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Finite Element Design and Crack–Deflection Verification of Reinforced Concrete Floor Slabs

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A B S T R A C T

This paper presents the design and verification of reinforced concrete floor slabs using the finite element method (FEM). The study focuses on a multi–story residential building located in Ho Chi Minh City, Vietnam. Structural analysis was performed to determine internal forces, reinforcement requirements, and serviceability checks including cracking and deflection. The floor system was modeled as two–way slabs supported by beams and columns, subjected to dead load, live load, and wall loads according to TCVN 2737:2023. The results show that the slabs satisfy strength, crack, and deflection requirements. FEM analysis confirms that the adopted slab thickness and reinforcement layout ensure both safety and serviceability under design loads.

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1. INTRODUCTION

The rapid development of urban areas in Vietnam, particularly Ho Chi Minh City, has led to a growing demand for high–rise residential buildings (Seo & Kwon, 2017; Nguyen *et al*., 2017; Liang *et al*., 2025; Chung *et al*., 2018; Nguyen *et al*., 2025). Structural safety and serviceability of reinforced concrete slabs play a crucial role in ensuring durability and comfort for occupants (Krentowski, 2021; Yu *et al*., 2022; Pavic & Reynolds, 2022; Gholamhoseini *et al*., 2016; Biradar *et al*., 2024; Safi *et al*., 2025). Traditional calculation methods provide simplified results, while the finite element method (FEM) offers a more accurate prediction of stresses, deflections, and cracking behavior (Alshoaibi & Fageehi, 2024; Teng *et al*., 2021; Mohamad *et al*., 2025; Wu *et al*., 2025; Soltanpour & Sheikhi, 2025; Pereira *et al*., 2025; Kumar *et al*., 2025; Gindy *et al*., 2025).

This paper presents the design and verification of floor slabs for a nine–story reinforced concrete building. The study emphasizes the use of FEM for internal force determination, reinforcement detailing, and serviceability checks including cracking and deflection limits.

2. METHODS

2.1. Project Overview

The case study building is a nine–story reinforced concrete residential building with a basement, located in Ho Chi Minh City. The building has a structural height of 38.3 m with a floor grid of 9 m span. The structural system consists of a reinforced concrete frame with monolithic beam–slab construction (see **Figure 1**).

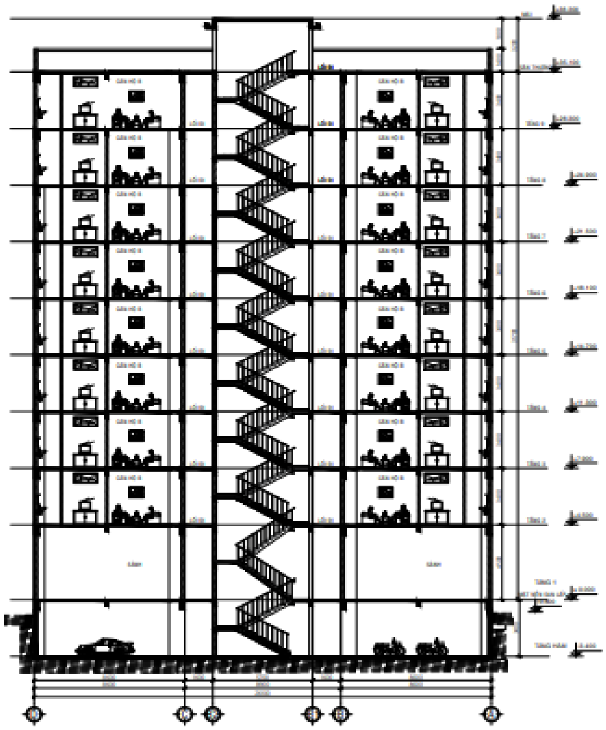

Figure 1. The structural system.

2.2. Materials

The materials are:

(i) Concrete: Grade B30, compressive strength Rb =17 MPa, tensile strength Rbt =1.15 MPa, modulus of elasticity Eb =32.5×103 MPa.

(ii) Reinforcement: CB300-V and CB400-V steel, with tensile strength Rs =260 MPa and modulus of elasticity Es =200×103 MPa.

2.3. Finite Element Modelling

The slabs were modeled as two–way plates supported on beams and columns. Dead load was determined from slab self-weight and finishing layers, while live loads were assigned according to TCVN 2737:2023. Equivalent wall loads were distributed on slabs without supporting beams. FEM analysis was conducted to compute bending moments, shear forces, and deflections.

2.4. Design Procedure

Design procedure are including several parts as follow.

(i) Load Calculation: Dead load, superimposed dead load, and live load were calculated.
(ii) Internal Force Analysis: FEM was used to obtain bending moments and shear forces for each slab panel.
(iii) Reinforcement Design: Slab reinforcement was designed according to TCVN 5574:2018, ensuring adequate flexural strength.
(iv) Crack and Deflection Checks: Crack control was performed using crack moment calculations, while deflections were checked against serviceability criteria.

3. RESULTS AND DISCUSSION

3.1. Load Analysis

The total design load for the critical slab panel (S9, 4.50 × 4.25 m) was determined as q=9.74 kN/m^2, including slab self-weight, finishing loads, and wall loads (see **Figure 2**).

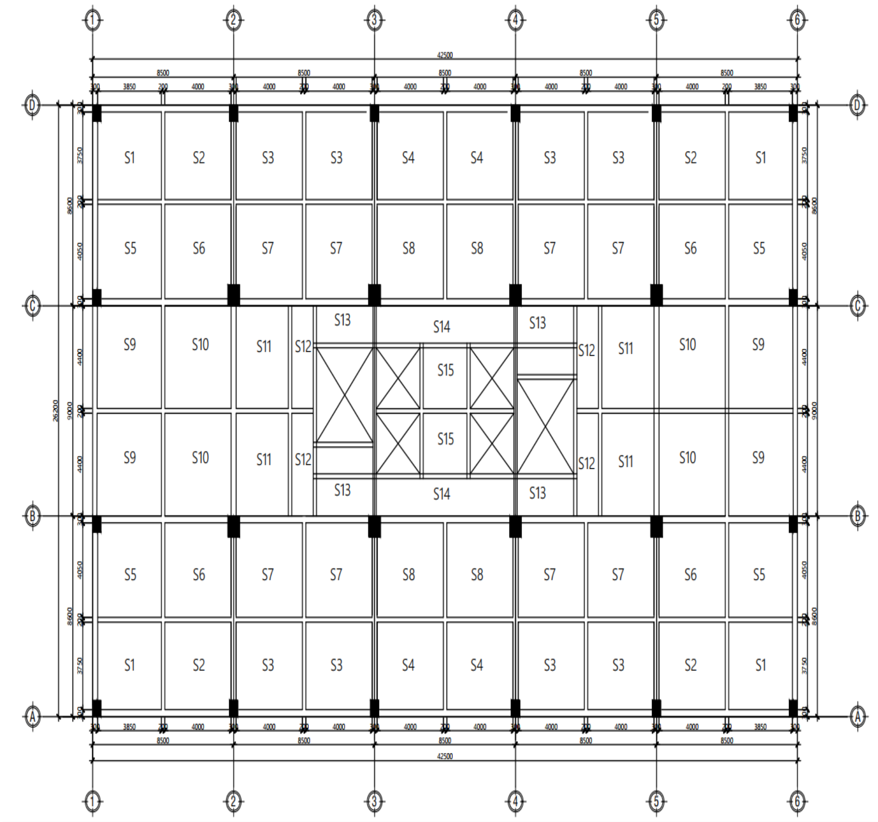

Figure 2. Symbols of slab panels.

3.2. FEM Internal Forces

For slab S9, FEM analysis yielded mid-span bending moments Mx =8.18 kNm/m and My =7.24 kNm/m. Edge negative moments were also obtained, confirming continuity effects (**Figures 3 and 4**).

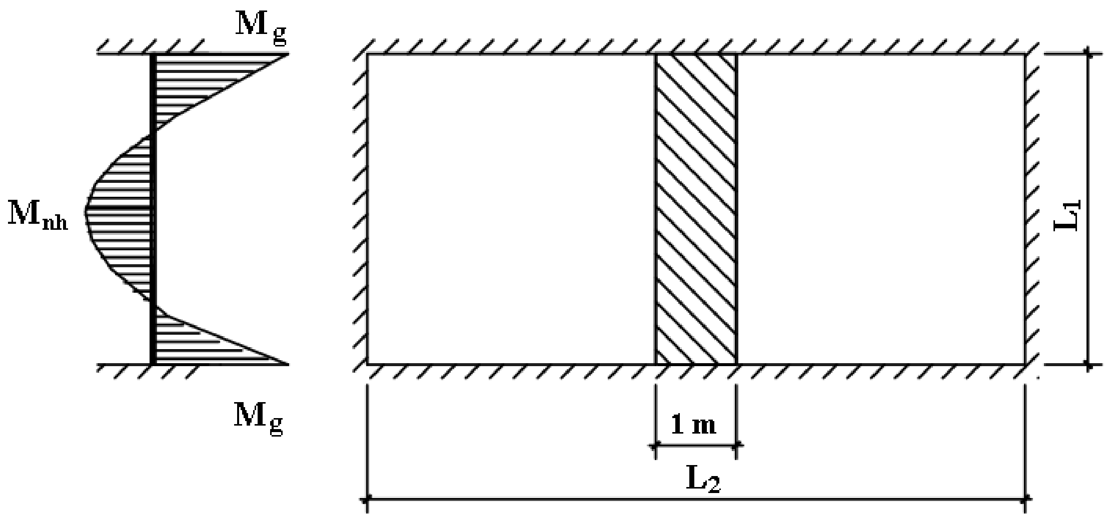

Figure 3. One-way slab diagram.

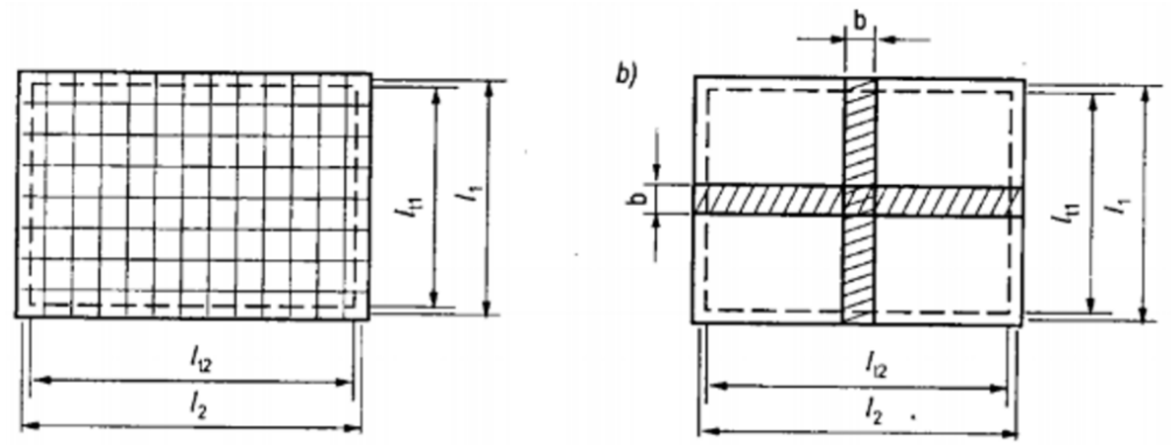

Figure 4. Two-way slab diagram.

3.3. Reinforced Layout

Based on flexural analysis, reinforcement requirements were satisfied with:

(i) Bottom reinforcement: Φ10@200 mm in both directions.

(ii) Top reinforcement at supports: Φ10@200 mm.

The reinforcement ratios were within permissible limits, and steel stresses were below yield.

3.4. Crack Control

The crack resistance check was carried out for slab S9. The cracking moment was calculated as M_{cr}=7.5 kNm, while the applied design moment was M_{tc}=2.67 kNm. Since $M_{tc} < M_{cr}$, no cracks are expected under service loads.

3.5. Deflection Verification

Deflections were verified using FEM results and serviceability criteria. The calculated maximum deflection did not exceed L/250, satisfying code requirements.

3.6. Shear Capacity

Shear verification showed that the design shear force Q=19.58 kN was less than the concrete shear capacity Qb=55.2 kN. Thus, punching shear and one-way shear failure are unlikely (see **Table 1**).

Table 1. Mid-span and support moments of a two-way slab supported on four edges.

Slab Panel	Size		Load			Ratio	Moment Coefficient		Moment	
	l_1 (m)	l_2 (m)	g (kN/m²)	p (kN/m²)	P (kN)	l_2/l_1	Coefficient	Value	Moment	Value (kN·m/m)
S1	4.25	4.15	4.90	1.95	120.82	1.02	m_{91}	0.0182	M_1	2.20
							m_{92}	0.0176	M_2	2.13
							k_{91}	0.0425	M^I	5.13
							k_{92}	0.0408	M^{II}	4.93
S2	4.25	4.15	4.90	1.95	120.82	1.02	m_{91}	0.0182	M_1	2.20
							m_{92}	0.0176	M_2	2.13
							k_{91}	0.0425	M^I	5.13
							k_{92}	0.0408	M^{II}	4.93
S3	4.25	4.15	6.56	2.60	161.56	1.02	m_{91}	0.0182	M_1	2.94
							m_{92}	0.0176	M_2	2.84
							k_{91}	0.0425	M^I	6.87
							k_{92}	0.0408	M^{II}	6.59
S4	4.25	4.15	6.16	2.60	154.50	1.02	m_{91}	0.0182	M_1	2.81
							m_{92}	0.0176	M_2	2.72
							k_{91}	0.0425	M^I	6.57
							k_{92}	0.0408	M^{II}	6.30
S5	4.45	4.25	6.31	2.60	168.51	1.04	m_{91}	0.0185	M_1	3.12
							m_{92}	0.0173	M_2	2.92
							k_{91}	0.0433	M^I	7.30
							k_{92}	0.0399	M^{II}	6.72
S6	4.45	4.25	6.56	1.95	160.89	1.04	m_{91}	0.0185	M_1	2.98
							m_{92}	0.0173	M_2	2.78
							k_{91}	0.0433	M^I	6.97
							k_{92}	0.0399	M^{II}	6.42
S7	4.45	4.25	6.49	1.95	159.56	1.04	m_{91}	0.0185	M_1	2.95
							m_{92}	0.0173	M_2	2.76
							k_{91}	0.0433	M^I	6.91
							k_{92}	0.0399	M^{II}	6.37
S8	4.45	4.25	6.49	1.95	159.56	1.04	m_{91}	0.0185	M_1	2.95
							m_{92}	0.0173	M_2	2.76
							k_{91}	0.0433	M^I	6.91
							k_{92}	0.0399	M^{II}	6.37
S9	4.50	4.25	7.14	2.60	186.22	1.06	m_{91}	0.0188	M_1	3.50
							m_{92}	0.0169	M_2	3.15
							k_{91}	0.0439	M^I	8.18
							k_{92}	0.0389	M^{II}	7.24
S10	4.50	4.25	7.07	1.95	172.51	1.06	m_{91}	0.0188	M_1	3.24
							m_{92}	0.0169	M_2	2.92
							k_{91}	0.0439	M^I	7.57

Table 1 (continue). Mid-span and support moments of a two-way slab supported on four edges.

Slab Panel	Size		Load			Ratio	Moment Coefficient		Moment	
	l_1 (m)	l_2 (m)	g (kN/m²)	p (kN/m²)	P (kN)	l_2/l_1	Coefficient	Value	Moment	Value (kN·m/m)
							k_{92}	0.0389	M^{II}	6.71
S11	4.50	3.40	4.90	3.90	134.64	1.30	m_{91}	0.0208	M_1	2.80
							m_{92}	0.0123	M_2	1.66
							k_{91}	0.0475	M^I	6.40
							k_{92}	0.0281	M^{II}	3.78
S15	2.90	2.80	4.90	3.90	71.46	1.03	m_{91}	0.0184	M_1	1.31
							m_{92}	0.0174	M_2	1.24
							k_{91}	0.0429	M^I	3.07
							k_{92}	0.0403	M^{II}	2.88

4. CONCLUSION

This study applied the finite element method to analyze and design reinforced concrete floor slabs for a high-rise building in Ho Chi Minh City. The results confirm that:

(i) The FEM provides reliable internal force distribution for two–way slabs.
(ii) Designed reinforcement ensures both strength and ductility under applied loads.
(iii) Serviceability requirements, including crack control and deflection limits, are satisfied.
(iv) The adopted slab thickness (120 mm) and reinforcement arrangement are adequate for safety and comfort.

The methodology presented in this paper can be applied to similar reinforced concrete structures, contributing to safe and efficient slab design in urban residential buildings.

5. ACKNOWLEDGMENT

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6. AUTHORS' NOTE

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

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