Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 11 Issue 10, October - 2025

Structural Analysis of Reinforced Concrete Soetta 8 Business Center Complex Balikpapan

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***Abstract*— The development of multi story buildings in business districts requires reliable structural planning to ensure safety and durability. This study evaluates the building loads, internal force distribution, and reinforcement requirements for the Soetta 8 Business Center Block E Commercial Complex in Balikpapan. The structural analysis was conducted using SAP2000 software with reference to Indonesian National Standards SNI 2847 2019, SNI 1727 2020, and SNI 1726 2019. The modeled loads consisted of dead loads, live loads, wind loads, and earthquake loads. The analysis results formed the basis for the reinforcement design of columns, beams, and slabs. The findings indicate that the maximum internal forces included bending moment, axial force, and shear force within acceptable limits. The final design consisted of 30 by 30 centimeter columns with 8D16 reinforcement, 30 by 50 centimeter beams with 12D16 reinforcement, and 12 centimeter thick slabs with D10 200 reinforcement. All structural components satisfied the required criteria for strength, stiffness, and safety. Therefore, the design is technically feasible and can be applied as a reference for similar building projects.**

Keywords—Structural analysis, building capacity, reinforcement calculation

I. INTRODUCE

Infrastructure development in Indonesia is increasing, especially in multi-story buildings for commercial and residential purposes. Reinforced concrete structures are widely chosen because of their strength, durability, and ease of implementation in the field.

The Soetta 8 Business Center Balikpapan Shopping Complex was selected as a case study to evaluate the performance of reinforced concrete structures under gravity loads and earthquakes. With structural analysis software such as SAP2000, 3D modeling can be performed more accurately.

The Soetta 8 Business Center Block E commercial complex is located on Jalan Soekarno Hatta KM 8, Graha Indah Sub-district, North Balikpapan District [1]. The building comprises three floors, with the ground floor functioning as a basement, while the top floor is designed as a rooftop area enclosed by lightweight brick walls.

Fig. 1 Project Location Map

The research questions in this study are:

1. How building loading is analyzed
2. How internal forces occur in the structure
3. How the design of column, beam, and slab reinforcement is obtained.

The objective of this research is to produce a safe structural design in accordance with national standards.

II. LITERATURE

A. Basic Understanding of Structure

In civil engineering, a structure refers to a system of interconnected elements that is designed and constructed to ensure stability, safety, and functionality under applied loads. In the context of multi-story building design, the structural system must demonstrate adequate load-bearing capacity and stability by safely transferring vertical loads, such as dead and live loads, as well as lateral forces resulting from wind and seismic actions, down to the foundation and ultimately to the ground.

To meet these requirements, reinforced concrete is widely employed as one of the most reliable structural materials. As a composite system, it integrates the compressive strength of concrete with the tensile resistance of embedded steel reinforcement, enabling the structure to withstand both axial and flexural

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demands. The interaction between concrete and steel is commonly represented in an interaction diagram, illustrating their combined capacity to resist complex load conditions and ensuring enhanced structural performance in multi-story buildings [2]. A building design can be considered successful when it effectively integrates diverse requirements, ensuring that design considerations align with the overall needs of the structure [14].

According to Asroni (2010) [3], concrete is essentially produced through the hardening process of a mixture consisting of cement, water, fine sand, and coarse aggregates such as gravel or crushed stone. To enhance its properties, additional admixtures may be incorporated into the mixture. While concrete exhibits excellent compressive strength, its tensile strength remains relatively low.

B. Load Theory

According to SNI 03-1727- [6] Article 1.0, the loads acting on the structural part of the building include:

1. Dead Loads: permanent static forces due to the self-weight of structural and non-structural components.
2. Live Loads: transient and movable forces such as occupancy, furniture, or vehicles.
3. Wind Loads: lateral pressures exerted by wind on structural surfaces.
4. Earthquake Loads: dynamic forces induced by ground motion, which require special design considerations for ductility and energy dissipation.

The proper combination of these loads, following national codes and design standards, ensures that structures remain stable under both normal and extreme conditions. In every building construction, technical requirements must be fulfilled that the building must be strong to accept design loads such as dead loads, live loads,wind loads, and earthquake loads [12].

To ensure that the structural capacity meets safety requirements both through analysis and field measurements, quality control of the construction work must also be carried out [13].

C. Load Factors and Load Combination

Structures must account for various load combinations in the design process to ensure safety and performance throughout their service life. These combinations include different types of loads such as dead load (*D*), live load (*L*), wind load (*W*), and earthquake load (*E*). Each combination is formulated to consider the possible simultaneous actions of loads on the structure.

According to SNI 2847-2019, article 5.3.1, the load combinations are as follows:

1. 1,4*D*
2. 1,2*D* + 1,6*L* + 0,6 (*Lr* atau *R*)
3. 1,2*D* + 1,6 (*Lr* atau *R*) + (1,0*L* atau 0,5 *W*)
4. 1,2*D* + 1,0*W* + 1,0*L* + 0,5 (*Lr* atau *R*)
5. 1,2*D* + 1,0*E* + 1,0*L*
6. 0,9*D* + 1,0*W*
7. 0,9*D* + 1,0*E*

D. Structural Elements

Structural elements are the parts of a building that keep the structure strong and stable under load. If the function of one element is disturbed, it can affect the behavior of the entire structure. Structural elements include columns, beams, foundations, roof trusses, and shear walls. Based on the function of the load they carry, structural elements are divided into three types [4]:

i. Column

A column is a primary structural element that carries axial and flexural loads before transferring them to the foundation. As a primary load-bearing component, it must provide high axial capacity and stability. Hence, the design of columns requires careful consideration of material strength, geometric dimensions, and load eccentricity to ensure safety and efficiency in high-rise and large-scale structures.

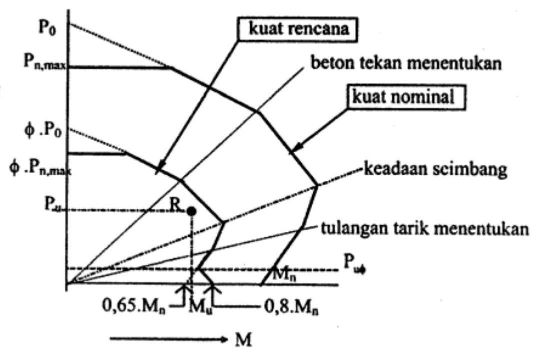

Fig. 2 Example of a column interaction diagram (M–N)

The column interaction diagram (M–N) is an essential tool in reinforced concrete design, as it illustrates the combined effect of axial load (N) and bending moment (M) on column capacity. This diagram defines the ultimate limit state of the column by mapping the failure domain, which represents the conditions under which the column may fail due to excessive axial load, flexure, or a combination of both. By plotting the relationship between axial capacity and flexural strength, engineers can determine whether the applied loads on a column fall within the safe region of the diagram. In practical design, this ensures that the column provides adequate strength and stability against critical failure modes, particularly in high-rise or large-scale structures subjected to complex loading conditions.

Columns can be classified into two types: long columns (slender columns) and short columns (stocky columns). The classification depends on the ratio of column height to its lateral dimensions. According to SNI 2847:2019 [5], Article 6.2.5, the effects of slenderness may be neglected thus the column may be considered a short column if the following conditions are satisfied:

1. For non-sway columns

$$\frac{k\,.\lambda_{n,k}}{r} \leq 22 \qquad (1)$$

2. For sway columns

$$\frac{k\,.\lambda_{n,k}}{r} \leq 12 \qquad (2)$$

The value of rrr, or the radius of gyration, is permitted to be calculated in accordance with SNI 2847:2019, Article 6.2.5.1, under the following provisions:

1. r = $\sqrt{\frac{I_g}{A_g}}$ (3)
2. 0.3 times the overall dimension in the direction of the considered stability for square columns.
3. 0.25 times the diameter for circular columns.

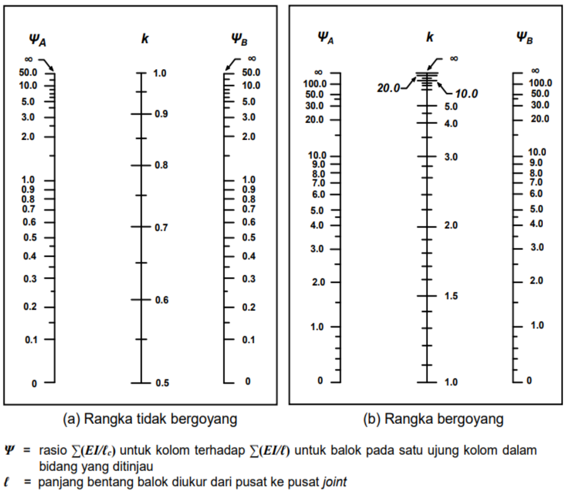

Fig. 3 Effective length factor, *k*

ii. Beam

Beams are essential structural members that transfer loads from slabs and walls to columns and foundations, primarily resisting bending and shear forces [8]. Reinforced concrete beams can generally be classified into two types:

1. Singly Reinforced Beam
   This type of beam contains reinforcement only in the tension zone, while the compression zone is resisted solely by the concrete [9]. It is suitable where compressive stresses can be adequately carried by concrete alone.

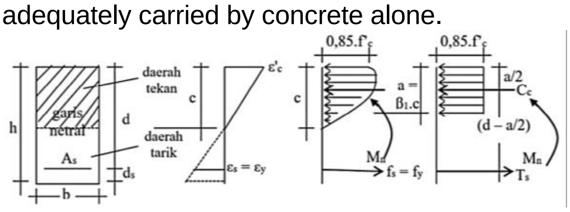

Fig. 4 Stress strain diagram of a singly reinforced beam

$$M_n = A_s . f_y (d - \frac{a}{2}) \quad (4)$$

2. Doubly Reinforced Beam
   This type of beam provides reinforcement in both the tension and compression zones, thereby increasing moment capacity, reducing deflection, and improving ductility. Such beams are particularly beneficial in high-rise and large scale structures [10].

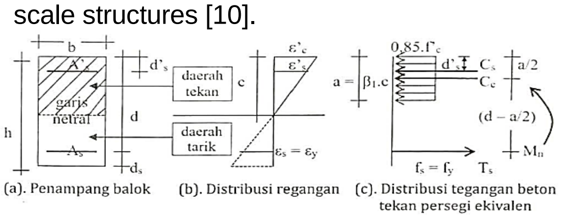

Fig. 5 Strain and stress distribution of a doubly reinforced beam

$$M_n = A_s . f_y (d - \frac{a}{2}) + A'_s . f'_y (d - d') \quad (5)$$

iii. Slab

Slab is a reinforced concrete structural element that forms the flat horizontal surface of floors or roofs in buildings. It functions to carry vertical loads such as dead loads and live loads, and transfer them to supporting beams, columns, or directly to walls, while also contributing to the overall rigidity and stability of the structure.

1. One-Way Slab
   One-way slab is a reinforced concrete slab that primarily spans in one direction, transferring loads only along the shorter span to two opposite supports. Reinforcement is provided mainly in the direction perpendicular to these supports, and the structural behavior resembles that of parallel beams subjected to bending moments.
2. Two-Way Slab
   Two-way slab is a reinforced concrete slab supported on all four edges, transferring loads in both the shorter and longer span directions. This type of slab distributes bending moments more evenly, resulting in a more efficient and economical structural system, particularly for square or nearly square panels [11].

III. RESEARCH METODHOLOGY

A. Research Location

The location of the project taken for research is at Soekarno Hatta Street, KM 8, Graha Indah Sub-district, North Balikpapan District.

B. Structural Data

The material specifications used are:

1. Concrete quality, f'_c
   - Structural concrete : 18,68 MPa
2. Steel quality, f_y
   - Deformed rebar : 420 MPa
   - Plain rebar : 280 MPa
3. Building data
   - Number of floors : 3 floors
   - Elevation : 4 meters
   - Building height : 13,5 meters
   - Building length : 35 meters
   - Building width : 12 meters

C. Research Method

The structure is analyzed for loads such as live loads, dead loads, additional dead loads, wind loads, and earthquake loads. The purpose is to determine the magnitude of the forces acting on the structural elements as a result of loading.

The following are the stages carried out in the research:

1. Data Collection
   All data related to structural analysis was collected from the field through observation and *as-built drawings*. The data collected directly included the quality of the concrete used and the dimensions of each structural

element, as well as the installed reinforcement data.

2. Structural Modeling
   Structural modeling is essentially a visualization of the planned design in accordance with specifications namely materials, sizes, or dimensions of forces at work, and so on.
3. Load Calculation
   The loads calculated in this final project report are dead load, live load, wind load, and earthquake load. The regulations used are SNI 1727-2020 [6], while SNI 1726-2019 [7] is used for earthquake calculations.
4. Internal Force Analysis
   The results of the internal force analysis are obtained from the structural modeling of the building, in the form of output data from the SAP2000 program.
5. Reinforcement Calculation
   The reinforcement calculation for structural elements such as columns, beams, and floor slabs is performed manually based on SNI 2847-2019 [5].
6. Conclusion
   At this stage, conclusions and recommendations will be made based on the results obtained, which are expected to be beneficial for the sustainability of the building.

IV. RESULT AND RESEARCH

A. Dimensions of Structural Elements

The following section provides the data gathered directly from fieldwork:

a. Column dimension : K1 30 cm / 30 cm
   : K2 25 cm / 25 cm
b. Beam dimension : BI 30 cm / 50 cm
   : BA 20 cm / 40 cm
c. Thickness of slab : 12 cm
d. Thickness of dak : 10 cm

B. Load Analysis Result

The loads analyzed were entered into the structural analysis program, as follows:

1) Live Load

The live loads entered into the structural modeling are based on SNI 1727:2020 [6], which can be seen in the table below.

TABLE 1. LIVE LOAD

Application	Load value	Unit
Shophouse	2,5	kN/m^2
Roof	4,79	kN/m^2

2) Dead Load

The types and values of dead loads included in the structural modeling can be seen in the table below.

TABLE 2. DEAD LOAD

Load Type	Load value	Unit
Self-weight: Reinforced concrete	24,0	kN/m^2

3) Super Dead Load

Super dead load is the additional load from the main structural elements such as floor finishing, ceilings, or walls. The values of additional dead load can be seen in the table below.

TABLE 3. SUPER DEAD LOAD

Description	Load value	Unit
Floor 1	0,86	kN/ m^2
Floor 2	1,94	kN/ m^2
Floor 3	1,94	kN/ m^2
Dak	1,08	kN/ m^2
Lightweight brick wall	5,625	kN/ m^2

4) Wind Load

Wind load is the pressure or suction force caused by wind blowing on the surface of a building. Wind load is regulated in SNI 1727:2020 [6]. For wind load input, see the table below.

TABLE 4. WIND LOAD

Load type	Load value	Unit
Basic wind speed	71,5	mph
Wind direction factor	0,85	-
Exposure category	C	-
Topographic factors	1,0	-
Wind influence factor	0,85	-
Wall pressure coefficient	0,8 -0,3	Suction Pressure

5) Earthquake Load

Earthquake loads on buildings are regulated in SNI 1726:2019 [7]. Earthquake loads for the City Balikpapan based on rsa.ciptakarya.pu.go.id are as follows.

TABLE 5. EARTHQUAKE LOAD

Load type	Load value	Unit
Site Class	C	-
Soil type	Soft	-
Ss parameter	0,1159	-
Parameter S_1	0,0799	-
Parameter S_{D1}	0,19	-
Parameter S_{DS}	0,22	-
Risk category	II	-
Earthquake priority factor	1,0	-
Response modification coefficient	5	-
System strength factor	3	-
Deflection magnification factor	4,5	-
Site coefficient, F_a	2,4	-
Site coefficient, F_v	4,2	-

Parameter S_{MS}	0,0929	-
Parameter S_{M1}	0,0639	-
Coefficient C_t	0,0466	-
Coefficient C_u	1,5	-
Coefficient, x	0,9	-
Building height	13,5	meter
Minimum period	0,4849	seconds
Maximum period	0,6788	seconds

C. *Calculation of Column Structural Components*

Reinforcement calculations for column structural elements are based on the analysis results generated by SAP2000.

- Column Length : 300 mm
- Column width : 300 mm
- Column height : 4000 mm
- Cross-sectional area : 90000 mm^2
- Main reinforcement : D16 mm
- Cross reinforcement : Ø10 mm
- Concrete cover : 30 mm
- Effective depth : 270 mm

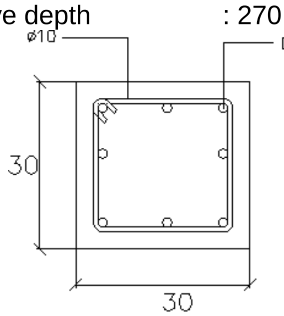

Fig. 6 Column reifoorcement detail K1

1) *Column Dimension Verification*

a) The minimum dimension of the cross-section shall not be less than 300 mm.

b ≥ 250 mm = 300 mm ≥ 250 mm → **OK!**

b) The ratio of the cross-sectional dimensions shall be at least 0.4.

$\frac{b}{h} \geq 0{,}4 = \frac{300}{300} \geq 0{,}4 = 1 \geq 0{,}4$ → **OK!**

2) *Seismic Component Requirement Check*

$P_u \leq 0{,}3\ A_g \times f'c$

406,277 kN ≤ 0,3 x 90000 mm^2 x 0,01868

406,277 kN ≤ 504,36 kN → **OK!**

3) *Analysis Of Columns With Slenderness Effect*

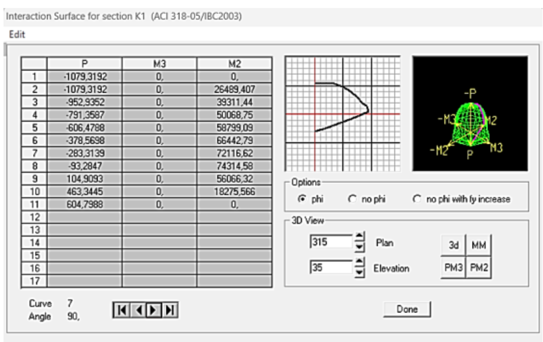

Fig. 7 P-M₂ interaction diagram for column K1

4) *Verification Of Longitudinal Reinforcement*

- $\frac{k\,.\lambda_{n,k}}{r} \leq 22 = \frac{1 \times 3500}{150} \leq 22$
  23,3 ≥ 22 → Classified as a slender column
- M_c = $M_{2b} + \delta s$. M_u atas
  = 0 + 1,036 x 27636,08
  = 28630,978 kN.mm

5) *Verification Of Shear Reinforcement*

$P_u \leq \phi.P_o$

406,277 ≤ 0,80 (ϕ(0,85 x f'$_c$x(A_g–A_{st})+f_yxA_{st}))

406,277 ≤ 0,80 (0,65(0,85x0,01868x(90000 – 1608,49) + 0,42 x 1608,49)

406,277 ≤ 0,80 (0,65 x 2079,046)

406,277 ≤ 1081,104 → **OK!**

According to SNI 2847:2019, Article 18.7.4.1, the area of longitudinal reinforcement A_s shall not be less than 0.01 A_g and not more than 0.06 A_g :

$\rho_{min} < \rho < \rho_{max}$

The longitudinal reinforcement ratio is checked as follows = $\frac{A_{st}}{b\ x\ d} = \frac{1608{,}495}{300\ x\ 300}$ = 0.0178

$\rho_{min} < \rho < \rho_{max}$ = 1% < 1,78% < 6% → **OK!**

D. *Calculation of Beam Structural Components*

The beam is designed using single reinforcement. A single-reinforced concrete beam refers to a concrete beam where the reinforcement is only calculated for the tension zone.

- Beam height : 500 mm
- Beam width : 300 mm
- Cross-sectional area : 150000 mm^2
- Main reinforcement : D16 mm
- Cross reinforcement : Ø10 mm
- Concrete cover : 30 mm
- Effective depth : 450 mm

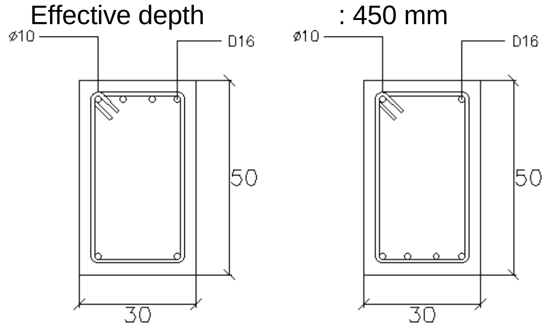

Fig. 8 Beam reinforcement detail BI

1) *Dimentional Limitation*

a) The clear span ℓn shall be at least 4d:

Beam length–($\frac{1}{2}$column width + $\frac{1}{2}$column width) ≥ 4xd

5000 mm – ($\frac{1}{2}$300 mm + $\frac{1}{2}$300 mm) ≥ 4 x 450 mm

4700 mm ≥ 1800 mm → **OK!**

b) The beam width b_w shall not exceed 0.3h or 250 mm

$b_w \geq$ 0,3h atau 250 mm

300 mm ≥ 0,3 x 500 mm

300 mm ≥ 150 or 250 mm → **OK!**

2) *Top Support Reinforcement*

a) Top support moment output from SAP2000

M_u = 52624,36 kN.mm

b) Verification of top support reinforcement based on as-built drawings

- *Provided reinforcement area, A_{st}*

  $A_{st} = n \times \frac{1}{4} \times \pi \times d_b^2$

  $= 4 \times \frac{1}{4} \times 3{,}14 \times 16^2$

  $= 803{,}84\ mm^2$

- The minimum required reinforcement area A_{smin} is 450 mm²

  $A_{st} \geq A_{s\,min}$ = 803,84 mm^2 ≥ 450 mm^2 → **OK!**

- Minimum Reinforcement Ratio, ρ_{min}

  $\rho_{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{420} =$ 0,0033

- Provided Reinforcement Ratio, ρ

  $\rho = \frac{A_{st}}{b \times d} = \frac{803{,}84}{300 \times 450} = 0{,}00595$

- Maximum Reinforcement Ratio, ρ_{max}

  ρ_{max} = 0,025 (SNI 2847 tahun 2019 pasal 18.6.3.1) Therefore, the beam reinforcement requirement is satisfied:

  $\rho_{min} \leq \rho \leq \rho_{max}$ = 0,0033≤0,00595≤0,025 → **OK!**

c) Moment control

$P_u < 0{,}10 f'c A_g$ = 0 < 0,10 x 0,01868 x150000

= 0 < 280,2 kN → *OK!*

d) Depth of concrete block, a

$a = A_{st} \times \frac{fy}{0{,}85 \times f'c \times b}$

$a = 803{,}84 \times \frac{420}{0{,}85 \times 18{,}68 \times 300}$

a = 70,876 mm

e) Flexural capacity, M_n

$M_n = A_{st} \times f_y \times (d - \frac{a}{2})$

$M_n = 803{,}84 \times 0{,}42 \times (450 - \frac{70{,}876}{2})$

M_n = 139961,437 kN.mm

f) Reduced flexural capacity, ϕM_n

ϕM_n = ϕ x M_n

= 0,90 x 139961,437 kN.mm

= 125965,293 kN.mm

Capacity Check:

The requirement, $\phi M_n \geq M_u$ = 125965,293 kN.mm ≥ 52624,36 kN.mm → **OK!**

The requirement is satisfied. Consequently, the beam reinforcement remains as 4D16 bars

3) Bottom Support Reinforcement

For the bottom support, the reinforcement shall be installed at a minimum of 50% of the provided reinforcement area.

a) Bottom support reinforcement area, A_{st}

= A_{st} x 0,5

= 803,84 mm2 x 0,5

= 401,92 mm2

b) Utilized deformed bars, D16 mm

$n = \frac{A_{st}}{\frac{1}{4} \times \pi \times d^2}$

$= \frac{803{,}84}{\frac{1}{4} \times 3{,}14 \times 16^2}$

= 4 bars, 4D16

TABLE 6. RECAPITULATION OF MAIN BEAM (BI) REINFORCEMENT

Main Beam (BI) 30 cm / 50 cm			
Longitudinal Reinforcement			
Upper Support	**Lower Support**	**Upper Field**	**Lower Field**
4D16	2D16	2D16	4D16
Shear reinforcement			
Support		Field	
Ø10-150		Ø10-150	

E. *Calculation of Slab Structural Components*

Slab data:

- Length of slab axis 1, Lx : 5000 mm
- Slab length along axis 2, Ly : 6000 mm
- Cross-sectional area : 150000 mm^2
- Slab thickness : 120 mm
- Reinforcement diameter : 10 mm
- Concrete cover : 30 mm
- Effective height : 85 mm

Slab Design Calculations Based on SNI 2847:2019 [5].

a) Moment output, M_u

M_u = 5,8413 kN.mm

b) Assumed reinforcement spacing, s=200 mm

S_{maks} = s ≤ 2*h* and 450 mm

= 200 ≤ 2 x 120 and 450 mm

= 200 ≤ 240 and 450 → **OK!**

c) Number of bars per meter, n

$n = \frac{b}{s} = \frac{1000}{200} = 5$

d) Clear spacing of reinforcement

Clear spacing ≥ d_b and 25 mm = 190 > 10 and 25 mm → **OK!**

e) Provided reinforcement area, A_{st}

$A_{st} = n \times \frac{1}{4} \times \pi \times d_b^2$

$= 5 \times \frac{1}{4} \times 3{,}14 \times 10^2$

= 392,5 mm

f) Minimum reinforcement area, A_{smin}

$0{,}0020 A_g$ = 0,0020 x 1000 x 120

= 240 mm^2

Check $A_{st} \geq As_{min}$ = 392,5 ≥ 240 → **OK!**

g) Minimum reinforcement ratio, ρ_{min}

$\rho_{min} = \frac{1{,}4}{fy} = 0{,}0033$

h) Provided reinforcement ratio, ρ

$\rho = \frac{A_{st}}{b \times d} = \frac{392{,}5}{1000 \times 85} = 0{,}00461$

i) Maximum reinforcement ratio, ρ_{max}

$\rho_{min} \leq \rho \leq \rho_{max}$

$0,0033 \leq 0,00461 \leq 0.025 \rightarrow$ **OK!**

j) Depth of concrete block, α

$\alpha = A_{st} \times \frac{f_y}{0,85 \times f'c \times b}$

$= 392,5 \times \frac{420}{0,85 \times 18,68 \times 1000}$

$= 10,38$ mm

k) Flexural capacity, M_n

$M_n = A_{st} \times f_y \times \left(d - \frac{a}{2}\right)$

$= 392,5 \times 0,42 \times \left(85 - \frac{10,38}{2}\right)$

$= 13156,67$ kN.mm

l) Location of neutral axis, c

$c = \frac{a}{\beta 1} = \frac{10,38}{0,85} = 12,21$ mm

m) Tensile reinforcement strain, ε_t

$\varepsilon_t = \frac{d-c}{c} \times 0,003$

$= \frac{85-12,21}{12,21} \times 0,003$

$= 0,017$

n) Strain of outermost tensile reinforcement, ε_{ty}

For deformed reinforcement with a grade of 420 MPa, the allowable strain of the outermost tensile reinforcement, εty\varepsilon_{ty}εty, may be taken as 0.002, in accordance with SNI 2847:2019 [5], Article 21.2.2.1**.**

o) Strength reduction factor, ϕ

$\phi = 0,90$

p) Reduced flexural capacity, ϕM_n

$\phi M_n = 0,90 \times 13156,67$

$= 11841,011$ kN.mm

Capacity Verification:

$\phi M_n \geq M_u$

11841,011 kN.mm ≥ 5,8413 kN.mm → **OK!**

Therefore, the slab continues to use D10 bars with 200 mm spacing in both x and y directions**,** as per the as-built drawings.

2) Negative Moment Reinforcement (First Layer Reinforcement)

a) Moment output, M_u

$M_u = 2,2113$ kN.mm

b) Assumed reinforcement spacing, s=200 mm

$S_{maks} = s \leq 2h$ and 450 mm

$= 200 \leq 2 \times 120$ and 450 mm

$= 200 \leq 240$ and 450 → **OK!**

c) Number of bars per meter, n

$n = \frac{b}{s} = \frac{1000}{200} = 5$

d) Clear spacing of reinforcement

Clear spacing ≥ d_b and 25 mm = 190 > 10 and 25 mm → **OK!**

e) Provided reinforcement area, A_{st}

$A_{st} = n \times \frac{1}{4} \times \pi \times d_b^2$

$= 5 \times \frac{1}{4} \times 3,14 \times 10^2$

$= 392,5$ mm

f) Minimum reinforcement area, A_{smin}

$0,0020A_g = 0,0020 \times 1000 \times 120$

$= 240$ mm^2

Check $A_{st} \geq As_{min} = 392,5 \geq 240 \rightarrow$ **OK!**

g) Minimum reinforcement ratio, ρ_{min}

$\rho_{min} = \frac{1,4}{fy} = 0,0033$

h) Provided reinforcement ratio, ρ

$\rho = \frac{Ast}{b \times d} = \frac{392,5}{1000 \times 85} = 0,00461$

i) Maximum reinforcement ratio, ρ_{max}

$\rho_{min} \leq \rho \leq \rho_{max}$

$0,0033 \leq 0,00461 \leq 0.025 \rightarrow$ **OK!**

j) Depth of concrete block, α

$\alpha = A_{st} \times \frac{f_y}{0,85 \times f'c \times b}$

$= 392,5 \times \frac{420}{0,85 \times 18,68 \times 1000}$

$= 10,38$ mm

k) Flexural capacity, M_n

$M_n = A_{st} \times f_y \times \left(d - \frac{a}{2}\right)$

$= 392,5 \times 0,42 \times \left(85 - \frac{10,38}{2}\right)$

$= 13156,67$ kN.mm

l) Location of neutral axis, c

$c = \frac{a}{\beta 1} = \frac{10,38}{0,85} = 12,21$ mm

m) Tensile reinforcement strain, ε_t

$\varepsilon_t = \frac{d-c}{c} \times 0,003$

$= \frac{85-12,21}{12,21} \times 0,003$

$= 0,017$

n) Strain of outermost tensile reinforcement, ε_{ty}

For deformed reinforcement with a grade of 420 MPa, the allowable strain of the outermost tensile reinforcement, εty\varepsilon_{ty}εty, may be taken as 0.002, in accordance with SNI 2847:2019 [5], Article 21.2.2.1**.**

o) Strength reduction factor, ϕ

$\phi = 0,90$

p) Reduced flexural capacity, ϕM_n

$\phi M_n = 0,90 \times 13156,67$

$= 11841,011$ kN.mm

Capacity Verification:

$\phi M_n \geq M_u$

11841,011 kN.mm ≥ 2,2113 kN.mm → **OK!**

Therefore, the slab continues to use D10 bars with 200 mm spacing in both x and y directions**,** as per the as-built drawings.

TABLE 7. RECAPITULATION OF SLAB REINFORCEMENT

Thick-ness (cm)	ϕMn (kN.mm)	ρ min	ρ	ρ min	Reinforce-ment used
12	11841	0,003	0,004	0,025	Ø10-200
10	11841	0,003	0,004	0,025	Ø10-200

V. Conclusion

Based on the structural analysis results of the Soetta 8 Business Center Block E Shopping Complex Building in Balikpapan, the following was obtained:

1) The building load includes a live load of 250 for shop houses and 488,28 kg/m² for roofs, an additional dead load of 130,4 kg/m², wind load in accordance with SNI 1727:2020 [6], and earthquake load using the response spectrum method in accordance with SNI 1726:2019 [7].

2) The analysis resulted in maximum forces in the form of a bending moment of 76.740,99 kN·mm, an axial force of 88.736 kN, and a shear force of 127,203 kN.

3) The structural element design complies with SNI 2847:2019, namely 30/30 cm columns with 8D16 reinforcement, 30/50 cm beams with 4D16 reinforcement at the supports and in the field, and 12 cm thick floor slabs with ∅10-200 reinforcement.

Although the initial SAP2000 analysis indicated potential *overstressing*, manual verification confirmed that the columns, beams, and slabs remain safe based on dimensional checks, reinforcement ratios, and interaction diagrams.

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