# *STRUCTURAL DESIGN FOR THE EXPANSION OF THE AIRPORT FACILITIES WORKSHOP USING THE LRFD METHOD AT JENDERAL AHMAD YANI INTERNATIONAL AIRPORT SEMARANG*

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**ABSTRACT**
The expansion of the airport facilities workshop building at Jenderal Ahmad Yani International Airport Semarang has become an essential need in line with the increasing operational activities and the capacity of supporting airport facilities. This study aims to design a safe steel structure for the workshop building using the Load and Resistance Factor Design (LRFD) method, as the Allowable Stress Design (ASD) method is no longer valid in the latest structural planning standards. In addition, a Cost Budget Plan is prepared to estimate the cost. The method used is engineering quantitative descriptive, with steel structure analysis using the LRFD method. The design process includes load analysis, selection of steel profiles, evaluation of structural safety factors, and the preparation of the cost estimation material, equipment, and labor according to work volume. In designing the structure, SNI 1729:2020 on Specifications for Structural Steel Buildings, SNI 1726:2019 on Earthquake Resistance Planning Procedures for Building and Non-building Structures, and SNI 1727:2020 on Minimum Loads for Building Planning and Other Structures are applied. This study uses SAP2000 V26 software for structural analysis and AutoCAD 2025 for building modeling. The airport facilities workshop building, measuring 6 × 10 (m), is designed as a single-story steel structure. Profiles used: CNP 150.50.20.2,3 for purlins; WF 300.150.6,5.9 for columns and regents; WF 250.125.6.9 for rafters; WF 150.75.5.7 for consoles; and D10 for wind braces. The cost estimation shows a total construction cost of IDR 388.000.000,00 including 11% VAT.

***Keywords:*** *Steel Structure, LRFD, Workshop, Steel Profiles, Cost Estimation.*

## INTRODUCTION

Airports play a crucial role in modern transportation systems, serving as essential nodes that facilitate the movement of passengers and cargo. According to the Indonesian Aviation Law No. 1 of 2009, an airport is defined as a designated area equipped with aviation security and safety infrastructure, along with primary and supporting facilities. Among Indonesia's international airports, Jenderal Ahmad Yani International Airport in Semarang stands out as a significant gateway in Central Java, serving numerous airlines and routes with growing passenger traffic.

Located in Semarang City and identified by the IATA code SRG and ICAO code WAHS, Jenderal Ahmad Yani International Airport features a 2,560-meter asphalt runway, taxiways and aprons that can accommodate critical aircraft such as the Boeing 737-900ER. The airport's rapid development, highlighted by a record-setting construction period recognized by the Indonesian Museum of Records (MURI), aims to expand its passenger capacity from 800,000 to 6.5 million annually. As passenger numbers have already surpassed 4 million, continuous facility improvements are necessary to meet operational demands and enhance service quality.

One of the key ground-side facilities is the airport workshop building, which functions as a coordination center for maintenance staff and storage for equipment and materials. However, the existing workshop is no longer adequate, with many materials stored outdoors and exposed to weather conditions, while the mezzanine floor design provides only a temporary and limited solution to space constraints. In line with regulations from the Ministry of Transportation and international standards set by ICAO Annex 14, airport infrastructure must be planned with foresight to ensure safety, efficiency, and sustainability in airport operations.

This research addresses the strategic need to expand the workshop airport facilities at Jenderal Ahmad Yani International Airport by employing an advanced structural design approach using the Load and Resistance Factor Design (LRFD) method and the SAP2000 software. By integrating LRFD design principles with local standards such as the Indonesian National Standard SNI 1729:2020, this project aims to develop a robust, efficient, and code-compliant steel structure design that accommodates seismic and wind loads typical for Indonesia's geological conditions. The study culminates in a comprehensive construction plan titled "Design of Workshop Airport Facilities Expansion Using LRFD Method at Jenderal Ahmad Yani International Airport Semarang," contributing to the advancement of airport infrastructure capable of supporting future growth and operational excellence.

## RESEARCH METHODS

### Types of research

The structural design of the steel building in this study was carried out using a quantitative descriptive technical approach, focusing on the analysis of steel structures through the Load and Resistance Factor Design (LRFD) method. LRFD is a probabilistic-based design approach that incorporates load factors and resistance factors to ensure both safety and efficiency in structural performance.

Unlike the traditional Allowable Stress Design (ASD) method, which has been widely used in the past, LRFD provides a more rational framework by explicitly accounting for uncertainties related to material properties and applied loads. This leads to a more reliable and precise assessment of the structural capacity under complex load combinations. The LRFD method applied in this project adheres to the Indonesian National Standard SNI 1729:2020, which is a revised version of the previous standards SNI 1729:2015 and SNI 1729:2002, and is based on the translated specifications of the American Institute of Steel Construction (AISC) 360-10.

By utilizing LRFD in conjunction with advanced structural analysis software, this study aims to produce an optimized structural design that meets current safety regulations and maximizes structural performance against probabilistic load demands specific to the region.

### Research Flow

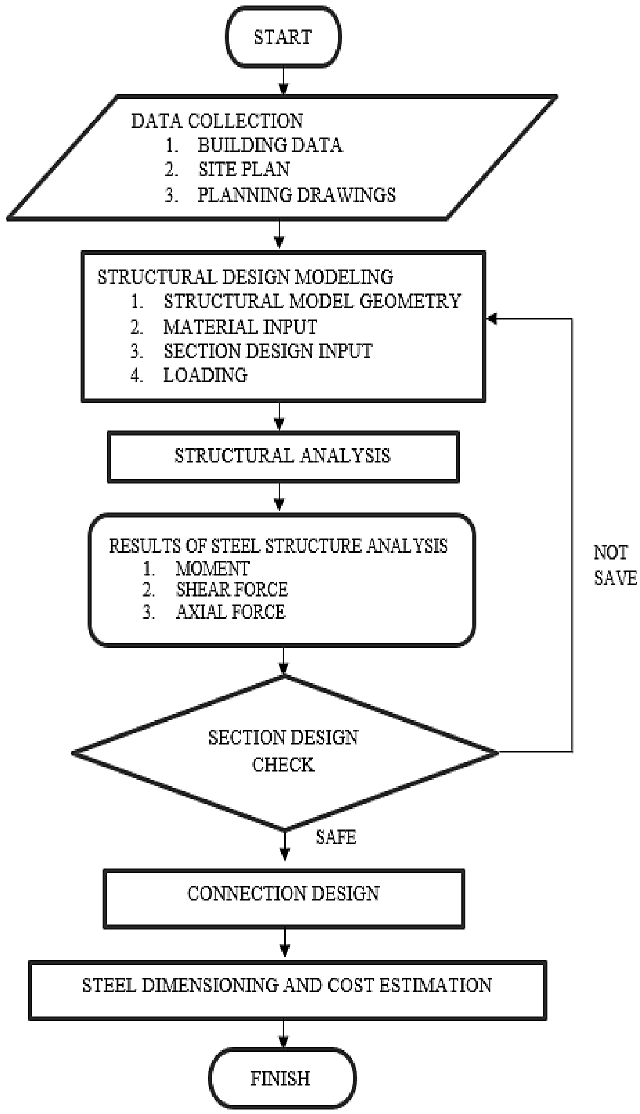


**Figure 1. Research Flow**
*Source: Author's Processing (2025)*

In Figure 1 above the detailed research stages are as follows.

1. **Start – Data Collection**

The preliminary two-dimensional structural design of the workshop airport facilities building was developed using AutoCAD software, with structural steel designated as the primary construction material. The input data for structural modeling and analysis in SAP2000 V26 were derived from detailed shop drawings, which serve as the foundation for numerical simulation employing the Load and Resistance Factor Design (LRFD) methodology. The design process strictly follows the criteria outlined in the Indonesian National Standard SNI 1729:2020, which governs specifications for structural steel buildings.

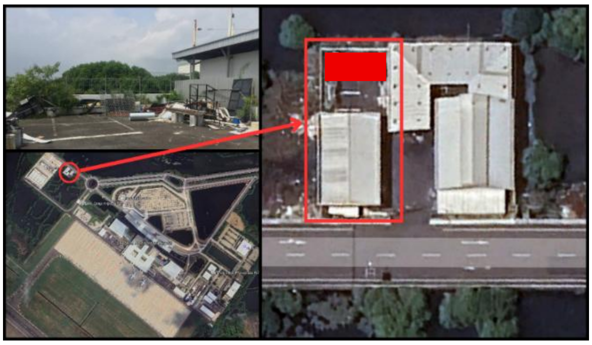

**Figure 2. Building Design Location**
*Source: Google Earth Pro (2025)*

In Figure 2 above it is explained building identification:

a. Name : Workshop Airport Facilities

b. Location : Jenderal Ahmad Yani International Airport, Semarang (Jalan Bandar Udara Ahmad Yani Semarang, Tambakharjo, Semarang Barat, Kota Semarang, Central Java 50149)

c. Primary Function : Coordination center for airport operational staff and storage facility for maintenance tools, materials, and equipment

d. Structural System : Steel frame construction

Geotechnical and Seismic Parameters:

a. Soil Classification : Soft soil conditions identified from BPBD (2023) geotechnical reports

b. Seismic Hazard Level : Zone 2 according to the 2017 National Earthquake Center classification

c. Seismic Input Data : Response spectrum parameters obtained from Puskim (Research and Development Center for Settlements) based on regional seismicity analysis.

The structural design criteria adhered to the following Indonesian standards and guidelines to ensure safety and serviceability under applicable load conditions:

a. SNI 1729:2020 : Structural Steel Building Specifications

b. SNI 1726:2019 : Earthquake Resistant Design Procedures for Building and Non-building Structures

c. SNI 1727:2020 : Minimum Load Requirements for Structural Design of Buildings and Other Structures

The workshop airport facilities building functions as a critical operational support structure, facilitating routine maintenance, equipment servicing, and testing activities essential to airport logistics. According to the Ministry of Transportation Regulation PM 36/2021, this type of facility is mandatory for airports exceeding a passenger throughput of five million annually. For Jenderal Ahmad Yani International Airport, with a current passenger capacity of approximately 6.9 million per year, compliance with this regulation is imperative.

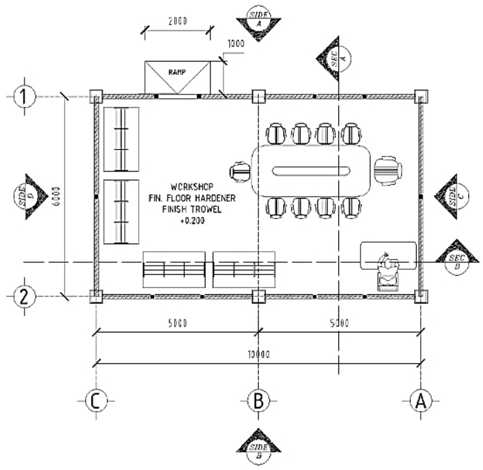


**Figure 3. Expansion Floor Plan**
*Source: Author's Processing (2025)*

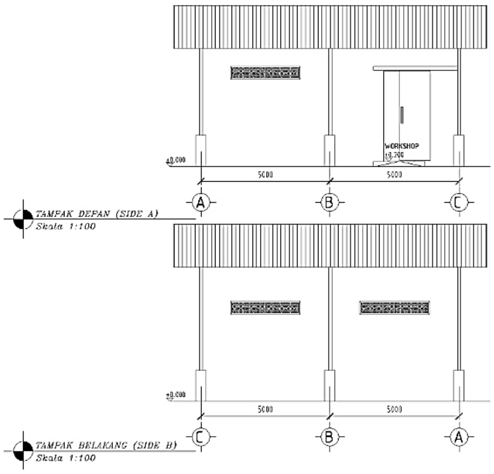


**Figure 4. Front and Back View of Expansion Plan**
*Source: Author's Processing (2025)*

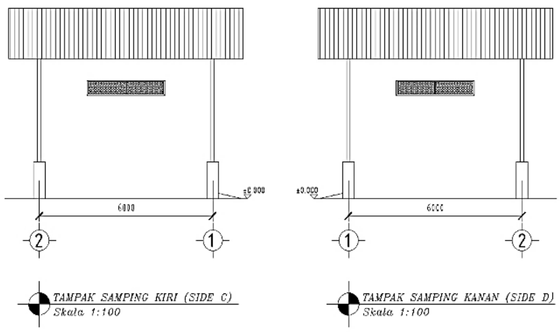


**Figure 5. Side View of Expansion Plan**
*Source: Author's Processing (2025)*

Figures 3, 4, and 5 above show the floor plan and views of the building plan design for the expansion of the airport facilities workshop, created by the author using AutoCAD software.

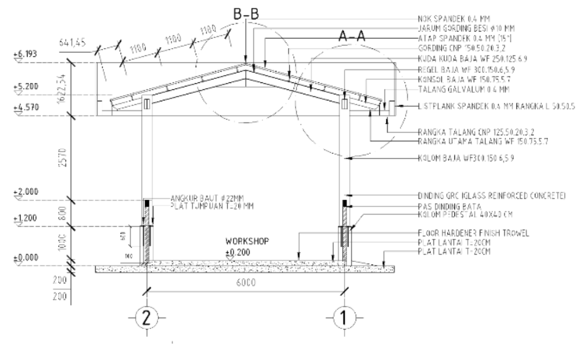


**Figure 6. Section A-A View of Expansion Plan**
*Source: Author's Processing (2025)*

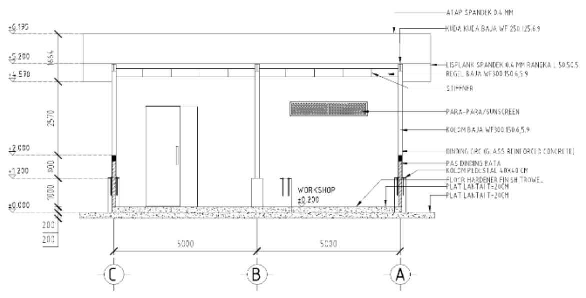


**Figure 7. Section B-B View of Expansion Plan**
*Source: Author's Processing (2025)*

Figures 6 and 7 above show the section A-A and section B-B of the building plan design for the expansion of the airport facilities workshop, created by the author using AutoCAD software.

Facility capacity analysis indicates the existing workshop covers an area of 94.5 m², with a planned expansion adding 60.0 m². This spatial augmentation aims to accommodate increasing operational demands and optimize material storage conditions, contributing to improved maintenance efficiency and asset management.

2. **Structural Design Modeling**

The three-dimensional structural model was developed based on the planning drawings, including roof trusses, purlins, and columns. The modeling and analysis were carried out using SAP2000 V26, while the preparation of shop drawings utilized AutoCAD 2025. The analysis adopted the Load and Resistance Factor Design (LRFD) method in accordance with SNI 1729:2020. All structural elements (columns, beams, and roof frames) were modeled as frame elements with cross-sections determined based on strength, stiffness, and material efficiency. Boundary conditions were assigned according to actual site conditions and relevant standards.

The model was created using the Grid Only template in SAP2000. The initial grid system was defined as follows:

a. X-direction : 3 grid lines : 5 m spacing
b. Y-direction : 2 grid lines : 6 m spacing
c. Z-direction : 3 grid lines : 5.2 m spacing

Adjustment of the roof truss height was required:
a. Column height : 5.20 m
b. Additional height : 0.8036 m (based on trigonometric calculation)
c. Total height (Z3) : 6.0036 m

Material Properties
a. Structural Steel : (SS400)
b. Yield Strength (Fy) : 245 MPa
c. Ultimate Strength (Fu) : 400 MPa
d. Elastic Modulus (E) : 200,000 MPa
e. Shear Modulus (G) : 80,000 MPa
f. Poisson's Ratio (μ) : 0.3
g. Thermal Expansion Coefficient (α) : $2 \times 10^{-6}$ / °C
h. Unit Weight : 7850 kg/m³
i. Reinforcing Steel : (BJTS 40)
j. Yield Strength (Fy) : 390 MPa
k. Ultimate Strength (Fu) : 400 Mpa

The applied loads followed SNI 1727:2020 (Loading for Buildings and Structures) and SNI 1726:2019 (Seismic Resistance).

a. Dead Load (DL & SIDL)
   - Zincalume roofing : 4.980 kg/m²
   - Purlin spacing : 1.10 m → q : 5.478 kg/m
   - Self-weight of purlin : 8.321 kg/m
   - Mechanical/Electrical load : 0.190 kN/m²
b. Live Load (LL & Lr)
   - Office area : 2.400 kN/m²
   - Roof live load : 100,000 kg
c. Rain Load (R)

   Water depth : 20 mm (assuming water ponding)

   R : 0.0098 x 20 mm

   R : 0.196kN/m² : 0.098 x 20 : 20 kg/m² (SNI1727:2020)

   Rtotal : 20 kg/m² x 1.10 m : 22 kg/m
d. Wind Load (W)
   - Location : Semarang
   - Building dimensions : 10 m × 6 m, height : 6.0036 m
   - Basic wind speed : 38.3 m/s

Wind factors:

- Kd : 0.85
- Exposure : D
- Kzt : 1.0
- Ke : 1.0
- G : 0.85
- Gcpi : 0.18
- Kz : 1.03
- qz : 80.278 kg/m²

e. Seismic Load (E)

- Location : Semarang
- Site class : E (soft soil)
- Ss : 0.8465 g; S1 : 0.3690 g
- TL : 6 s; T : 0.1 s
- Fa : 1.2228; Fv : 2.524
- Sms : 1.0351 g; Sm1 : 0.9314 g
- SDs : 0.690 g; SD1 : 0.621 g
- Seismic Design Category (SDC) : D
- Response modification factor (R) : 8
- Overstrength factor (Ω) : 3
- Deflection amplification factor (Cd) : 5.5

Load Combinations (LRFD – SNI 1729:2020)

a. 1.4DL+1.4SIDL
b. 1.2DL+1.2SIDL+1.6LL+0.5Lr
c. 1.2DL+1.2SIDL+1.6LL+0.5R
d. 1.2DL+1.2SIDL+1.6Lr+1.0LL
e. 1.2DL+1.2SIDL+1.6Lr+0.5Wx+0.5Wy
f. 1.2DL+1.2SIDL+1.6R+1.0LL
g. 1.2DL+1.2SIDL+1.6R+0.5Wx+0.5Wy
h. 1.2DL+1.2SIDL+1.0LL+0.5Lr+1.0Wx+1.0Wy
i. 1.2DL+1.2SIDL+1.0LL+0.5R+1.0Wx+1.0Wy
j. 0.9DL+0.9SIDL+1.0Wx+1.0Wy
k. 1.34DL+1.34SIDL+1.0LL+1.30Ex+0.39Ey
l. 1.34DL+1.34SIDL+1.0LL+1.30Ex-0.39Ey
m. 1.34DL+1.34SIDL+1.0LL-1.30Ex+0.39Ey
n. 1.34DL+1.34SIDL+1.0LL-1.30Ex-0.39Ey
o. 1.34DL+1.34SIDL+1.0LL+0.39Ex+1.30Ey
p. 1.34DL+1.34SIDL+1.0LL+0.39Ex-1.30Ey
q. 1.34DL+1.34SIDL+1.0LL-0.39Ex+1.30Ey
r. 1.34DL+1.34SIDL+1.0LL-0.39Ex-1.30Ey
s. 0.76DL+0.76SIDL+1.3Ex+0.39Ey
t. 0.76DL+0.76SIDL+1.3Ex-0.39Ey
u. 0.76DL+0.76SIDL-1.3Ex+0.39Ey
v. 0.76DL+0.76SIDL-1.3Ex-0.39Ey
w. 0.76DL+0.76SIDL+0.39Ex+1.3Ey
x. 0.76DL+0.76SIDL+0.39Ex-1.3Ey
y. 0.76DL+0.76SIDL-0.39Ex+1.3Ey
z. 0.76DL+0.76SIDL-0.39Ex-1.3Ey

3. **Structural Analysis**

The run analysis stage is conducted after all structural elements, section properties, loads, and load combinations are correctly inputted. The analysis results include internal forces (moments, shear, axial), deformations, and the strength ratio of elements relative to allowable limits. These results are evaluated to ensure that all structural elements comply with the strength and stability criteria specified in SNI 1729:2020. If any element fails to meet the requirements, revisions are made to the section dimensions or structural configuration.

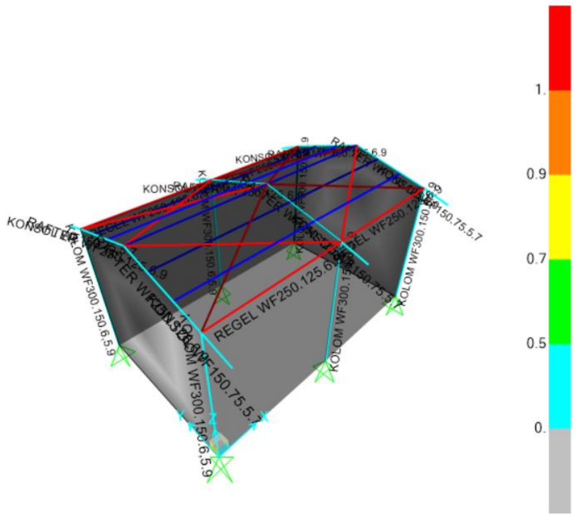


**Figure 8. Run Analysis**

*Source: Author's Processing (2025)*

As shown in Figure 8, to expedite the redefinition process of the frame sections, “auto selection” is utilized to avoid prolonged trial and error. The input data for frame sections should be derived from the import of new properties (AISC14) in accordance with the design code applied. Before redefining the frame sections, release and partial fixity must be performed on the girders to free them from axial loads caused by earthquake and wind, as these loads should be carried by the main structure, namely the columns and trusses. The following are the steps for releasing and partially fixing the girders.

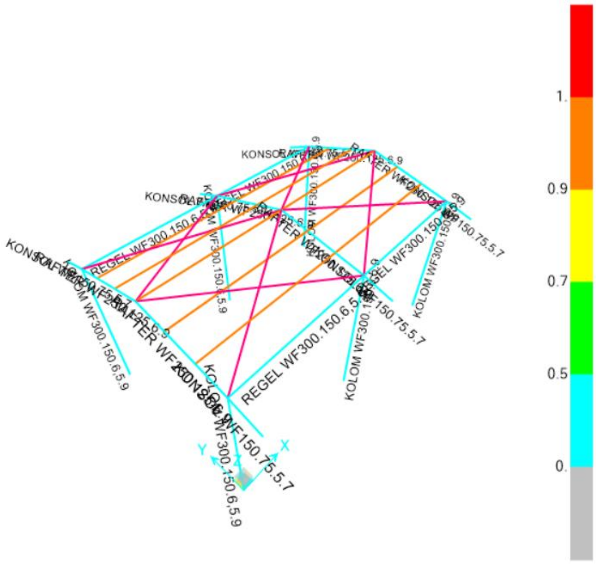


**Figure 9. Run Analysis Result**
*Source: Author's Processing (2025)*

Based on Figure 9, if the frame uses auto selection, the SAP2000 program automatically determines the appropriate section to adequately support the loads. After assigning auto selection, the program is run again, yielding the following analysis results. All frames have passed with section strength ratios less than 1.

## 4. Results of Steel Structural Analysis

To display moments, shear forces, and axial forces in the steel structure using SAP2000, the analysis must first be completed by selecting Analyze > Run Analysis. Once the analysis finishes without errors, internal forces can be shown by navigating to Display > Show Forces/Stresses > Frame/Cable/Tendon Force and selecting the desired load case or combination and force type—axial force (P), shear force (V2 or V3), or moment (M2 or M3). The resulting force diagrams on structural elements are then evaluated against SNI 1726:2019, which requires at least 90% cumulative mass participation in both X and Y directions for minimum seismic design. The analysis yielded UX and UY values of 0.999 (99.9%), demonstrating that the mass participation criteria are fulfilled and the design complies with the relevant standards.

TABLE: Base Reactions

| OutputCase | CaseType | GlobalFX | GlobalFY | GlobalFZ | GlobalMX | GlobalMY | GlobalMZ | GlobalX | GlobalY | GlobalZ |
|---|---|---|---|---|---|---|---|---|---|---|
| Text | Text | KN | KN | KN | KN-m | KN-m | KN-m | m | m | m |
| Wx | LinStatic | -0.467 | -6.206 | 4.462 | 30.461 | -23.959 | -29.631 | 0.000 | 0.000 | 0.000 |
| Wy | LinStatic | 0.000 | 0.911 | 4.770 | 12.564 | -23.849 | 4.557 | 0.000 | 0.000 | 0.000 |

**Figure 10. V Static Base Reaction**
*Source: Author's Processing (2025)*

Based on Figure 10, the static base reaction output shows that the values of ΣFX and ΣFY are nearly zero, indicating that the loads acting on the structure are balanced.

TABLE: Base Reactions

| OutputCas | CaseType | StepType | GlobalFX | GlobalFY | GlobalFZ | GlobalMX | GlobalMY | GlobalMZ | GlobalX | GlobalY | GlobalZ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Text | Text | Text | KN | KN | KN | KN-m | KN-m | KN-m | m | m | m |
| Ex | LinRespSp | Max | 0.180 | 0.000 | 0.000 | 0.000 | 0.988 | 0.543 | 0.000 | 0.000 | 0.000 |
| Ey | LinRespSp | Max | 0.000 | 4.625 | 0.006 | 25.291 | 0.016 | 23.223 | 0.000 | 0.000 | 0.000 |

**Figure 11. V Dynamic Base Reaction**
*Source: Author's Processing (2025)*

Based on Figure 11, the dynamic base reaction output shows that the earthquake in the X direction produces a dominant reaction in the X direction, and similarly for the Y direction, indicating that the behavior is as expected.

TABLE: Joint Displacements

| Joint | OutputCase | CaseType | StepType | U1 | U2 | U3 | R1 | R2 | R3 |
|---|---|---|---|---|---|---|---|---|---|
| Text | Text | Text | Text | m | m | m | Radians | Radians | Radians |
| 9 | 4b | Combination | | 0 | 0 | 0 | -0.000264 | 0.174306 | 0.041081 |
| 9 | 6e | Combinatior | Max | 0 | 0 | 0 | 0.002428 | 0.04088 | 0.00966 |
| 14 | 5 | Combination | | 0 | 0 | 0 | -0.000586 | 0.174387 | 0.041012 |
| | | | | | | MAX | 0.002428 | 0.174387 | 0.041081 |

**Figure 12. Joint Displacements**
*Source: Author's Processing (2025)*

Based on Figure 12, the joint displacement output shows all values as zero, indicating compliance for supports or fixed elements. The following presents the internal force output of structural elements, serving as a reference for section checks and connection design.

## 5. Section Design Check

Section control includes analysis of local buckling in the flange and local buckling in the web, with the following formula.

- Local Buckling of Flange

$$\lambda \quad \leq \quad \lambda p$$

$$\frac{b_f}{2tf} \leq 0{,}38\sqrt{\frac{E}{F_y}}$$

- Local Buckling of Web

$$\lambda \quad \leq \quad \lambda p$$

$$\frac{h}{tw} \leq 3{,}76\sqrt{\frac{E}{F_y}}$$

Bending calculation for beam includes stress control, flexural strength control, and slenderness ratio control, described as follows.

- Stress Control

  Stress Ratio ≤ 1

- Flexural Strength Control

$$Mu \leq \phi b M_n$$

$$Mu \leq \phi b \; x \; (Fy \; x \; Zx)$$

$\frac{Mu}{\phi bMn} \leq 1{,}0$

- Slenderness Ratio Control

  $Lr \leq 300$

Compression calculation on columns described as follows.

- Stress Control

  Stress Ratio ≤ 1

- Compressive Strength Control

  $Pu \leq \phi c P_n$

  $Pu \leq \phi c\ x\ (Fcr\ x\ A)$

  $\frac{Pu}{\phi cPn} \leq 1{,}0$

- Shear Strength Control

  $\frac{h}{tw} \leq 1{,}10\sqrt{\frac{kv \cdot E}{fy}}$

  $\frac{Vu}{\phi vVn} \leq 1{,}0$

- Slenderness Ratio Control

  $\frac{L}{r} \leq 300$

6. **Connection Design**

Bolt connection design is divided into two categories: beam-to-column connections and beam-to-beam connections. The required data include:

1. Bolt Data
   a. Type of Bolt Connection
   b. Nominal Tensile Strength (Fnt)
   c. Nominal Shear Strength (Fnv)
   d. Bolt Strength Reduction Factor ()
2. Connection Plate
   a. Plate Yield Stress (fy)
   b. Plate Ultimate Stress (fu)
   c. Width of Beam-to-Column Plate
   d. Width of Beam-to-Beam Plate

Bolt strength control includes shear strength, tensile strength, combined shear and tensile strength, and bearing strength, explained as follows.

1. Bolt Shear Strength

Rn = Fnv x A$b$

Rn = Fnv x (1/4. Π.d$^2$)

ϕRn = 0,75 x Rn > Pu

2. Bolt Tensile Strength

Rn = Fnt x A$b$

Rn = Fnt x (1/4. Π.d$^2$)

ϕRn = 0,75 x Rn > Pu

3. Combined Bolt Shear and Tensile Strength

Rn = F'nt x A$b$

Rn = $\left(1{,}3Fnt - \frac{Fnt}{\phi Fnv} frv \leq Fnt\right) x$ (1/4. Π.d$^2$)

ϕRn = 0,75 x Rn > Pu

4. Bearing Strength

Rn = 2,4 x db x tp x Fu

ϕRn = 0,75 x Rn > Pu

Calculation of Number and Spacing of Column Bolts

1. Number of Bolts

If Mu > Pu

$\frac{Mu}{e} = Pu$

$n = \frac{Pu}{\phi Rn}$

2. Bolt Spacing

3d < S < 12 t

S < 150 mm.

3. Bolt Edge Distance to Plate

Smin < S < 12 t

S < 150 mm.

Calculation of Column Connection Plate Thickness

$t \quad \geq \quad \frac{n+b}{90}$

## CONCLUSION

Based on the research results and discussion, the conclusions that can be drawn are as follows.

1. The design of the airport facilities workshop building at Jenderal Ahmad Yani International Airport Semarang uses a steel structure with the LRFD (Load

and Resistance Factor Design) method. It consists of a single floor with dimensions of 6 x 10 meters. This size represents a new building constructed as an expansion of the existing airport facilities workshop, which did not yet meet operational needs. The structural profiles used for the building are as follows:
1) Girders use CNP 150.50.20.2.3 profiles
2) Main columns use WF 300.150.6.5.9 profiles
3) Consoles use WF 150.75.5.7 profiles
4) Rafter beams use WF 250.125.6.9 profiles
5) Regel beams use WF 300.150.6.5.9 profiles
6) Wind braces use 10 mm diameter reinforcing bars (D10)

2. The structural design of the airport facilities workshop building, which is earthquake resistant for the area of Jenderal Ahmad Yani International Airport Semarang, is carried out using the LRFD approach in accordance with SNI 1729:2020 for steel structures. The seismic effect evaluation is performed through response spectrum analysis, referring to SNI 1726:2019 on earthquake-resistant design requirements for buildings. A dynamic analysis is conducted on the lateral earthquake forces. From the SAP2000 dynamic base reaction output, the earthquake in the X direction produces a dominant reaction in the X direction, and similarly in the Y direction, indicating that the design complies with the requirements.
3. Based on the calculations, detailed technical drawings of the steel structure connections have been produced.
4. Based on the budget plan calculations using the unit price coefficients for Semarang City in 2024 and the unit prices for 2025 plus 11% VAT, the total cost for constructing the airport facilities workshop building is One Hundred Seventy-Five Million Rupiah (Rp. 175,000,000.00).

**Recommendations**

Based on the research results, several suggestions are as follows.

1. This research can be used as a reference for the planning of the expansion of the airport facilities workshop building at Jenderal Ahmad Yani International Airport Semarang to meet the operational needs of the airport's landside facilities.
2. Future research could include structural analysis of the entire building foundation (overall building analysis) and mechanical-electrical (ME) works.

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