimizing performance against earthquake-induced damages. These methodologies offer valuable insights and suggest improvements for future designs, aiding engineers and researchers in developing seismic-resilient structures [6]. A construction frame comprises of several stories and bays. A complex, statically transient plan is a multistory, multioutlined package. A G+6 story frame was used for the R.C. working arrangement. Parts of the design in progress were developed to establish an association. The building is 40 × 60 feet in dimension. There were 20 segments. It is a three-bedroom private building.

2. Literature Review

Mr. S. Mahesh et al. (2014) studied the behavior of a G+11 multi-story building with regular and irregular designs during earthquakes. Wind loads were assumed to act simultaneously with earthquake loads. This paper examines a G+11 multi-story building for both earthquake and wind loads using ETABS and STAAD Pro V8i. The material properties are assumed to be linear, and both static and dynamic analyses are conducted. These analyses consider different seismic zones, and for each zone, the behavior is assessed based on three soil types: Hard, Medium, and Soft. Various responses, such as story drift and base shear, are plotted for different zones and soil types.

Ramanand Shukla and Prithwish Saha (2014) conducted a comparative study of a G+10 storied building using ETABS and STAAD. In STAAD, the wind load is applied directly to the model, while in ETABS, it is applied using a diaphragm, which manages the load more effectively.

Borugadda Raju et al. (2015) designed and analyzed a G+30 multi-story building using STAAD Pro based on the limit state method. STAAD Pro features a user-friendly interface that enables users to easily input dimensions and load values. The structural elements are designed with reinforcement details for RCC frames. The analysis is done for two-dimensional frames, followed by a study of more complex multi-story 2-D and 3-D frames under various load combinations.

D. Ramya and A.V.S. Sai Kumar (2015) compared the designs from STAAD Pro and ETABS for a G+10 house. The goal of the paper is to assess the effectiveness of these two programs. They found that while STAAD Pro is generally useful, ETABS is more commonly used. The designs considered Live, Dead, and wind loads.

Aman et al. (2016) analyzed and designed a G+5 residential and commercial building based on the criteria outlined in the IS codes, using STAAD Pro software. The loads imposed were only dead and live loads, leading to a load combination of 1.5 (Dead load + Live load). The building analysis focused on the frame, examining the resulting bending moments and shear forces. The details of all building members, including the slab, beam, column, footing, and staircase, were included. The study concluded that horizontal deflections remained within 20mm, confirming that the structure was safe and economical. There was a minimal difference between the results obtained using Kani's method and STAAD Pro.

3. Materials and Methods

3.1. Research Objectives

- To assess the design and seismic performance of a G+6 multi-story residential building using STAAD Pro and ETABS software.
- To compare the reinforcement requirements for the columns and beams, as determined by STAAD Pro and ETABS software.
- To evaluate the limitations of STAAD Pro in automatically managing slab reinforcement design according to Indian standards.
- To conduct seismic response analyses, including base shear, story drift, and displacement, and to highlight differences in accuracy between the two software packages.

3.2. Building Specifications

- Location: Nepalgunj Sub-Metropolitan City, Ward no. 6, Banke, Nepal.
- Utility of Building: Private Structure, Residential (G+6, 3 BHK flats)
- Region of the site: 40 × 60 ft²

- Building Height: 24 m
- Structure Type: R.C.C. Framed Structure
- Foundation Type: Fixed Supports
- Number of flights of stairs: Seven
- Walls: Brick Masonry (140 mm thickness)

3.3. Scope of Work

The primary goal of this project is to apply the knowledge gained during the course through the design of a multistory private building using STAAD software. Typically, organizations rely on experts for fundamental needs. Therefore, it is crucial to understand the features of STAAD. The process begins with STAAD Pro, which is very helpful in the later stages. STAAD Pro assists in determining the required support for each key section based on IS: 456:2000, utilizing Indian Standard Codes and Practices to maximize structural use. This program is highly accurate and saves considerable time.

3.4. Steps involved in STAAD. Pro

- Generation of Nodes
- Modelling of the Structure
- Assignment of the structural members
- Restraints
- Application of loads
- Run analysis

3.5. Steps involved in ETABS

- Generation of Grids and Stories
- Defining Material Properties
- Assigning frame properties, such as slab thickness and dimensions of beams and columns.
- Modelling of Structure
- Assigning Restraints to Supports
- Defining Load Pattern (Load Cases)
- Apply load acting on the structure.
- Applying Load Combinations
- Run Analysis

3.6. Load Applications

Various loads can affect the structure.

- Dead load
- Live Load
- Wind Load
- Seismic Load

In STAAD Pro, there is an option called self-weight that automatically calculates the self-weight of members. All loads were calculated according to Indian Standard Codes and assigned in STAAD Pro. After applying different loads, various load combinations were generated using STAAD Pro.

3.7. Structural Investigation of G+6 Storey Building

Generation of Grids and Stories

We open a blank model in ETABS and enter the building's framework and story measurements. A window appears where we input the building data. Fig.1 illustrates the hub creation process in ETABS.

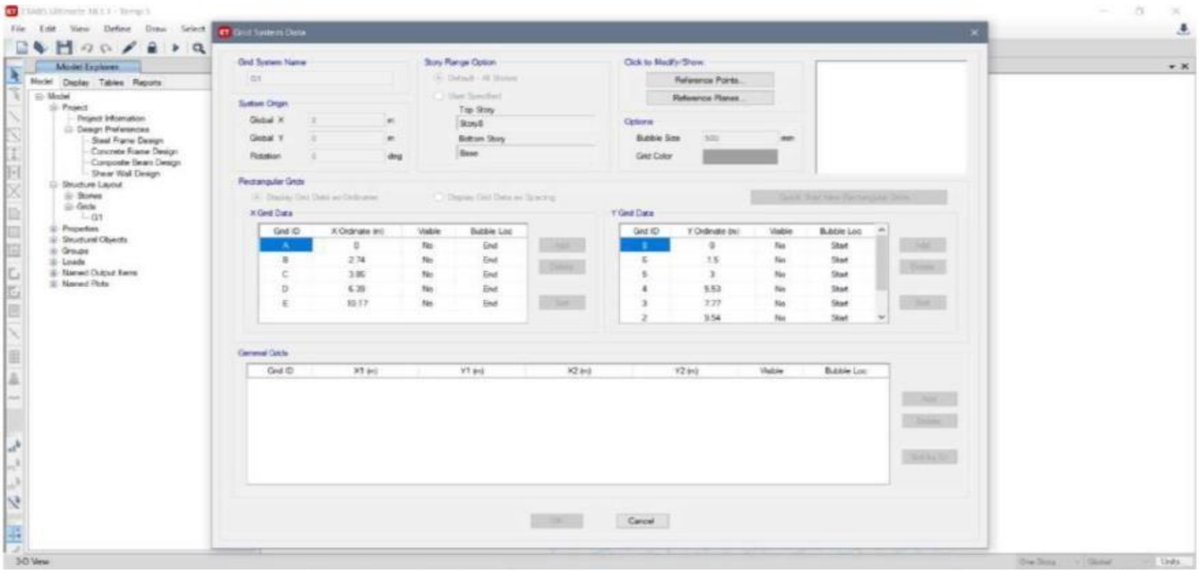

Fig. 1 Generation of Grids and Stories.

3.8. The Stack is Positioned on the Structure

All members, including columns, bars, and slabs, should have their weight and load added separately in ETABS. They must be connected properly to the structure. You can find the stack in the menu under equivalent stack cases. For dead load, we used a distributed stack with the outline stack option. For live and floor loads, we used a uniform stack with the shell stack option.

4. Results and Discussion

Table 1. Axial Force, Shear Force, and Bending Moment Values extracted from STAAD. Pro

Result extracted from STAAD. Pro			
Forces	**Dead Load**	**Live Load**	**Floor Load**
Column			
Axial Force F_X (KN)	679.9	62	27.237
Shear Force F_y (KN)	15.37	1.733	0.671
Shear Force F_z (KN)	1.531	0.051	0.070
Bending Moment M_x (KNm)	0.026	0.016	0.001
Bending Moment M_x (KNm)	1.345	0.107	0.089
Bending Moment M_x (KNm)	33.562	3.198	1.476
Beam			
Axial Force F_X (KN)	0.676	0.573	0.156
Shear Force F_y (KN)	27.076	3.507	1.301
Shear Force F_z (KN)	0.084	0.032	0.010
Bending Moment M_x (KNm)	0.064	0.096	0.034
Bending Moment M_x (KNm)	0.161	0.060	0.018
Bending Moment M_x (KNm)	18.626	2.837	1.038

Table 2. Axial Force, Shear Force, and Bending Moment Values extracted from ETABS

Result extracted from ETABS			
Forces	**Dead Load**	**Live Load**	**Floor Load**
Column			
Axial Force F_X (KN)	682	64.6306	28.1902
Shear Force F_y (KN)	14.5774	1.7012	0.6421
Shear Force F_z (KN)	10.2906	0.1	0.0944
Bending Moment M_x (KNm)	0.3075	0.0007	0.005
Bending Moment M_x (KNm)	1.7601	0.3204	0.2

Bending Moment M_x (KNm)	21.6967	1.1839	0.4565
Beam			
Axial Force F_X (KN)	0	0	0
Shear Force F_y (KN)	33.1209	3.3225	1.2361
Shear Force F_z (KN)	0	0	0
Bending Moment M_x (KNm)	0.1285	0.0899	0.032
Bending Moment M_x (KNm)	0	0	0
Bending Moment M_x (KNm)	9.401	1.8439	0.6744

Both ETABS and STAAD. Pro gave very small differences in the bending moment and shear force results. This made it hard to conclude which software is more reliable for shear force and bending moment since the differences were minimal.

Comparative study based on the Reinforcement area

Column

STAAD. Pro output indicates that we need 16 bars of 12 mm size for longitudinal reinforcement. For tie reinforcement, we should use a rectangular tie of an 8 mm bar at 190 mm center-to-center spacing. The ETABS output shows that we need 12 bars of 16 mm size for longitudinal reinforcement and a 10 mm bar at 100 mm center-to-center spacing for tie reinforcement.

Table 3. Area of reinforcement for column

Area of Steel	STAAD. Pro	ETABS
$(A_{st})_{Prpvided}$	1809 mm^2	2471 mm^2
$(A_{st})_{Required}$	1774 mm^2	1620 mm^2

Although the area of reinforcement provided in ETABS is higher than in STAAD. Pro, the required area of reinforcement is smaller in the ETABS results.

Beam

According to STAAD. Pro, we need 10 bars of 12 mm diameter on top and 3 bars of 20 mm diameter on the bottom for longitudinal reinforcement. For shear reinforcement, we should use two-legged 8 mm bars at 145 mm center-to-center spacing. ETABS results show that we need 4 bars of 14 mm and 2 bars of 16 mm diameter on the top and 4 bars of 14 mm diameter on the bottom. For shear reinforcement, we use a 10 mm bar at 150 mm spacing in Zone A and 175 mm in Zone B from center to center.

Table 4. Area of reinforcement for the beam

Area of Steel	STAAD. Pro	ETABS
$(A_{st})_{Prpvided}$ at top	1130 mm^2	1016 mm^2
$(A_{st})_{Prpvided}$ at bottom	942 mm^2	615 mm^2
$(A_{st})_{Required}$ at top	1028 mm^2	394 mm^2
$(A_{st})_{Required}$ at bottom	566 mm^2	520 mm^2

5. Conclusions

- Reinforcement design: ETABS generally suggested larger reinforcement areas for columns compared to STAAD Pro, but it required smaller areas overall. For beams, ETABS offered more cost-effective solutions because of its flexibility in selecting bar sizes and quantities.
- Software limitations: STAAD Pro could not automatically design slab reinforcements according to Indian standards, which is a significant limitation.
- Seismic analysis: The study performed detailed seismic response analyses, including evaluations of base shear, story drift, and displacement.
- Design efficiency: ETABS showed better capabilities in creating economical designs for beams and columns than STAAD Pro.

These results highlight the importance of using software tools for effective and efficient structural design and analysis, especially in areas prone to earthquakes. The comparison showed that while both software packages produced similar results for bending moments and shear forces, ETABS provided more flexibility and cost-effectiveness in reinforcement design.

The findings of this study are important for structural engineers and designers, stressing the need to choose and use software carefully to improve building performance and safety in seismic zones. Future research should look at validating these results across different building types and seismic conditions to improve the reliability and usefulness of these software tools in structural design practices.

6. Declarations

Author Contributions

V.P. and A.L. handled conceptualization and methodology. I.Y. and A.L. took care of software, validation, resources, and supervision. V.P. and I.Y. were responsible for formal analysis, investigation, and visualization. V.P. managed data curation, wrote the original draft, reviewed and edited the writing, administered the project, and acquired funding. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data will be available upon request

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Ethical Compliance

The research in this study followed ethical standards and guidelines. All experiments received the necessary ethical approval and informed consent.

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