World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(Research Article)

Check for updates

A Comparative Study of the ACI Coefficients Method and the Finite Element Method in Reinforced Concrete Beam Analysis

Fathi M Layas [1] and Vail Karakale [2,*]

[1] *Department of Civil Engineering, Faculty of Engineering, University of Benghazi, Benghazi Libya.*
[2] *Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Istanbul Medeniyet University, Istanbul Turkey.*

World Journal of Advanced Engineering Technology and Sciences, 2025, 17(01), 018-027

Publication history: Received on 21 August 2025; revised on 28 September 2025; accepted on 01 October 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.17.1.1376

Abstract

This paper presents a comparative study between the approximate analysis using the ACI coefficients method and the finite element method for reinforced concrete beams. The investigation focuses on the influence of slab openings and irregular loading conditions. While the ACI coefficients method proves effective for preliminary design, it tends to be overly conservative, particularly in cases involving complex load patterns or irregular slab configurations.

Keywords: ACI moment coefficients; RC beams; RC slabs; Approximate analysis

1. Introduction

Structural analysis is a critical component in the design and evaluation of reinforced concrete beams, ensuring their safety, stability, and serviceability under different loading conditions. The accuracy of structural analysis directly affects performance, durability, and cost-efficiency, making the choice of the appropriate analytical method essential.

This study presents a comparative analysis of reinforced concrete beams using two different methods:

1.1. ACI Code Coefficients Method

This method is based on standardized empirical coefficients provided by the American Concrete Institute (ACI) Code, offering a simplified approach to structural analysis [1,2,3]. It is widely used for preliminary design to determine bending moments, shear forces, and deflections. However, since it relies on predefined coefficients and idealized conditions, it may not fully capture the effects of non-uniform loading, slab openings, or complex boundary conditions as shown in Fig1[4,5].

*Corresponding author: Vail Karakale. Email: vail.karakale@medeniyet.edu.tr

Figure 1 RC slabs with openings

1.2. Finite Element Method (FEM)

The Finite Element Method (FEM) is a numerical analysis technique that divides the beams and slabs into smaller elements and solves for internal stresses, deformations, and load distributions. Unlike the ACI Coefficients Method, FEM provides a more detailed and precise analysis, accounting for actual material behavior, support conditions, and structural irregularities. It is especially useful for modeling complex slab configurations, including slabs with openings, asymmetrical loading, and varying support conditions.

2. Objective and Significance of the Study

The primary goal of this study is to compare the accuracy and limitations of the ACI Coefficients Method with the Finite Element Analysis (FEA) in evaluating one-way slab systems. Specifically, the study focuses on:

Identifying discrepancies in moment distribution and consequently stress variations between the two methods. Assessing the effectiveness of the ACI method in predicting structural response under different conditions. Demonstrating the advantages of FEM for more irregular slab loading and configuration where the ACI method may be insufficient.

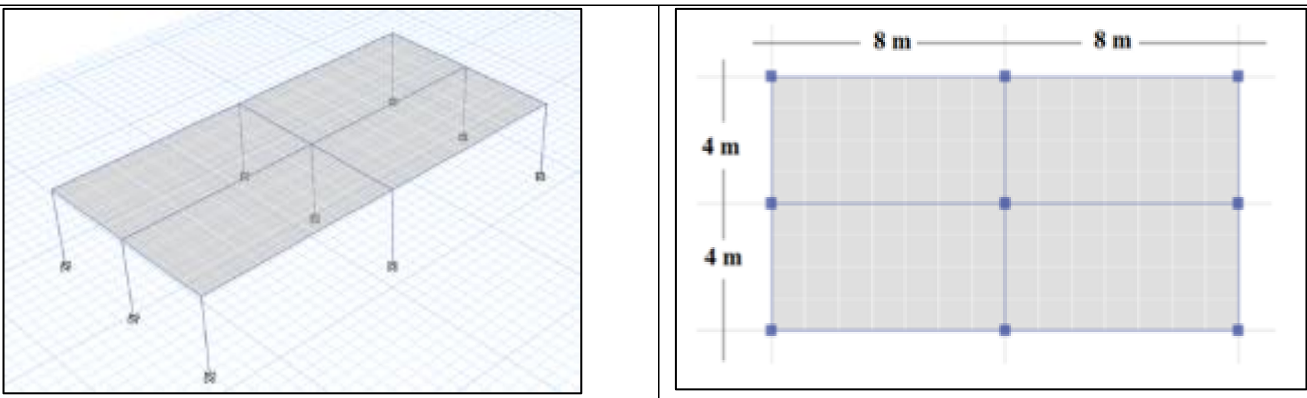
By comparing these approaches, this research provides valuable insights into:

The applicability and accuracy of the ACI Coefficients Method. The benefits of FEM in capturing real-world structural behavior. Potential limitations of relying solely on the ACI method for complex designs.

The findings contribute to better structural design decision-making, ensuring safer, more efficient, and optimized reinforced concrete slab systems.

3. Case Study Description

To conduct this comparison, a two-span solid slab system with dimensions 8 m × 4 m is analyzed using ETABS software [6]. The slab is supported by reinforced concrete beams with a 0.4 m × 0.5 m cross-section, which transfer loads to 0.4 m × 0.4 m columns, providing vertical support to the structure. The structural configuration is illustrated in Fig 2.



All columns 40 cm x 40 cm

All beams 40 cm x 50 cm

All slabs 20 cm thick

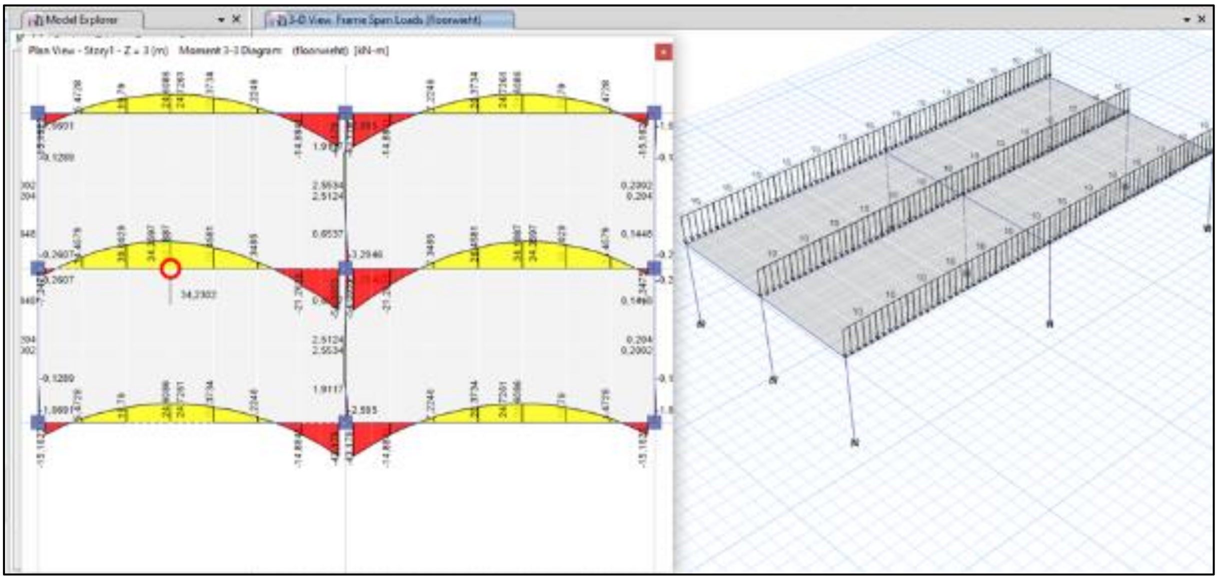
Figure 2 Finite element model

4. Structural Analysis

The structural behavior of the beam is examined under the effect of 10 kN/m uniformly distributed load with four different conditions, reflecting the following four realistic design cases:

4.1. Beams with Regular Uniform Load and Solid Slab

A standard design scenario where loads are evenly distributed across the slab, enabling a direct comparison between the two methods. The FEM results are shown in Fig 3.



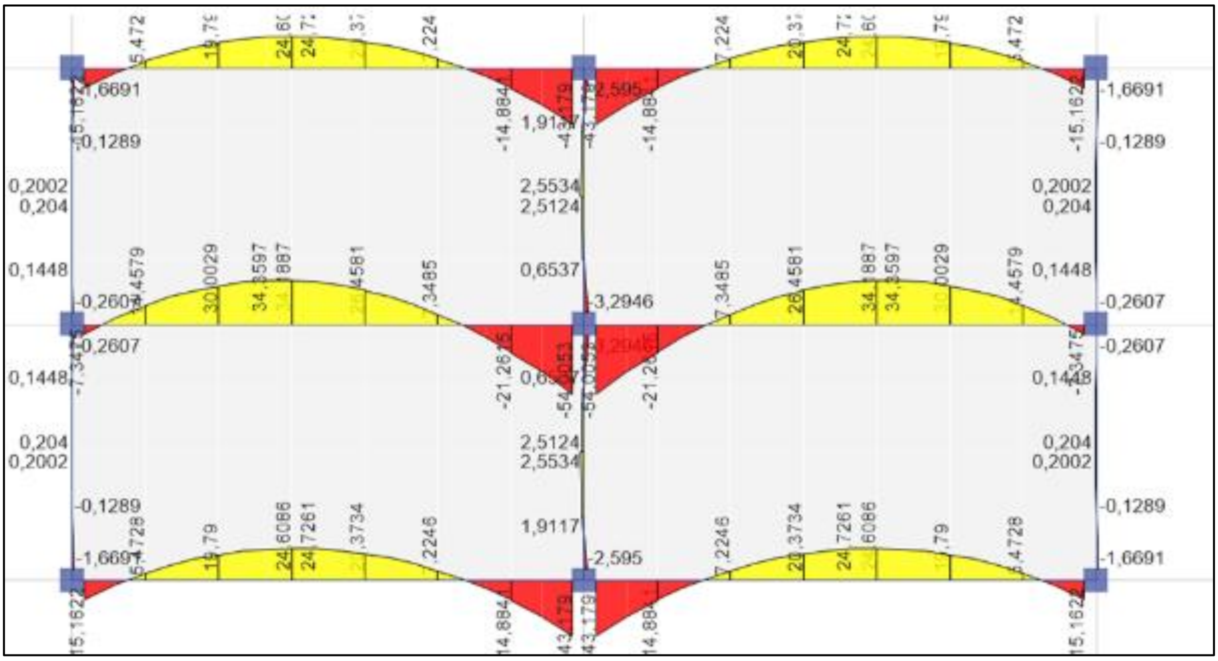
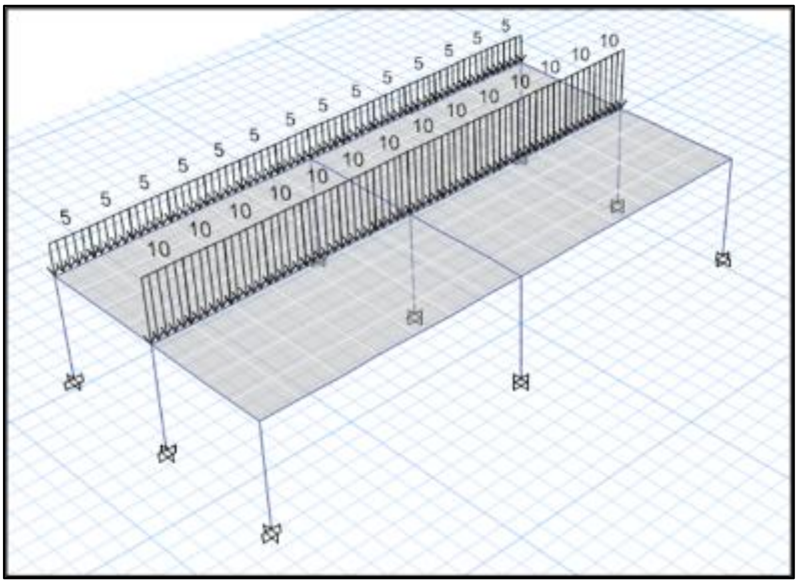


Figure 3 Bending moment values for beams with solid slabs

4.2 Beams with Irregular Loading and Solid Slab

The ACI coefficient method is primarily developed for two-dimensional analysis. When extended to three-dimensional cases—especially under irregular loading conditions (10kN/m,5kN/m and 0) as shown in Fig. 4—it can produce substantially different responses in the beam under consideration compared to FEM.



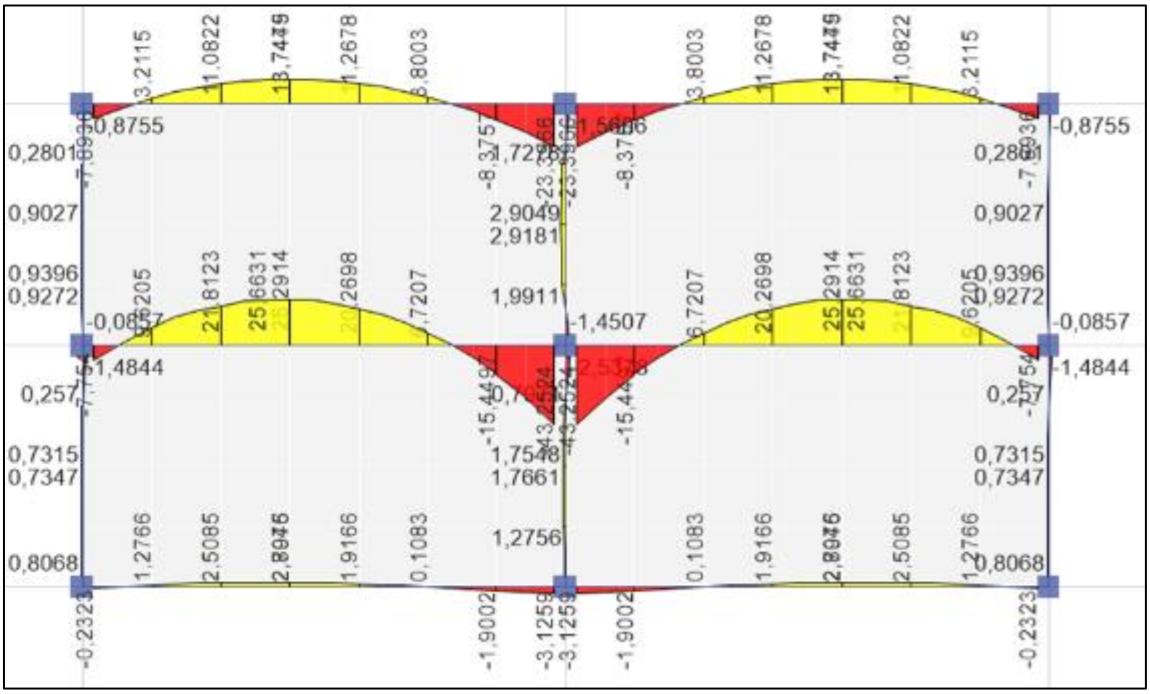
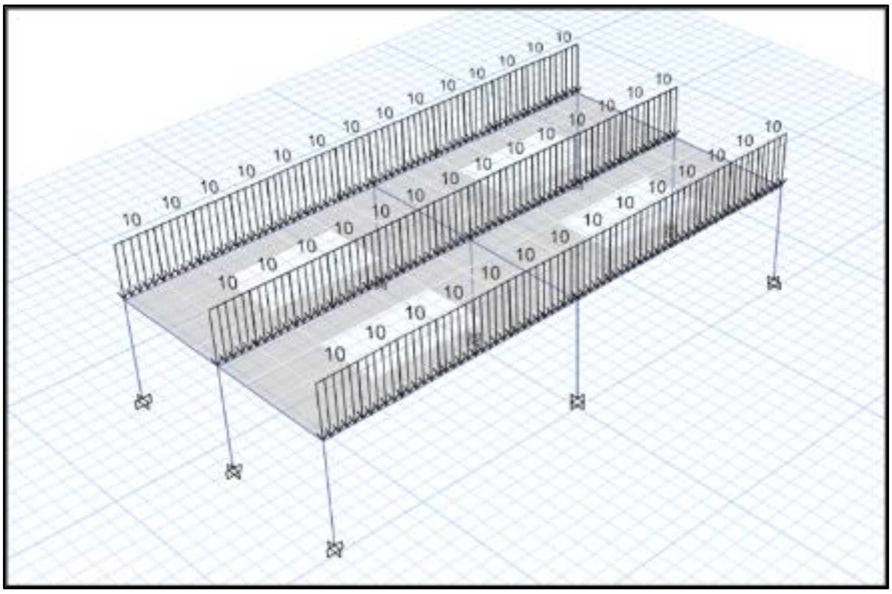


Figure 4 Bending moment values for beams with solid slabs under irregular loading

4.3 Slab with an Opening

A scenario where an opening of 22% is introduced in the slab, testing how each method predicts stress redistribution and structural response. Analysis results are shown in Fig 5 and Fig 6.



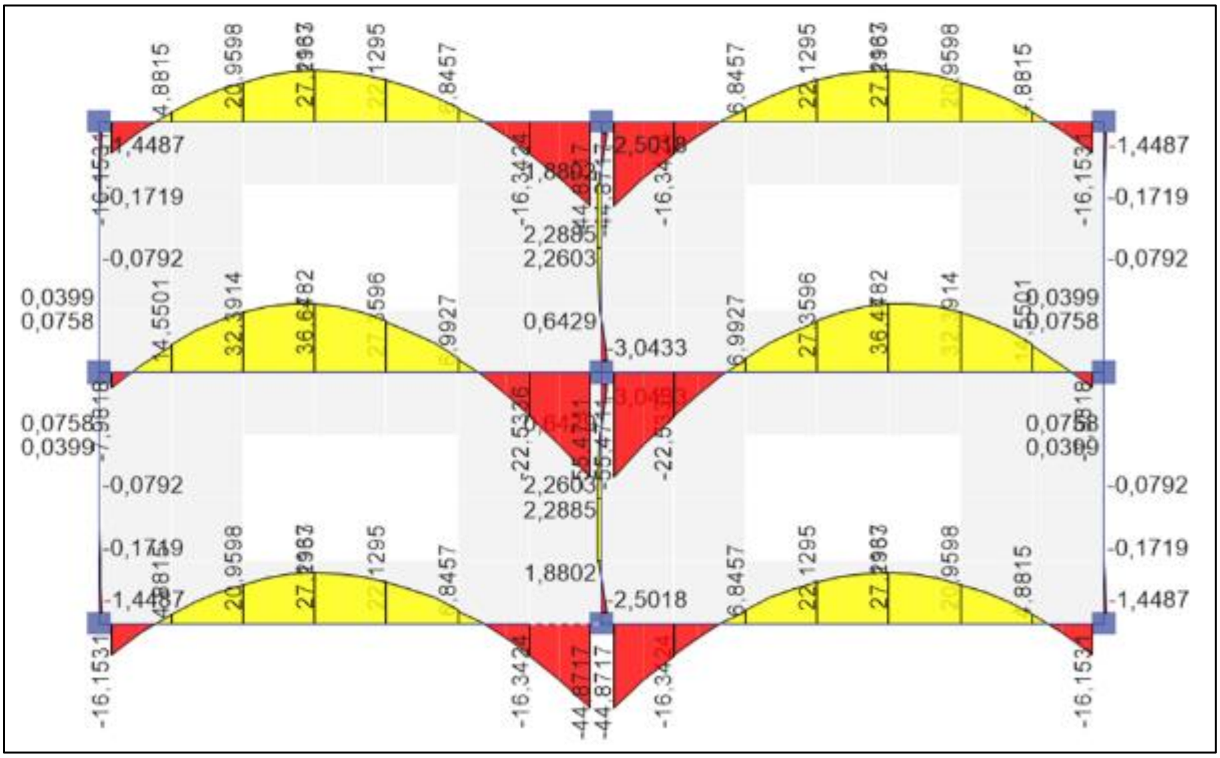
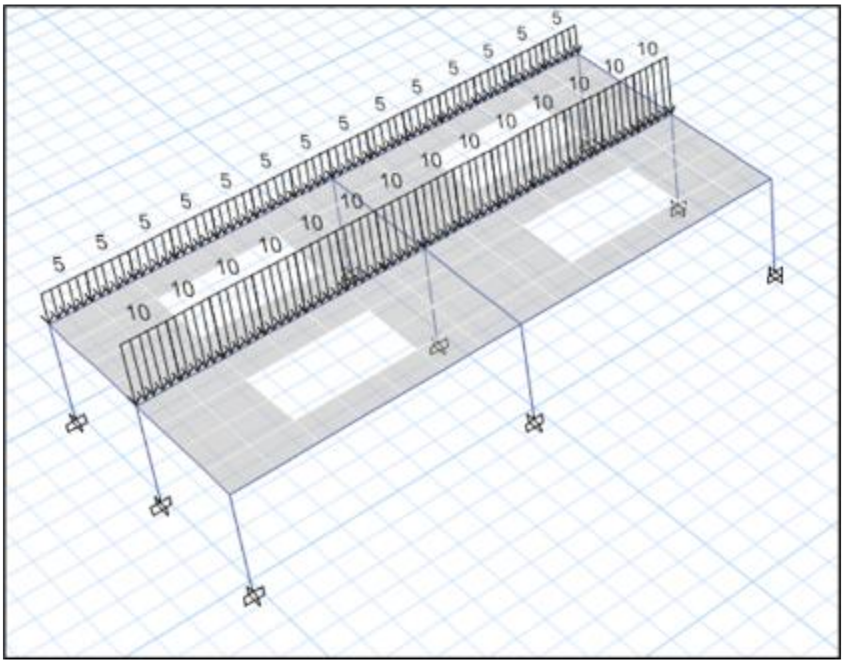


Figure 5 Bending moment values for slabs with 22% openings under regular loading



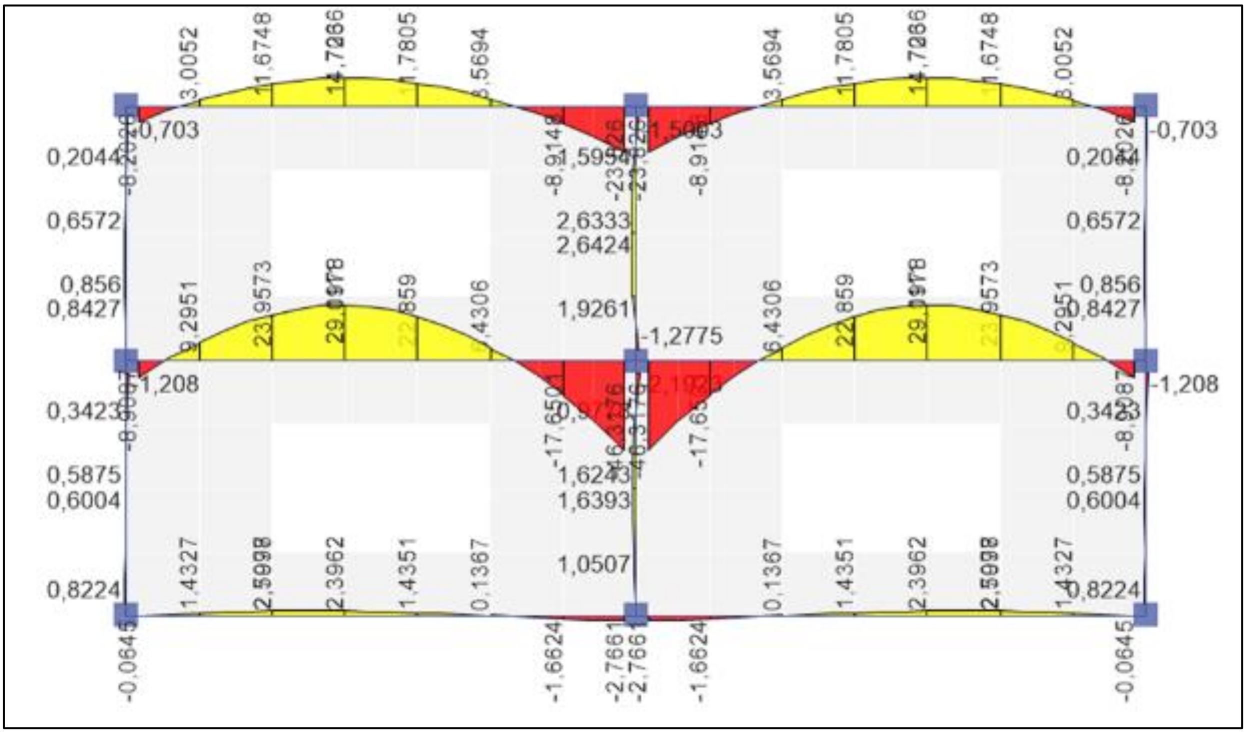
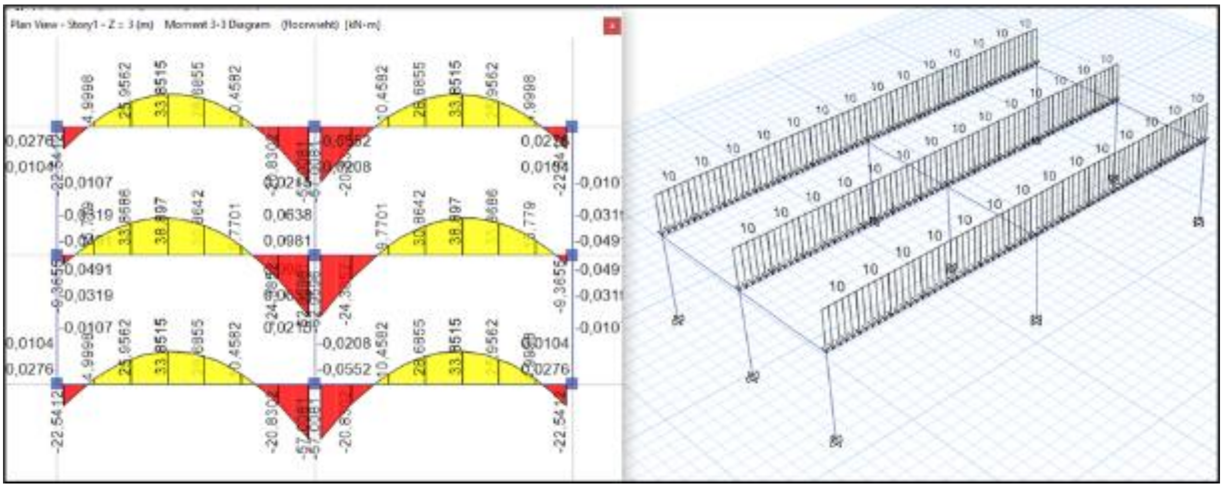


Figure 6 Bending moment values for slabs with 22% openings under irregular loading

4.4 Beams with Regular Loading and without Slab

For comparison the RC frames without slab are analyzed, and the results are given in Fig7.



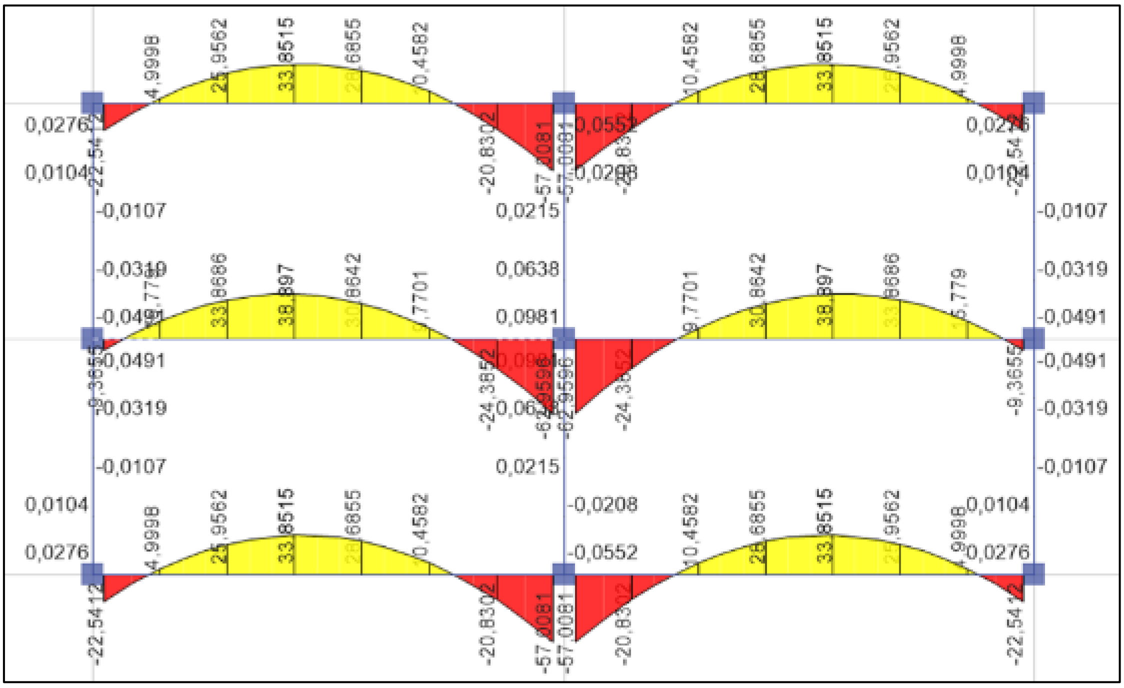


Figure 7 Bending moment values for beams without solid slabs

5. Results

The table below presents a comparative analysis of bending moments calculated using the ACI Code Coefficients Method and Finite Element Method (FEM) under different slab configurations and loading conditions. It highlights the differences in mid-span moments, mid-support moments, and edge moments, providing insights into how different structural scenarios impact the results. Analysis results are shown also in Fig 8.

Table 1 ACI method and FEM results

Moment Type (Kn.m)	**ACI Code Method**	**FEM Without Slab**	**FEM With Slab**	**FEM With Slab 22% Opening**	**FEM With Slab & irregular loads**	**FEM Slab with 22% opening & irregular loads**
Mid-Span Moment	41.25	39.00	34.20	36.6	22.34	26.5
Mid-Support Moment	64.00	63.00	54.00	55.4	39.60	43.2
Edge Moment	36.10	9.30	7.34	8.00	7.88	8.2

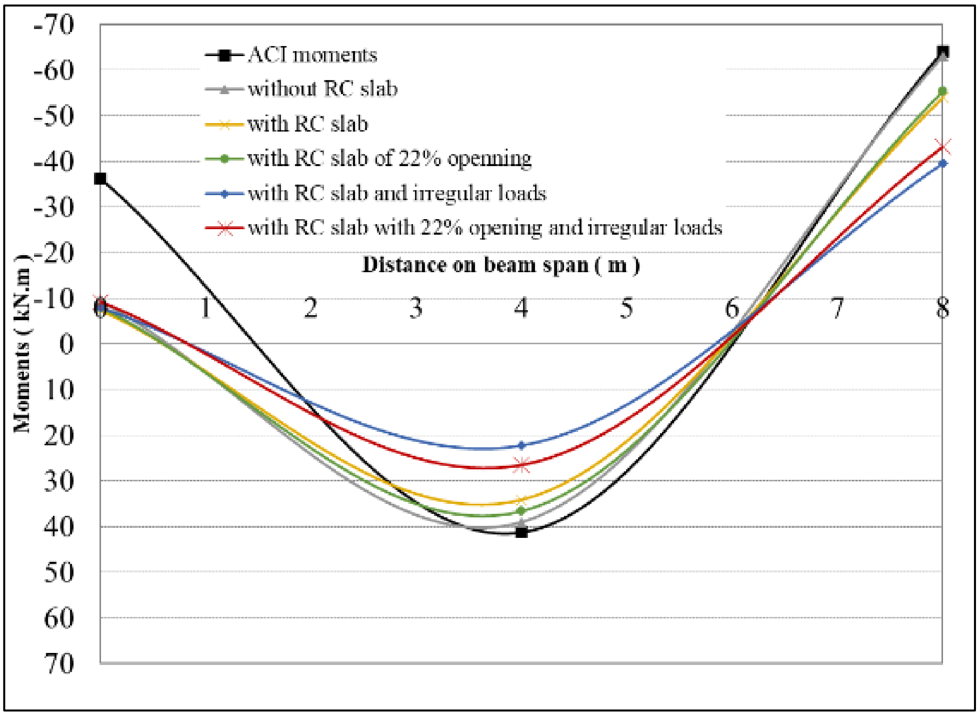


Figure 8 Analysis results for all cases

6. Interpretation of Results

The comparative analysis between the ACI Code Method and FEM results shows clear reductions in bending moments under different slab and loading conditions.

6.1. Mid-Span Moment

The ACI method gives 41.25 kN·m. FEM results show reductions ranging from 5.45% without slab to 17.09% with slab participation. When a 22% slab opening is introduced, the reduction decreases to 11.27%, while the presence of irregular loads drastically increases the reduction to 45.85%. Combining both slab opening and irregular loading gives a reduction of 35.76%. This highlights the strong influence of irregular loading in reducing mid-span moments.

6.2. Mid-Support Moment

The ACI method gives 64.00 kN·m. Reductions are modest without slab (1.56%) but increase significantly with slab participation (15.63%) and with slab opening (13.44%). Under irregular loading, the reduction becomes much larger (38.13%), and when both opening and irregular loads are present, the reduction remains high at 32.50%. This indicates that slab continuity and load distribution strongly influence support moments.

6.3. Edge Moment

The ACI method gives 36.10 kN·m. The FEM results show very large reductions at the edges: 74.26% without slab, increasing to nearly 80% with slab. With slab openings and irregular loads, the reductions remain consistently high (77–79%). This demonstrates that edge regions are the most sensitive to slab participation, openings, and irregular load patterns, with significant moment redistribution occurring compared to the ACI estimate.

Overall, the results show that ACI coefficients tend to overestimate bending moments, particularly at edges. FEM highlights the effect of slab participation, slab openings, and irregular loads, which substantially reduce bending moments through redistribution.

7. Conclusion

This comparative investigation highlights the strengths and limitations of the two approaches. The ACI Code Coefficients Method, while straightforward and practical for preliminary design applications, tends to overestimate bending moments—particularly along slab edges—since it does not adequately consider slab participation, the influence of openings, or the effects of irregular loading conditions. As a result, its applicability is best suited for regular, symmetric structural systems where design simplicity is prioritized over precision.

By contrast, FEM offers a more rigorous and reliable prediction of structural behavior. Through its ability to model three-dimensional responses, account for load redistribution, and capture complex slab–beam interactions, FEM delivers more realistic results that align more closely with actual performance. This makes it especially valuable in cases involving irregular loading or the presence of slab openings, where conventional two-dimensional approaches may prove insufficient.

Therefore, while the ACI Coefficients Method remains a useful tool for initial assessments and simplified calculations, FEM should be the preferred method when accuracy, material efficiency, and reinforcement optimization are critical to ensuring both safety and economy in structural design.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] ACI Code 1963; "Building Code Requirements for Reinforced Concrete", ACI Publication 318-63, American Concrete Institute, Forming Hills, MI, 1963, USA.

[2] ACI Code 2014; "Building Code Requirements for Structural Concrete and Commentary "ACI 318-2014, American Concrete Institute, Forming Hills, MI 48331, USA, 2014; 520pp.

[3] Hassan M. I. and Ahmed A., "Design Comparison of Flat Plat System by Direct Design Method and Equivalent Frame Method", https://www.researchgat.net/publication/281837415,17 January, 2016.

[4] Layas F. M., Karakale V. and Hachem F. "Case study of bearing capacity failure in a 4-story reinforced concrete building" World Journal of Advanced Engineering Technology and Sciences, 2024, 13(01), 892–898.

[5] Layas F. M., Karakale V., Suleiman R. E. "Behavior of RC Buildings under Blast Loading: Case Study". Recent Progress in Materials 2023; 5(3): 029; doi:10.21926/rpm.2303029.

[6] ETABS 16 software, Berkeley, CA: Computers and Structures, Inc.