# ANALYSIS OF THE SUPERSTRUCTURE DESIGN OF THE EMPLOYEE DORMITORY BUILDING AT SYUKURAN AMINUDDIN AMIR AIRPORT, LUWUK, CENTRAL SULAWESI

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**ABSTRACT**
Syukuran Aminuddin Amir Airport in Luwuk, Central Sulawesi, has experienced an increase in the number of personnel, while the availability of staff housing only meets a portion of the total demand. To support comfort and work productivity, a two-story staff dormitory building is designed as a small-scale vertical residence that is earthquake-resistant. This final project designs the upper structure of the staff dormitory building using the Special Moment Resisting Frame (SMRF) system in accordance with the provisions of SNI 2847:2019, SNI 1726:2019, and SNI 1727:2020. Structural analysis is carried out for dead loads, live loads, and equivalent static earthquake loads based on the seismic parameters of Banggai Regency. The structural modeling is conducted in three-dimensional form using SAP2000 v22 software. The design results show that the main structural elements consist of primary beams measuring 30×40 cm, secondary beams 25×35 cm, columns 40×40 cm, and one-way slabs with a thickness of 14 cm. Longitudinal and shear reinforcement are designed based on the results of internal force analysis and anchorage length as per the SNI standards. Section capacity evaluation shows that all elements meet the strength and ductility requirements. The estimated construction cost for the upper structure is Rp940,800,000.00 (nine hundred forty million eight hundred thousand rupiahs). This SMRF structural design is declared safe against the planned loads and can serve as a reference for vertical residential planning in earthquake-prone areas.

***Keywords:*** SMRF, Staff Dormitory Building, Reinforced Concrete, SAP2000.

## INTRODUCTION

Syukuran Aminuddin Amir Luwuk Airport is one of the continuously developing airports that supports air transportation activities in the Banggai Regency, Central Sulawesi. The airport has a runway with a capacity of 2,250 x 45 meters, an apron measuring 315 x 70 meters, and a taxiway measuring 55 x 18 meters, allowing it to accommodate aircraft such as the Airbus A320. Meanwhile, the terminal building, with an area of 5,000 m², is capable of handling up to 500 passengers per day during peak hours.

As a public transportation infrastructure, Syukuran Aminuddin Amir Luwuk Airport not only handles aircraft landing and take-off processes, but also serves passengers using air transportation modes and provides services for its employees. These services are manifested through the provision of adequate facilities in accordance with applicable technical standards. While adequate facilities for passengers are essential, the presence of supporting facilities for employees is also a vital aspect in supporting optimal service delivery. One important facility to support airport operations is employee housing or dormitory (mess).

With the increasing number of employees assigned to Syukuran Aminuddin Amir Luwuk Airport, the need for adequate accommodation facilities has become increasingly important. Currently, many employees are forced to live far from the airport, with as many as seven people sharing one official residence, resulting in discomfort and reduced employee productivity. According to the latest data, the number of available and habitable official housing units is 30, whereas the number of employees in 2025 has reached 52 individuals. Therefore, in the review of the master plan prepared in 2023 and the submission of a new master plan in 2025, the construction of an employee dormitory is planned as a solution to the limited housing facilities for employees.

This planned construction of the employee dormitory will be based on the Director General of Civil Aviation Decree No. PR 21 of 2022 concerning Guidelines for the Design of Operational Buildings for State Housing at the Offices of Airport Operating Units. The construction of the employee dormitory is planned in the form of a two-story building, with each floor having a height of 3.5 meters, as a solution to save land and increase accommodation capacity for employees.

In planning this two-story dormitory, one important aspect that needs to be considered is the risk of earthquake disasters. According to the 2023 Indonesian Disaster Risk Index, Banggai Regency in Central Sulawesi has a high disaster risk score of 162.03, with an earthquake score of 21.08. Considering the high risk of earthquakes in the area, the design of the employee dormitory building must be carried out using a Special Moment Resisting Frame System (SMRFS) to ensure the safety and security of the occupants.

## METHOD

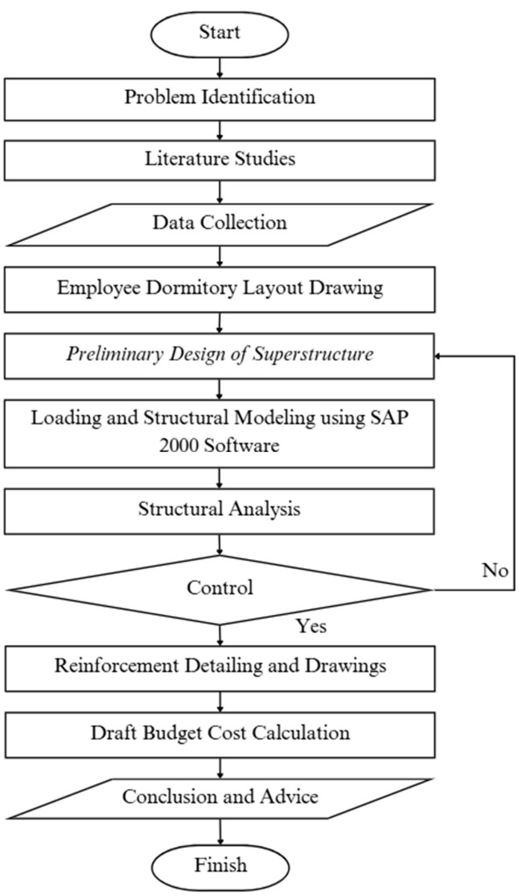


**Figure 1** Research Flow Chart

**Data Collection**

a) Literature Data

- SNI 2847:2019 – Procedures for Calculating Concrete Structures for Buildings.
- SNI 1726:2019 – Seismic Resistance Design for Building and Non-Building Structures.
- SNI 1727:2020 – Minimum Loads for Building and Structure Design.
- Directorate General of Civil Aviation Decree No. PR 21/2022 – Guidelines for Designing Operational Buildings for State Housing at Airport Offices.

b) General Data

- Building Name: Employee Dormitory
- Location: Jl. Mandapar No. 2, Bubung Village, South Luwuk District, Banggai Regency
- Function: Residential facility for airport employees without private housing
- Number of Floors: 2
- Building Height: 7 m
- Soil Type: Dense hard soil with soft rock
- Main Structure: Reinforced concrete

**Preliminary Design**

The building layout for the employee dormitory was created using AutoCAD, following PR No. 21/2022. The structural system and element dimensions were determined based on seismic design classification, which considers the design response spectrum acceleration and building risk category. The selected earthquake-resistant structural system—Ordinary, Intermediate, or Special Moment Resisting Frame (OMRF, IMRF, or SMRF)—serves as the basis for sizing beams, columns, and slabs in compliance with SNI 2847:2019 requirements. Beam dimensions are calculated using $h = \frac{L}{16}$ and $b = \frac{2}{3}h$, column dimensions using $A = \frac{W}{\emptyset\, f'c}$, while slab thickness follows the minimum requirements in SNI 2847:2019.

**Table 1** Minimum thickness for one-way solid slabs

| Support Condition | Minimum $h$[1] |
|---|---|
| Simple support | ℓ/20 |
| One end continuous | ℓ/24 |
| Both end continuous | ℓ/28 |
| cantilever | ℓ/10 |

**Table 2** Minimum thickness for two-way solid slabs

| $\alpha_{fm}$ | $h$ minimum, mm | | |
|---|---|---|---|
| $\alpha_{fm} \leq 0{,}2$ | 8.3.1.1 applies | | (a) |
| $0.2 < \alpha_{fm} \leq 2{,}0$ | Greater of: | $\frac{\ell n\left(0{,}8+\frac{fy}{1400}\right)}{36+5\beta(\alpha fm-0{,}2)}$ | (b)[2],[3] |
| | | 125 | (c) |
| $\alpha_{fm} > 2{,}0$ | Greater of: | $\frac{\ell n\left(0{,}8+\frac{fy}{1400}\right)}{36+9\beta}$ | (d)[2],[3] |
| | | 90 | (e) |

### Loading and Structural Modeling

The collected data were used to develop a structural model in SAP2000 software. The software functions to calculate the structural strength, particularly for multi-story buildings, and ensure the structure remains strong and resistant to applied loads. The loads acting on the superstructure of the employee dormitory include dead load, live load, rain load, and equivalent static seismic load for Banggai Regency, in accordance with SNI 1727:2020, SNI 1726:2019, and SNI 2847:2019.

### Structural Analysis and Control

The output from the loading and structural modeling in SAP2000 consists of internal forces (moment, shear force, and axial force). Based on these results, structural design control is performed to ensure that the main structural elements—beams, columns, and slabs—comply with SNI standards. This ensures that the design is safe, stable, and efficient during construction. Earthquake-resistant structural planning must strictly adhere to building requirements to prevent collapse or accidents, both during construction and in service [10].

### Reinforcement Detailing and Drawings

Reinforcement calculations were carried out in accordance with SNI standards and the Directorate General of Civil Aviation Decree No. PR 21/2022 on Guidelines for Designing Operational Buildings for State Housing at Airport Offices. The calculation data were derived from SAP2000 analysis results. Based on these results, detailed reinforcement drawings were prepared for main structural elements such as columns, beams, and floor slabs, indicating the size, quantity, and placement of reinforcing bars.

### Draft Budget Cost Calculation

Draft Budget Cost (DBC) is a calculation used to determine the total project cost, including materials, labor, and equipment. This is done by calculating the work volume and multiplying it by the applicable unit prices in each region or district. This calculation is crucial for cost efficiency and smooth project execution. The DBC preparation refers to the 2025 Project Cost Estimate Document of Syukuran Aminuddin Amir Airport.

## RESULT AND DISCUSSION

### Employee Dormitory Layout

To facilitate structural analysis for the employee dormitory at Syukuran Aminuddin Amir Airport, the building layout was developed and simplified into a regular, symmetrical two-story frame system. The column bases were assumed to be fixed to the foundation, representing rigid moment-resisting conditions. The layout was prepared based on Directorate General of Civil Aviation Decree No. 21/2022, with an increased number of rooms to meet occupancy requirements, resulting in a two-story building design.

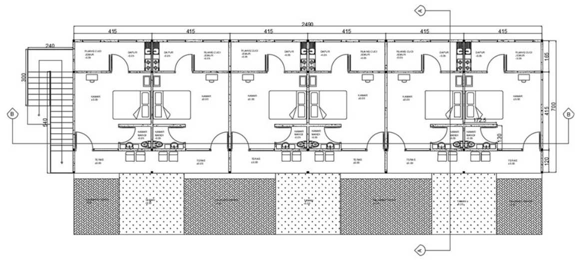

**Figure 2** First Floor Plan of Employee Dormitory

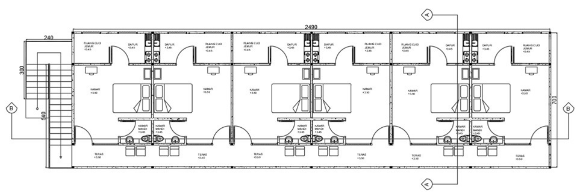

**Figure 3** Second Floor Plan of Employee Dormitory

### Preliminary Design of Beams

Main beams are designed as simply supported members using steel grade 420 MPa and concrete grade K-300 ($fc'$ = 24.9 MPa). The minimum beam height ($h_{min}$) is determined based on Table 9.3.1.1 of SNI 2847:2019, with the width assumed as two-thirds of the height.

For a span $L$ = 415 cm, the calculated dimensions were $h \approx 30$ cm and $b \approx 20$ cm for main beams, and $h \approx 20$ cm and $b \approx 15$ cm for secondary beams. However, these do not meet the Special Moment Resisting Frame (SMRF) requirements ($ln \geq 4d$ and $b \geq 0.3h$ or $b \geq 250$ mm). Therefore, the adopted dimensions are 30 × 40 cm for main beams and 25 × 35 cm for secondary beams, which are assumed adequate for reinforcement spacing in compliance with SNI 2847:2019.

### Preliminary Design of Slabs

According to PR No. 21/2022, the minimum slab thickness is 12 cm. Based on SNI 2847:2019, minimum thickness is determined using Clause 8.3.1.2 for two-way slabs and Clause 7.3.1.1 for one-way slabs. Calculations were performed for the longest column-to-column span of 415 × 207.5 cm.

$$Ln = L - \left(\frac{BI}{2}\right) - \left(\frac{BI}{2}\right) = 415 - \left(\frac{30}{2}\right) - \left(\frac{30}{2}\right) = 385 \text{ cm}$$

$$Sn = S - \left(\frac{BI}{2}\right) - \left(\frac{BA}{2}\right) = 207.5 - \left(\frac{30}{2}\right) - \left(\frac{25}{2}\right) = 180 \text{ cm}$$

$$\beta = \left(\frac{Ln}{Sn}\right) = \left(\frac{395}{190}\right) = 2.13 > 2 \text{ (One-way slab)}$$

Minimum thickness:

$$hmin = \left(\frac{Ln}{28}\right) = \left(\frac{385}{28}\right) = 13.75 \approx 14 \text{ cm}$$

Although PR No. 21/2022 specifies a 12 cm minimum thickness, SNI calculations indicate 14 cm. Therefore, a slab thickness of 14 cm was adopted for both roof and floor slabs to ensure structural strength and serviceability requirements are met.

**Preliminary Design of Columns**

The preliminary column design was carried out by determining the column dimensions based on the maximum axial load. The calculation focused on a column assumed to bear the largest axial load, which supports a slab area of 415 cm × 290 cm.

Input Data:

- Slab thickness: 14 cm
- Main beam dimensions: 30 × 40 cm
- Secondary beam dimensions: 25 × 35 cm
- Initial assumed column dimensions: 40 × 40 cm

Axial Load Calculation:

- Dead Load (DL): Includes self-weight of slab, beams, and columns, totaling 16,579.32 kg.
- Live Load (LL): Includes residential and non-residential roof loads, totaling 3,533.36 kg.
- Additional Dead Load (SDIL): Includes ceiling, hangers, MEP, finishes, and walls, totaling 4,088.03 kg (floor) and 1,046.32 kg (roof).

Factored Load:

$W_{\text{total}}$ = 1.2 (DL+SDIL) + 1.6(LL)
= (1.2×(16,579.3+4,088.02+1,046.32)) + (1.6×3,533.35)
= 31,709.78 kg

Required Column Area:

$$A = \frac{W}{\emptyset f'c} = \frac{31709.775}{0.85 \times 254} = 146.8 \text{ cm}^2 \quad < \quad 1600 \text{ cm}^2$$

$$b = h = \sqrt{146.873} = 12.11 \text{ cm} \quad < \quad 40 \text{ cm}$$

Since the calculated minimum column size (12.11 × 12.11 cm) is smaller than the initial assumption, the column dimension of 40 × 40 cm was adopted for design to ensure safety and stiffness.

**Loading**

The building structure is subjected to various gravity and lateral loads analyzed using SAP2000, including dead loads from the self-weight of structural elements, live loads from occupant activities, additional loads such as roof rainwater, and earthquake loads.

1. Dead Loads consist of the self-weight of structural components (automatically calculated in SAP2000) and superimposed dead loads such as ceiling finishes, MEP installations, flooring, and masonry walls. Special cases include:
   - Additional Wall Load: Converted to an equivalent uniform load on slabs without supporting beams, calculated at 129.1 kg/m².
   - Steel Stair Load: Modeled as concentrated loads at four main supports, totaling 8,705 kg, based on self-weight, finishes, and live load requirements from SNI 1727:2020.
2. Live Loads follow SNI 1727:2020, with 195.73 kg/m² for floors and 97.86 kg/m² for non-residential roofs.
3. Rain Load is calculated using regional rainfall data from BMKG, with a design rainfall depth of 115 mm. Under normal drainage conditions, a ponding depth of 1 cm is assumed, resulting in 10 kg/m².
4. Earthquake Load is determined using the equivalent static method per SNI 1726:2019. Based on site-specific seismic parameters (Sds = 0.93, Sd1 = 0.48), the structure falls under Seismic Design Category D, requiring the Special Moment Resisting Frame (SMRF) system with R = 8, $\Omega_0$ = 3, Cd = 5.5, and Ie = 1.

These loads are modeled in SAP2000 to evaluate the structural performance and ensure safety under operational conditions.

**Structural Analysis**

1. Creating the Structural Model
   After opening SAP2000, the first step is to set the units to kg/m. Next, click **File → New Model → Grid Only**. Fill in the data covering the spans in the X and Y directions, the number of floors, and the building height to be modeled. Then, use Draw Frame to draw beams and columns, and Draw Poly Area to create slabs.
2. Supports
   Change all supports to fixed by clicking **Assign → Joint → Restraint → Fixed.**
3. Defining Material
   Structural materials are defined first by selecting **Define → Material → Add New Material**. Since the structure is designed with reinforced concrete, concrete K-300 (24.9 MPa) was used as the main material, and reinforcing steel with a yield strength of 420 MPa was applied.
4. Defining Cross-Sections
   This step includes defining the cross-sections of beams, columns, and slabs according to the preliminary design, including dimensions and material properties. Beam and column sections are created via **Define → Section Properties → Frame Section → Add New Property**, while slabs are defined via **Area Section → Add New Section**.
5. Defining Load Types
   Various load types such as self-weight, additional dead loads, live loads, roof loads, rain loads, and seismic loads must be defined first. This process is done via **Define → Load Pattern → Add New Load Pattern** in SAP2000.
6. Defining Load Combinations
   Load combinations based on SNI 1727:2019 are defined by opening **Define → Load Combinations → Add New Combo.**

7. Assigning Loads
   The process of assigning dead, live, and wind loads is done by first selecting the structural elements, then going to **Assign → Frame Load → Distributed** for beams and columns. For slab loads, use **Assign → Area Load → Uniform to Frame.** Meanwhile, static seismic loads are defined via **Define → Load Cases**.
8. Running the Analysis
   After all data has been entered, proceed with the structural analysis to obtain internal force outputs from SAP2000. The analysis is run via **Analyze → Run Analysis → Run Now.**
9. Output Analysis
   Once the analysis process is complete, internal force information can be obtained by accessing **Display → Show Forces/Stresses → Frame/Cable/Tendon Force**, then selecting the bending moment M3 from the defined ultimate load combinations.

**Design Control**

1. Natural Period of the Structure

   The vibration period T does not simply represent the time for one complete oscillation cycle returning to the initial position; rather, it reflects the dynamic characteristics of the structure in responding to disturbances from its equilibrium state. The value of T is calculated to describe the tendency of the structure to oscillate under earthquake forces. Moment-resisting concrete frame has a value of,

   - $C_t = 0.0466$
   - $x = 0.9$

   The dominant period value of the structure T=0.27532 was obtained from modal analysis results using the *Show Deformed Shape* feature in SAP2000. To determine the verification limits for the period, a theoretical approach was used to calculate $Ta_{min}$ and $Ta_{max}$ as reference points for comparison.

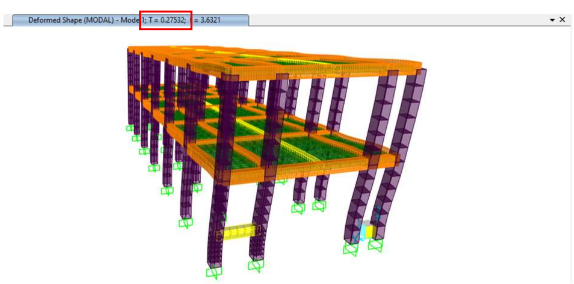


**Figure 4** Natural Period of the Structure Output

$Ta_{min} = Ct \times h_m^x = 0.0466 \times 7^{0.9} = 0.26$

$Ta_{max} = 1,4 \times Ta_{min} = 1,4 \times 0.26 = 0.36$

Where:

hm = building height

Thus:

$Ta_{min} < T < Ta_{max} = 0.26 < 0.27532 < 0.36$ (OK)

2. Base Shear

   Base shear is the total seismic shear force acting at the base of the structure, representing the initial measure of seismic load transferred from the superstructure to the foundation. This check compares the static base shear (Vstatic) obtained from manual calculation with that generated by SAP2000 ($Vstatic_{SAP}$). According to SNI 1726:2019, Vstatic must be greater than or equal to $Vstatic_{SAP}$. Otherwise, the static seismic analysis results should be adjusted by a correction factor of Vstatic /$Vstatic_{SAP}$.

   The parameters used are: Response Modification Factor ($R$) = 8, Deflection Amplification Factor ($C_d$) = 5.5, Seismic Importance Factor ($I_e$) = 1, with Sds = 0.93 and Sd1 = 0.48.

   - $Cs = \frac{Sds}{R/Ic} = \frac{0.93}{8/1} = 0.116$
   - $Cs = \frac{Sd1}{T\ x \frac{R}{Ic}} = \frac{0.48}{0.26809\ x\ 8/1} = 0.223$ (governing value)
   - $Cs = 0.044\ x\ Sds\ x\ Ie \geq 0.01 = 0.044\ x\ 0.93\ x\ 1 = 0.04 \geq 0.01$

   Hence,

   - $Vstatic = W\ x\ Cs = 557732.9\ x\ 0.223 = 124374.44$

Base Reactions

File View Edit Format-Filter-Sort Select Options

Units: As Noted — Base Reactions

Filter:

| OutputCase | CaseType Text | GlobalFX Kgf | GlobalFY Kgf | GlobalFZ Kgf | GlobalMX Kgf-m | GlobalMY Kgf-m | GlobalMZ Kgf-m | GlobalX m | GlobalY m | GlobalZ m | XCe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ex | LinStatic | -47079.2 | 3.217E-09 | -7.64E-11 | -2.592E-08 | -254120.27 | 161564.62 | 0 | 0 | 0 | |
| Ey | LinStatic | 3.065E-09 | -47079.2 | -2.419E-10 | 254120.27 | 2.809E-08 | -580376.36 | 0 | 0 | 0 | |

**Figure 5** $V_{Statik}$ Output SAP2000

From SAP2000, the base shear output was GlobalFX = 47079.2 and GlobalFY = 47079.2. Since Vstatic≥$Vstatic_{SAP}$, the requirement is satisfied, with an amplification factor of:

$$\frac{Vstatic}{VstaticSAP} = \frac{124374.44}{47079.2} = 2.641$$

3. Mass Participation

   In the equivalent static earthquake analysis, multiple vibration modes are considered to ensure that the dynamic characteristics of the structure are properly represented. Although the approach is static, mass participation must reach at least 90% as verification that the dominant structural vibration behavior is adequately captured.

Modal Participating Mass Ratios

File View Edit Format-Filter-Sort Select Options

Units: As Noted — Modal Participating Mass Ratios

Filter:

| OutputCase | StepType Text | StepNum Unitless | Period Sec | UX Unitless | UY Unitless | UZ Unitless | SumUX Unitless | SumUY Unitless | SumUZ Unitless | RX Unitless |
|---|---|---|---|---|---|---|---|---|---|---|
| MODAL | Mode | 1 | 0.275323 | 0.897 | 8.641E-07 | 8.349E-09 | 0.897 | 8.641E-07 | 8.349E-09 | 1.032E-08 |
| MODAL | Mode | 2 | 0.261367 | 1.345E-06 | 0.902 | 7.703E-06 | 0.897 | 0.902 | 7.711E-06 | 0.062 |
| MODAL | Mode | 3 | 0.23542 | 0.0001486 | 0.0003117 | 8.111E-10 | 0.898 | 0.903 | 7.712E-06 | 0.0003347 |
| MODAL | Mode | 4 | 0.099515 | 0.091 | 1.163E-05 | 1.648E-09 | 0.988 | 0.903 | 7.713E-06 | 3.889E-05 |
| MODAL | Mode | 5 | 0.097931 | 1.367E-05 | 0.085 | 4.192E-05 | 0.988 | 0.988 | 4.963E-05 | 0.271 |
| MODAL | Mode | 6 | 0.088485 | 2.754E-07 | 7.747E-05 | 1.636E-07 | 0.988 | 0.988 | 4.979E-05 | 0.0003009 |
| MODAL | Mode | 7 | 0.051764 | 1.785E-07 | 5.015E-07 | 0.368 | 0.988 | 0.988 | 0.368 | 0.002243 |
| MODAL | Mode | 8 | 0.050893 | 1.477E-06 | 5.693E-07 | 5.722E-07 | 0.988 | 0.988 | 0.368 | 1.237E-06 |
| MODAL | Mode | 9 | 0.049364 | 3.549E-06 | 3.643E-06 | 0.039 | 0.988 | 0.988 | 0.407 | 0.0001413 |
| MODAL | Mode | 10 | 0.049182 | 2.169E-05 | 0.0005577 | 0.0002511 | 0.988 | 0.989 | 0.408 | 0.0009724 |
| MODAL | Mode | 11 | 0.047127 | 7.339E-06 | 1.323E-06 | 2.9E-06 | 0.988 | 0.989 | 0.408 | 3.305E-06 |
| MODAL | Mode | 12 | 0.046988 | 5.665E-07 | 6.269E-08 | 0.00285 | 0.988 | 0.989 | 0.411 | 9.15E-06 |

**Figure 6** Mass Perticipation Output

Based on the output, the structure meets this requirement, since the cumulative values of SumUX and SumUY from modes 1 to 12 exceed 0.9 (90%). This indicates that the number of modes analyzed is sufficient to accurately represent the seismic response of the structure.

4. Interstory Drift

The interstory drift due to seismic loading, calculated elastically, must remain below the maximum allowable limit (Δa). For a dormitory building with Risk Category II and the selected structural system, the allowable drift is defined as 0.025 times the story height (hsx), in accordance with SNI 1726:2019.

For the first story (Δ1):

$$\Delta a = 0.025 \text{ x } 3.5 = 0{,}0875$$

$$\delta 1 = \frac{\text{Cd x } \delta e}{\text{Ie}} \leq \Delta a$$

- $\text{Ex} = \frac{5{,}5 \text{ x } 0.001734}{1} = 0{,}009537 \leq 0{,}0875$ **(OK)**
- $\text{Ey} = \frac{5{,}5 \text{ x } 0.001581}{1} = 0.0086955 \leq 0{,}0875$ **(OK)**

For the second story (Δ2):

$$\Delta a = 0.025 \text{ x } 3.5 = 0{,}0875$$

$$\delta 1 = \frac{\text{Cd x } (\delta e2 - \delta e)}{\text{Ie}} \leq \Delta a$$

- $\text{Ex} = \frac{5{,}5 \text{ x } (0.003243 - 0.001734)}{1}$

  $= 0.0082995 \leq 0{,}0875$ **(OK)**
- $\text{Ey} = \frac{5{,}5 \text{ x } (0.002906 - 0.001581)}{1}$

  $= 0.0072875 \leq 0{,}0875$ **(OK)**

5. Deflection

To ensure comfort and functionality, structural deflection under loading must remain within the allowable limits specified by the standard. Excessive deflection may lead to non-structural damage as well as reduced aesthetics and comfort.

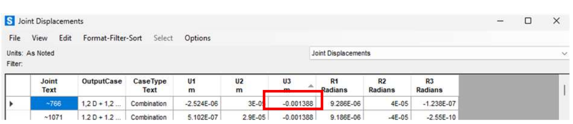


**Figure 7** Deflection Output

Based on the analysis results, the maximum vertical deflection (U3/Uz) is 0.001388 m (1.388 mm). This value is compared with the permissible deflection limit of L/240. With an effective span length of 1.2 m (1200 mm), the allowable deflection is:

$$\frac{L}{240} = \frac{1200}{240} = 5\ mm$$

Since 1.388 mm < 5 mm, the structure satisfies the serviceability requirement, and the deflection remains within acceptable limits.

**Structural Reinforcement**

1. Main Beam Reinforcement

The main beam was designed with concrete compressive strength *fc'* = 24.9 MPa and reinforcing steel yield strength *fy* = 420 MPa for flexural bars and *fy* = 240 MPa for stirrups. Beam dimensions are *b* = 300 mm, *h* = 400 mm, with effective depth *d* = 345.5 mm and cover thickness *ts* = 40 mm. The effective flange width, determined from SNI 2847:2019, is *bf* = 768.75 mm.

- Flexural Reinforcement

  The balanced steel ratio and effective flange reinforcement were evaluated, resulting in a total reinforcement ratio of $\rho_b$ = 0.0154, with permissible limits of $\rho_{min}$ = 0.0033 and $\rho_{max}$ = 0.0116.

  For the ultimate negative moment $Mu^-$ = 61.55 kN\m, the required steel area is *As'* = 525.5 mm, equivalent to 4D13. For the ultimate positive moment $Mu^+$ = 34.36 kN\m, the required steel area is less than the minimum requirement; therefore, the minimum value is adopted, also equivalent to 4D13.
- Shear Reinforcement

  The ultimate shear force is *Vu* = 75.29 kN, while the concrete shear capacity is $\phi Vc$ = 66.62 kN. Since $Vu > \phi Vc$, shear reinforcement is required. The design provides Ø8 stirrups at 125 mm spacing, which satisfies the maximum spacing criteria.
- Torsional Reinforcement

  The ultimate torsional moment is *Tu* = 8.05 kN\m, yielding a required longitudinal torsion reinforcement of $A_l$ = 375.4 $mm^2$. Transverse torsional reinforcement was provided with spacing of 125 mm, ensuring compliance with code requirements.
- Summary of Reinforcement
  - Negative moment reinforcement: 4D13
  - Positive moment reinforcement: 4D13
  - Shear reinforcement: Ø8-125 mm spacing

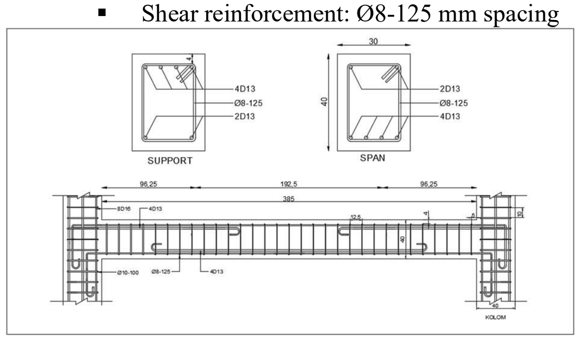


**Figure 8** Cross-Section and Longitudinal Section Details of the Main Beam

2. Secondary Beam Reinforcement

The secondary beam has dimensions of *b* = 250 mm and *h* = 350 mm, with effective depth *d* = 299 mm and effective flange width *bf* = 718.75 mm.

- Flexural Reinforcement

  For the ultimate negative moment $Mu^-$ = 2.91 kN\m, the required steel area is *As'* = 249.2 mm, equivalent to 4D10.

For the ultimate positive moment $Mu^+ = 6.78$ kN\m, the required steel area is less than the minimum requirement; therefore, the minimum value is adopted, also equivalent to 4D10.

- Shear Reinforcement

The ultimate shear force is $Vu = 16.2$ kN, while the concrete shear capacity is $\phi Vc = 47.87$ kN. Since $Vu < 0.5\ \phi Vc$, only minimum shear reinforcement is required. The design provides Ø6 stirrups at 150 mm spacing.

- Torsional Reinforcement

The ultimate torsional moment is $Tu = 0.25$ kN\m. With design torsional strength $Tn = 0.338$ kNm, the effect is negligible, and no additional torsional reinforcement is required.

- Summary of Reinforcement
  - Negative moment reinforcement: 4D13
  - Positive moment reinforcement: 4D13
  - Shear reinforcement: Ø8-125 mm spacing

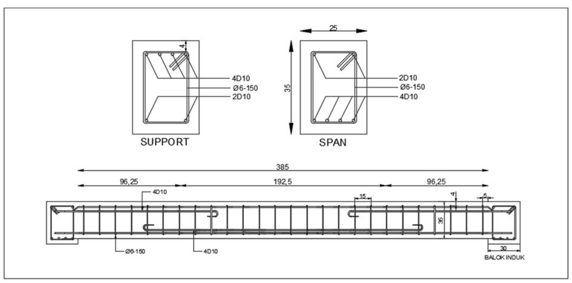


**Figure 9** Cross-Section and Longitudinal Section Details of the Secondary Beam

3. Floor and Roof Slab Reinforcement

A one-way slab spanning 2.075 m × 4.15 m with thickness 140 mm was designed using concrete $fc' = 24.9$ MPa and reinforcement steel $fy = 420$ MPa. The required reinforcement area based on design ratio is $As_{req} = 383\ mm^2$ per metre width. Accordingly, Ø10 mm bars at 200 mm spacing were selected, providing an actual reinforcement area of $As_{prov} = 393\ mm^2$ per metre — therefore $As_{prov} > As_{req}$ and the slab is safe in flexure.

Deflection checks include instantaneous and long-term effects (creep and shrinkage). The calculated total deflection is $d_{tot} = 0.056$ mm, which is well below the allowable limit $L_x/240 = 8.646$ mm; hence the slab satisfies serviceability requirements.

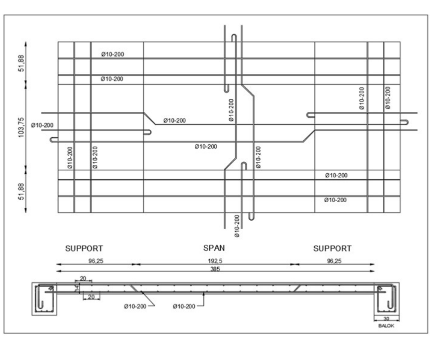


**Figure 9** Detail of Top and Longitudinal Section of Slab

4. Column Reinforcement

The column was designed with concrete compressive strength $fc' = 24.9$ MPa and reinforcing steel yield strength $fy = 420$ MPa for longitudinal bars and $fy = 240$ MPa for stirrups. Column dimensions are $b = 400$ mm, $h = 400$ mm, with effective depth $d = 342$ mm and cover thickness $ts = 40$ mm.

- Flexural and Axial Capacity

The required reinforcement area is $A_s = 1607.68\ mm^2$, provided by 8D16 longitudinal bars. The column nominal axial strength is $P_n = 1448$ kN with reduced strength $\phi Pn = 1158\ kN > Pu = 408.70$ kN. The nominal moment is $Mn = 358$ kNm, with reduced moment capacity $\phi Mn = 286\ kNm > Mu = 47.52$ kNm. Thus, strength requirements are satisfied.

- Shear Reinforcement

The ultimate shear demand is Vu=25.15 kN, while the concrete shear strength is $\phi Vc = 7.20$ kN. Since $Vu > \phi Vc$ , shear reinforcement is required. Stirrups Ø10 are provided at 150 mm spacing, satisfying the maximum spacing limit.

- Confinement at Beam–Column and Foundation Joints

Confinement length is taken as 450 mm above and below the joint. Within this zone, stirrup spacing is limited to 100 mm.

- Summary of Reinforcement
  - Longitudinal reinforcement: 8D16
  - Shear reinforcement: Ø10-150 mm spacing
  - Confinement reinforcement (joint and foundation zone): Ø10-100 mm spacing

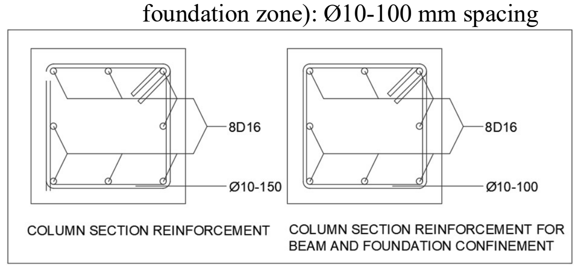


**Figure 10** Cross-Section Details of the Column

5. Support and Span Lenghts
   - Support Region $lt = \frac{1}{4} * ln$ : Top reinforcement is placed here due to negative moment.
   - Span Region $lt = \frac{1}{2} * ln$ : Bottom reinforcement is required here due to positive moment.

6. Development Length

The development length applies to all reinforced concrete elements, where reinforcement must transfer stresses into the concrete. At beam ends, tensile reinforcement must be properly anchored into the supports (columns). If the available length is insufficient, hooks are required (SNI 2847:2019, Clause 25.4.2.2).

$$ld = \frac{0.8 * fy * db}{2.1 * \lambda * \sqrt{fc'}} = \frac{0.8 * 420 * db}{2.1 * 1 * \sqrt{24.9}} = 32db$$

**D16** $ld = 32 * db = 512\ mm$

**D13** $ld = 32 * db = 416\ mm$

**D10** $ld = 32 * db = 320\ mm$

7. Hook Length
- Tensile Bar Hook
  (SNI 2847:2019 Clause 25.3.1, 180° bend, minimum inside bend diameter = 6db)

$$lh = max(4 \cdot db), min\ (65mm)$$

**D16** $4d = 64 < 65 \rightarrow\ lekor = 65\ mm$

**D13** $4d = 52 < 65 \rightarrow\ lekor = 65\ mm$

**D10** $4d = 40 < 65 \rightarrow\ lekor = 65\ mm$

- Stirrup Hook
  (SNI 2847:2019 Clause 25.3.2, 135° bend, minimum inside bend diameter = 4db)

$$lhs = max(6 \cdot db), min\ (75mm)$$

**P6** $6d = 36 < 75 \rightarrow\ lekor = 75\ mm$

**P8** $6d = 48 < 75 \rightarrow\ lekor = 75\ mm$

**P10** $6d = 60 < 75 \rightarrow\ lekor = 75\ mm$

**Special Moment Resisting Frame (SMRF) Control**

1. Strong Column – Weak Beam (SCWB) Check

The SCWB concept ensures that the column moment capacity is greater than that of the beam, so that plastic hinges form in the beams rather than in the columns during seismic events. To satisfy SCWB and avoid column failure, the following requirement must be met:

$$\sum Mn\ kolom \geq 1.2 \times \sum Mn\ balok$$

- Main Beam (30/40 cm)
  $Mn_i$ = 81,588 kNm
- Secondary Beam (25/35 cm)
  $Mn_a$ = 29,918 kNm
  $\sum$ **Mn_beam** = 23,31 + 14,97 = 111,506 kNm
- Column (40/40 cm)
  $Mn_k$ = 358 kNm
  $\sum$**Mn_column** = 2 × 358 = 716 kNm
- Evaluasi Rasio SCWB
  $\sum$Mn column ≥ 1.2 x $\sum$Mn balok

$$\frac{\sum Mn\ column}{\sum Mn\ beam} \geq \frac{716}{111.506} = 6.42 \quad \textbf{(OK)}$$

2. SMRF Beam

**Table 3** SMRF Beam Check

| Desciption | SNI 2847:2019 | Modeling Result | Safe / Unsafe |
|---|---|---|---|
| Beam Dimension Limits | $\ell n \geq 4d$ | 4,15 ≥ 4 x 0.34 | Safe |
| | $b \geq 0.3h$ or $b \geq 250$ mm | $b_i$ = 300 mm<br>$b_a$ = 250 mm | Safe |
| | $c_2 < b$ B>K $< 0{,}75c_1$ | Beam width < column | Safe |
| Beam Longitudinal Reinforcement | $AS_{min} = \frac{1{,}4}{fy} bwd =$ 340 mm² | $AS_{min} = \frac{1{,}4}{fy} bwd =$ 570 mm² | Safe |
| | $\rho < 0{,}025$ & $0{,}75\ \rho b$ | $\rho = 0.00333$ | Safe |
| Beam Transverse Reinforcement | Confining stirrups must be installed at both ends of the beam along 2h from the column face toward midspan | Stirrups spaced 125 mm and 150 mm using 3P8 and 2P6 | Safe |
| Beam Shear Strength | Shear force calculated between joint faces; maximum flexural moment assumed to act at the joint face and beam | Mu = 61,6539 kNm Vu = 75,572 kNm; flexural moment considere d at joint face and beam | Safe |

3. SMRF Column

**Table 4** SMRF Column Check

| Desciption | SNI 2847:2019 | Modeling Result | Safe / Unsafe |
|---|---|---|---|
| Column Dimension Limits | Minimum cross-sectional dimension ≥ 300 mm | 400 x 400 mm | Safe |
| Column Longitudinal Reinforcement | $A_{st} > 0{,}01A_g$ and $< 0{,}06A_g$. | $Ag = 400x400 = 160000\ mm^2$<br>Ast = 1607.68 $mm^2$<br>Min = 0.01 x Ag = 1600 $mm^2$<br>Max = 0.06 x Ag = 9600 $mm^2$ | Safe |
| Column Transverse Reinforcement | Maximum stirrup spacing 150 mm | Stirrups installed at 150 mm spacing | Safe |

**Draft Budget Cost Calculation**

**Table 5** Draft Budget Cost
Cost Budget Plan
Construction of the Superstructure of the Employee Dormitory Building at Syukuran Aminuddin Amir Airport, Luwuk, Central Sulawesi

| NO | DESCRIPTION OF WORK | AMOUNT (Rp.) |
|---|---|---|
| | | |
| I | PREPARATORY WORKS | |
| | SUBTOTAL | 6,160,982.80 |
| | | |
| II | CONCRETE WORKS | |
| | CONCRETE WORKS - 1st FLOOR | |
| 1 | Column 40/40 - K300 | 72,139,536.29 |
| 2 | Main Beam 30/40 - K300 | 246,351,923.12 |
| 3 | Secondary Beam 25/35 - K300 | 9,089,843.40 |
| 4 | Slab t=14 cm-K300 | 93,307,952.45 |
| | SUBTOTAL | 420,889,255.25 |
| | | |
| | CONCRETE WORKS - 2nd FLOOR | |
| 1 | Column 40/40 - K300 | 72,139,536.29 |
| 2 | Main Beam 30/40 - K300 | 246,351,923.12 |
| 3 | Secondary Beam 25/35 - K300 | 8,717,717.40 |
| 4 | Slab t=14 cm-K300 | 93,307,952.45 |
| | SUBTOTAL | 420,517,129.26 |
| | | |
| | TOTAL | 847,567,367.31 |
| | VAT 11 % | 93,232,410.40 |
| | GRAND TOTAL | 940,799,777.72 |
| | ROUNDED | 940,800,000.00 |
| **In Words: Nine hundred forty million eight hundred thousand rupiah.** | | |

## CONCLUSION

Based on the planning results for the construction of the employee dormitory building at Syukuran Aminuddin Amir Airport, Luwuk, the structure was designed using a Special Moment Resisting Frame (SMRF) system in accordance with SNI 2847:2019, SNI 1726:2019, and SNI 1727:2020. The structural design outcomes are summarized as follows:

1. Architectural Layout
   The employee dormitory is designed as a two-story building with a total of 12 rooms, adjusted to meet the accommodation needs of the occupants. The building dimensions are 24.9 meters × 7 meters with a total height of 7 meters, in compliance with the national housing design standards as stipulated in Director General of Civil Aviation Decree No. PR 21 of 2022.
2. Loading Plan and Structural Modeling
   The loading plan and structural modeling were carried out based on SNI 2847:2019, SNI 1726:2019, and SNI 1727:2020. The loads considered include:
   - Dead Loads: self-weight of concrete at 2,400 kg/m³, floor finishing load of 124.4 kg/m², roof slab finishing of 86.94 kg/m², partition wall load of 129.1 kg/m², and steel staircase load of 8,705.31 kg.
   - Live Loads: 195.73 kg/m² for floor areas and 97.86 kg/m² for the roof.
   - Environmental Loads: rainfall load of 10 kg/m².
   - Seismic Loads: determined using the equivalent static method with seismic parameters corresponding to Banggai Regency.

   Three-dimensional structural modeling was performed using SAP2000, applying the SMRF system. The analysis results served as the basis for structural element design.
3. Internal Force Analysis (SAP2000 Results)
   - Flexural Moment:
     - Mu- = 627,675 kg.m;
     - Mu+ = 4,704.9 kg.m
   - Shear Force: Vu = 7,677.42 kg
   - Axial Force: Pu = 41,677.08 kg

   These values were used as the design basis for the structural elements:
   - Primary Beams: 30 × 40 cm with 4D13 longitudinal reinforcement (tension and compression) and Ø8 stirrups at 125 mm spacing.
   - Secondary Beams: 25 × 35 cm with 4D10 longitudinal reinforcement and Ø6 stirrups at 150 mm spacing.
   - Columns: 45 × 45 cm with 8D16 longitudinal reinforcement, Ø10 confinement reinforcement at 100 mm spacing for beam-column joints and foundations, and Ø10 main stirrups at 150 mm spacing.
   - Slabs: 14 cm thick with Ø10 reinforcement at 200 mm spacing.
4. Cost Estimation
   The cost estimation for the superstructure of the employee dormitory building resulted in a total of Rp940,800,000.00 (nine hundred forty million eight hundred thousand rupiah).

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