
Design of Reinforced Concrete Floor Slabs in a 3-Story Office Building in Lumajang Regency

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Abstract

The design of reinforced concrete floor slabs is critical for load distribution and structural stability in multi-story office buildings. Objective: This study aims to design a two-way reinforced concrete floor slab for a three-story office building in Lumajang Regency using the direct design method according to national standards. Methods: A quantitative research approach was employed with document review as the primary data collection method. The study followed SNI 2847:2019 and SNI 1727:2020 standards. Population included all structural components of the building's floor slab, with a sample focusing on the two-way slab system. Data analysis consisted of calculations based on the direct design method and software verification. Results: The optimal slab thickness was determined to be 210 mm with D12 mm reinforcement, satisfying strength and safety criteria. Stiffness ratio analysis confirmed effective load distribution between beams and slab for both exterior and interior zones. Conclusion: The application of the direct design method in this context ensures structural reliability and design efficiency for mid-rise office buildings. Further research is recommended to include experimental validation and consideration of advanced materials and seismic effects.

Keywords: Concrete, Floor Slab, Load Distribution, Reinforced Concrete, Structural Design

INTRODUCTION

In multi-story building construction, the floor slab serves as a crucial structural component that not only functions as the floors and roof covering but also plays an essential role in load distribution to beams and columns. Reinforced concrete slabs provide the necessary rigidity to the supporting beams and effectively distribute loads, ensuring building stability and occupant safety. Particularly, two-way slabs are commonly employed in office buildings due to their capacity to resist bending moments in two perpendicular directions, accommodating various load conditions (Mayanti & Nurmaidah, 2021; Pratomo & Hudori, 2021). The importance of meticulous structural design in reinforced concrete slabs lies in guaranteeing both serviceability and safety of the entire building structure (Gusmareta & Inra, 2022).

Structural design accuracy is fundamental as errors in the design phase can trigger cost overruns, schedule delays, and potentially catastrophic failures affecting user safety. Design discrepancies often arise from misunderstandings among stakeholders concerning design concepts, highlighting the importance of clear, methodical planning procedures in civil engineering projects (Fuadie, 2017; Athallah, 2023). Therefore, ensuring compliance with recognized standards like SNI 2847:2019 for reinforced concrete design and SNI 1727:2020 for load planning is essential to produce structurally sound floor slabs capable of bearing expected loads throughout their service life (Mayanti & Nurmaidah, 2021; Gusmareta & Inra, 2022).

The objective of this study is to design a two-way reinforced concrete floor slab for a three-story office building in Lumajang Regency, applying the direct design method according to national standards. This method is selected for its suitability based on slab system geometry, loading conditions, and span ratios, aiming to determine optimal slab thickness and reinforcement to meet strength and safety requirements. This research contributes to the field by providing a practical design case grounded in recent Indonesian codes, offering insights into

implementing the direct design method in mid-rise office buildings while highlighting the importance of integrating up-to-date load provisions and design practices (Athallah, 2023; Tampubolon, 2022).

RESEARCH METHODS

This study employed a quantitative research approach coupled with the direct design method for floor slab structural analysis, following national standards SNI 2847:2019 and SNI 1727:2020. Quantitative methodology was chosen to facilitate objective measurement and analysis of slab thickness, reinforcement details, and load responses based on collected secondary data (Mayanti & Nurmaidah, 2021; Athallah, 2023). As Sugiyono (2021) explains, quantitative research effectively tests hypotheses through numerical data, enhancing reliability in engineering design contexts.

Data collection utilized document review as the primary instrument, encompassing architectural plans, structural drawings, material specifications, and relevant code provisions. This technique enabled accurate extraction of slab dimensions, concrete and steel material quality, and loading conditions applicable to the office building project (Sudaryono et al., 2022; Emzir, 2023). The analysis was performed through calculation models consistent with the direct design method, supplemented by software verification where applicable, to determine moments, minimum slab thickness, and reinforcement requirements (Athallah, 2023; Creswell, 2022).

The population for this research consisted of all structural components related to the floor slab design in the planned office building. The sample focused specifically on the two-way reinforced concrete slab components of the three-story structure located in Desa Krajan, Kecamatan Tempursari, Kabupaten Lumajang. Selection was based on project feasibility, slab system suitability for the direct design method, and the availability of comprehensive technical data (Mayanti & Nurmaidah, 2021; Sugiyono, 2021).

The procedural steps included systematic literature review, data compilation from the building's structural documents, application of SNI design guidelines, calculation of load combinations, flexural reinforcement design, and validation of slab thickness and detailing (Athallah, 2023; Sudaryono et al., 2022). This process ensured adherence to engineering standards and optimized structural safety and efficiency.

RESULTS AND DISCUSSION

1. Regulations and Technical Data

The reinforcement design for this floor slab is applied in accordance with the provisions of SNI 2847-2019, while the applied load transfer refers to SNI 1727-2020. The technical data to be used in designing the floor slab reinforcement structure are as follows:

- Span length in x and y directions : 4 x 6 m
- Beam 1 dimensions : 25/50 cm
- Beam 2 dimensions : 20/35 cm
- Live load : 2.5 kN/m²
- Concrete grade ($f'c$) : 35 MPa
- Steel grade (f_y) : 400 MPa
- Flexural reinforcement to be used : D12 mm
- Shrinkage reinforcement to be used : D12 mm

2. Determining the Type of Floor Slab

The type of floor slab reviewed is a two-way floor slab because $L_y/L_x = 6000/4000 = 1.5$ where $L_y/L_x \leq 2$.

3. Determining the Floor Slab Thickness

In determining the thickness of the floor slab, it is carried out on both slabs, namely the exterior slab and the interior slab.

- Effective dimensions of beam 1 (b_e)

$$b_w = 250 \text{ mm}$$

$$h_t = 500 \text{ mm}$$

$$h_f = 120 \text{ mm (initial assumption of slab thickness)}$$

$$h_b = h_t - h_f = 380 \text{ mm}$$

$$b_e = b_w + (2 \times h_b) \quad b_e = b_w + 8h_f = 1,010 \text{ mm}$$

$$= 1,210 \text{ mm}$$

$$\text{Check} = b_w + (2 \times h_b) < b_w + 8h_f \text{ (ok),}$$

minimum value is taken, which is 1,010 mm

- Moment of Inertia of the Beam (I_b)

$$k = \frac{1 + \left(\frac{b_e}{b_w} - 1\right) \times \left(\frac{h_f}{h_t}\right) \times \left[4 - 6\left(\frac{h_f}{h_t}\right) + 4\left(\frac{h_f}{h_t}\right)^2 + \left(\frac{b_e}{b_w} - 1\right) \times \left(\frac{h_f}{h_t}\right)^3\right]}{1 + \left(\frac{b_e}{b_w} - 1\right) \times \left(\frac{h_f}{h_t}\right)} = 1.773$$

$$I_b = k \times \frac{b h^3}{12} = 4.62 \times 10^9 \text{ mm}^4$$

- Moment of inertia of the plate (I_s)

$$I_s = \frac{b h^3}{12} = 0.864 \times 10^9 \text{ mm}^4$$

- Stiffness Ratio of Beam 1 to the Slab

$$\alpha_{fy1} = \frac{E_c \times I_b}{E_c \times I_s} = 5.34$$

From the ratio analysis conducted, the stiffness calculations have been completed for all beams located on the outer plate as well as the inner part. The results of these calculations are summarized and presented in Table 1 below.

Table 1. Recapitulation of beam stiffness ratio calculations on exterior and interior slabs

Type of Plate	Block	Effective Beam Dimensions (mm)	Moment of Inertia of the Beam (mm ⁴)	Moment of Inertia of the Plate (mm ⁴)	Beam stiffness ratio
Eksterior	Block 1	1.010	4.62×10^9	0.864×10^9	5.34
	Block 2	660	0.667×10^9	0.576×10^9	1.158
	Block 3	630	$4,796 \times 10^9$	$0,864 \times 10^9$	5.55
	Block 4	430	$1,118 \times 10^9$	0.576×10^9	1.94
	Average total stiffness				
Interior	Block 1	1.010	4.62×10^9	0.864×10^9	5.34

Block 2	660	0.667×10^9	0.576×10^9	1.158
Block 3	1.010	4.62×10^9	0.864×10^9	5.34
Block 4	660	0.667×10^9	0.576×10^9	1.158
Average total rigidity				3.25

Source: Processed data results, 2025

- Determining the minimum plate thickness

If the stiffness value between the exterior and interior plates is > 2 , then the minimum plate thickness is as follows:

a. Dead load

qD Pelat (210 mm)	=	0.21×24	=	5.04	kN/m ²
qD ceiling and hanger			=	0.18	kN/m ²
qD ceramic (1 cm)	=	0.01×21	=	0.21	kN/m ²
qD spesi (3cm)	=	0.03×20	=	0.6	kN/m ² +
qD total			=	6.03	kN/m ²

b. Life burden (qL) = 2.5 kN/m²

c. Necessary Load (qU) = 1,2 x qD + 1.6 x qL

$$= 1.2 \times 6.03 + 1.6 \times 2.5 = 11.236 \text{ kN/m}^2$$

4. Load Analysis

On the slab, the loads considered are the dead load and the live load. The load on the floor slab is calculated as follows:

$$h = \frac{\ln(0.8 + \frac{fy}{1400})}{36 + 9\beta} \geq 90 = 126 \text{ mm} \geq 90$$

Control = $h_{\min} < h_{\text{rencana}} = 126 > 120$ (not safe), so the value of 210 mm was taken

a. Dead load

qD Pelat (210 mm)	=	0.21×24	=	5.04	kN/m ²
qD plafond dan penggantung			=	0.18	kN/m ²
qD keramik (1 cm)	=	0.01×21	=	0.21	kN/m ²
qD spesi (3cm)	=	0.03×20	=	0.6	kN/m ² +
qD total			=	6.03	kN/m ²

b. Life burden (qL) = 2.5 kN/m²

c. Necessary Load (qU) = 1,2 x qD + 1.6 x qL

$$= 1.2 \times 6.03 + 1.6 \times 2.5 = 11.236 \text{ kN/m}^2$$

5. Floor Slab Moment Analysis

a. Static moment about the longitudinal axis

$$M_{01} = \frac{q_u \cdot l_2 \cdot l_n^2}{8} = 176.46 \text{ kNm}$$

The same equation is used to calculate the factored static moment in the short direction, with a result of 116.62 kNm.

b. Factored distribution of static moments

Based on the calculations using the Direct Design Method, the distribution of factored static moments for each slab panel was obtained. The following Table 2 presents a summary of the factored moment values occurring in the interior and exterior spans, both in the longitudinal direction (Ly) and the transverse direction (Lx), which will later be used as the basis for slab reinforcement design.

Table 2. Recapitulation of the factored static moment distribution values and the factored moment distribution for the outer span in the Ly and Lx directions

	Direction Ly			Direction Lx		
	Exterior negative moment (kNm)	Positive moment (kNm)	Negative interior moment (kNm)	Exterior negative moment (kNm)	Positive moment (kNm)	Negative interior moment (kNm)
Factored Static Moment Distribution	- 52.94	88.23	- 123.52	- 34.98	58.31	- 81.63
	Factored moment					
Column lane	- 33.09	55.14	- 77.20	- 21.87	36.44	- 51.02
Middle lane	- 19.85	33.09	- 46.32	- 13.12	21.87	- 30.61

Source: Processed data results, 2025

Table 3 below presents a summary of the factored moment values occurring in the interior spans, both in the longitudinal direction (Ly) and the transverse direction (Lx)

	Direction Ly		Direction Lx	
	Negative moment (kNm)	Positive moment (kNm)	Negative moment (kNm)	Positive moment (kNm)
Factored Static Moment Distribution	- 114.7	61.76	- 75.8	40.82
	Factored moment			
Column lane	- 71.69	38.6	- 47.38	25.51
Middle lane	- 43.01	23.16	- 28.43	15.31

Source: Processed data results, 2025

6. Floor Slab Reinforcement

Based on the results of the factored moment distribution on each slab panel, the calculation of the bending reinforcement requirements has been carried out according to the loading direction. The following table presents a summary of the floor slab reinforcement design results, both in the longitudinal direction (Lx) and the transverse direction (Ly), for each slab panel.

Table 4. Recapitulation of floor slab reinforcement

No	Interior and Exterior Plates	Reinforcement
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1			Negative	D12-250
2		Column Lane	Positive	D12-250
3	Long Direction (Ly)	Middle Lane	Negative	D12-250
4			Positive	D12-300
5		Depreciation		D12-250
6		Column Lane	Negative	D12-250
7			Positive	D12-250
8	Short Direction (Lx)	Middle Lane	Negative	D12-250
9			Positive	D12-250
10		Depreciation		D12-300

Source: Processed data results, 2025

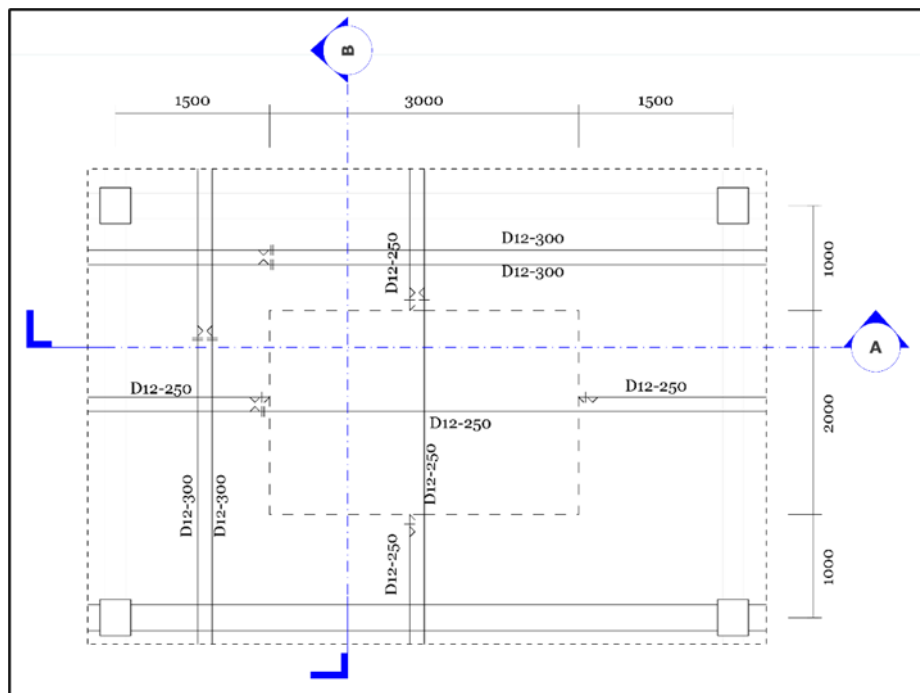


Figure 3. Floor slab reinforcement plan
 Source: Processed data results, 2025

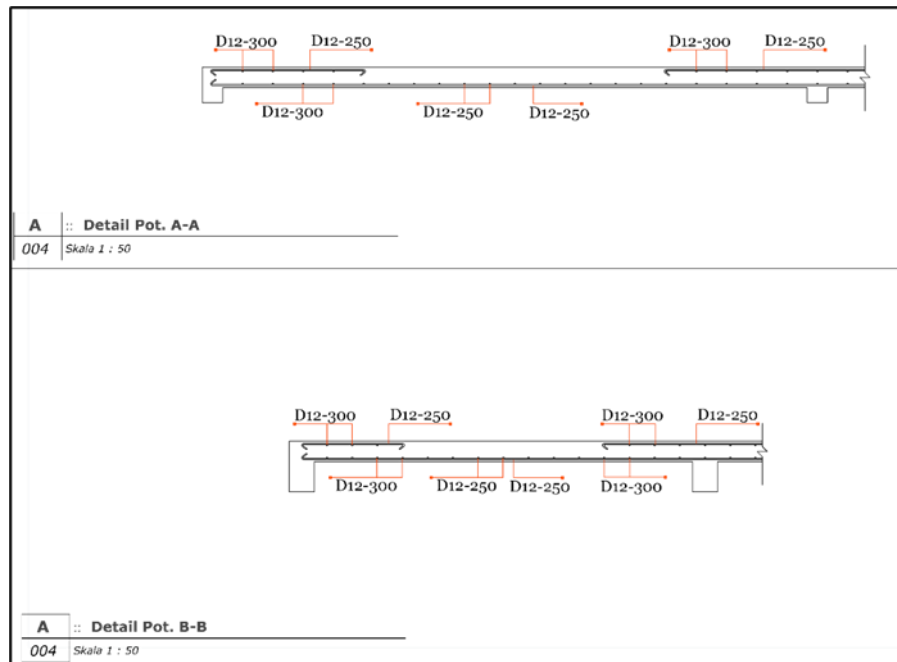


Figure 4. Cross-Sectional Images A-A and B-B
Source: Data analysis results, 2025

CONCLUSION

The study successfully demonstrated the design of a two-way reinforced concrete floor slab for a three-story office building in Lumajang Regency using the direct design method aligned with Indonesian national standards SNI 2847:2019 and SNI 1727:2020. Key findings indicate that the chosen slab thickness of 210 mm and D12 mm reinforcement meet the strength and safety requirements for both interior and exterior slabs under prescribed loads. The stiffness ratio analysis of beams and slabs confirmed the suitability of the design approach, ensuring effective load distribution and structural stability. The moment and reinforcement calculations provide a practical reference for mid-rise office buildings, reinforcing the importance of adhering to updated design codes and load provisions.

However, this study's scope is limited to a specific slab system and building type in a particular geographic area, which may constrain its generalizability to other structural configurations or environments. The reliance on secondary document data and the absence of experimental validation suggest the need for further research incorporating empirical testing and different building typologies. Future studies should explore the integration of advanced materials and construction techniques, as well as seismic considerations relevant to Indonesia. Practically, the findings support civil engineers and designers in applying the direct design method with confidence, promoting safer and cost-effective reinforced concrete floor slab designs consistent with contemporary engineering standards.

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