"ANALYSIS OF THE SUPER STRUCTURE DESIGN OF THE OPERATIONAL BUILDING AT UPBU CLASS III MELALAN, EAST KALIMANTAN"

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ABSTRACT

Melalan Airport in West Kutai (IATA: GHS, ICAO: WALE, formerly WRLE) is located in Gemuhan Asa Village, Barong Tongkok District, approximately 8 km from the city center. Positioned at an elevation of 100.5 meters (330 feet) above sea level, the airport is currently undergoing development, including the construction of a new operational building. This project addresses the increasing need for staff and operational space at the airport. The research method used is a descriptive qualitative approach through data collection. According to the 2023 Term of Reference (TOR) for Melalan Airport, the development plan includes the construction of an operational building to support daily operations and maintenance of airport facilities. The structural design uses the Medium Moment Resisting Frame System (SRPMM), as the area of Sendawar lies within a low to moderate seismic zone (0.05 – 0.1 g). The structure was analyzed using SAP2000 software for earthquake-resistant design. The final design includes main beams of 25 × 40 cm, secondary beams of 20 × 15 cm, slab thickness of 11 cm, and columns of 40 × 40 cm. The total construction cost for the operational building is estimated at Rp 1,215,000,000.00 (One billion two hundred fifteen million rupiah).

Keywords: *Melalan Airport, Operational Building, SRPMM, SAP2000, Budget Plan*

1. INTRODUCTION

Indonesia, one of the world's largest archipelagic developing nations, relies heavily on air transportation to connect its many islands. Air travel is especially vital for remote areas with limited transport options. Geographically, the country lies on the Pacific Ring of Fire and between three tectonic plates: Indo-Australian, Eurasian, and Pacific [1]. Melalan Airport (IATA: GHS, ICAO: WALE, formerly WRLE) is located in Gemuhan Asa Village, Barong Tongkok District, Kutai Barat, East Kalimantan. It lies about 8 km from the town center and sits at an elevation of 100.5 meters (330 feet) above sea level.

Melalan Airport has a flexible asphalt runway initially measuring 900 x 23 m, extended on July 17, 2014, to 1300 x 30 m—capable of handling ATR 72-600 aircraft. It features runway 03/21, an apron of 170 x 75 m, a taxiway of 17 x 75 m, and a 1,000 m² terminal accommodating up to 200 passengers. According to the 2015 Master Plan, facilities are mostly complete, including terminal expansion and new administrative, PKPPK, and staff buildings. However, the airport still lacks an operational building, a key infrastructure component.

A 2024 field review by the Directorate of Airports highlighted the need for preventive maintenance of the power house at Melalan Airport, which currently doubles as a warehouse and operations office. The space is not well-organized and lacks proper safety standards. Since technician offices and equipment storage are still housed there, a dedicated operations building is needed to support airport activities. This would improve efficiency, centralize operations, and ensure compliance with administrative standards.

BMKG Balikpapan recorded ten earthquakes in Kalimantan during January 2025, with magnitudes ranging from 2.3 to 3.7 SR. Notably, a 2.8 SR quake occurred 157 km southeast of Berau, and a 3.7 SR quake struck near Balikpapan at a depth of 38 km. Sendawar falls within a low to moderate seismic zone (0.05–0.1g)[2]. Given recent seismic activity, earthquake-resistant building design is essential for the area.

A moment-resisting frame system is a structural system that includes a space frame that completely resists gravity loads. Lateral loads are resisted by the moment-resisting frame through a flexural mechanism [3]. Oktariansyah's (2009) research on Moment-Resisting Frame Systems found that it was difficult to achieve ductile behavior in frame structures due to the discontinuous columns on each floor [4]. The reference standard is SNI 1726:2019 concerning Earthquake Resistance Planning Procedures for Building and Non-Building Structures. This standard explains the Intermediate Moment Resisting Frame System (SRPMM) method used in earthquake-resistant building structure planning. Previous research supporting the implementation of this SNI is the Redesign Of The Steel Structure Of The Sugimanuru Airport Administration Office Building, West Muna by Dimas Prayoga (2024)[5].

2. RESEARCH METHODS

The research flow diagram has been prepared as shown below:

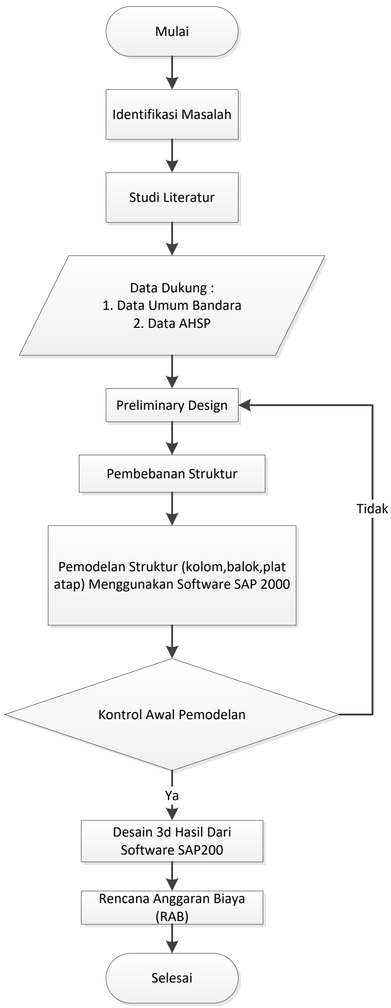

Figure 1 Research Flowchart
Source: Author, 2025

a. Identification of problems

Melalan Airport is currently undergoing development. According to the 2023 Terms of Reference (TOR), the plan includes construction preparation, runway development, and equipment procurement. The TOR also outlines the planned construction of an operations building to support both airport operations and facility maintenance.

b. Literature study

The practice of collecting and reviewing various sources such as books, journals, articles, archives, and magazines is part of a literature review. Its purpose is to develop concepts and theories that support the application of the study.

c. Data collection

- Building name : Operational Building
- Function : As a supporting facility for airport maintenance and smooth flight operations
- Location : Melalan Airport
- Number of floor : 2
- First floor height : 3,5 m
- Second floor height : 3,5 m
- Roof type : Concrete slab
- Building area : 200 m2
- Main structure : Concrete
- Soil type : soft ground (SE)
- Earthquake data: Earthquake data was obtained using response spectrum analysis, based on calculations from the Research and Development Center for Settlements (Puskim), published in 2021. The following is the earthquake response spectrum graph for the Kutai Barat region, East Kalimantan.

d. Preliminary design

The 2D design of the operations building was created using AutoCAD, focusing on the superstructure with a concrete design. A 3D model was visualized using SketchUp, while structural analysis (columns, beams, slabs) was performed with SAP2000. The building includes essential rooms such as meeting rooms, staff offices, toilets, an archive room, server room, and equipment storage. The structural planning considers dead loads, live loads, earthquakes, and wind. Below is the design plan for the Operations Building at Melalan Airport.

Figure 2 3D Design of Operational Building
Source: Author, 2025

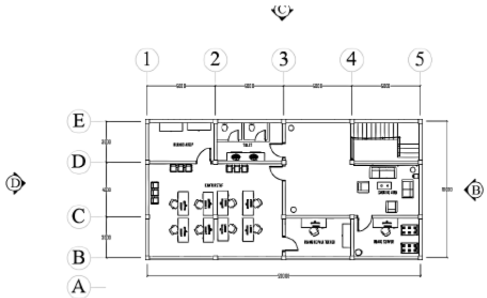

Figure 3 First Floor
Source: Author, 2025

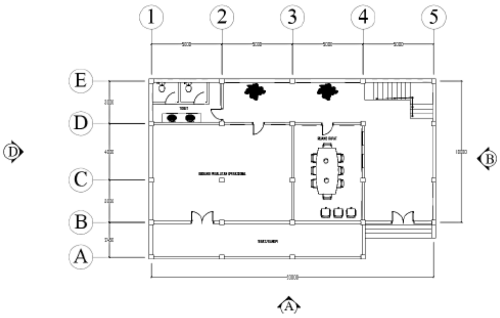

Figure 4 Second Floor
Source: Author, 2025

e. Structural loading and modeling

In this context, structural loading and modeling were carried out using SAP2000. The software is used to analyze both static and dynamic aspects of structures, particularly for high-rise buildings. Its main function is to assess structural capacity and ensure earthquake resistance. SAP2000 is applied to design and analyze structures under dead loads, live loads, seismic forces, and wind loads.

f. Superstructure analysis

The output from structural loading and modeling in SAP2000 includes internal forces (moment, shear, and axial forces). After obtaining these results, the next step is to check dimensions and reinforcement. This allows for comparison between SAP2000 results and manual calculations. Additionally, seismic data can be analyzed using rsa.ciptakarya. This verification ensures that key structural elements beams, columns, and slabs comply with SNI standards, resulting in a safer, more stable, and efficient design[7].

g. Detailed depiction of the superstructure

This stage involves detailing the dimensions and reinforcement based on analysis results from SAP2000 and manual calculations. The goal is to visually present the structural elements of the operational building at UPBU Class III Melalan, making it easier for readers to understand the design.

h. RAB calculation

Every construction project involves a Bill of Quantities (BoQ), used to estimate the required materials, equipment, and manpower. The BoQ is prepared based on the 2024 Unit Price Standards (HSP) applicable in East Kalimantan.

3. RESULTS AND DISCUSSION

A. Preliminary Design

Preliminary design is the initial stage of designing a building which will later produce the dimensions of the beams, columns and plates of the building.

1. Preliminary Beam Design

a. Main beam calculation

- Beam height

$$h = \frac{l}{16} = \frac{500}{16} = 31{,}25 \text{ cm}$$

- Beam width

$$b = \frac{2}{3}h = \frac{2}{3}\, 31{,}25 = 20{,}8 \text{ cm}$$

1 = longest span between columns

The initial dimensions based on the calculations for the main beam (Bi) are 31.25 cm x 20.8 cm, so the planned main beam (Bi) is 40 x 25 cm.

b. Secondary beam calculation

- Beam height

$$h = \frac{l}{21} = \frac{400}{21} = 19 \text{ cm}$$

- Beam width

$$b = \frac{2}{3}h = \frac{2}{3}\, 19 = 12{,}6 \text{ cm}$$

1 = longest span between columns

The initial dimensions based on the calculation for main beam (Ba) are 19 cm x 12,6 cm, therefor the planned main beam (Ba) is 20 cm x 15 cm.

2. Preliminary plate design

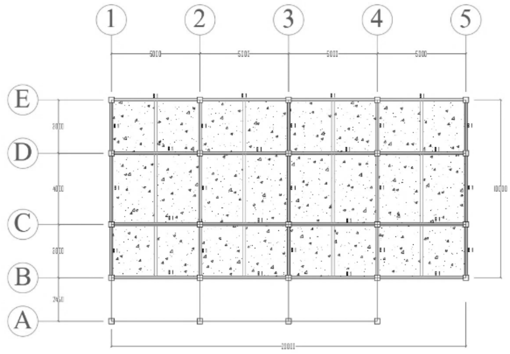

Figure 5 ELV +7000 Structure Plan
Source: Author, 2025

a. Floor plate 400 x 250

$$Ln \quad = 400 - \left(\frac{25}{2}\right) - \left(\frac{25}{2}\right) \quad = 375 \text{ cm}$$

$$Sn \quad = 250 - \left(\frac{25}{2}\right) - \left(\frac{25}{2}\right) \quad = 225 \text{ cm}$$

$$\beta \quad = \left(\frac{Ln}{Sn}\right) = \left(\frac{375}{225}\right) = 1.66 < 2$$ (Two ways plate)

b. effective width of the beam 40 x 25

hw = 40

bw = 25

Assuming the thickness of the plate hf = 11 cm

be = bw + 2 (hw – hf)

= 25 + 2 (35 – 11)

= 73

be = bw + (4 x hf)

= 25 + (4 x 11)

= 69

Smallest be value is = 71

$$k = \frac{1+\left(\frac{be}{bw}-1\right)\left(\frac{hf}{hw}\right)\left[4-6\left(\frac{hf}{hw}\right)+4\left(\frac{hf}{hw}\right)^2+\left(\frac{be}{bw}-1\right)\left(\frac{hf}{hw}\right)^3\right]}{1+\left(\frac{be}{bw}-1\right)\left(\frac{hf}{hw}\right)}$$

$$k = \frac{1+\left(\frac{71}{25}-1\right)\left(\frac{11}{40}\right)\left[4-6\left(\frac{11}{40}\right)+4\left(\frac{11}{40}\right)^2+\left(\frac{71}{25}-1\right)\left(\frac{11}{40}\right)^3\right]}{1+\left(\frac{71}{25}-1\right)\left(\frac{11}{40}\right)}$$

$$k = \frac{1+(1.84)(0.275)\left[4-6\,(0.275)+4\,(0.275)^2+(1.84)\,(0.275)^3\right]}{1+(1.84)(0.275)}$$

$$k = 1{,}662$$

c. Moment of inertia of the cross section

$$Ib = k \text{ x } \frac{bw \text{ x } hw^3}{12} = 1{,}575 \; x \; \frac{25 \; x \; 40^3}{11}$$

$$= 221.658{,}7 \; cm^4$$

d. moment of inertia of the plate

$$Ip = \frac{bp \text{ x } hf^3}{12} = \frac{400 \; x \; 11^3}{12}$$

$$= 44.366{,}67 cm^4$$

e. Beam to Plate Stiffness Ratio

$$\alpha = \frac{lb}{lp} = \frac{221.658{,}7}{44.366{,}67} = 5$$

With the result α = 5 > 2.0, according to SNI 2847:2019

$$h_{min} = \frac{Ln\left(0.8 + \frac{fy}{1400}\right)}{36 + 9\beta}$$

$$= \frac{375\left(0.8 + \frac{420}{1400}\right)}{36 + (9x1{,}66)} = 8{,}08 \; cm$$

This is the thickness of the slab, with the calculated value being 8.08 cm. The planned slab thickness is 11 cm.

3. Preliminary column design

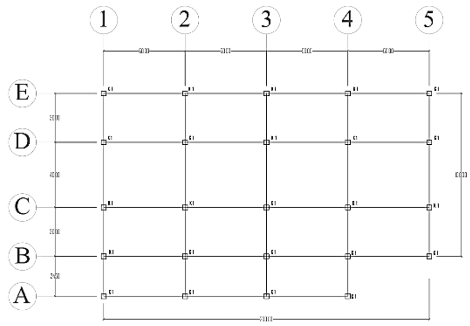

Figure 6 Column Plan
Source: Author, 2025

a. The available data are as follows:

- Column: 40 cm x 40 cm
- Slab thickness: 11 cm
- Floor height (1st floor): 3.5 m
- Floor height (2nd floor): 3.5 m
- Main beam (Bi): 40 x 25 cm
- Secondary beam (Ba): 20 x 15 cm

b. Self-weight of the structure

Table 1 self-weight of structure

Berat Sendiri Struktur						
Objek	Luas(m2)	Panjang(m)	Lebar (m)	Tinggi (m)	Berat (kg/m3)	Beban Aksial (kg)
Pelat	20			0.11	2400	10560
Balok Induk		20	0.25	0.4	2400	9600
Balok Anak		4	0.15	0.2	2400	576
Kolom		5	0.4	3.5	2400	33600
Total						56064

Source: Author, 2025

c. Additional dead load

Table 2 Additional dead load

Lantai	Jenis Beban	Luas (m2)	Panjang	Berat (kg/m2)	Beban Aksial (kg)
2	Plafon	20		6.4	128
	Penggantung	20		7	140
	ME + Plumbing	20		25	500
	Spesi Tebal 2 cm	20		42	840
	Keramik	20		24	480
	Sanitasi	20		20	400
	Dinding Tebal 15 cm	63.		90	5670
	Total				8158
Atap	Plafon	20		6.4	128
	Penggantung	20		7	140
	ME + Plumbing	20		25	500
	Sanitasi	20		20	400
	Waterproof Aspal tebal 2 cm	20		28.54	570.8
	Total				1738.8

Source: Author, 2025

d. Living load

Table 3 Living load

Beban Hidup				
Lantai	Jenis Beban	Luas (m2)	Berat (kg/m2)	Beban Aksial (kg)
2	Perkantoran	20	244.7	4894
atap	Atap non hunian	20	97.86	1957.2
Total				6851.2

Source: Author, 2025

e. Load recapitulation

Table 4 Load recapitulation

Total Beban Mati	
jenis	berat
Beban Sendiri Struktur	56064 kg
Beban Mati Tambahan	65960 kg
Beban Hidup	6851.2 kg

Source: Author, 2025

Total weight

W = 1,2 DL+ 1,6 LL

= (1,2 x 65960,8) (1,6 x 6851.2)

= 90114.8 kg

Concrete grade = 25 Mpa

25 Mpa = 300 kg/cm^2

Ø = 0,85

A = $W Ø$ x fc

= 90114.8 /(0,85 x 300)

= 353.39 cm^2 < 1600 cm^2 (OK)

Kolom = $\sqrt{353.39}$

= 18.8 cm < 40 cm (OK)

Therefore, the previously planned 40 x 40 cm column is safe to use.

B. Loading

Building structural elements carry gravity loads based on SNI 1727:2020 for additional dead loads. These loads, including dead, live, and seismic loads, are analyzed using SAP2000.

1. Self-loading structure

Table 5 Self-loading structure

Berat Sendiri Struktur						
Objek	Luas(m2)	Panjang(m)	Lebar (m)	Tinggi (m)	Berat (kg/m3)	Beban Aksial (kg)
Pelat	20			0.11	2400	10560
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Kolom		5	0.4	3.5	2400	33600
Total						56064

Source: Author, 2025

2. Additional dead load

Table 6 Additional dead load

Lantai	Jenis Beban	Luas (m2)	Panjang	Berat (kg/m2)	Beban Aksial (kg)
2	Plafon	20		6.4	128
	Penggantung	20		7	140
	ME + Plumbing	20		25	500
	Spesi Tebal 2 cm	20		42	840
	Keramik	20		24	480
	Sanitasi	20		20	400
	Dinding Tebal 15 cm	63.		90	5670
	Total				8158
Atap	Plafon	20		6.4	128
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	ME + Plumbing	20		25	500
	Sanitasi	20		20	400
	Waterproof Aspal tebal 2 cm	20		28.54	570.8
	Total				1738.8

Source: Author, 2025

3. Living load

Table 7 Living load

Beban Hidup				
Lantai	Jenis Beban	Luas (m2)	Berat (kg/m2)	Beban Aksial (kg)
2	Perkantoran	20	244.7	4894
atap	Atap non hunian	20	97.86	1957.2
Total				6851.2

Source: Author, 2025

4. Rain load

Table 8 Rain load

Beban Hidup			
Lantai	Jenis Beban	Luas (m2)	Berat (kg/m2)
atap	Hujan	20	10

Source: Author, 2025

5. Earthquake load

The seismic design category at Melalan Airport falls under Risk Category B, with a short-period spectral response acceleration (Sds) of 0.27. Therefore, the operational building structure is designed using SMRF (Special Moment Resisting Frame).

Table 9 Earthquake load

Nilai S_{DS}	Kategori risiko	
	I atau II atau III	IV
$S_{DS} < 0,167$	A	A
$0,167 \le S_{DS} < 0,33$	B	C
$0,33 \le S_{DS} < 0,50$	C	D
$0,50 \le S_{DS}$	D	D

Source: SNI 726, 2019

Site Class (SE)

Based on the 2021 administrative building construction data from the Melalan Airport Service Unit, the soil type in the airport area is classified as Soft Soil (SE).

The following table presents the R and Cd factors for the seismic force-resisting system, which are used to determine the earthquake analysis method. These coefficients are essential for calculating the seismic scale factor.

Table 10 Factor R, Cd, for seismic force resisting systems

Sistem pemikul gaya seismik	Koefisien modifikasi respons, R^a	Faktor kuat lebih sistem, Ω_0^b	Faktor pembesaran defleksi, C_d^c	Batasan sistem struktur dan batasan tinggi struktur, h_n (m)[d] — Kategori desain seismik				
				B	C	D[e]	E[e]	F[f]
19. Dinding geser batu bata polos didetail	2	2½	2	TB	TI	TI	TI	TI
20. Dinding geser batu bata polos biasa	1½	2½	1¾	TB	TI	TI	TI	TI
21. Dinding geser batu bata prategang	1½	2½	1¾	TB	TI	TI	TI	TI
22. Dinding rangka ringan (kayu) yang dilapisi dengan panel struktur kayu yang dimaksudkan untuk tahanan geser	7	2½	4½	TB	TB	22	22	22
23. Dinding rangka ringan (baja canai dingin) yang dilapisi dengan panel struktur kayu yang dimaksudkan untuk tahanan geser, atau dengan lembaran baja	7	2½	4½	TB	TB	22	22	22
24. Dinding rangka ringan dengan panel geser dari semua material lainnya	2½	2½	2½	TB	TB	10	TB	TB
25. Rangka baja dengan bresing terkekang terhadap tekuk	8	2½	5	TB	TB	48	48	30
26. Dinding geser pelat baja khusus	7	2	6	TB	TB	48	48	30
C. Sistem rangka pemikul momen								
1. Rangka baja pemikul momen khusus	8	3	5½	TB	TB	TB	TB	TB
2. Rangka batang baja pemikul momen khusus	7	3	5½	TB	TB	48	30	TI
3. Rangka baja pemikul momen menengah	4½	3	4	TB	TB	10[k]	TI[k]	TI[k]
4. Rangka baja pemikul momen biasa	3½	3	3	TB	TB	TI[l]	TI[l]	TI[l]
5. Rangka beton bertulang pemikul momen khusus[m]	8	3	5½	TB	TB	TB	TB	TB
6. Rangka beton bertulang pemikul momen menengah	5	3	4½	TB	TB	TI	TI	TI
7. Rangka beton bertulang pemikul momen biasa	3	3	2½	TB	TI	TI	TI	TI
8. Rangka baja dan beton komposit pemikul momen khusus	8	3	5½	TB	TB	TB	TB	TB
9. Rangka baja dan beton komposit pemikul momen menengah	5	3	4½	TB	TB	TI	TI	TI
10. Rangka baja dan beton komposit terkekang parsial pemikul momen	6	3	5½	48	48	30	TI	TI
11. Rangka baja dan beton komposit pemikul momen biasa	3	3	2½	TB	TI	TI	TI	TI
12. Rangka baja canai dingin pemikul momen khusus dengan pembautan[n]	3½	3[o]	3½	10	10	10	10	10
D. Sistem ganda dengan rangka pemikul momen khusus yang mampu menahan paling sedikit 25 % gaya seismik yang ditetapkan								
1. Rangka baja dengan bresing eksentris	8	2½	4	TB	TB	TB	TB	TB
2. Rangka baja dengan bresing konsentris khusus	7	2½	5½	TB	TB	TB	TB	TB
3. Dinding geser beton bertulang khusus[g,h]	7	2½	5½	TB	TB	TB	TB	TB
4. Dinding geser beton bertulang biasa[g]	6	2½	5	TB	TB	TI	TI	TI
5. Rangka baja dan beton komposit dengan bresing eksentris	8	2½	4	TB	TB	TB	TB	TB
6. Rangka baja dan beton komposit dengan bresing konsentris khusus	6	2½	5	TB	TB	TB	TB	TB
7. Dinding geser pelat baja dan beton komposit	7½	2½	6	TB	TB	TB	TB	TB
8. Dinding geser baja dan beton komposit khusus	7	2½	6	TB	TB	TB	TB	TB
9. Dinding geser baja dan beton komposit biasa	6	2½	5	TB	TB	TI	TI	TI
10. Dinding geser batu bata bertulang khusus	5½	3	5	TB	TB	TB	TB	TB
11. Dinding geser batu bata bertulang menengah	4	3	3½	TB	TB	TI	TI	TI

Source: SNI 1726, 2019

This operational building is designed with a regular building design, so the earthquake load used in the calculations is a static earthquake load. The following is the calculation of the earthquake factor scale:

$$\frac{g \times i}{R} = \frac{9{,}8 \times 1}{5} = 1{,}96$$

Noted

g = gravity

I = earthquake priority factor

R = response modification coefficient

The following are the response spectrum design values based on the soil parameters at Melalan Airport, classified as SE – Soft Soil.

Design parameter:

- Soil Class: SE – Soft Soil
- Period Range T (s): up to 6 seconds
- PGA MCEG (Peak Ground Acceleration on MCE bedrock): 0.0850g
- SS MCEr (Short-period spectral response acceleration): 0.1710 g
- S1 MCEr (1-second period spectral response acceleration): 0.1090 g
- TL (Long-period transition): 16 seconds

Table 11 Important points on the spectrum

Parameter	Nilai	Keterangan
T0	0.22 detik	Batas awal plateau SA
Ts	1.11 detik	Batas akhir plateau SA
SDS	0.27 g	Nilai percepatan desain spektral maksimum
SD1	0.30 g	Nilai percepatan desain pada periode 1 detik

Source: Ministry of PUPR, 2021

These values are used in seismic analysis to determine earthquake forces based on soil classification and design parameters, ensuring the structure responds effectively to earthquakes in accordance with Indonesian regulations.

C. Design Control

1. Base Shear

Base shear is the total seismic shear force acting at the base of a structure. It represents the initial estimate of the total earthquake force transferred from the superstructure to the foundation. This check compares the manually calculated Vstatic with the Vstatic from SAP2000. According to SNI 1726:2019, Vstatic must be ⩾ VstaticSAP. If not, the static seismic analysis results must be multiplied by a correction factor of Vstatic / Vstatic.

a. **response modification coefficient (R)** = 5

b. **deflection magnification factor (Cd)**= 4,5

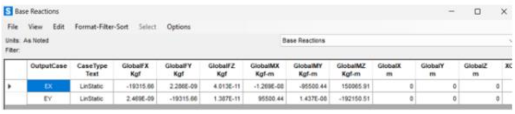
- **seismic response coefficient calculation:**

Cs = $\frac{Sds}{(\frac{R}{Ie})}$;**Cs** = $\frac{0.11}{(\frac{5}{1})}$ From the equation we get the results = **0.022 first Cs**

Cs = $\frac{Sd1}{T(\frac{R}{Ie})}$; **Cs**= $\frac{0.17}{0.34(\frac{5}{1})}$ From the equation we get the results = **0.1 second Cs**

The seismic base shear (Vstatic) is calculated using the first Cs value if it does not exceed the second and third Cs values. Therefore, a Cs value of 0.1 will be used in the calculation of Vstatic.

Vsx = Vsy = 0.1 x W; Cs: seismic response coefficient result **(0.1);** W: structural load (625107).



OutputCase	CaseType Text	GlobalFX Kgf	GlobalFY Kgf	GlobalFZ Kgf	GlobalMX Kgf-m	GlobalMY Kgf-m	GlobalMZ Kgf-m	GlobalX m	GlobalY m	GlobalZ m
EX	LinStatic	-19315.66	2.286E-09	4.013E-11	-1.269E-08	-95500.44	150065.91	0	0	0
EY	LinStatic	2.469E-09	-19315.66	1.387E-11	95500.44	1.437E-08	-192150.51	0	0	0

Figure 7 Base Reaction
Source: Author, 2025

The results to be considered are GlobalFX for QUAKEx and GlobalFY for QUAKEy, with values of 6724.02 kN and 6722.78 kN, respectively. These two results are then compared to the manually calculated Vstatic = 62,510.7 kN to verify compliance. If both GlobalFX and GlobalFY are less than Vstatic, a correction factor must be applied using:

Vsx > GlobalFX = 62510> 19315.66 (OK)

Vsy > GlobalFY = 62510> 19315.66 (OK)

So the earthquake scale factor value is Vsx/Globalearthquake = 62510/19315 = 3.23

2. **mass participation**

In dynamic analysis, as many mode shapes as possible are used (at least 12) to ensure that the structure's mass participation reaches a minimum of 90%.

	OutputCase	StepType Text	StepNum Unitless	Period Sec	UX Unitless	UY Unitless	UZ Unitless	SumUX Unitless	SumUY Unitless	SumUZ Unitless	RX Unitless
	MODAL	Mode	1	0.326457	0.847	0.002139	2.124E-07	0.847	0.002139	2.124E-07	3.2E-05
	MODAL	Mode	2	0.302603	0.003712	0.883	3.309E-07	0.85	0.885	5.432E-07	0.025
	MODAL	Mode	3	0.261507	0.022	0.009962	2.478E-08	0.872	0.895	5.68E-07	0.00055
	MODAL	Mode	4	0.127775	0.11	1.439E-10	3.821E-07	0.982	0.895	9.502E-07	3.565E-08
▸	MODAL	Mode	5	0.124269	7.719E-07	0.089	1.363E-05	0.982	0.984	1.458E-05	0.129
	MODAL	Mode	6	0.110047	8.283E-05	0.000316	3.9E-06	0.983	0.984	1.848E-05	0.0002833
	MODAL	Mode	7	0.084711	5.669E-05	3.362E-07	5.024E-05	0.983	0.984	6.872E-05	0.0001036
	MODAL	Mode	8	0.0819	4.455E-07	9.287E-07	0.005656	0.983	0.984	0.005724	3.578E-05
	MODAL	Mode	9	0.075426	1.898E-06	1.938E-07	0.036	0.983	0.984	0.042	0.014
	MODAL	Mode	10	0.07423	0.000103	8.468E-11	0.008087	0.983	0.984	0.05	0.018
	MODAL	Mode	11	0.072156	2.167E-06	1.715E-07	0.035	0.983	0.984	0.085	0.002557
	MODAL	Mode	12	0.071187	3.775E-05	2.283E-07	0.068	0.983	0.984	0.152	0.00851

Figure 8 Modal participacing mass ratios
Source: Author, 2025

As seen in **mode 5**, **SumUX** = **0.982 (98.2%)** and **SumUY** = **0.984 (98.4%)**, indicating that the building design complies with the regulation, as both values exceed the required minimum of **0.9 (90%).**

3. **control of the natural period of the structure**

The natural period T is the time required for a structure to complete one full cycle of vibration after being displaced from its static equilibrium and returning to its original position. The formula used to calculate the period T of a structure is:

Tipe struktur	C_t	x
Sistem rangka pemikul momen di mana rangka memikul 100 % gaya seismik yang disyaratkan dan tidak dilingkupi atau dihubungkan dengan komponen yang lebih kaku dan akan mencegah rangka dari defleksi jika dikenai gaya seismik:		
• Rangka baja pemikul momen	0,0724	0,8
• Rangka beton pemikul momen	0,0466	0,9
Rangka baja dengan bresing eksentris	0,0731	0,75
Rangka baja dengan bresing terkekang terhadap tekuk	0,0731	0,75
Semua sistem struktur lainnya	0,0488	0,75

Ct = **0.0466**; X = **0.9**; The planned building is a "moment resisting concrete frame".

Controlled by the formula **Ta min < T < Ta max; xT is obtained from the results of running SAP (Show Deformed Shape – Case Modal).**

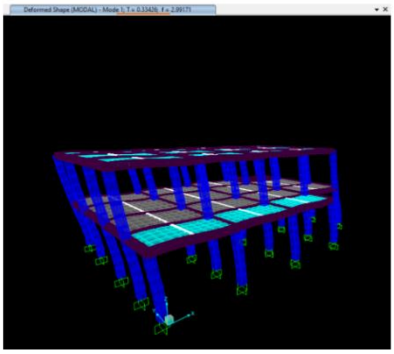


Figure 9 Deformed shape
Source: Author, 2025

Ta min = Ct x hmx;
Ta max = 1.4 x Ta min.
hm is the building height.
Ct and **X** for the "**moment-resisting concrete frame**" building are obtained from Table 14 (approximation period parameter values); **Ct = 0.0466 & X = 0.9**
Overall calculation:
a**Ta min** = 0.0466 x 7 x 0.9 = 0.29
b. **Ta max** = 1.4 x Ta min = 1.4 x 0.29 = 0.406
Therefore, the design is appropriate:
Ta min < T < Ta max = 0.29 < 0.33426 < 0.406 (OK)

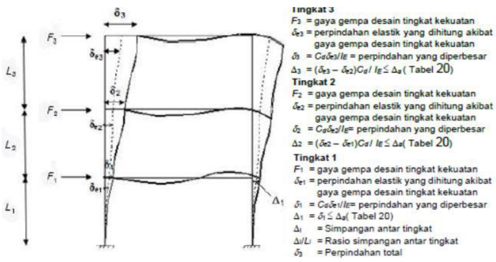
4. **mass deviation control**

The design inter-story drift (Δ) caused by elastic seismic analysis must not exceed the allowable drift limit (Δa). For the building designed by the author, which falls under Category II and the "all other structures" classification, the allowable drift is 0.020 hsx (where hsx is the story height). Therefore, the allowable drift (Δa) for the building is 0.025 ×

Table 12 Deviation between permit levels

Struktur	Kategori risiko		
	I atau II	III	IV
Struktur, selain dari struktur dinding geser batu bata, 4 tingkat atau kurang dengan dinding interior, partisi, langit-langit dan sistem dinding eksterior yang telah didesain untuk mengakomodasi simpangan antar tingkat.	$0{,}025h_{sx}$[c]	$0{,}020h_{sx}$	$0{,}015h_{sx}$
Struktur dinding geser kantilever batu bata[d]	$0{,}010h_{sx}$	$0{,}010h_{sx}$	$0{,}010h_{sx}$
Struktur dinding geser batu bata lainnya	$0{,}007h_{sx}$	$0{,}007h_{sx}$	$0{,}007h_{sx}$
Semua struktur lainnya	$0{,}020h_{sx}$	$0{,}015h_{sx}$	$0{,}010h_{sx}$

Source: SNI 1726, 2019



1. Formula for deviation Ex at level 1 (Δ1)

$\Delta 1 \quad = 0.025 \times 3.5 = 0.0875$

$\delta_m \quad = \frac{C_d . \delta 1}{le} < \Delta a$

$= \frac{4.5 \ x \ 0.000883}{1}$

$= 0.0039735 < 0.0875$ (OK)

2. Formula for deviation Ey at (ROOF) (Δ2)

$\Delta 2 \quad = 0.025 \times 3.5 = 0.0875$

$\delta_m \quad = \frac{C_d . \ \delta 2 - \delta 1}{le} < \Delta a$

$= \frac{4.5 \ x \ (0.00174 - 0.000883)}{1}$

$= 0.00386 < 0.0875$ (OK)

1. Formula for deviation Ey at level 1 (Δ1)

$\Delta 1 \quad = 0.025 \times 3.5 = 0.0875$

$\delta_m \quad = \frac{C_d . \delta 1}{le} < \Delta a$

$= \frac{4.5 \ x \ 0.000836}{1}$

$= 0.003762 < 0.0875$ (OK)

2. Formula for deviation Ey at (ROOF) (Δ2)

$\Delta 2 \quad = 0.025 \times 3.5 = 0.0875$

$\delta_m \quad = \frac{C_d . \ \delta 2 - \delta 1}{le} < \Delta a$

$= \frac{4.5 \ x \ (0.001547 - 0.000836)}{1}$

$= 0.003199 < 0.0875$ (OK)

D. Calculation of structure and building

Calculating reinforced concrete building structures is a crucial step in the planning and design process. Reinforced concrete, a combination of concrete and steel reinforcement, is widely used in construction due to its complementary compressive and tensile strengths.

E. Budget Plan

The construction cost estimate (RAB) for the Operational Building at Melalan Airport uses the 2024 East Kalimantan HSPK. Below is the total cost summary for the superstructure (excluding interior work). The operational building construction requires a budget of **Rp 1,215,000,000.00 (One billion two hundred fifteen million rupiah).**

Table 13 RAB recapitulation

NO	URAIAN PEKERJAAN	VOLUME	SATUAN	HARGA SATUAN (Rp.)	JUMLAH
1	2	3	4	5	6
I	PEKERJAAN PERSIAPAN				
1	Pek. Pembersihan Lapangan & Peralatan	260	m3	Rp 451,130.00	Rp 117,293,800.00
2	Pek. Pengukuran dan Pemasangan Bowplank	66	ml	Rp 127,027.50	Rp 8,383,815.00
3	Pek. Pemadatan Tanah Konvensional	130	m3	Rp 90,135.00	Rp 11,717,550.00
				SUBTOTAL	Rp 137,395,165.00
II	PEKERJAAN BETON				
	PEK BETON LANTAI 1				
1	Pek. Beton Kolom 40/40 - K300				
	Pek. Cor Beton K-300	13.44	m3	Rp 1,833,359.90	Rp 24,640,357.06
	Pek. Pembesian Tul Ulir	1592.64	kg	Rp 23,505.53	Rp 37,435,847.30
	Pek. Pembesian Tul Polos	2623.6	kg	Rp 23,505.53	Rp 61,669,108.51
	Pek. Begisting	67.2	m2	Rp 604,972.30	Rp 40,654,138.56
2	Pek. Beton Balok 25/40 - K300				
	Pek. Cor Beton K-300	15.5	m3	Rp 1,833,359.90	Rp 28,417,078.45
	Pek. Pembesian Tul Ulir	1391.98	kg	Rp 23,505.53	Rp 32,719,227.65
	Pek. Pembesian Tul Polos	433.2		Rp 23,505.53	Rp 10,182,595.60
	Pek. Begisting	65.875	m2	Rp 618,025.90	Rp 40,712,456.16
3	Pek. Beton Balok 15/20 - K300				
	Pek. Cor Beton K-300	1.38	m3	Rp 1,833,359.90	Rp 2,530,036.66
	Pek. Pembesian Tul Polos	348.04	kg	Rp 23,505.53	Rp 8,180,864.66
	Pek. Begisting	8.28	m2	Rp 618,025.90	Rp 5,117,254.45
4	Pek. Plat Lantai Beton t=11 cm-K300	26.125	m3	Rp 8,623,308.66	Rp 225,283,938.82
				SUBTOTAL	Rp 517,542,903.88
	PEK BETON LANTAI 2 (Atap)				
1	Pek. Beton Kolom 40/40 - K300				
	Pek. Cor Beton K-300	11.2	m3	Rp 1,833,359.90	Rp 20,533,630.88
	Pek. Pembesian Tul Ulir	1327.2	kg	Rp 23,505.53	Rp 31,196,539.42
	Pek. Pembesian Tul Polos	2186.4		Rp 23,505.53	Rp 51,392,490.79
	Pek. Begisting	56	m2	Rp 604,972.30	Rp 33,878,448.80
2	Pek. Beton Balok 25/40 - K300				
	Pek. Cor Beton K-300	14.5	m3	Rp 1,833,359.90	Rp 26,583,718.55
	Pek. Pembesian Tul Ulir	1137.6	kg	Rp 23,505.53	Rp 26,739,890.93
	Pek. Pembesian Tul Polos	353.6		Rp 23,505.53	Rp 8,311,555.41
	Pek. Begisting	61.625	m2	Rp 618,025.90	Rp 38,085,846.09
3	Pek. Beton Balok 15/20 - K300				
	Pek. Cor Beton K-300	1.2	m3	Rp 1,833,359.90	Rp 2,200,031.88
	Pek. Pembesian Tul Polos	278.52	kg	Rp 23,505.53	Rp 6,546,760.22
	Pek. Begisting	7.2	m2	Rp 618,025.90	Rp 4,449,786.48
4	Pek. Plat Lantai Beton t=11 cm-K300	22	m3	Rp 8,623,308.66	Rp 189,712,790.58
				SUBTOTAL	Rp 439,631,490.02
				TOTAL	Rp 1,094,569,558.90
				PPN 11 %	Rp 120,402,651.48
				TOTAL	Rp 1,214,972,210.38
				DIBULATKAN	Rp 1,215,000,000.00

Source: Author, 2025

4. CONCLUSION AND RECOMMENDATION

A. CONCLUSION

From the implementation and testing process of this final project, it can be concluded that:

1. The following is the layout design of the two-story operational building with a total area of 200 square meters at UPBU Class III Melalan, East Kalimantan.

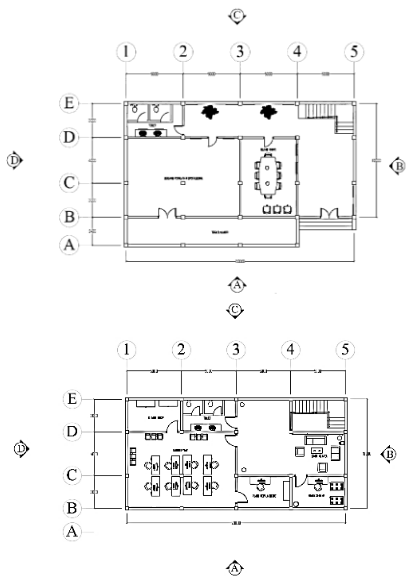


Figure 10 Operational building layout design
Source: Author, 2025

2. The loads considered in the superstructure analysis include: dead load of 56,064 kg; additional dead loads—such as ceiling, hangers, plumbing, 2 cm thick mortar, ceramic tiles, sanitation, and walls—totaling 65,960 kg; and live load of 6,851 kg.

3. The following are the maximum internal forces obtained from the structural analysis of the reinforced concrete in the Operational Building at UPBU Class III Melalan, using SAP2000 software: Regarding the projects that have been carried out, the author's suggestions according to the evaluation are:

In the beam:

Ultimate axial force Nu	: 1.7 Kn
Ultimate shear force Vu	: 80 Kn
Designed torsional force Tu	: 6.3 Kn
Negative moment value Mu -	: 74.6 Kn
Positive moment value Mu +	: 43.5 Kn

In the column:

Axial compressive force	: 488 Kn
Ultimate moment	: 52 Kn

The values of these forces and moments are used in the design control calculations and reinforcement of concrete structures.

4. The following are the dimensions and reinforcement of the operational building structure resulting from SAP 2000 calculations and manual calculations:

Table 15 Dimensions and reinforcement of the structure

Nama Struktur	Dimensi	Tulangan Utama	Tulangan Sengkang
Balok Induk (B1)	25 cm x 40 cm	TUMPUAN Positif : 2 D 16 Negatif : 4 D 16 LAPANGAN Positif : 2 D 16 Negatif : 2 D 16	TUMPUAN 2 P 8 - 100 LAPANGAN 2 P 8 - 250
Balok Anak (BA)	15 x 20 cm	TUMPUAN Positif : 2 P 8 Negatif : 3 P 8 LAPANGAN Positif : 2 P 8 Negatif : 2 P 8	2 P 6 – 70
Plat Dua Arah	Ketebalan 11 cm	D 10	Tiap Jarak 140 mm
Kolom (K)	40 cm x 40 cm	12 D 16	2 P 8 – 160 mm

Source: Author, 2025

5. The construction of the operational building requires a cost of **Rp. 1,215,000,000.00 (One billion two hundred and fifteen million rupiah).**

B. RECOMMENDATIONS

Regarding the project that have been carried out, the author’s suggestions according to the evaluation are:

1. To ensure a sturdy and stable building, the airport must design the substructure or foundation in addition to the strength of the superstructure when planning the construction of an operational building.
2. In planning the budget, the airport should conduct a unit price survey at shops in the nearest area so that the construction does not result in losses.
3. The time or duration of the construction of this operational building needs to be designed carefully and in detail.

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