

Steel Structure Design for a 4-Story Apartment Building on Tanjungpura Street, Pontianak City

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To cite this article:

Repo, M., Leojarma, A., Anggraini, I., & Rasiwan. (2026). Steel Structure Design for a 4-Story Apartment Building on Tanjungpura Street, Pontianak City. *International Journal of Research in Vocational Studies (IJRVOCAS)*, 5(4), 30–34. <https://doi.org/10.53893/ijrvocas.v5i4.228>

Received: 10 18, 2025; Revised: 11 23, 2025; Accepted: 12 19, 2025; Published: 01 30, 2026



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Abstract: The construction of apartments on the banks of the Kapuas River in Pontianak City has become an urgent necessity due to high urbanization rates and limited land availability. The design of this steel structure uses the LRFD method based on SNI 1729:2020, SNI 7860:2020, SNI 1726:2019, and SNI 2847-2019 with a Regular Moment Resisting Frame System. The four-story building, measuring 40x30 meters and made of BJ37 steel, uses composite floor slabs, with steel profiles consisting of main beams. The design uses a Moment Resisting Frame (MRF) system to withstand lateral loads on soft soil in Pontianak. The analysis results show a maximum inter-story drift of 26.7 mm, still far below the 80 mm limit according to SNI 1726:2019. This study confirms that the use of BJ37 steel with composite plates significantly reduces dead loads compared to conventional concrete, making it a viable solution for the area. Structural connections at the intersections of beams and columns use high-quality A325 bolts.

Keywords: Apartment, Building, Flats, Steel, Pontianak

1. Introduction

The city of Pontianak, especially along the banks of the Kapuas River, urgently needs apartment buildings. This area has a high level of urbanisation with limited residential land, so apartment buildings can be a solution to accommodate the growing population. In addition, apartment buildings can also increase land use efficiency, reduce population density in slums, and provide decent and affordable housing for low-income communities. With proper planning, apartment buildings can also be part of efforts to preserve the environment and improve the quality of life for communities around the Kapuas River.

2. Literature Review

Rapid urbanisation in Indonesia has caused various urban

problems, particularly the emergence of slums due to the imbalance between population growth and the availability of infrastructure and public facilities. Slums are characterised by high population density, poor housing conditions, lack of social facilities, and low-income communities [12]

Steel structure design has two methods, namely Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD). The LRFD (Load and Resistance Factor Design) and ASD (Allowable Stress Design) methods are two different approaches to structural design. LRFD applies the principle of reducing the capacity of a structure based on load and resistance factors, while ASD focuses on limiting the allowable stress in a structure. The two methods have

fundamental differences, such as the combination of loads used and the application of reduction factors (ϕ) in LRFD and safety factors (Ω) in ASD, which affect the overall results of structural design [9]

A moment-resisting frame system consists of structural elements such as beams, columns, and connections designed to resist loads through flexural, shear, and axial mechanisms [11]. Steel is one of the most widely used construction materials in various projects, but like other materials, steel also has advantages and disadvantages that need to be considered in its use. Steel has several advantages over other construction materials, such as ductility and relatively faster processing compared to reinforced concrete. However, steel also has several disadvantages that need to be considered, including its susceptibility to temperature changes. If a steel structure experiences a fire, the strength of the steel structure will decrease, thereby affecting the function of the steel structure [10].

The strength of steel in bearing loads is largely determined by its mechanical properties. The mechanical properties of a material are its ability to resist the loads acting on it. The mechanical properties of structural steel materials required in planning include yield strength, tensile strength (ultimate strength), modulus of elasticity, shear modulus, Poisson's ratio, and coefficient of expansion [1].

This planning will use the LRFD method based on SNI 1729:2020, SNI 7860:2020, SNI 1726:2019, SNI 2847-2019, PPPURG 1987, SNI 1727:2020, and using the Ordinary Moment Resisting Frame System (SRPMB) which provides a high level of ductility and structural reliability, making it safer and more resilient for dense residential buildings such as apartment buildings, even in low earthquake zones.

3. Methodology

This study focuses on the structural design of a four-story residential building using a steel frame system located in Tanjungpura road, Benua Melayu Laut Subdistrict, Pontianak City. The design process follows the Load and Resistance Factor Design (LRFD) method with reference to relevant Indonesian National Standards (SNI).

The research methodology includes the following stages:

1. **Data Collection:**
Gathering site information such as soil characteristics, seismic zone, and basic design parameters, as well as population and urban data relevant to the study area.
2. **Preliminary Design:**
Determination of structural layout, material selection, and load assumptions based on SNI 1727:2020 and building function requirements.
3. **Structural Analysis:**
The building is modelled using structural analysis software to determine internal forces and displacements under various load combinations according to SNI 1726:2019.

4. **Design of Structural Components:**
Structural elements such as beams, columns, and connections are designed and checked according to SNI 1729:2020 and SNI 7860:2020.
5. **Evaluation and Optimisation:**
The design is evaluated for strength, serviceability, and cost efficiency. Adjustments are made to ensure compliance with safety and performance requirements.

This methodology ensures that the proposed steel structure meets structural safety, economic efficiency, and seismic performance standards, making it suitable for urban residential development in soft soil areas such as Pontianak.

4. Result and Discussion

4.1. Earthquake Shear Force Scaling

Based on [4] the combination of modal response for the base shear force obtained from the response spectrum analysis (V_t) shall not be less than 100% of the base shear force (V) calculated using the equivalent static method. $V_t \geq 1.0V$.

Table 1. Base Reaction from Response Spectrum Analysis

OutputCase	CaseType	GlobalFX	GlobalFY
Esx	LinStatic	-2009.59	0.00
Esy	LinStatic	0,00	-2009.59
Edx	LinRespSpec	2009.58	852.229
Edy	LinRespSpec	426.484	2009.588

4.2. Mass Participation Control

To ensure accurate structural analysis, the number of vibration modes must be sufficient so that the cumulative mass participation reaches at least 90% of the total structural mass. The mass participation results obtained from SAP2000 are 97% in the X-direction and 93% in the Y-direction, thus meeting the requirement.

4.3. Displacement Control

Inter-story drift analysis is performed to prevent the structure from experiencing excessive drift. The design inter-story drift is calculated based on the difference in centre-of-mass displacement at the upper and lower stories.

Table 2. Interstory Drift

Floor	Deviation between Design Floors(Δ)		permit deviation(Δ) [$\Delta < \Delta_a$] mm
	X Direction	Y Direction	
	mm	mm	
Dak	13,226	6,892	80
3	21,803	10,642	80
2	26,777	12,288	80
1	17,318	7,377	80
Base	0	0	80

Based on the displacement output from SAP2000, the calculated story drift does not exceed the allowable limit, as shown in Table 2.

4.4. P-Delta Effect Analysis

The P-Delta effect must be considered when the stability coefficient (θ) exceeds 0.10.

Table 3. P-Delta Calculation for Each Story (X-Direction)

Floor	θ Rasio	θ Max	check
4	0,010	0,167	Ok
3	0,027	0,167	Ok
2	0,042	0,167	Ok
1	0,030	0,167	Ok

Table 4. P-Delta Calculation for Each Story (Y-Direction)

Floor	θ Rasio	θ Max	check
4	0,004	0,167	Ok
3	0,011	0,167	Ok
2	0,016	0,167	Ok
1	0,012	0,167	Ok

Based on the results in the table above, the value of the stability coefficient (θ) for the first floor is still far below the maximum stability coefficient (θ_{max}), so the effect of P-Delta on the structure does not need to be taken into account.

4.5. Horizontal Irregularity Analysis

The results of the horizontal irregularity check show that the structural model does not exhibit any of the following: torsional irregularity (1a), extreme torsional irregularity (1b), horizontal irregularity type 2, type 3, type 4, or type 5.

4.6. Vertical Irregularity Analysis

The results of the vertical irregularity check indicate that the structural model does not exhibit vertical irregularity type 4 or vertical irregularity type 5b.

4.7. Slab Calculation

The results of the slab reinforcement design for the floor and roof slabs, based on the internal force output from SAP2000, are presented in Table 5 and Figure 1.

Table 5. Slab Reinforcement Design

Position	Span	Thickness	Reinforcement
Flat roof	2m	9cm	$\phi 8-200$
Ground floor-3r floor	2m	10cm	$\phi 8-200$

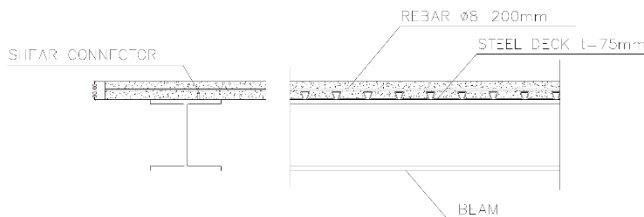


Figure 1. Reinforcement Details of Floor and Roof Slabs

4.8. Beam Calculation

The results of the beam profile calculation, based on the internal force output from SAP2000 and the available profile tables [2] are presented in Table 6.

Table 6. Steel Construction Profile

Beam Type	Web Thickness	Flange Thickness	Radius
B1	14 mm	22 mm	20 mm
B2	8 mm	12 mm	18 mm
BA	6,5 mm	9 mm	10 mm

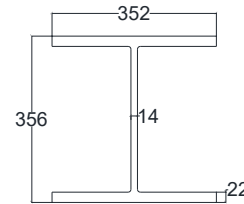


Figure 2. Beam Profile 1 IWF 356 x 352 x 14 x 22

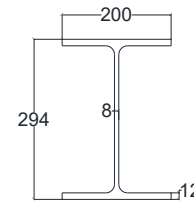


Figure 3. Beam Profile 2 IWF 294 x 200 x 8 x 12

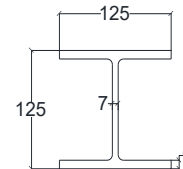


Figure 4. Secondary Beam 3 IWF 125 x 125 x 6,5 x 9

4.9. Shear Connector Calculation

The shear connectors used in this design are stud-type connectors.

Table 7. Recapitulation of Shear Connector Quantity for Each Span

Beam Span	D _{stud}	Number of Studs
IWF 356.352.14.22 6 meters	62	124

IWF 294.200.8.12 4 meters	23	46
IWF 125.125.6,5.9 2 meters	10	20

4.10. Column Calculation

The results of the column profile calculation, based on the internal force output from SAP2000, are presented in Table 8.

Table 8. Steel Construction Profile

Beam Type	Web Thickness	Tebal Thickness	Radius
K1	30 mm	50 mm	22 mm

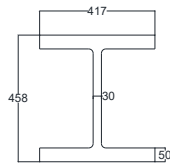


Figure 5. Hbeam Column Profile 458x417x30x50

4.11. Connection Calculation

Table 9. Summary of Calculation Results for Each Connection

Connection Type	Bolt Spacing	Bolt Diameter	Joint Plate Thickness
	mm	mm	
Bolt	108	6D20	8
Bolt	102	6D16	8
Bolt	80	24D20	10

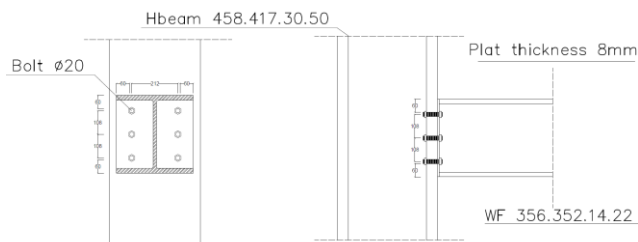


Figure 6. Connection of Main Beam 1 to Column

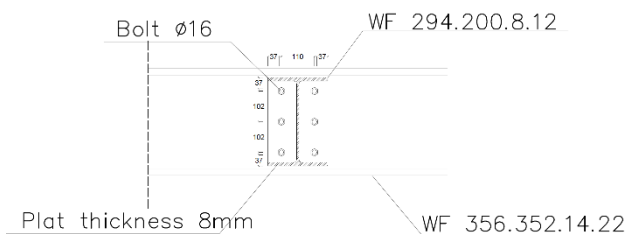


Figure 7. Connection of Main Beam 2 to Main Beam 1

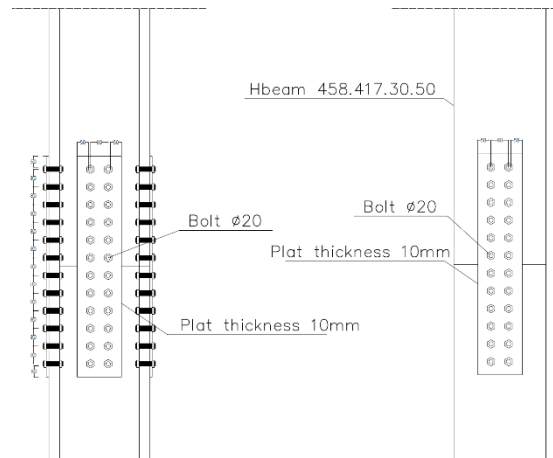


Figure 8. Column to Column Connection

4.12. Base Plate Planning

Table 10. Summary of Base Plate Connection Calculations

Connection Type	Bolt Spacing	Bolt Diameter	Joint Plate Thickness
	mm	mm	mm
Baut	250	6D22	40

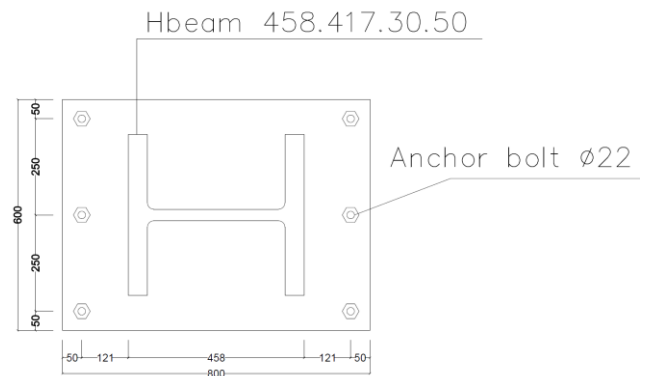


Figure 9. Top View of Base Plate

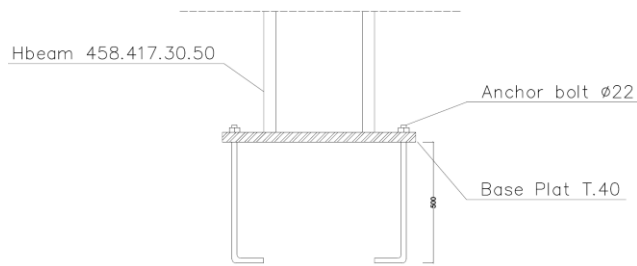


Figure 10. Section of Base Plate

5. Conclusion

Based on the results of the analysis and design that have been carried out, several conclusions can be drawn as follows:

1. The four-story residential building designed using the LRFD method with a Moment Resisting Frame (MRF) system meets all the requirements listed in SNI 1729:2020, SNI 7860:2020, and SNI 1726:2019.
2. The analysis results show that the inter-story drift and lateral displacement remain within the permissible limits, indicating that the building has good seismic performance and overall stability.
3. The MRF system provides an optimal balance between strength, stiffness, and flexibility, making it suitable for multi-story residential buildings in low-seismic areas such as Pontianak.

Acknowledgements

The author would like to express sincere gratitude to Mrs. Irene Anggraini, S.T., M.Sc. as supervisor and Mr. Ir. Rasiwan, M.T. for their guidance, direction, and patience in supervising the author from start to finish, as well as the Civil Engineering Laboratory of Pontianak State Polytechnic for providing data that supports and improves the quality of this planning work.

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