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Structural Analysis of the Office Building for the Regional Disaster Management Agency (BPBD) of Samarinda City Using Etabs Software

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Abstract**—*The construction of the BPBD (Regional Disaster Management Agency) Office Building in Samarinda City is an important development to support the performance of BPBD in managing regional disasters that can occur at any time in Samarinda City. The BPBD office building is a dilated structure consisting of 3 (three) floors at the front building and 2 (two) floors at the rear building. The building calculation uses an earthquake-resistant system in the form of a special moment-resisting frame (SRMPK) with earthquake analysis using the equivalent static method. The structural calculations of the building refer to SNI 2847:2019 regarding structural concrete requirements for building construction, SNI 1726:2019 concerning earthquake resistance planning procedures for building and non-building structures, and SNI 1727:2020 as the minimum design load requirements and related criteria for buildings and other structures. The building calculations use beam B1 with dimensions of 30/60 cm with longitudinal/main reinforcement of D19 and transverse/shear reinforcement of Ø10-70, column K1 with dimensions of 50/50 cm with main reinforcement D19 and shear reinforcement Ø10, floor slab thickness of 120 mm, and roof slab thickness of 100 mm with a main building height of 13 meters. Based on these calculations, the maximum inter-story drift is obtained at 100 mm.*

Keywords**—** *Earthquake, Etabs v22.0.0, Reinforced Concrete.*

I. INTRODUCTION

The construction of multi-story buildings with reinforced concrete structures requires meticulous planning to safely and efficiently withstand loads. This becomes even more crucial when buildings are intended for public facilities with vital functions, such as the Office Building of the Samarinda City Regional Disaster Management Agency (BPBD). The building serves as a coordination center in disaster management, so the building structure must be designed while considering factors of strength, safety, and earthquake resistance in accordance with technical standards.

The issues addressed in this research are how to calculate the load acting on the BPBD Samarinda building structure, how to determine the internal forces resulting from that loading, and how to plan the reinforcement requirements for the main structural elements consisting of beams, columns, and slabs. These issues are relevant considering that Samarinda has disaster potential, so public building structures must be designed to remain safe and function optimally in emergency conditions.

The research objective is to conduct a structural building analysis based on national standards, specifically SNI 2847:2019, SNI 1726:2019, and SNI 1727:2020, with the assistance of ETABS software. This research is expected to contribute to the field of civil engineering, particularly in the application of standard-based seismic-resistant structural analysis. The results can serve as a technical reference for the construction of government buildings and other public facilities that require high structural resistance against seismic loads.

II. THEORETICAL FRAMEWORK

An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

A. Structural Elements

Structural elements are parts of a structure that each have their own functions, among which are as follows:

- Column

A column is a structural compression element that plays an important role in a building. If a building column collapses, it indicates a critical location that can cause the collapse of the affected floor. Additionally, column collapse can also lead to the total collapse of a building. (Willem et al., 2017)

- Beam

The beam structure is a structural element that receives loads acting transversely to its axis, which can cause bending moments and shear forces along its span. A beam is a structural element that has the role of transmitting loads from floor slabs to columns as vertical supports. (Roy Wardana Jurusan et al., 2019)

- Floor Tiles

A floor slab is a solid structural element with a three-dimensional shape that has flat, straight surface planes and a thickness much smaller than other structural elements. The floor slab itself functions to receive loads that will be channeled to other structures. (Astri et al., 2022)

B. Loading Combination

Loading combinations are used in the planning of building structures and other structures, in accordance with SNI 1726:2019. Regarding the loading combinations (U) in SNI 2847:2019, the combinations consist of:

- 1,4D
- 1,2D + 1,6L + 0,5(Lr or S or R)
- 1,2D + 1,6(Lr or R) + (L or 0,5W)
- 1,2D + 1,0W + L 0,5(Lr or R)
- 0.9D + 1.0W
- 1,2D + Ev + Eh + L
- 0.9D - Ev + Eh

Explanation:
D = Dead Load R = Earthquake Reduction Factor
L = Live Load W = Wind Load
Lr = Live Roof Load E = Earthquake Load
S = Snow Load

C. Structural Calculations

- Column Calculations

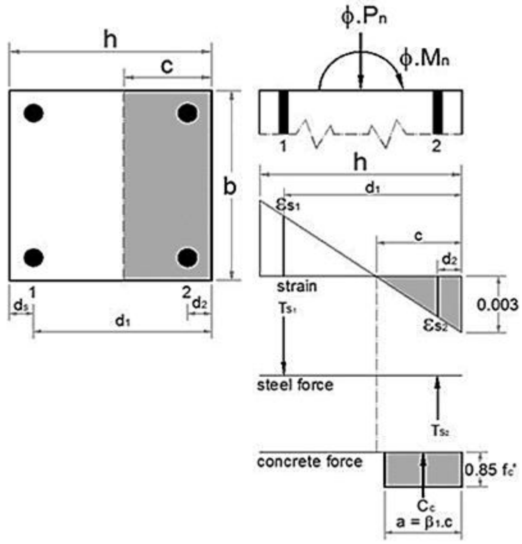

Fig. 1. Strain and Stress Diagram of Double-Sided Columns

The calculation of reinforcement in columns refers to the concept of equilibrium of forces due to Pu and Mu forces, as shown in Figure 1 below. Based on the equilibrium of forces $\sum V = 0$ then,

$\mathrm{Pn} + \mathrm{Ts} = \mathrm{Cc} + \mathrm{Cs}$……………………………………….(2.1)

Or,

$\mathrm{Pn} = \mathrm{Cc} + \mathrm{Cs} - \mathrm{Ts}$……………………………………….(2.2)

Explanation:
Pn = Nominal axial load due to external loading
Cc = Compression concrete
= 0,85.f'c.c.b.a
Cs = Compression steel
= A's.f's-0,85.f'c), (If the area of compression concrete is taken into account)
= A's.f's, (If the area of compression concrete is ignored)
Ts = Tensile steel
= As.fs

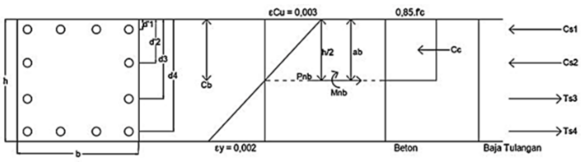

Fig. 2. Strain Reinforcement Diagram of Column Cross-Sections

The reinforcement requirements for four-sided columns can be calculated using the following formulas:

$P_{nb} = C_c + C_{s1} + C_{s2} - T_{s3} - T_{s4}$………………..(2.3)

$\mathrm{M_{nb}} = \mathrm{C_c}\left(\frac{h}{2} - \frac{a_b}{2}\right) + \mathrm{C_{s1}}\left(\frac{h}{2} - d_1'\right) + \mathrm{C_{s2}} - \mathrm{T_{s4}}\left(d_3 - \frac{h}{2}\right) - \mathrm{T_{s4}}\left(d_4 - \frac{h}{2}\right)$…..(2.4)

Explanation:
Pn = Nominal axial load due to external loading
Cc = Compression concrete
= 0,85.f'c.c.b.a
Cs = Compression steel
= A's.f's-0,85.f'c), (If the area of compression concrete is taken into account)
= A's.f's, (If the area of compression concrete is ignored)
Ts = Tensile steel
= As.fs

- Beam Calculation

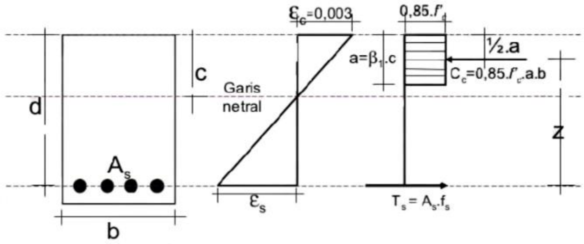

Fig. 3. Strain and Stress Distribution in Single Reinforced Beams

The formulas used in calculating beam reinforcement according to the sequence of activities are as follows:

$\mathrm{Mn} = 0{,}85.\,\mathrm{fc'}.\,\mathrm{b.\,a.}\left(\mathrm{d} - \frac{\mathrm{a}}{2}\right)$

$\mathrm{Mn} = \mathrm{Ts.\,Z} = \mathrm{As.\,fy.}\left(\mathrm{d} - \frac{1}{2}\mathrm{a}\right)$

$= \rho\mathrm{bd.\,fy.}\left(\mathrm{d} - \frac{1}{2}\mathrm{a}\right)$

$\mathrm{Mu} = \Phi.\mathrm{Mn}$

$\mathrm{Mu} = \Phi.\,\rho\mathrm{bd.\,fy}\left(\mathrm{d} - \frac{1}{2}\mathrm{a}\right)$

$\frac{\mathrm{Mu}}{\mathrm{bd}^2} = \Phi.\rho.fy.\left[1 - 0{,}588\rho.\frac{fy}{f'c}\right]$

Explanation:
ρb = Reinforcement ratio in a balanced state
fy = Yield stress of steel in the tension zone of the beam (MPa)
d = Distance from the outer tension fiber to the center of gravity of the longitudinal tension reinforcement (mm)
a = Height of the equivalent square compression concrete stress block (mm)
Φ = Reduction factor
Mu = Ultimate moment (Nmm)
Mn = Nominal moment (Nmm)

III. RESEARCH METHODOLOGY

To perform structural calculations for the Samarinda City BPBD Office building, the process that needs to be carried out is to conduct a literature study by examining references that will support the calculation process, such as SNI 2847:2019 (Requirements for structural concrete for buildings), SNI 1727:2020 (Minimum design loads and related criteria for buildings and other structures), 1726:2019 (Procedures for earthquake resistance planning for building and non-building structures), and other reference books that support the calculation process and data collection process, ranging from image data, construction data, concrete quality, and steel quality.

The structural data contained within the Samarinda City BPBD office building are as follows:

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A.	Concrete quality	:	$f'c$ 21.7 Mpa
B.	Reinforcing steel quality	:	$f'y$ 420 Mpa
			$f'y$ 280 Mpa
C.	Columns	:	K1 – 50 cm × 50 cm
			K2 – 40 cm × 40 cm
			K3 – 30 cm × 50 cm
			K4 – 40 cm × 40 cm
			K5 – 25 cm × 40 cm
D.	Beams	:	B1 – 30 cm × 60 cm
			B2 – 30 cm × 50 cm
			B3 – 25 cm × 45 cm
			B4 – 20 cm × 40 cm
			B5 – 20 cm × 35 cm

Structural modeling using ETABS, as shown in Figure 4 below

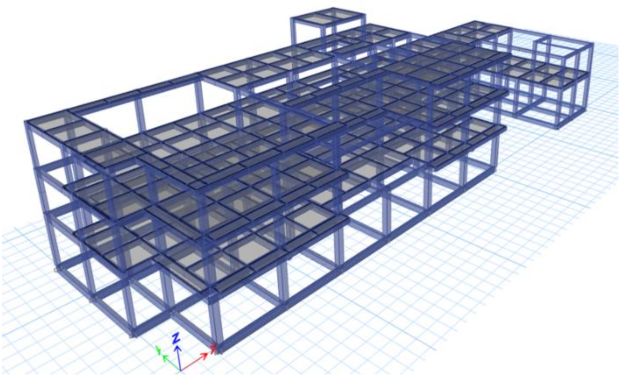
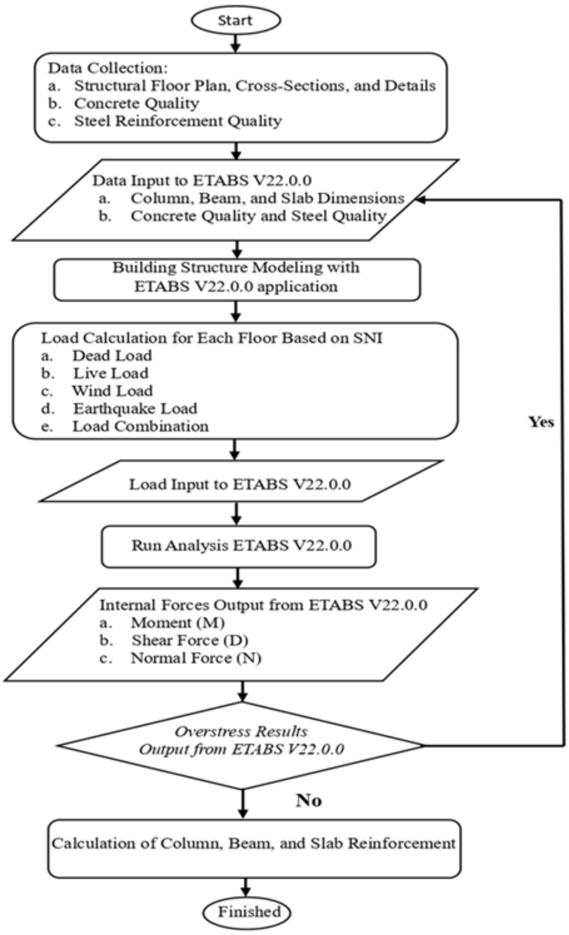


Fig. 4. BPBD Building Structure Design



IV. RESULTS AND DISCUSSION.

A. *Loading*

Dead load, additional dead load, self-weight of structure, weight of architectural finishes, and weight of ducting/cables/ME pipes are included and calculated as Dead Load. Dead Load of building materials and components is calculated based on Table 4.1 below:

TABLE 4. 1 Specific Gravity

No	Material	Dead Load
1	Steel	7850 kg/m^3
2	Reinforced concrete	2400 kg/m^3
3	Screed per cm thickness	21 kg/m^2
4	15 cm brick wall	250 kg/m^2
5	Ceiling with frame	18 kg/m^2
6	Floor finishing per cm thickness	24 kg/m^2
7	Mechanical ducting	19,3 kg/m^2
8	Waterproofing layer	5,1 kg/m^2

- Live Load

The uniform live load used follows the provisions of SNI 1727:2020 with a minimum load for the Room function of:

TABLE 4. 2 Live Load

No	Live Load	Berat kN/m^2
1	Office Space	2.4
2	Roof Floor Plates	0.96

- Additional Dead Load (SD)

The dead load calculated is the dead load on the slab, not the weight of the slab or column itself. The dead load is automatically calculated in the Etabs v22.0.0 application.

TABLE 4. 3 Additional Dead Load (SD)

No	Load Location	Load Type	Weight kN/m^2	Thickness cm	Q (kN/m^2)
1	Concrete Floor Load	Weight of 3 cm thick mortar	0.21	3	0.617819
		Weight of 1 cm thick ceramic tiles	0.24	1	0.2353596
		Ceiling and hangers	0.18	1	0.1765197
		Weight of electrical and mechanical installations	0.20	1	0.196133
Total					1.23
2	Dead Load of Floor Slabs	Ceiling and hangers	0.18	1	0.1765197
		Weight of ME installation	0.20	1	0.196133
Total					0.37
3	Evenly Distributed Load on the First Floor Walls	Red Brick	2.45	4.5	11.025
4	Evenly Distributed Load on	Red Brick	2.45	3.55	8.698

Tumingan, Vica Moni, Budi Nugroho, "Structural Analysis of the Office Building for the Regional Disaster Management Agency (BPBD) of Samarinda City Using Etabs Software," *International Research Journal of Advanced Engineering and Science*, Volume 10, Issue 4, pp. 34-42, 2025.

TABLE 4. 3 Additional Dead Load (SD)

No	Load Location	Load Type	Weight kN/m²	Thickness cm	Q (kN/m²)
	the Walls of Floors 2 and 3				
5	Even Load on Floor Slab Walls	Red Brick	2.45	2.65	6.493

- Wind Load

Table 4. 4 Wind Direction Value of Front Building

Surface	Cp (Wx)	Cp (Wy)
Windward wall	0,8	0,8
Leeward wall	-0,29	-0,5
Edge wall	-0,7	-0,7
Roof plate	-0,9	-0,81

Explanation:

Plus sign: Wind direction toward the building surface

Minus sign: Wind direction away from the building surface

- Earthquake Load

1.) Determining Risk Categories

The determination of building risk categories is based on the function of the building. Referring to Table 3 on page 19 (SNI 1726-2019), in this case, the building risk category is determined based on the function of the building. This construction project has a risk level in category 2 (two), which refers to office buildings.

2.) Determining Land Site Classification

The determination of earthquake priority factors is based on the function of the building. Referring to Table 4 on page 25 (SNI 1726-2019), in this case, the earthquake priority factor category is taken based on the value of the building risk category.

TABLE 4. 6 Earthquake Magnitude Factors

Risk category	Earthquake priority factor, I_e
I or II	1,0
Risk category	Earthquake priority factor, I_e
III	1,25
IV	1,50

Source: (National Standardization Agency 1726, 2019)

Priority factor (I_e) = 1

Based on the sounding data obtained from field test data, there are 4 sounding points as follows:

TABLE 4. 7 Sondir Test Results

No	Point	Depth (m)	Cone Resistance (Kg/cm²)
1	CPT 01	25	125
2	CPT 02	25	80
3	CPT 03	25	85
4	CPT 04	25	80

$$q_c = \frac{qc1 + qc2 + qc3 + qc4}{n} = 92{,}5 \text{ kg/cm}^2$$

So that the value of N is obtained:

$$N = \frac{qc}{4} = \frac{92{,}5}{4} = 23{,}125 \text{ kg/cm}^2$$

Based on SNI 1726:2019 article 5.3, the definition of site class in Table 5, the soil site class type is classified as medium soil (SD) because N is in the interval of 15 to 50.

TABLE 4. 8 Correlation of qc with N-SPT

Subsurface Condition	Penetration Resistance Range N	Friction Angle ϕ (deg)	Poisson Ratio (v)	Cone Penetration $q_c = 4$ N	Relatief Density Dr (%)	Young's Modulus Range E_s* (psi)	Shear Modulus Range G**(psi)
Very loose	0-4	28	0.45	0-16	0-15	0-440	0-160
Loose	4-10	28-30	0.40	16-40	15-35	440-1100	160-390
Medium	10-30	30-36	0.35	40-120	35-65	1100-3300	390-1200
Dense	30-50	36-41	0.30	120-100	65-85	3300-5500	1200-1990
Very Dense	50-100	41-45	0.20	200-400	85-100	5500-11000	1990-3900

Schmertman (1970) $E_s^* = 2q_c$ psf $\qquad G^{**} = \frac{E_s}{2(1+v)}$; dimana $v = 0{,}5$

Source: Scientific Journal; Ardiansyah, Rony (2011)

TABLE 4. 5 Wind Direction Value of the Rear Building

Surface	Cp (Wx)	Cp (Wy)
Windward wall	0,8	0,8
Leeward wall	-0,45	-0,5
Edge wall	-0,7	-0,7
Roof plate	-0,9	-0,18

3.) Spectral Response Design

The design parameters for spectral response are obtained from the design response spectrum data accessed via https://rsa.ciptakarya.pu.go.id/. The spectral response design parameters obtained are as follows:

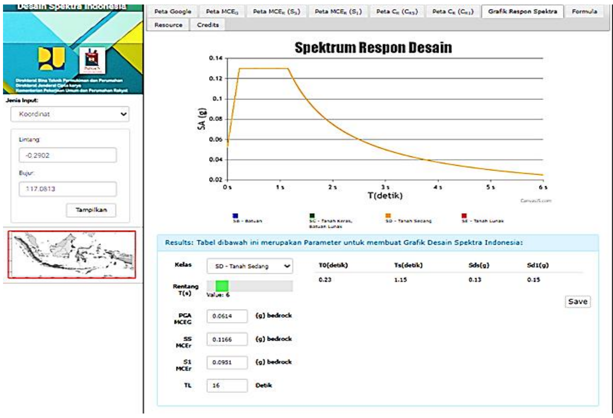


Fig. 5. Spectral Response Design

4.) Determining Seismic Design Categories

The determination of building structure systems for earthquake resistance systems is based on the table (SNI 1726 – 2019), which provides the following parameters:

Data :

Structure type : Reinforced Concrete Frame with Medium Moment Resisting Members

Modification Coefficient (R) : 5

Strength Factor (Ω) : 3

Amplification Factor (Cd) : 4.5

B. Load Combinations

S_{DS} 0.190

ρ 1.3

Q_E 0.1

TABLE 4. 9 Load Combinations

Nomor	DL	SDL	LL	Lr	W_x	W_y	E_x	E_y

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1	1.1	1.4	1.4						
2	2.1	1.2	1.2	1.6	0.5				
3	3.1	1.2	1.2	1	1.6				
	3.2	1.2	1.2		1.6	0.5			
	3.3	1.2	1.2		1.6	-0.5			
	3.4	1.2	1.2		1.6		0.5		
	3.5	1.2	1.2		1.6		-0.5		
4	4.1	1.2	1.2	1	0.5	1			
	4.2	1.2	1.2	1	0.5	-1			
	4.3	1.2	1.2	1	0.5		1		
	4.4	1.2	1.2	1	0.5		-1		
5	5.1	0.9	0.9			1			
	5.2	0.9	0.9			-1			
	5.3	0.9	0.9				1		
	5.4	0.9	0.9				-1		
6	6.1	1.2	1.2	1				0.13	0.046
	6.2	1.2	1.2	1				0.13	-0.046
	6.3	1.2	1.2	1				-0.13	0.046
	6.4	1.2	1.2	1				-0.13	-0.046
7	7.1	0.9	0.9					-0.13	0.034
	7.2	0.9	0.9					0.13	-0.034
	7.3	0.9	0.9					-0.13	-0.034
	7.4	0.9	0.9					0.13	0.034

C. Forces in Structures

The summary of maximum moments and maximum shear forces in the support beams and field beams is shown in the table below:

TABLE 4. 10 Maximum Moment on a Beam

Beam (B)		Moment (kNm)						
		Comb 1	Comb 2	Comb 3	Comb 4	Comb 5	Comb 6	Comb 7
1	+	124,76	**137,96**	126,33	126,34	80,22	126,33	80,21
	-	161,95	**169,86**	158,22	158,65	104,54	158,30	104,18
2	+	119,32	**121,35**	113,25	116,09	79,54	113,50	76,94
	-	117,92	**134,37**	121,88	121,95	75,87	121,93	75,85
3	+	48,73	**54,81**	49,92	53,06	53,06	49,93	31,33
	-	73,55	**84,51**	76,46	46,52	76,52	76,48	47,30
4	+	**41,96**	37,80	37,11	37,59	27,45	37,31	27,15
	-	41,92	**47,64**	43,25	45,22	28,92	43,26	26,95
5	+	16,78	**18,36**	16,87	16,88	11,17	16,87	10,81
	-	34,06	**36,79**	33,94	33,96	21,92	33,95	21,90

TABLE 4. 11 Maximum Shear Force on a Beam

Beam (B)		Shear Force (kNm)						
		Comb 1	Comb 2	Comb 3	Comb 4	Comb 5	Comb 6	Comb 7
1	+	**223,59**	214,54	205,96	206,70	144,48	206,28	144,04
	-	175,04	**177,47**	167,18	167,35	112,69	167,22	112,55
2	+	**173,64**	166,87	160,11	160,84	112,36	160,52	112,00
	-	124,48	**135,78**	123,52	123,54	82,91	123,54	80,28
3	+	64,74	**72,67**	66,23	66,30	66,30	66,25	41,64

Continuation TABLE 4. 11 Maximum Shear Force on a Beam

Beam (B)		Shear Force (kNm)						
		Comb 1	Comb 2	Comb 3	Comb 4	Comb 5	Comb 6	Comb 7
3	-	66,00	**73,88**	67,39	67,41	67,41	67,40	42,43
4	+	**102,17**	93,68	91,39	92,45	66,75	91,81	66,05
	-	**36,83**	35,39	33,96	33,97	23,69	33,96	23,68
5	+	36,28	**37,48**	35,09	35,10	23,33	27,77	23,32
	-	**30,02**	28,99	27,77	27,78	19,31	35,09	19,31

Meanwhile, the maximum moment (Mu), axial force (Pu), and shear force (Vu) on the column are shown in the table below:

TABLE 4. 12 Maximum Moment on Columns

Column (K)	Moment (kNm)						
	Comb 1	Comb 2	Comb 3	Comb 4	Comb 5	Comb 6	Comb 7
1	136.68	**154.51**	140.50	140.72	88.09	140.5	87.90
2	46.06	**49.00**	45.43	45.82	30.00	45.49	29.66
3	1.63	**1.65**	1.56	1.64	1.13	1.57	1.06
4	56.4	**65.08**	58.80	58.82	36.27	58.82	36.27
5	18.88	**21.36**	19.42	19.43	12.14	19.43	12.15

TABLE 4. 13 Maximum Shear Force on Columns

Column (K)	Shear Force (kNm)						
	Comb 1	Comb 2	Comb 3	Comb 4	Comb 5	Comb 6	Comb 7
1	70.04	**79.45**	72.17	72.24	45.10	72.19	45.04
2	18.76	**19.92**	18.48	18.71	12.29	18.53	12.10
3	0.20	**0.22**	0.20	0.22	0.16	0.21	0.13
4	21.14	**24.38**	22.03	22.04	13.60	22.04	13.60
5	**2.63**	2.50	2.41	2.41	1.69	2.41	1.70

TABLE 4. 14 Maximum Axial Force on Columns

Column (K)	Axial Force (kNm)						
	Comb 1	Comb 2	Comb 3	Comb 4	Comb 5	Comb 6	Comb 7
1	**1878**	1788	1721	1724	1210	1723	1209
2	423.9	**474.0**	432.5	435.5	275.5	432.5	272.5
3	**116.1**	100.1	101.0	102.8	77.6	101.7	76.2
4	354.0	**406.4**	367.8	367.8	227.6	367.9	227.6
5	**98.4**	96.2	91.8	94.3	65.3	91.9	63.4

D. Beam Calculation

1.) Floor Beam Data (B1)

Reinforcement Calculation

- Stress distribution factor f'c ≤ 30 Mpa, using β 0,85
- Reinforcement ratio in balanced conditions (ρ_b)

$\rho_b = \beta \times 0,85 \times \frac{f'c}{fy} \times \frac{600}{(600+fy)}$

$\rho_b = 0,85 \times 0,85 \times \frac{21,7}{420} \times \frac{600}{(600+420)}$

$\rho_b = 0,0220$

- Maximum moment resistance factor (R_{max})

$(R_{max}) = 0,75\times \rho\beta \times fy \times [1 - \frac{1}{2} \times 0,75 \times \rho\beta \times \frac{fy}{(0,85\times f'c)}]$

$(R_{max}) = 0,75\times 0,0220 \times 420 \times [1 - \frac{1}{2} \times 0,75 \times 0,0220\times \frac{420}{(0,85\times 21,7)}]$

$(R_{max}) = 5,62$

Positive moment reinforcement

- Momen Positif Rencana

$M_n = \frac{M_u^+}{\Phi}$

$M_n = \frac{137,960}{0,80}$

$M_n = 172,450$ kNm

- Estimated distance from the center of the flexible reinforcement to the concrete side (d') = 150 mm
- Effective height of the beam (d)

d = h – d'

d = 500 – 150

d = 450 mm

- Moment resistance factor (R_n)

$R_n = \frac{M_n \times 10^6}{(b \times d^2)}$

$R_n = \frac{172,450 \times 10^6}{(300\times 450^2)}$

$R_n = 2,8387$

$R_n < R_{max} \rightarrow$ Ok.

- Required reinforcement ratio (ρ)

$\rho = 0{,}85 \times \frac{f'c}{fy} \times \left[1 - \sqrt{[\frac{1 - 2 \times R_n}{(0{,}85 \times f'c)}]}\right]$

$\rho = 0{,}85 \times \frac{21{,}7}{420} \times \left[1 - \sqrt{\left[\frac{1 - 2 \times 2{,}8387}{(0{,}85 \times 21{,}7)}\right]}\right]$

$\rho = 0{,}00738$

- Minimum Reinforcement Ratio (ρ_{min})

$\rho_{min} = \frac{\sqrt{f'c}}{(4 \times 420)}$

$\rho_{min} = \frac{\sqrt{21{,}7}}{(4 \times 420)}$

$\rho_{min} = 0{,}00277$

- Minimum Reinforcement Ratio (ρ_{min})

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

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

$\rho_{min} = 0{,}00333$

The reinforcement ratio used is $\rho = 0{,}00738$

- Required reinforcement area (As)

$A_s = \rho \times b \times d$

$A_s = 0{,}00738 \times 300 \times 450$

$A_s = 996 \ mm^2$

- Number of reinforcements required (n)

$n = \frac{A_s}{(\frac{\pi}{4 \times D^2})}$

$n = \frac{996}{\left(\frac{3{,}14}{4 \times 19^2}\right)}$

$n = 3{,}513$

Digunakan tulangan 4 D 19

Tulangan momen negatif

- Negative Moment of Plan (M_n)

$M_n = \frac{M_u^+}{\Phi}$

$M_n = \frac{169{,}960}{0{,}80}$

$M_n = 212{,}327 \ kNm$

- Moment resistance factor (R_n)

$R_n = \frac{M_n \times 10^6}{(b \times d^2)}$

$R_n = \frac{212{,}327 \times 10^6}{(300 \times 450^2)}$

$R_n = 3{,}4951$

$R_n < R_{max} \rightarrow$ Ok.

- Required reinforcement ratio (ρ)

$\rho = 0{,}85 \times \frac{f'c}{fy} \times \left[1 - \sqrt{[\frac{1 - 2 \times R_n}{(0{,}85 \times f'c)}]}\right]$

$\rho = 0{,}85 \times \frac{21{,}7}{420} \times \left[1 - \sqrt{\left[\frac{1 - 2 \times (-3{,}4951)}{(0{,}85 \times 21{,}7)}\right]}\right]$

$\rho = 0.00931$

Since $\rho > \rho min$, the reinforcement ratio used is 0.00931

- Required reinforcement area (A_s)

$A_s = \rho \times b \times d$

$A_s = 0{,}00931 \times 300 \times 450$

$A_s = 1257 \ mm^2$

- Number of reinforcements required (n)

$n = \frac{A_s}{(\frac{\pi}{4 \times D^2})}$

$n = \frac{1257}{\left(\frac{3{,}14}{4 \times 19^2}\right)}$

$n = 4{,}432$

Digunakan tulangan 5 D 19

Shear Reinforcement

- Ultimate shear force $V_u = 223{,}591$ kN
- Shear strength reduction factor $\Phi = 0{,}60$
- Shear reinforcement yield stress fy = 280 Mpa
- Concrete shear strength (V_c)

$V_c = \frac{\sqrt{f'c}}{6 \times b \times d \times 10^{-3}}$

$V_c = \frac{\sqrt{21{,}7}}{6 \times 300 \times 450 \times 10^{-3}}$

$V_c = 104{,}812 \ kN$

- Concrete shear resistance

$\Phi \times V_c = 0{,}60 \times 104{,}812$

$= 62{,}887$ kN (shear reinforcement required)

- Shear resistance of the tie bar

$= \Phi \times V_s = V_u - \Phi \times V_s$

$= 160{,}704 \ kN$

- Shear strength of the tie bar (V_s)

$V_s = 267{,}839 \ kN$

Use 2 Ø10 cross-section stirrups

- Shear reinforcement area of stirrups (A_v)

$A_v = \frac{n_s \times \pi}{4 \times Ø^2}$

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

$A_v = 157{,}08 \ mm^2$

- Required clamp distance (s)

$s = \frac{A_v \times fy \times d}{V_s \times 10^3}$

$s = \frac{157{,}08 \times 280 \times 450}{267{,}839 \times 10^3}$

$s = 73{,}90 \ mm$

- Maximum clamp distance (s_{max})

$s_{max} = \frac{d}{2}$

$s_{max} = \frac{550{,}50}{2}$

$s_{max} = 275{,}25 \ mm$

$s_{max} = 250 \ mm$

The clamp distance that must be used is 73.90 mm, taking a clamp distance of 70 mm.

- Column Calculation

1.) K1 50 x 50

Data Input

Column Geometry

Short Side of Column (b) = 500 mm d1 = 460.5 mm

Long Side of Column (h) = 500 mm d2 = 460.5 mm

Height of Column (L) = 5000 mm

Clear Cover (cc) = 20 mm h - cc - ds - db/2

Beam Height (hb) = 500 mm

Column Clear Height (Ln) = 4500 mm

Material

Concrete Compressive Strength f'c = 21.7 MP β1 = 0.850

Yield Strength of Longitudinal Reinforcing Steel fy = 420 MP

Yield Strength of Transverse Reinforcing Steel f_{yy} = 280 MPa

Aggregate Diameter d_{agg} = 10 mm

Reinforcing Bar Diameter

Longitudinal Reinforcing Bar Diameter d_b = 19 mm, Ab = 283.53 mm²

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Diameter of stirrup reinforcement d_s = 10 mm,
Av = 78.54 mm²
Longitudinal/main reinforcement
Number of X-direction reinforcements (n_x) = 4
Number of Y-direction reinforcements (n_y) = 4
Total Number of Longitudinal Reinforcement Bars n = 12
As = 3402.34 mm^2
Transverse Reinforcement/Stirrups
Number of X-direction support legs ($n_{vs,x}$) = 2,
$A_{vs,x}$ = 157.08 mm^2
Number of Y-direction support legs ($n_{vs,y}$) = 2,
$A_{vs,y}$ = 157.08 mm^2
Number of Field Support Feet in the X Direction ($n_{vm,x}$) = 2, $A_{vm,x}$ = 157.08 mm^2
Number of Field Support Feet in the Y Direction ($n_{vm,y}$) = 2, $A_{vm,y}$ = 157.08 mm2
Sengkang Spacing Support S_s = 150 mm
Field Spacing S_m = 150 mm

TABLE 4. 15 Axial-Flexural Stress

Combination	Condition	P (kN)	MX (kNm)	MY (kNm)	Mu (kNm)
Comb 1	P Max	1877.55	-7.95	-56.78	57.33
Comb 2.1	P Min	30.63	-3.00	0.93	3.14
Comb 2.1	MX Max	403.34	73.06	-12.20	74.07
Comb 2.1	MX Min	428.05	-92.96	-12.94	93.86
Comb 2.1	MY Max	443.14	-13.40	154.51	155.09
Comb 2.1	MY Min	418.43	12.65	-123.6	124.20

Shear
Shear Force on X-axis X V_{ux} = 42.1586 kN
Shear Force on Y-axis V_{uy} = 72.1687 kN
Axial-Flexural Design

- Checking Reinforcement Ratio Requirements
  Longitudinal Reinforcement Area As = n × Ab
  = 12 × 283,529
  = 3402,34 mm^2
  Cross-sectional Area Ag = b × h
  = 500 × 500
  = 250000 mm^2
  Reinforcement Ratio
  (SNI 2847:2019 article 10.6.1.1)
  $\rho = \frac{A_s}{A_g} = \frac{3402,3448}{250000} = 1,36\%$
  1% < 1,36% < 8% …(OK)
  Clean Space Between Reinforcements
  (SNI 2847:2019 pasal 25.2)
  S_h = 121.3 mm > 25 mm…(OK)
- Axial-Flexural Capacity Check

TABLE 4. 16 Axial-Flexural Capacity Check

Condition	P (kN)	MX (kNm)	MY (kNm)	$\varphi M_n / M_u$	c (mm)	d_t (mm)	ε_{st}	φ	Check
P Max	1877.6	-7.949	-56.8	5.061	359.3	519.9	0.0013	0.650	OK
P Min	30.635	-2.997	0.926	87.890	167.1	576.0	0.0074	0.900	OK
MX Max	403.34	73.056	-12.2	4.488	165.6	530.0	0.0066	0.900	OK
MX Min	428.05	-92.96	-12.9	3.585	160.0	519.6	0.0068	0.900	OK
MY Max	443.14	-13.4	154.5	2.195	146.1	498.6	0.0073	0.900	OK
MY Min	418.43	12.653	-124	2.710	148.3	505.0	0.0072	0.900	OK

- Shear Design

Support Shear Design
X-axis Concrete Shear Capacity
(SNI 2847:2019 article 22.5.6.1)

$$V_{c,x} = 0,17\left(1+\frac{N_u}{14A_g}\right)\lambda\sqrt{f'c}hd_2$$

$$V_{c,x} = 0,17\left(1+\frac{30634,8}{14\times 250000}\right)\times 1\times\sqrt{21,7}\times 500\times 460.5$$

$$V_{c,x} = 183934.4933\text{ N}$$

Y-axis Concrete Shear Capacity
(SNI 2847:2019 article 22.5.6.1)

$$V_{c,y} = 0,17\left(1+\frac{N_u}{14A_g}\right)\lambda\sqrt{f'c}hd_1V_{c,y}$$

$$V_{c,y} = 0,17\,(1+\frac{30634,8}{14\times 250000})\times 1\times\sqrt{21,7}\times 500\times 460.5$$

$$V_{c,y} = 183934,4933\text{ N}$$

Shear Capacity of Reinforcing Steel in the X-axis
(SNI 2847:2019 article 22.5.10.5.3)

$$V_{s,x} = \frac{A_v\times f_{yv}\times d_2}{s}$$

$$V_{s,x} = \frac{157,08\times 280\times 460,5}{150}$$

$$V_{s,y} = 135025.6523\text{ N}$$

Reduction Factor $\Phi = 0,75$
(SNI 2847:2019 table 21.2.1)
Nominal Capacity of X-Axis Columns
(SNI 2847:2019 article 22.5.10.1)

$$V_{n,x} = \Phi\times(V_{c,x}+V_{s,x})$$

$$V_{n,x} = 0,75\times(183934.4933+135025.65230)$$

$$= 239220.1092\text{ N} > 3054,4\text{ N...(OK)}$$

Nominal Capacity of Y-Axis Column
(SNI 2847:2019 article 22.5.10.1)

$$V_{n,y} = \Phi\times(V_{c,y}+V_{s,y})$$

$$V_{n,y} = 0,75\times(183934.4933+135025.65230)$$

$$= 239220.1092\text{ N} > 12939,2\text{ N...(OK)}$$

- Field Shear Design
  Concrete shear capacity of axis X,
  $V_{c,x} = 183934.4933$ N
  Concrete shear capacity of axis Y,
  $V_{c,x} = 183934.4933$ N
  Reinforcing steel shear capacity of axis X
  (SNI 2847:2019 article 22.2.10.5.3)

$$V_{s,x} = \frac{A_{vm,x}\times f_{yv}\times d_2}{S_m}$$

$$V_{s,x} = \frac{157,08\times 280\times 460,5}{150}$$

$$V_{s,x} = 135026\text{ N}$$

Shear capacity of Y-axis reinforcement steel
(SNI 2847:2019 article 22.2.10.5.3)

$$V_{s,y} = \frac{A_{vm,y}\times f_{yv}\times d_1}{S_m}$$

$$V_{s,y} = \frac{157,08\times 280\times 460,5}{150}$$

$$V_{s,y} = 135026\text{ N}$$

Reduction Factor $\Phi = 0,8$
Nominal Capacity of X-Axis Column
(SNI 2847:2019 article 22.5.10.1)

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$V_{n,x} = \Phi \times (V_{c,x} + V_{s,x})$
$V_{n,x} = 0{,}8 \times (183934 + 135026)$
$= 255168 \text{ N} > 42158{,}6 \text{ N}$...(OK)
Nominal Capacity of Y-Axis Column
(SNI 2847:2019 article 22.5.10.1)
$V_{n,y} = \Phi \times (V_{c,y} + V_{s,y})$
$V_{n,y} = 0{,}8 \times (183934 + 135026)$
$= 255168 \text{ N} > 42158{,}6 \text{ N}$...(OK)

- Checking Confinement, Spacing Between Studs, and Stud Spacing
Minimum Stud Reinforcement
Area per Stud Spacing X installed
$\frac{A_{v,x}}{S} = \frac{A_{Vs,x}}{S_s}$
$\frac{157{,}07963}{150} = 1{,}047 \text{ mm}^2/\text{mm}$
Area per installed Sengkang Y spacer
$\frac{A_{v,y}}{S} = \frac{A_{Vs,y}}{S_s}$
$\frac{157{,}07963}{150} = 1{,}047 \text{ mm}^2/\text{mm}$
Area per sengkang X space required
a. $\frac{A_{v,x}}{s} > \left(0{,}062 \times \sqrt{f'c} \times \frac{h}{f_y}\right)$
$1{,}047 > (0{,}062 \times \sqrt{21{,}7} \times \frac{500}{420})$
$1{,}047 > 0{,}344$
b. $\frac{A_{v,x}}{s} > (0{,}35 \times \frac{h}{f_y})$
$1{,}047 > (0{,}35 \times \frac{500}{420})$
$1{,}047 > 0{,}357$
$1{,}047 > 0{,}357 \text{ mm}^2/\text{mm}$...(OK)
Area per sengkang Y space required
a. $\frac{A_{v,y}}{s} > \left(0{,}062 \times \sqrt{f'c} \times \frac{h}{f_y}\right)$
$1{,}047 > (0{,}062 \times \sqrt{21{,}7} \times \frac{500}{420})$
$1{,}047 > 0{,}344$
b. $\frac{A_{v,y}}{s} > (0{,}35 \times \frac{h}{f_y})$
$1{,}047 > (0{,}35 \times \frac{500}{420})$
$1{,}047 > 0{,}357$
$1{,}047 > 0{,}357 \text{ mm}^2/\text{mm}$...(OK)

- Minimum Field Spacing
Area per installed X spacing
$\frac{A_{v,x}}{S} = \frac{A_{Vs,x}}{S_s}$
$\frac{157{,}07963}{150} = 1{,}047 \text{ mm}^2/\text{mm}$
Area per installed Sengkang Y spacer
$\frac{A_{v,y}}{S} = \frac{A_{Vs,y}}{S_s}$
$\frac{157{,}07963}{150} = 1{,}047 \text{ mm}^2/\text{mm}$
Area per sengkang X space required
a. $\frac{A_{v,x}}{s} > \left(0{,}062 \times \sqrt{f'c} \times \frac{h}{f_y}\right)$
$1{,}047 > (0{,}062 \times \sqrt{21{,}7} \times \frac{500}{420})$
$1{,}047 > 0{,}344$
b. $\frac{A_{v,x}}{s} > (0{,}35 \times \frac{h}{f_y})$
$1{,}047 > (0{,}35 \times \frac{500}{420})$
$1{,}047 > 0{,}357$
$1{,}047 > 0{,}357 \text{ mm}^2/\text{mm}$...(OK)
Area per sengkang Y space required
a. $\frac{A_{v,y}}{s} > \left(0{,}062 \times \sqrt{f'c} \times \frac{h}{f_y}\right)$
$1{,}047 > (0{,}062 \times \sqrt{21{,}7} \times \frac{500}{420})$
$1{,}047 > 0{,}344$
b. $\frac{A_{v,y}}{s} > (0{,}35 \times \frac{h}{f_y})$
$1{,}047 > (0{,}35 \times \frac{500}{420})$
$1{,}047 > 0{,}357$
$1{,}047 > 0{,}357 \text{ mm}^2/\text{mm}$...(OK)

- Maximum Spacing of Braces
Maximum Spacing of Support Braces
Reinforcement Ratio for Support Braces
(SNI 2847:2019 article 10.7.6.5.2)
$\frac{V_{s,required}}{\sqrt{f'c} \times b \times d_1} = \frac{0}{1072580} = 0 < 0{,}3$
Maximum support spacing
(SNI 2847:2019 article 10.7.6.5.2)
a. $S_{s,max} = \frac{d}{2}$
$S_{s,max} = \frac{460{,}5}{2}$
$S_{s,max} = 230{,}25$
b. $S_{s,max} = \frac{3h}{4}$
$S_{s,max} = \frac{3 \times 500}{4}$
$S_{s,max} = 375$
c. 600
$230{,}25 > 150 \text{ mm}^2/\text{mm}$...(OK)

- **Maximum Spacing of Stirrups**
Reinforcement requirement ratio for stirrups
(SNI 2847:2019 article 10.7.6.5.2)
$\frac{V_{s,required}}{\sqrt{f'c} \times b \times d_1} = \frac{0}{1072580} = 0 < 0{,}3$
Maximum support spacing
(SNI 2847:2019 article 10.7.6.5.2)
a. $S_{s,max} = \frac{d}{2}$
$S_{s,max} = \frac{460{,}5}{2}$
$S_{s,max} = 230{,}25$

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b. $S_{s,max} = \frac{3h}{4}$

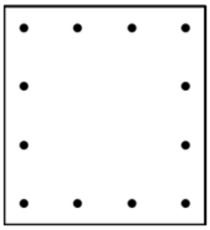
$S_{s,max} = \frac{3 \times 500}{4}$

$S_{s,max} = 375$

c. 600

$230{,}5 > 150\ mm^2/mm$...(OK)

Conclusion:



12 D 19

Dimensions	:	500 x 500
Longitudinal	:	1,36%
Support Clamp	:	2/2 ∅10-150
Field Clamp	:	2/2 ∅10-150

Design Results Recap

No	Parameters	Check
1	Longitudinal Reinforcement Ratio and Spacing	OK
2	Axial-Flexural Capacity	OK
3	Bearing Shear Capacity	OK
4	Field Shear Capacity	OK
5	Bearing Stirrup Reinforcement	OK
6	Field Stirrup Reinforcement	OK
7	Bearing Stirrup Spacing	OK
8	Field Stirrup Spacing	OK

V. CONCLUSIONS

Based on the results of the reinforcement calculation for the reinforced concrete structure of the Samarinda City BPBD Office Building, the following reinforcement results were obtained:

- Beam

TABLE 4. 17 Recapitulation of beam calculations

Block Name	Dimensions	Flexible Reinforcement		Reinforcement Sengkang
		Support	Field	
B1	30 x 60	5 D19	4 D19	2 Ø10
B2	30 x 50	5 D19	5 D19	2 Ø10
B3	25 x 45	4 D19	3 D19	2 Ø10
B4	20 x 40	3 D19	3 D19	2 Ø10
B5	20 x 35	3 D19	2 D19	2 Ø10

TABLE 4. 18 Recapitulation of column calculations

Column Name	Dimensions	Flexible Reinforcement	Sengkang Reinforcement	
			Support	Field
K1	50 x 50	12 D19	Ø10-150	Ø10-150
K2	40 x 40	12 D19	Ø10-150	Ø10-150
K3	30 x 50	10 D19	Ø10-150	Ø10-150
K4	40 x 40	12 D16	Ø10-150	Ø10-150
K5	40 x 25	10 D16	Ø10-150	Ø10-150

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