

## Analysis of Steel Truss Performance Using The LRFD Method on Basko City Mall Building In Padang City

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### Abstract

West Sumatra is an earthquake-prone region that requires structural systems with sufficient strength, stiffness, and ductility to withstand seismic loads. This study evaluates the performance of a steel truss structure in Basko City Mall, Padang, using the Load and Resistance Factor Design (LRFD) method. Load calculations refer to loading protocol, while numerical analysis is carried out using Patran Nastran Student Edition 2023 to model structural behavior through the finite element method. The analysis focuses on five beam variations (B1, B2, B3, B4, and B5) tested under displacement to determine ultimate load capacity, stiffness, and plastic deformation capability. Results indicate that all beams are safe and stable under the applied loads. Beam B1 has the highest ultimate load capacity of 4153.09 kN, while Beam B3 provides the greatest stiffness of 41.048 N/mm. Beams B2, B4, B5 and B exhibit better ductility, allowing effective energy absorption before reaching failure. This study concludes that all beam variations are suitable for multi-story buildings in seismic-prone areas. The LRFD method proves effective in providing efficient and safe designs, while Patran Nastran supports more detailed analysis and can serve as a reference for future research on steel structure design.

Keywords: Steel truss, LRFD, Patran Nastran, ultimate load, deformation, structural stability.

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### 1. Introduction

Indonesia is one of the countries located in the “Ring of Fire” zone, which is marked by high seismic and volcanic activity. Geologically, Indonesia lies at the convergence of three major tectonic plates, namely the Eurasian plate, the Indo-Australian plate, and the Pacific plate. These plates collide and shift, making Indonesia a region with a very high potential for earthquakes. One area with significant earthquake risk is West Sumatra Province, especially the city of Padang. Based on data from the Meteorology, Climatology, and Geophysics Agency (BMKG), this region has experienced several major earthquakes that caused damage, thus requiring the implementation of a resilient building structural system that is earthquake-resistant.

In this context, the challenge in designing a structural system is not only in terms of material and cost but also in ensuring the building is reliable against earthquake loads. Steel is one of the most widely used structural materials in construction, especially for multi-story and bridge buildings. The

use of steel has many advantages, such as high tensile and compressive strength, relatively lightweight structure, ease of fabrication and installation, and high ductility. High ductility is very important in earthquake-resistant structures because it allows the material to absorb and redistribute earthquake energy through plastic deformation without causing sudden structural failure.

One of the most commonly used steel structural systems in construction is the truss system. Steel trusses have an efficient configuration and are often used for wide-span multi-story buildings. However, under extreme earthquake conditions, structures still face significant challenges, particularly related to large lateral forces causing excessive deflection and large stress on structural elements. Problems that often occur include local plastic deformation, weak connections, and damage to critical structural elements. Therefore, an appropriate structural design is crucial to ensure building stability and safety.

The Load and Resistance Factor Design (LRFD) method is one of the widely used approaches in steel structure design. LRFD combines various load and strength factors with a probabilistic approach, producing safer and more economical designs. This method is based on the premise that design strength must always be greater than the effect of loads, which are multiplied by certain factors. In the context of earthquake-resistant design, LRFD is very relevant because it provides a proper safety margin against various load uncertainties.

Several previous studies have examined the performance of steel structures against earthquakes, both experimentally and numerically. Research results show that modifications to structural elements, such as the use of stiffeners, variations in profile dimensions, and optimal connection placement, can increase strength, stiffness, and ductility of the structure. The use of finite element-based software such as Msc. Patran/Nastran has also been proven effective in simulating realistic structural responses under earthquake loads, making it possible to predict structural performance more accurately.

## 2. Research Methodology

This research is descriptive-quantitative with a case study approach on the steel structure of the Basko City Mall building. The research steps consist of structural modeling, load determination, finite element analysis, and evaluation based on LRFD design criteria.

### 2.1. Location and Data

The research location is in Padang City, West Sumatra. The object analyzed is the truss structural system of the multi-story Basko City Mall building. The steel profile used in the design is intended to evaluate structural behavior under extreme conditions before being applied in the field.

This research aims to analyze the performance of the truss structural system of the Basko City Mall building in Padang City using the LRFD method. Finite element analysis with Msc. Patran/Nastran software is used to obtain structural performance parameters, namely maximum strength, stiffness, and ductility, against earthquake loads. The IWF steel profile design is used as the analysis reference to determine structural response under earthquake loads.

The expected outcome of this research is to provide a real contribution to the development of earthquake-resistant steel structure design in disaster-prone areas and to serve as a technical reference for designers and practitioners in civil engineering in Indonesia.

### 2.2. Calculation Standards

The structural design refers to the following standards:

- SNI 1726:2019 concerning procedures for earthquake resistance planning.
- SNI 1729:2020 concerning general specifications for structural steel buildings.

### 2.3. Software and Modeling

Structural modeling was carried out using MSC Patran Nastran V 2023 software, which allows for numerical analysis based on the finite element method. The model was created in 3D form and included joints, load-bearing elements, and material properties.

The WF profile used refers to the 500.200.10.18 profile in the form of L. The beam length used is 4000 mm. The beam length analyzed was set at 4000 mm to match the actual conditions in the field.

Tabel 2. Beam Variation Parameters Data

Variasi	Beam Parameter Variations				
	Panjang balok (mm)	Tinggi profil balok	Lebar sayap	Tebal Badan	Tebal Sayap
B1	4000	500	200	10	18
B2	4000	400	200	8	13
B3	4000	350	175	7	11
B4	4000	600	400	11	17
B5	4000	700	300	13	24
B	4000	200	100	5,5	8

### 2.4 Loading Types

The input properties and loading properties entered into the Msc. Patran/Nastran program consist of elastic modulus = 200,000 MPa and Poisson ratio = 0.3. The loading applied to the test object was in the form of displacement control applied step by step.

To obtain the values of strength, stiffness, and ductility parameters, the loading was performed in monotonic stages with increments of 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, and 30 mm.

The results of the analysis are expressed in the form of a curve of the relationship between force vs. displacement, which is presented in Figure 2, while

the stress-strain relationship data is shown in Table

Table 2. Stress-Strain

Strain	Stress
0	0
0.0015	300
0.015	300
0.0306	364
0.0579	424
0.0944	450
0.1289	450
0.1563	440
0.17	425
0.18	406

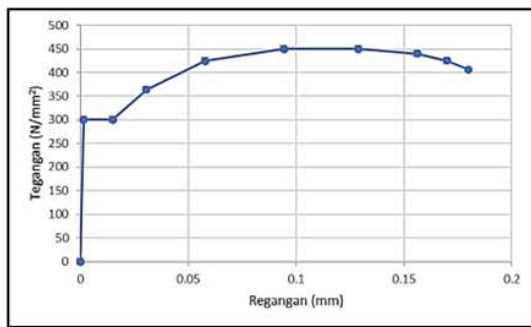
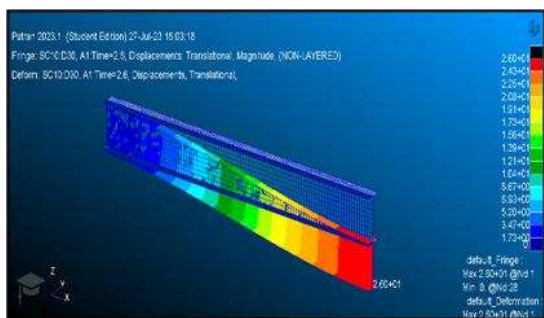


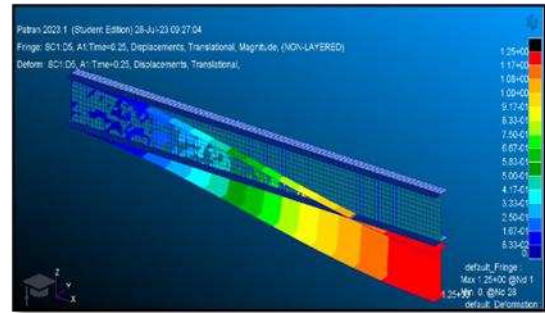
Figure 2. Stress-Strain Data Graph

### 2.5 Data Collection

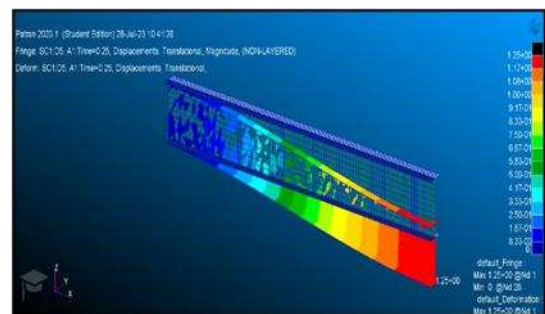
After running the application on Msc. Patran, we can observe the condition of the beam structure after being subjected to loading as shown in the following figures:



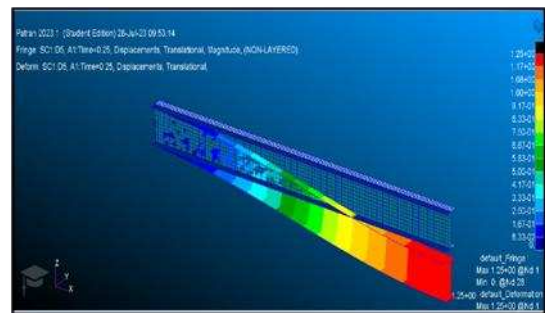
(B1)



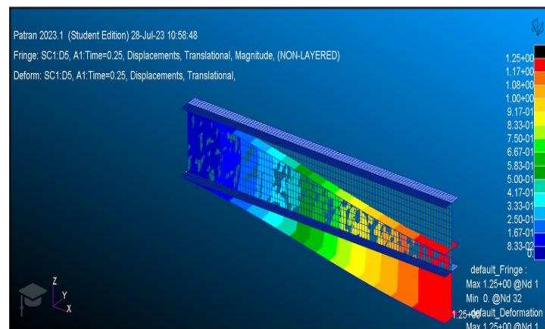
(B2)



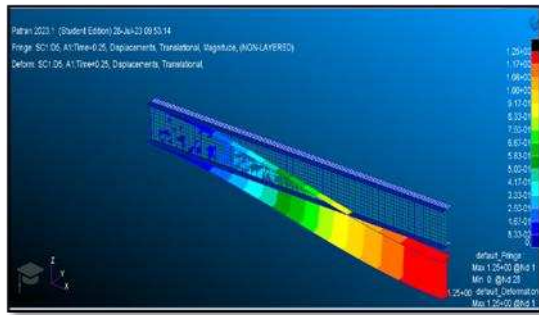
(B3)



(B4)



(B5)



(B)

### 3. Results and Discussion

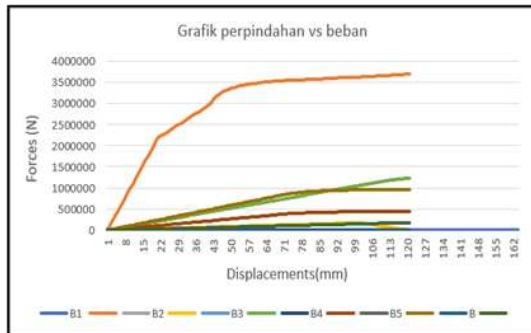


Figure 3 Comparison of All Modeling Variations

The analysis results show that each profile variation provides a different structural response. Most profiles display curves dominated by the elastic phase, where the increase in load is directly proportional to the increase in displacement. However, there are profile variations that indicate entering the plastic phase, marked by a decrease in stiffness on the curve approaching the degradation point.

This indicates that changes in profile geometry significantly affect load capacity, stiffness, and structural ductility, although the displacement differences between profiles are not too large.

#### 3.1 Inelastic Parameter Check

Next, the structure was checked for inelastic parameters consisting of strength, stiffness, and ductility, as presented in Table 3.

Table 3. Inelastic Parameters

Variation	Strength (Kn)	Stiffness (Kn/Mm)	Ductility
B1	4153,090	25,957	10,78
B2	177,841	5,928	1
B3	1231,438	41,048	1
B4	449,615	14,987	2,4

B5	961,944	32,065	10,5
B	180,648	6,022	0,25

### 4. Conclusion

Based on the analysis, it can be concluded that all six beams B1, B2, B3, B4, B5, and B6 are able to work properly under the applied loading.

Beam B1 showed the highest ultimate load of 1231.43 kN, while the highest stiffness was found in beam B3 with 41.048 kN/mm. Meanwhile, beams B2, B4, B5 and B had relatively lower capacities but better plastic deformation, allowing energy absorption and redistribution of forces before failure.

All tested variations remained within the planned safety limits. These results show that all beams can be applied according to their respective structural functions. For example, B3 with high stiffness is suitable for structural applications that require maximum stability, while B2, B4, and B5 are more suitable for structural systems subjected to dynamic loads or varying conditions, since their ductility improves the ability to absorb energy and reduce failure risk.

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