



Engineering-Based Community Service for Urban Building Safety: Finite Element Analysis of Reinforced Concrete Frame Structures Using ETABS

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ABSTRACT

This study presents an engineering-based community service approach to support urban building safety through the application of the Finite Element Method (FEM) using ETABS software. The research focuses on the structural analysis and design of a reinforced concrete frame axis of a multi-story building in Vietnam, conducted in accordance with national structural and seismic standards. The method involves modeling the building structure, applying gravity, wind, and seismic loads, and evaluating internal forces, displacements, and reinforcement requirements to ensure structural safety and serviceability. The results indicate that the designed structural system satisfies strength and deformation criteria, contributing to safer building performance in dense urban environments. This work serves as a practical educational reference for engineering students and practitioners while supporting community-oriented objectives by enhancing public safety awareness and promoting the application of standardized structural design practices. The study highlights the role of applied engineering analysis in advancing sustainable urban development and community resilience.

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1. INTRODUCTION

Rapid urbanization in many countries, including Vietnam, has led to a growing demand for multi-story buildings in densely populated areas. Many reports regarding this matter have been well-documented (Jadhav & Shawale, 2022; Muzaffar & Ali, 2025; Anjaneyulu & Rao, 2024; Nagaraju & Ramakrishna, 2025). This condition increases the responsibility of engineers and educational institutions to ensure that building structures are not only technically adequate but also safe for the communities that use them. Structural failure in urban environments may result in severe social and economic consequences, highlighting the importance of reliable structural analysis as part of community-oriented engineering practice.

The Finite Element Method (FEM) has been widely adopted in structural engineering as an effective analytical approach for predicting the behavior of reinforced concrete structures under complex loading conditions. Software platforms such as ETABS allow engineers and students to model structural systems, apply design loads, and evaluate internal forces, displacements, and serviceability performance with a high degree of accuracy. Beyond professional practice, FEM-based analysis also plays a critical role in engineering education by bridging theoretical knowledge and real-world structural safety challenges.

In Vietnam, national design standards such as TCVN 2737, TCVN 5574, and TCVN 9386 provide essential guidelines for load determination, reinforced concrete design, and seismic considerations. However, the practical application of these standards in urban building projects requires systematic analysis and clear demonstration, particularly for educational and community service purposes. Engineering studies that document standardized design procedures can function as learning references while supporting safer construction practices within the community.

Previous studies have extensively demonstrated the effectiveness of the finite element method (FEM) and its extended variants in analyzing fracture behavior, stress distribution, and structural response in functionally graded materials (FGMs). Early foundational works established fracture mechanics concepts and numerical approaches for crack growth and stress intensity evaluation in elastic and graded materials (Raju, 1987; Erdogan & Kaya, 1985). Subsequent studies applied FEM to investigate mixed-mode fracture, crack orientation effects, and impact loading in FGMs, confirming its reliability for complex structural problems (Kim & Paulino, 2002; Ding & Li, 2013; Bai et al., 2013). Advanced developments introduced XFEM and inverse FEM techniques to address arbitrary cracks, holes, and material discontinuities with improved accuracy and computational efficiency (Bayesteh & Mohammadi, 2013; Singh et al., 2011; Dai & Xie, 2025). Recent research further expanded FEM applications to include strain energy release rate prediction, crack propagation analysis, dynamic response, and structural health monitoring in plates and mechanical systems (Nguyen, 2025a; Nguyen, 2025b; Nguyen, 2025c; Nguyen, 2025d; Nguyen, 2025e; Nguyen & Huang, 2021; Nguyen & Huang, 2022a; Nguyen & Huang, 2022b; Nguyen & Huang, 2023; Nguyen & Huang, 2025). These studies collectively highlight FEM and XFEM as robust analytical tools for evaluating structural integrity and safety, providing a strong scientific basis for applying standardized finite element analysis in engineering design, education, and community-oriented structural safety assessment.

This study aims to apply FEM-based structural analysis using ETABS to evaluate the safety and serviceability of a reinforced concrete frame axis in a multi-story building located in an urban area of Vietnam. By presenting a standardized and reproducible analysis process, this research contributes to engineering education and community service by promoting

structural safety awareness, knowledge transfer, and sustainable urban development within the ASEAN context.

2. METHODS

This study employed an applied engineering approach to support educational dissemination and community-oriented building safety assessment. The Finite Element Method (FEM) was used to analyze the reinforced concrete frame axis of a multi-story building located in an urban area of Vietnam.

The structural analysis was conducted using ETABS software. The reinforced concrete frame system was modeled with fixed boundary conditions at the foundation level. Material properties were defined according to Vietnamese standards, including concrete grade B30 and reinforcement steel types CB400-V and CB300-T.

Design loads consisted of dead and live loads, wind loads, and seismic loads. Load determination followed TCVN 2737:2023, while seismic effects were considered using the response spectrum method based on TCVN 9386:2012. Load combinations were applied to represent ultimate and serviceability limit states.

The analysis results included internal forces, structural displacements, and reinforcement demands for beams and columns. These outputs were evaluated in accordance with TCVN 5574:2018 to verify structural safety and serviceability, contributing to applied engineering education and community-focused construction safety practices.

3. RESULTS AND DISCUSSION

This section presents the results of the FEM-based structural analysis and discusses their implications for building safety, engineering education, and community-oriented construction practices. The analysis outcomes demonstrate how standardized structural evaluation contributes to safer urban environments and knowledge dissemination for practitioners and students.

3.1 Structural Modeling and Load Representation.

The reinforced concrete frame axis was modeled using ETABS to visualize the structural configuration and support the evaluation of load effects on the building system. The three-dimensional structural model is presented in **Figure 1**, illustrating the reinforced concrete frame arrangement used as a reference for safety assessment and educational demonstration.

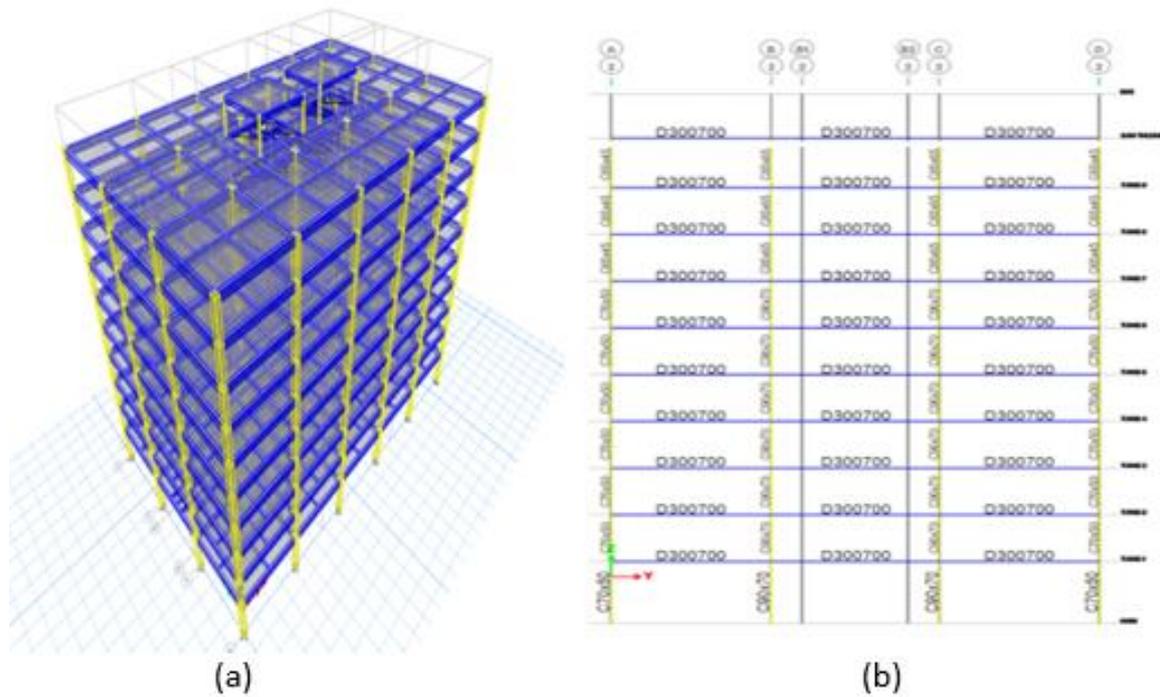


Figure 1. Structural model of the reinforced concrete frame in ETABS: (a) model and (b) calculation results.

The structural representation enabled clear identification of load paths, boundary conditions, and element connectivity. This modeling approach supports community-oriented objectives by providing a transparent framework for understanding how loads are transferred within buildings commonly used for residential and commercial purposes.

3.2 Wind and Seismic Load Effects.

Wind and seismic loads were applied in accordance with Vietnamese standards to assess lateral load resistance. The assigned wind loads in the X and Y directions are shown in **Figures 2 and 3**, respectively. These load cases represent realistic environmental actions experienced by urban buildings in Ho Chi Minh City.

Seismic effects were evaluated using the response spectrum method to reflect earthquake-induced structural behavior. The combined consideration of wind and seismic actions highlights the importance of comprehensive load assessment in community safety planning, particularly in regions exposed to multiple environmental hazards.

Number of Load Sets Loads are Reversible for Combos

Load Set 1 of 1

Story	Diaphragm	Fx kN	Fy kN	Mz kN-m	X Ordinate m	Y Ordinate m
MAI	D1	80,8	0	0	21,25	13,1
SAN THUONG	D1	85,8	0	0	21,25	13,1
TANG 9	D1	85,8	0	0	21,25	13,1
TANG 8	D1	76,9	0	0	21,25	13,1
TANG 7	D1	76,9	0	0	21,25	13,1
TANG 6	D1	76,9	0	0	21,25	13,1
TANG 5	D1	76,9	0	0	21,25	13,1
TANG 4	D1	76,9	0	0	21,25	13,1
TANG 3	D1	76,9	0	0	21,25	13,1
TANG 2	D1	76,9	0	0	21,25	13,1
TANG 1	D1	101,8	0	0	21,25	13,1

1

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Figure 2. Wind load assignment in the X direction.

Number of Load Sets Loads are Reversible for Combos

Load Set 1 of 1

Story	Diaphragm	Fx kN	Fy kN	Mz kN-m	X Ordinate m	Y Ordinate m
MAI	D1	0	130,6	0	21,35	13,1
SAN THUONG	D1	0	138,8	0	21,25	13,1
TANG 9	D1	0	138,8	0	21,25	13,1
TANG 8	D1	0	138,8	0	21,25	13,1
TANG 7	D1	0	138,8	0	21,25	13,1
TANG 6	D1	0	138,8	0	21,25	13,1
TANG 5	D1	0	138,8	0	21,25	13,1
TANG 4	D1	0	138,8	0	21,25	13,1
TANG 3	D1	0	138,8	0	21,25	13,1
TANG 2	D1	0	138,8	0	21,25	13,1
TANG 1	D1	0	183,7	0	21,25	13,1

1

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Figure 3. Wind load assignment in the Y direction.

3.3 Internal Forces and Structural Response.

The FEM analysis generated internal force distributions, including bending moments, shear forces, and axial forces in beams and columns. The bending moment envelope for the analyzed frame axis is presented in **Figure 4**, while the corresponding shear force envelope is shown in **Figure 5**.

The results indicate that critical internal forces occur at lower story levels, where axial loads and bending moments are highest due to accumulated gravity and lateral effects. These findings align with expected structural behavior and serve as an educational example for understanding force distribution in multi-story reinforced concrete frames.

To improve readability and summarize key force demands, the main internal force results are presented in **Table 1**.

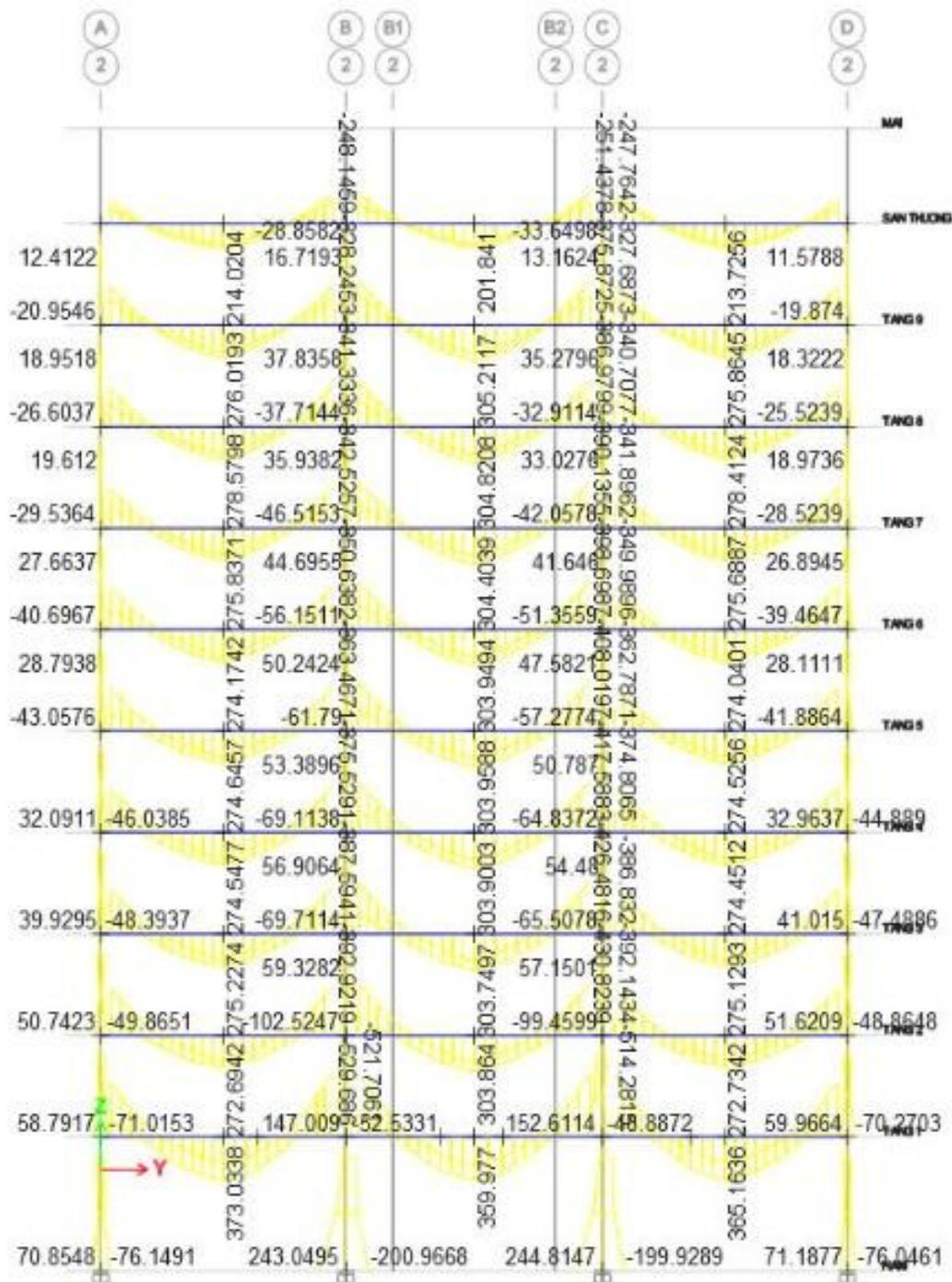


Figure 4. Bending moment envelope diagram of the frame axis.

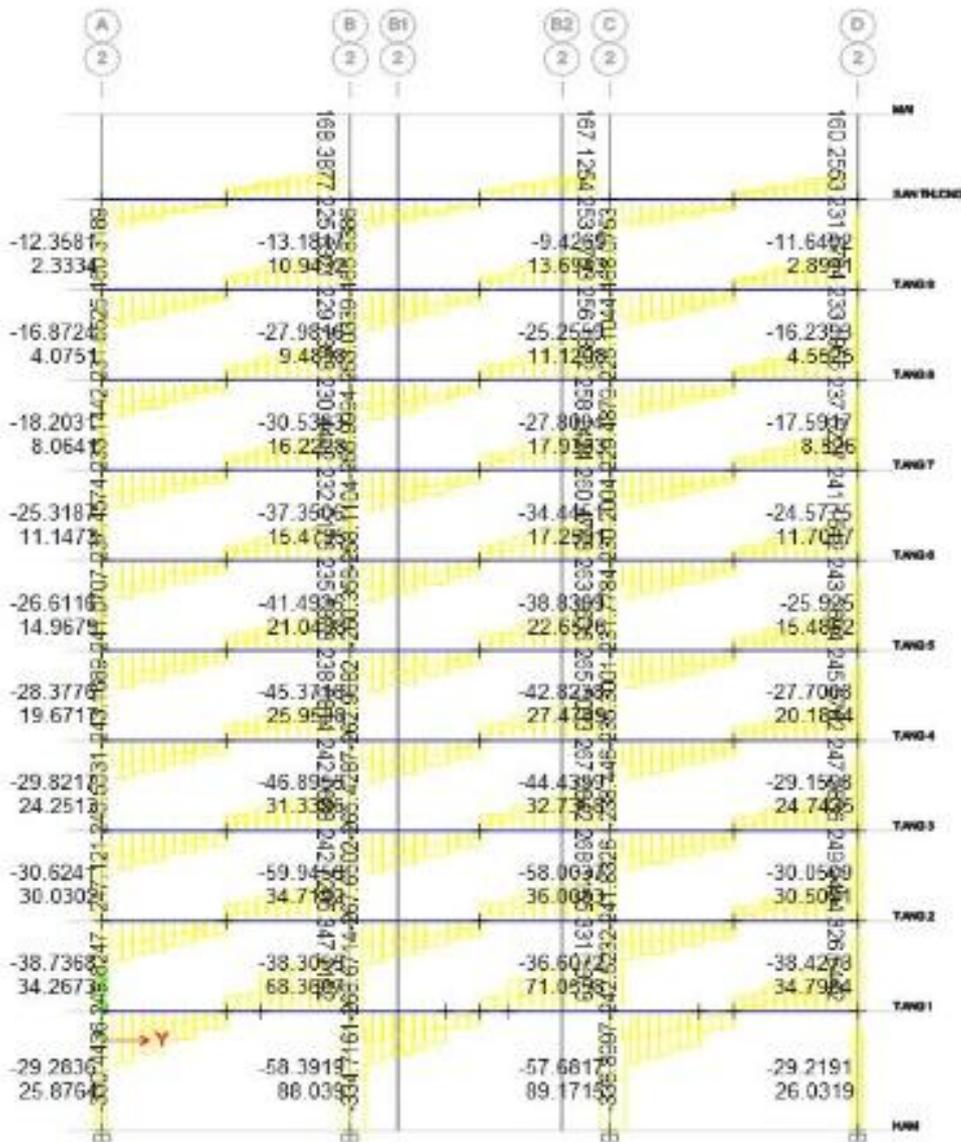


Figure 5. Shear force envelope diagram of the frame axis.

Table 1. Summary of critical internal forces in structural elements.

Structural Element	Maximum Bending Moment (kNm)	Maximum Shear Force (kN)	Maximum Axial Load (kN)
Beam (critical span)	485	349.5	-
Column (lower story)	420	310	11,400

This tabulated presentation supports both educational clarity and practical interpretation for engineers involved in community construction projects.

3.4 Displacement and Serviceability Performance.

Structural displacements and inter-story drifts were evaluated to verify serviceability performance. The maximum horizontal displacement of the building remained within the allowable limit of $h/500$, as specified by the applicable design standards. This compliance confirms that the structure provides acceptable comfort and safety levels for occupants.

The displacement results demonstrate the effectiveness of FEM-based analysis in identifying potential serviceability issues at the design stage. From a community service perspective, ensuring controlled structural movement is essential for preventing non-structural damage and maintaining building usability during extreme environmental events.

A summary of serviceability performance is provided in **Table 2**.

Table 2. Serviceability evaluation results.

Parameter	Calculated Value	Allowable Limit	Status
Maximum horizontal displacement	Within $h/500$	$h/500$	Satisfactory
Inter-story drift	Below limit	Code limit	Satisfactory

3.5 Reinforcement Requirements and Structural Safety.

Based on the internal force results, reinforcement requirements for beams and columns were determined following TCVN 5574:2018. Beam reinforcement was designed to resist maximum bending moments and shear forces, while column reinforcement accounted for combined axial load and biaxial bending conditions.

The reinforcement ratios for columns ranged between 1.2% and 2.2%, satisfying code requirements for strength and ductility. These results demonstrate that the structural system achieves an appropriate balance between safety and constructability, which is particularly relevant for community-based building projects with economic and material constraints.

3.6 Educational and Community Service Implications.

Beyond technical verification, the results highlight the value of FEM-based structural analysis as an educational and community service tool. The use of ETABS provides a practical learning platform for engineering students to understand real-world structural behavior, while the documented analysis process serves as a reference for local practitioners.

By demonstrating compliance with national standards and acceptable performance under combined loads, this study contributes to public safety awareness and supports sustainable urban development. The findings emphasize how applied engineering analysis can bridge academic knowledge and community needs, reinforcing the role of engineering education in enhancing resilience and safety within ASEAN urban environments.

4. CONCLUSION

This study demonstrated the application of the Finite Element Method using ETABS as an effective engineering-based approach to support building safety, education, and community-oriented construction practices. The structural analysis confirmed that the reinforced concrete frame satisfied strength and serviceability requirements under gravity, wind, and seismic loads in accordance with Vietnamese standards. The results highlight the importance of standardized structural evaluation in ensuring safer urban buildings for community use. In addition to technical verification, the study contributes to engineering education by providing a practical reference for FEM-based analysis and design. Overall, the findings support the role

of applied engineering knowledge in promoting public safety, sustainable urban development, and community resilience within the ASEAN context.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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