COMPARATIVE ANALYSIS OF WARREN, PRATT, AND HOWE STEEL TRUSS BRIDGES (60 M SPAN) BASED ON SNI 1725:2016

Frinsilia Jaglien Liando[1*], Steenie Edward Wallah[2], Fabian Johanes Manoppo[3], Ficky Marcellino Oroh[4]
[1234] Universitas Sam Ratulangi, Indonesia
*Corresponding Author: frinsiliajaglienli@gmail.com

ABSTRACT
The rapid development of transportation infrastructure requires bridge designs that are safe, efficient, and economical. Steel truss bridges are widely used for medium- to long-span applications due to their high strength-to-weight ratio. This study aims to analyze and compare the structural performance of Warren Truss, Pratt Truss, and Howe Truss steel bridges with a 60 m span and to determine the most optimal truss configuration based on structural performance parameters. The main contribution of this study is the integration of truss-type comparison with two seismic loading scenarios, namely locally derived seismic parameters developed from site-specific seismic hazard and soil condition data, and seismic parameters specified in SNI 2833:2016. A quantitative approach was employed through numerical structural analysis using MIDAS Civil software based on the Load and Resistance Factor Design (LRFD) method. Each bridge model was analyzed using identical geometric, material, and loading conditions. Structural performance was evaluated based on the Demand Capacity Ratio (DCR), maximum deflection, structural weight, and support reactions. Two seismic scenarios were considered, namely local seismic parameters generated using EZ-FRISK and seismic parameters based on SNI 2833:2016. The results indicate that all truss configurations satisfy the structural safety requirements with DCR values not exceeding 1.0. The Warren Truss exhibits the best overall performance, with maximum DCR values of 0.989 under local seismic loading and 0.970 under SNI seismic loading, a maximum deflection of 66.14 mm, and the lightest structural weight of 3000.8 kN. The Pratt Truss and Howe Truss have structural weights approximately 2.31% and 7.94% greater than that of the Warren Truss, respectively. The analysis further reveals that the locally derived seismic parameters generate higher internal forces, DCR values, and support reactions than those obtained from SNI 2833:2016, although their influence on structural deflection is relatively insignificant. Based on the evaluation of DCR, deflection, structural weight, and support reactions, the Warren Truss is identified as the most optimal configuration for a 60 m span steel truss bridge. This truss type provides the best balance of structural safety, stiffness, stability, and material efficiency. The findings of this study may serve as a reference for selecting steel truss configurations and highlight the importance of incorporating site-specific seismic characteristics into bridge design.
Keywords: Demand Capacity Ratio, Howe Truss, MIDAS Civil, Pratt Truss, Warren Truss

INTRODUCTION

With the rapid development of urban environments and the increasing demand for modern infrastructure, steel truss bridges are increasingly utilized due to their ability to carry large loads with relatively lightweight materials and high material efficiency. The main advantage of steel truss bridges lies in the mechanical properties of steel, which exhibit high elasticity and good fatigue resistance, enabling the structure to withstand heavy traffic loads as well as dynamic effects such as wind and vibrations. Due to these characteristics, steel truss bridges have become a preferred solution for connecting separated areas such as rivers, valleys, and transportation corridors, particularly in regions with challenging geographical conditions (Kadir et al., 2021; Sari et al., 2025).

Various types of steel truss bridges have been developed and applied in bridge structural design, including Pratt Truss, Howe Truss, Warren Truss, Parker Truss, Camelback Truss, K-Truss, Baltimore Truss, Pennsylvania Truss, Fink Truss, Bowstring Truss, Double Intersection Pratt, Double Intersection Warren, Lattice Truss, and Waddell "A" Truss. Each truss type has different geometric configurations and force distribution mechanisms, resulting in varying structural performance characteristics under applied loads (Sari et al., 2025; Shinde et al., 2021).

Although many truss types are available for bridge design, not all configurations have comparable efficiency and complexity for direct comparative analysis. Therefore, this study focuses on three representative steel truss types, namely Warren Truss, Pratt Truss, and Howe Truss. These three configurations are commonly used for short- to medium-span bridges, approximately up to 60 m, and exhibit distinct internal force distribution mechanisms. The Warren Truss is characterized by a triangular pattern that results in relatively uniform force distribution between tension and compression members. The Pratt Truss has diagonal members that predominantly carry tensile forces, while the Howe Truss exhibits the opposite behavior, where diagonal members primarily carry compressive forces (Purwanto & Hariadi, 2018; R.C hibbeler, 2012).

These characteristics make the three truss types suitable for comparative analysis in evaluating structural performance. Previous studies have also shown differences in efficiency and behavior among truss configurations such as Warren, Pratt, and Howe in terms of strength and deflection (Handayani et al., 2022; Putri & Nindyawati, 2024)

In recent years, several researchers have conducted studies on steel truss bridge analysis and design. These include studies on Warren Truss bridge design using software (Fahmi et al., 2024), comparison between Warren and Pratt trusses in the Brantas Bridge (Santoso & Sumaidi, 2021), comparative performance analysis of Warren, Pratt, and Howe trusses (Handayani et al., 2022), structural design of the Ake Toduku Bridge in West Halmahera (Adryana & Suprapto, 2016), and the influence of Warren, Pratt, Howe, and K-Truss configurations on the efficiency of an 80 m span steel truss bridge (Putri & Nindyawati, 2024). Although previous studies have provided valuable insights into the structural behavior and efficiency of steel truss bridges, most of them primarily focused on superstructure performance indicators such as member strength, structural capacity, and deflection. Comparisons among Warren, Pratt, and Howe truss configurations have generally been limited to evaluating structural efficiency and serviceability performance. Limited attention has been given to the influence of truss configuration on support reactions, which directly affect load transfer mechanisms and foundation design. Furthermore, studies assessing the sensitivity of steel truss bridge performance to different seismic parameter sources remain scarce, particularly those comparing site-specific seismic parameters derived from local seismic hazard and soil data with the seismic provisions specified in SNI 2833:2016. Therefore, a comprehensive evaluation that simultaneously considers superstructure performance, substructure response, and seismic parameter variation is still lacking.

The novelty of this study lies in the integrated comparison of Warren Truss, Pratt Truss, and Howe Truss bridge configurations under two different seismic scenarios. Unlike previous studies that primarily focused on structural strength and deflection, this research evaluates bridge performance using multiple indicators, including Demand Capacity Ratio (DCR), deflection, structural weight, and support reactions. In addition, locally processed seismic parameters derived from site-specific seismic hazard and geotechnical data are incorporated and compared with the seismic parameters prescribed by SNI 2833:2016. This approach provides a broader analytical perspective by linking truss configuration not only to superstructure behavior but also to foundation-related responses and seismic sensitivity.

Accordingly, this study compares Warren, Pratt, and Howe trusses in terms of structural strength, deflection, structural weight, support reactions, and seismic response to determine the most optimal configuration for a 60 m span steel truss bridge. The findings are expected to contribute to bridge engineering practice by providing a more comprehensive basis for selecting an efficient, safe, and reliable steel truss system under varying seismic conditions and by demonstrating the importance of considering both support reactions and site-specific seismic characteristics in bridge design.

METHOD

Research Type and Research Location

This study is a quantitative research employing a numerical analysis approach and a comparative method to evaluate the performance of three types of steel truss bridges, namely Warren Truss, Pratt Truss, and Howe Truss, through structural modeling. The research location is situated in Wori, which serves as the basis for determining local seismic parameters and soil conditions.

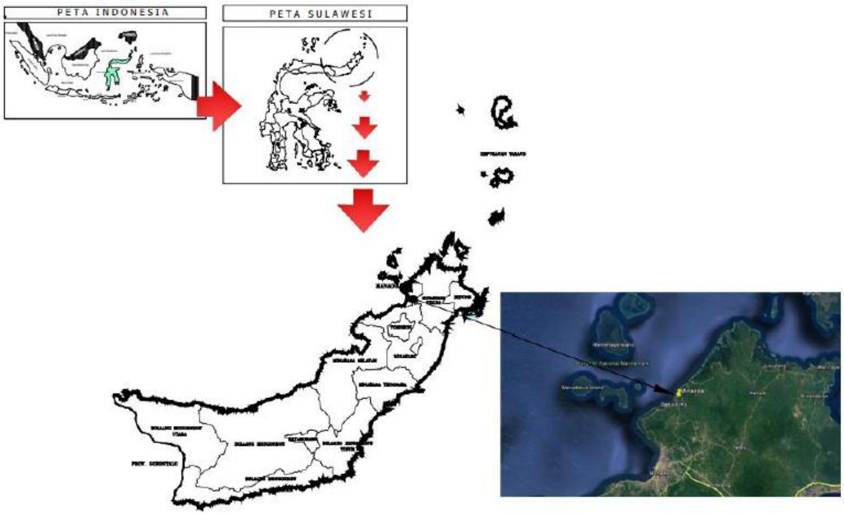


Figure 1. Research Location Map

Research Data

The data used in this study consist of geotechnical data, seismic data, and bridge geometry data, which serve as the basis for the structural modeling and analysis process.

The geotechnical data were obtained from the research location in Wori and were used to determine soil characteristics through the calculation of the average shear wave velocity (Vs30). The Vs30 value was subsequently used to classify the site class, which plays an important role in seismic loading analysis (Badan Standardisasi Nasional Indonesia, 2016b).

The seismic data used in this study consist of two types, namely reference seismic data based on national standards and locally processed seismic data. The reference seismic data refer to parameters specified in the standards, such as Peak Ground Acceleration (PGA) and response spectrum parameters (Ss and S1). Meanwhile, the local seismic data were obtained from earthquake catalog records provided by the United States Geological Survey (USGS). The seismic records were collected from earthquake events surrounding the study area and subsequently processed using EZ-FRISK software to perform seismic hazard analysis and develop site-specific seismic parameters, including PGA and response spectrum characteristics. These locally derived parameters were then used as an alternative seismic input to evaluate the sensitivity of the bridge structural response compared with the seismic parameters specified in SNI 2833:2016. The use of these two types of seismic data aims to compare structural responses and assess the influence of different seismic characteristics on bridge performance. The bridge geometry analyzed in this study consists of a steel truss bridge with a main span of 60 m and three truss configuration variations, namely Warren Truss, Pratt Truss, and Howe Truss. The technical specifications of the bridge are presented in Table 1.

Table 1. Bridge Technical Data

Parameter	Value
Bridge type	Steel truss bridge
Main span	60 m
Total bridge width	9.6 m
Roadway width	6.8 m
Number of traffic directions	2 directions
Number of lanes	2 lanes (3.4 m/lane)
Bridge class	Class A (SNI 1725:2016)
Truss type	Warren, Pratt, Howe
Deck system	Longitudinal girders, transverse girders, and concrete slab

Material Properties

The steel truss bridge models were designed using structural steel grade SM570, which is commonly applied for bridge structures due to its high strength and good ductility characteristics. The material properties were defined in MIDAS Civil based on the Japanese Industrial Standard (JIS) database available in the software. The material parameters used in the analysis are presented in Table 2.

Table 2. Material Properties of Structural Steel (SM570)

Property	Value
Material Type	Steel (Isotropic)
Steel Grade	SM570
Elastic Modulus (E)	200,000 MPa
Poisson's Ratio (ν)	0.30
Unit Weight	77 kN/m³
Mass Density	7.852 t/m³
Thermal Expansion Coefficient	1.2×10^{-5} /°C
Damping Ratio	0.02

Boundary Conditions and Support Configuration

The bridge support system consisted of one pinned support and one roller support. The pinned support restrained translational movement in all directions while allowing rotational movement. The roller support restrained vertical and transverse movement while permitting longitudinal displacement to accommodate thermal expansion and contraction. This support arrangement reflects common bridge engineering practice and prevents the development of excessive secondary stresses caused by temperature effects.

Load Application

Bridge loading was applied in accordance with SNI 1725:2016 and consisted of: Dead Load (DL) : Self-weight of structural steel members, Reinforced concrete deck slab, Asphalt pavement, Sidewalks and parapets. Live Load (LL) : Traffic load according to bridge loading provisions. Environmental Loads : Wind load, Temperature load, Rainwater load. Seismic Load : Seismic parameters based on SNI 2833:2016, Site-specific seismic parameters developed from locally processed seismic hazard and geotechnical data

Load Combinations

The bridge structure was designed using the Load and Resistance Factor Design (LRFD) method in accordance with SNI 1725:2016. The load combinations were generated to evaluate the structural performance under various loading conditions, including dead load, live load, and seismic load. The principal load combinations considered in this study are as follows:

1. Strength I (TD) : 1.2 DC + 1,8 TD + 1,8 TB + 1.8 TP + 0.5 Eun + 1,8 MVL BGT
2. Strength I (TT) : 1.2 DC + 1,8 TB + 1.8 TP + 0.5 Eun + 1,8 MVL TT
3. Strength II (TD) : 1.2 DC + 1,4 TD + 1,4 TB + 1.4 TP + 0.5 Eun + 1,4 MVL BGT
4. Strength II (TT) : 1.2 DC + 1,4 TB + 1.4 TP + 0.5 Eun + 1,4 MVL TT
5. Strength III : 1,0 DC + 1,4 EWs + 0.5 Eun
6. Strength IV : 1.2 DC + 0.5 Eun
7. Strength V : 1.2 DC + 0.4 EWs + 0.5 Eun
8. Extreme event I – Traffic : 1,0 DC + 0,3 TD + 0,3 TB + 0,3 TP + 1,0 MVL BGT
9. Extreme event I – Seismic 1 : 1,0 DC + 0,3 TD + 1,0 EQx ± 0,3 EQy
10. Extreme event I – Seismic 2 : 1,0 DC + 0,3 TD + 0,3 EQx ± 1,0 EQy
11. Service I – TD : 1,0 DC + 1,0 TD + 1,0 TB + 1,0 TP + 0,3 EWs + 1,0 EUn + 1,0 MVL BGT
12. Service I – TT : 1,0 DC + 1,0 TB + 1,0 TP + 0,3 EWs + 1,0 EUn + 1,0 MVL TT
13. Service II – TD : 1,0 DC + 1,3 TD + 1,3 TB + 1,3 TP + 1,0 EUn + 1,3 MVL BGT
14. Service II – TT : 1,0 DC + 1,3 TB + 1,3 TP + 1,0 EUn + 1,3 MVL TT
15. Service III – TD : 1,0 DC + 0,8 TD + 0,8 TB + 0,8 TP + 1,0 EUn + 0,8 MVL BGT
16. Service III – TT : 1,0 DC + 0,8 TB + 0,8 TP + 1,0 EUn + 0,8 MVL TT
17. Service IV – TD : 1,0 DC + 0,7 EWs + 1,0 EUn

18. Service IV – TT : 1,0 DC + 0,7 EWs + 1,0 EUn

Note: DC represents the combined dead loads, including self-weight of the steel truss (MS-Steel), structural dead load (MS-SW), reinforced concrete deck (MS-Concrete Deck), asphalt layer, handrails, sidewalks, and rainwater load. TD = design lane load; TB = truck load; TP = pedestrian load; MVL BGT= braking force load; MVL TT = traffic load effect; EWs = wind load; EUn = environmental load; EQx = longitudinal seismic load; and EQy = transverse seismic load.

Seismic Analysis Procedure

Seismic analysis was performed using the Response Spectrum Method in MIDAS Civil. Two seismic scenarios were considered: SNI-based seismic parameters, derived from SNI 2833:2016 and Site-specific seismic parameters, developed using local seismic hazard data and geotechnical information processed through EZ-FRISK software. The local seismic parameters were generated by considering regional seismic source characteristics and site soil conditions represented by the Vs30 value. Response spectra for both scenarios were subsequently applied to evaluate the sensitivity of structural performance to different seismic inputs.

Section Optimization Procedure

To obtain an efficient and safe structural design, member sections were optimized iteratively for each truss configuration.

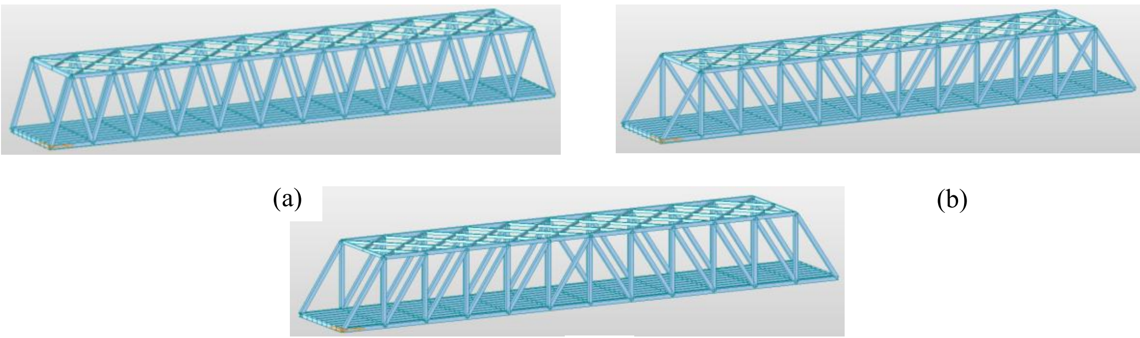
The optimization process followed the same procedure for Warren, Pratt, and Howe models:

1. Initial steel sections were assigned.
2. Structural analysis was performed.
3. Demand Capacity Ratio (DCR) values were evaluated.
4. Member sections were adjusted until all members satisfied: $\text{DCR} \leq 1.0$
5. The final section configuration was selected when: All members met strength requirements, Deflection remained within allowable limits, and The overall structural weight was minimized.

This optimization procedure ensured that all three truss configurations were evaluated under equivalent design criteria, allowing a consistent comparison of structural performance.

Structural Modeling

The bridge structural modeling in this study was carried out using MIDAS Civil software with the finite element approach. The analyzed bridge model consists of a 60 m span steel truss bridge modeled in three truss configuration variations, namely Warren Truss, Pratt Truss, and Howe Truss. The geometry, material properties, and support conditions were kept identical for each model so that the differences in the analysis results were influenced solely by the truss configuration used. The developed structural models were subsequently used for loading analysis and structural performance evaluation.



(a) (b) (c)

Figure 2. 3D Modeling of Steel Truss Bridges: (a) Warren Truss Type, (b) Pratt Truss Type, (c) Howe Truss Type

Initial Section Data

The initial section data were used as assumptions in the structural modeling of the steel truss bridge. The sections were standardized for all three truss types, namely Warren Truss, Pratt Truss, and Howe Truss, and were based on commonly used structural steel profiles. These sections were used as initial input parameters in the MIDAS Civil modeling process and were subsequently evaluated to satisfy the design criteria. The initial sections of the structural elements are presented in Table 2.

Table 3. Initial Sections of Structural Elements

No.	Structural Element	Warren	Pratt	Howe
1	Middle Top Bracing	IWF 300.200.9.14	IWF 300.200.9.14	IWF 300.200.9.14
2	End Top Bracing	IWF 300.200.9.14	IWF 300.200.9.14	IWF 300.200.9.14
3	Top Chord	HB 400.400.20.35	HB 400.400.20.35	HB 400.400.20.35
4	Bottom Chord	HB 400.400.20.35	HB 400.400.20.35	HB 400.400.20.35
5	Diagonal Chord	HB 400.400.20.35	HB 400.400.20.35	HB 400.400.20.35
6	Vertical Chord	–	HB 400.400.20.35	HB 400.400.20.35
7	Cross Girder	HB 400.400.30.50	HB 400.400.30.50	HB 400.400.30.50
8	Stringer	IWF 450.200.9.14	IWF 450.200.9.14	IWF 450.200.9.14

Local Seismic Load Analysis

The local seismic load analysis in this study was conducted systematically, including earthquake data collection, soil classification determination based on the Vs30 value, and seismic hazard parameter processing using EZ-FRISK to obtain the PGA, Ss, and S1 values. These parameters were subsequently used to develop the seismic response spectrum, which was then applied in the structural analysis. In addition, the obtained local seismic parameters were compared with the reference seismic parameters based on SNI 2833:2016 to evaluate differences in earthquake characteristics. All stages of the calculation process are presented in the following flowchart.

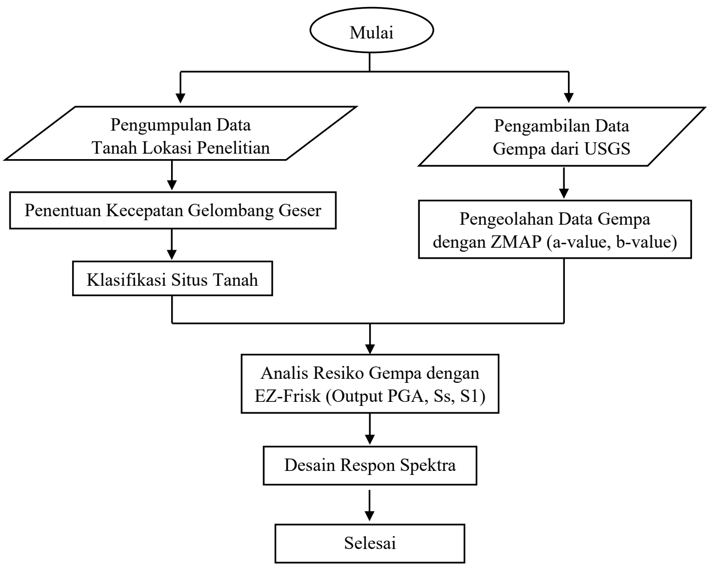


Figure 3. Flowchart of Seismic Load Calculation

Research Procedure

The research procedure carried out in this study is presented in the following flowchart:

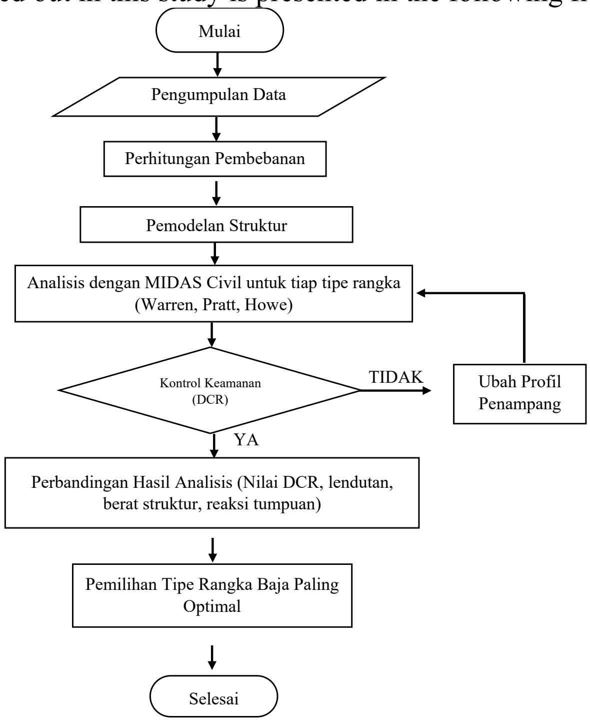


Figure 4. Research Flowchart

RESULTS AND DISCUSSION

Structural Loading Calculation Results

The structural loading of the bridge in this study was determined based on SNI 1725:2016, which includes dead loads, traffic loads, and environmental loads (Badan Standardisasi Nasional Indonesia, 2016a). The calculations were carried out to obtain the load magnitudes used in the structural analysis. The loading recapitulation is presented in Tables 3, 4, 5, 6, and 7.

Table 4. Dead Loads (MS & MA)

Load Type	Description	Middle Cross Girder (kN/m)	End Cross Girder (kN/m)
MS – Steel Deck	0.095 × 5	0.475	0.238
MS – Concrete Deck	24 × 0.2 × 5	24.00	12.00
MA – Sidewalk	24 × 0.2 × 5	24.00	12.00
MA – Rainwater	9.801 × 0.05 × 5	2.450	1.225
MA – Asphalt	22 × 0.1 × 5	11.00	5.50
MA – Handrail	0.5 kN/m	Bottom Chord Location	–

Table 5. Traffic Loads

Load Type	Description	Loading Area	Position	Value
BTR	q = 6.75 kPa	Roadway	Middle	33.75 kN/m
			End	16.875 kN/m
BGT + FBD	–	Roadway	–	67.375 kN/m
BTR Moving	–	Roadway	–	23.625 kN/m
BGT Moving	–	Roadway	–	235.8125 kN
Total Truck Load	–	Roadway	–	500 kN
Front Axle	–	Roadway	–	50 kN
Middle Axle	–	Roadway	–	225 kN
Rear Axle	–	Roadway	–	225 kN

Table 6. Braking and Pedestrian Loads

Load Type	Description	Loading Area	Position	Value
Total Braking Load	–	Roadway	–	56.25 kN
Braking Load per Cross Girder	–	Roadway	–	9.375 kN
Braking Load per Joint	–	Roadway	–	1.339 kN
Midspan Moment	–	Roadway	Middle	2.411 kNm
End Moment	–	Roadway	End	1.205 kNm
Pedestrian Load	–	Sidewalk	Middle	25 kN/m
			End	12.5 kN/m

Table 7. Wind Loads

Load Type	Loading Area	Value
Pressure per Joint (Warren)	Structure	19.94 kN
Pressure per Joint (Pratt & Howe)	Structure	20.77 kN
Suction per Joint (Warren)	Structure	9.97 kN
Suction per Joint (Pratt & Howe)	Structure	10.39 kN

Table 8. Temperature Load

Parameter	Value
ΔT	25°C
ΔL	18 mm

Seismic Loading Calculation Results

The seismic loading analysis in this study was conducted using two approaches, namely seismic parameters based on SNI 2833:2016 and locally processed seismic parameters (Badan Standardisasi Nasional Indonesia, 2016b). The analysis results consist of response spectrum parameters and seismic forces used as input in the structural modeling to evaluate the influence of variations in earthquake characteristics on the response of steel truss bridges. The following figures and tables present the results of the local seismic loading analysis.

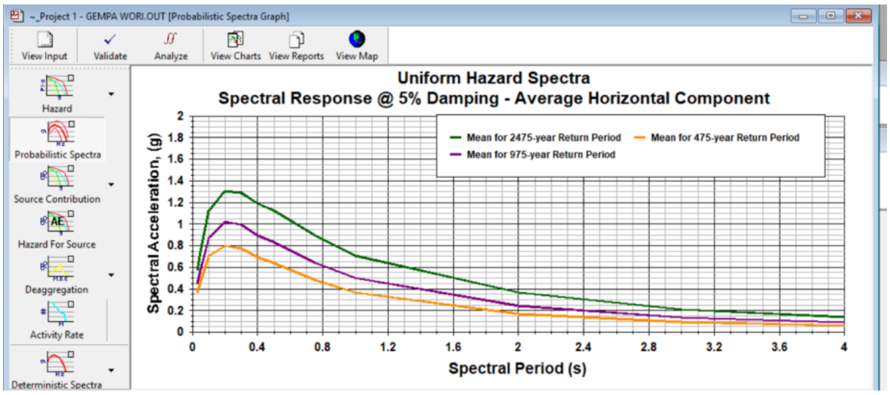


Figure 5. Uniform Hazard Spectrum (UHS) for 500-, 1000-, and 2500-Year Return Periods (Local Earthquake – Seismic Hazard Analysis Results Using EZ-FRISK)

Table 9. Seismic Acceleration Parameters and PGA (Local Earthquake)

Return Period (Years)	500	1000	2500
PGA (g)	0.368	0.455	0.5776
Ss	0.799	1.019	1.307
S1	0.367	0.5005	0.706

The seismic parameters based on SNI 2833:2016 were obtained using the Lini Bina Marga application according to the bridge location in Manado and the soil classification (Soft Soil / SE).

The following parameters were obtained:
Peak Ground Acceleration (PGA) = 0.353 g
Short-period spectral acceleration, Ss = 0.716 g
1-second spectral acceleration, S1 = 0.274 g

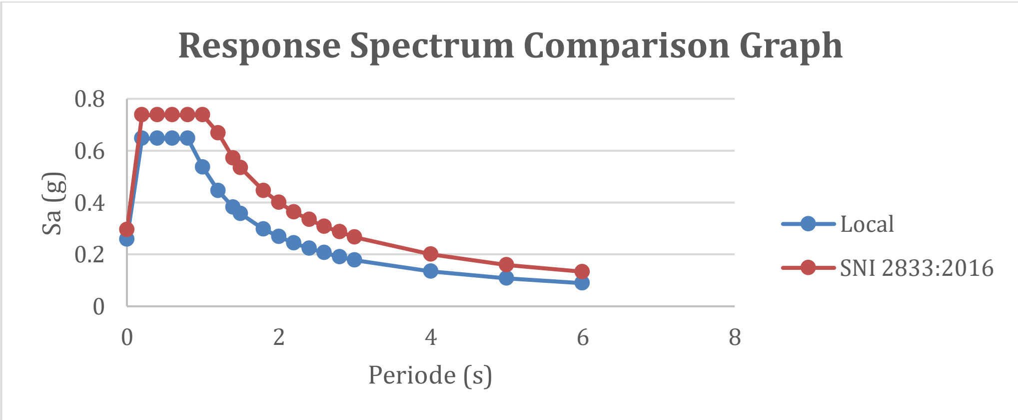


Figure 6. Comparison of the Response Spectra of Local Earthquake and SNI 2833:2016 Earthquake

Member Force Distribution Analysis Results

Member force distribution was analyzed to identify the patterns of tensile and compressive force flow in each truss type due to local earthquake loading and earthquake loading based on SNI 2833:2016. The force distribution results were used to evaluate the differences in structural behavior among the Warren Truss, Pratt Truss, and Howe Truss configurations. The member force distribution obtained from the analysis is presented in the following figures.

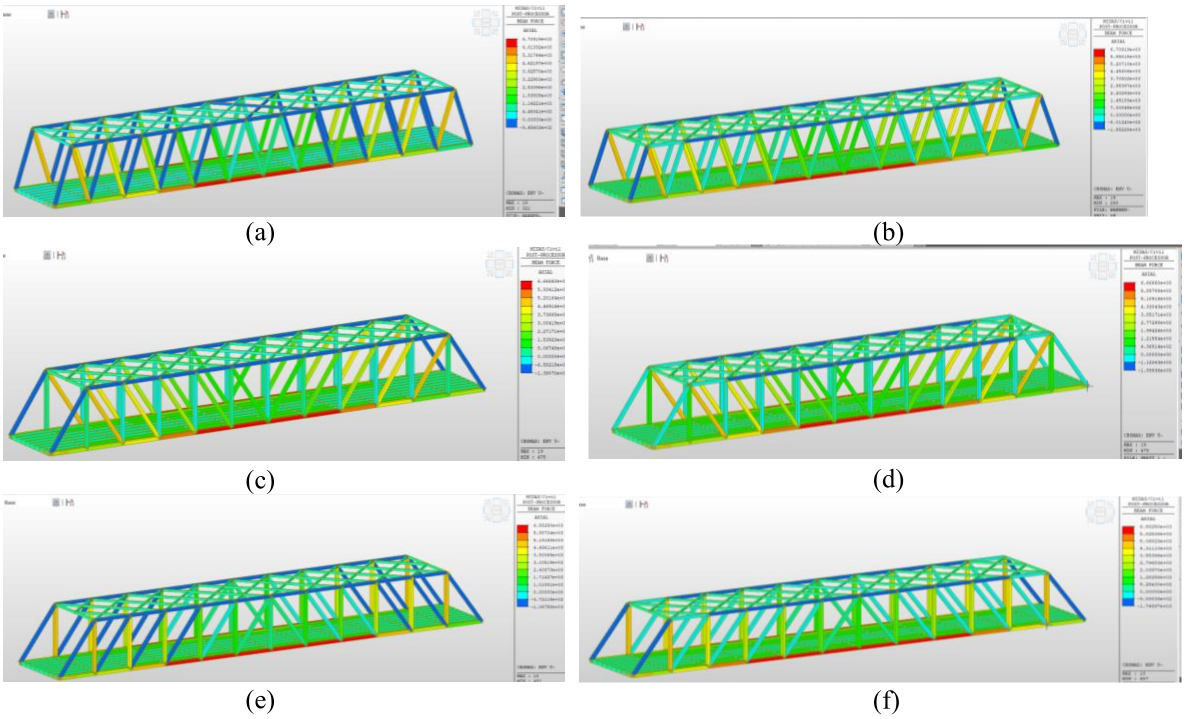


Figure 7. Member Force Distribution Due to Local Earthquake and SNI 2833:2016 Earthquake Loading: (a) Warren Truss under Local Earthquake, (b) Warren Truss under SNI 2833:2016, (c) Pratt Truss under Local Earthquake, (d) Pratt Truss under SNI 2833:2016, (e) Howe Truss under Local Earthquake, and (f) Howe Truss under SNI 2833:2016

Based on the analysis results, the force distribution in the Howe Truss indicates that the diagonal members are predominantly subjected to compressive forces, while the vertical members mainly experience tensile forces. This is indicated by the dominance of blue color in the diagonal members and orange–green colors in the vertical members. The top chords remain predominantly under compression, whereas the bottom chords are mainly subjected to tension, particularly at the midspan section.

This pattern indicates that the loads tend to be transferred through the compression diagonal system, resulting in a greater potential for compressive force concentration and instability (buckling) risk in the diagonal members compared to the other truss types. The force distributions under local earthquake loading and SNI 2833:2016 loading show similar patterns, with differences only in the magnitude of the resulting forces.

The Warren Truss exhibited a more uniform distribution of internal forces due to its triangular configuration, which allows tensile and compressive forces to be distributed more evenly throughout the structure. This balanced force transfer mechanism reduces force concentration in individual members and improves the efficiency of structural capacity utilization.

The Pratt Truss showed a force distribution pattern in which the diagonal members predominantly resisted tensile forces, while the vertical members carried compressive forces. This mechanism reduces the risk of buckling in diagonal members and provides adequate structural stiffness; however, the force distribution is less uniform than that of the Warren Truss.

In contrast, the Howe Truss exhibited a concentration of compressive forces in its diagonal members. Since compression members are more susceptible to buckling, larger member sections are required to satisfy the design criteria. Consequently, the Howe Truss tends to require more material and exhibits lower structural efficiency compared with the Warren and Pratt configurations.

Structural Analysis Results

The Demand Capacity Ratio (DCR) analysis was conducted to evaluate the safety level of each structural element in the Warren Truss, Pratt Truss, and Howe Truss under local earthquake loading and earthquake loading based on SNI 2833:2016. The analysis results of the initial sections indicate that several elements did not satisfy the safety criteria (DCR > 1), particularly the cross girder (CG), stringer (ST), and several truss members due to insufficient section capacity.

In the Pratt and Howe Trusses, the end top bracing elements exhibited high DCR values due to the influence of large axial forces, while in the Howe Truss the diagonal members were more critical because they were predominantly subjected to compressive forces, making them more susceptible to buckling. Therefore, section optimization was carried out on the critical elements until all structural members satisfied the design criteria with DCR values ≤ 1.0. After the section optimization process, all structural elements fulfilled the safety requirement with DCR values < 1. The optimized section DCR results are presented in the tables below.

Table 10. Comparison of DCR Values for Each Section Property (Final Optimization)

Truss Type	Section	DCR – Local	DCR – SNI 2833:2016
Warren	Middle TB IWF 250.150.6.9	0.368	0.357
	End TB IWF 400.300.9.14	0.858	0.583
	BC HB 400.400.18.18	0.967	0.755
	DC HB 400.400.20.35	0.834	0.834
	TC HB 400.400.20.35	0.951	0.951
	Middle CG HB 400.400.20.35	0.989	0.970
	End CG (2 Left Segments) HB 400.400.45.70	0.868	0.639
	ST IWF 700.300.13.24	0.968	0.703
Pratt	Middle TB IWF 250.150.6.9	0.488	0.444
	End TB IWF 400.300.9.14	0.969	0.655
	BC HB 400.400.11.18	0.994	0.781
	DC HB 400.400.20.35	0.984	0.984
	TC HB 400.400.20.35	0.963	0.963
	Middle CG HB 400.400.30.50	0.778	0.778

	End CG (2 Left Segments) HB 400.400.45.70	0.878	0.632
	ST IWF 800.300.14.26	0.992	0.717
	VB HB 400.400.21.21	0.953	0.953
Howe	Middle TB IWF 250.150.6.9	0.414	0.408
	End TB IWF 400.300.10.16	0.984	0.675
	BC HB 400.400.18.18	0.960	0.775
	DC HB 400.400.30.50	0.763	0.763
	TC HB 400.400.20.35	0.962	0.962
	Middle CG HB 400.400.30.50	0.861	0.714
	End CG (2 Left Segments) HB 400.400.45.70	0.954	0.698
	ST IWF 800.300.14.26	0.990	0.725
	VB HB 400.400.15.15	0.975	0.975

Based on the optimization results, all elements in each truss type satisfied the safety criteria with DCR values ≤ 1.0 under both local earthquake loading and earthquake loading based on SNI 2833:2016. The DCR values resulting from local earthquake loading were generally higher than those obtained from the SNI earthquake loading, indicating the influence of variations in seismic parameters on the structural response.

The higher DCR values obtained under local seismic loading indicate that the locally derived seismic parameters generated greater seismic demands than those specified by SNI 2833:2016. This finding suggests that the local seismic hazard characteristics at the study site may be more severe than those represented by the generalized national seismic parameters. From a design perspective, the use of local seismic data may lead to a more conservative assessment of structural performance and provide an additional margin of safety for bridge structures located in seismically active regions.

The differences in structural response are associated with variations in seismic parameters such as Peak Ground Acceleration (PGA), short-period spectral acceleration (Ss), and one-second spectral acceleration (S1), which influence the shape and amplitude of the response spectrum. Higher spectral acceleration values generally result in larger seismic forces, thereby increasing member forces, support reactions, and DCR values.

The differences in section requirements among the truss types were influenced by the force distribution patterns. The Warren Truss exhibited a more uniform force distribution, the Pratt Truss tended to transfer loads through tension diagonals, while the Howe Truss showed a dominance of compressive forces in the diagonal members, thereby requiring larger member capacities to maintain structural stability.

The DCR results indicate that the Warren Truss achieved the most efficient utilization of structural members, as reflected by its lower maximum DCR values compared with the Pratt and Howe Trusses. This behavior can be attributed to the more balanced distribution of axial forces within the Warren configuration, which minimizes excessive force demand in individual members. Although all bridge models satisfied the design requirement of DCR ≤ 1.0, the Warren Truss demonstrated a more favorable margin between structural demand and member capacity.

Furthermore, the deflection results for each truss type under local earthquake loading and earthquake loading based on SNI 2833:2016 were compared with the allowable deflection limit (L/800). The comparison results are presented in Table 11.

Table 11. Comparison of Maximum Deflection

Truss Type	Deflection (mm) – Local	Deflection (mm) – SNI 2833:2016	Deflection Limit (L/800) (mm)	Remarks
Warren	66.14	66.14	75	OK
Pratt	67.26	67.26	75	OK
Howe	71.22	71.22	75	OK

Based on the analysis results, the maximum deflection values due to local earthquake loading and earthquake loading based on SNI 2833:2016 show relatively similar results for each truss type because vertical deflection is more influenced by dead loads and traffic loads than by lateral seismic loads.

The differences in deflection among the truss types indicate differences in structural stiffness, where the Howe Truss produced the largest deflection, followed by the Pratt Truss and the Warren Truss. However, all deflection values remained below the allowable limit of L/800, indicating that all bridge models satisfied the structural serviceability criteria.

As a continuation of the structural performance evaluation based on the Demand Capacity Ratio (DCR) and deflection, an analysis of support reactions was carried out to determine the magnitude of forces transferred to the substructure. This result is important for assessing the influence of truss type on the loads that must be carried by the foundation.

The analysis results of support reactions for each truss type are presented in the following table 12.

Table 12. Support Reactions

Truss Type	Fx max (kN) Local	Fy max (kN) Local	Fz max (kN) Local	Fx max (kN) SNI	Fy max (kN) SNI	Fz max (kN) SNI
Warren	2907.1	1397.8	5174.4	2457.4	1015.1	5174.4
Pratt	2875.3	1408.2	5180.1	2422.2	1019.0	5180.1
Howe	2785.3	1450.2	5237.9	2352.5	1068.4	5237.9

The support reaction results of the three truss types show relatively similar patterns, with differences in magnitude due to variations in force distribution. In the horizontal direction (Fx), the highest value occurs in the Warren Truss (2907.1 kN), followed by the Pratt and Howe Trusses. In the transverse direction (Fy), the Howe Truss produces the highest value (1450.2 kN), while in the vertical direction (Fz), all truss types show relatively similar values (approximately 5174–5238 kN), indicating the dominance of gravitational loads.

Local earthquake loading results in higher lateral reactions (Fx and Fy) compared to SNI-based seismic loading, indicating a more significant influence of horizontal forces. From a foundation design perspective, the vertical capacity requirements are relatively similar across all truss types; however, differences in lateral forces affect shear resistance, overturning stability, and overall foundation performance. Therefore, truss types with higher lateral reactions require a stronger and more robust foundation design. Among the evaluated configurations, the Warren Truss generated the lowest vertical support reaction (Fz) and relatively high structural efficiency, indicating a more favorable load transfer mechanism to the substructure. Conversely, the Howe Truss produced the highest support reactions due to its larger structural weight and greater concentration of compressive forces. These findings demonstrate that truss configuration not only affects superstructure behavior but also influences foundation design requirements.

As the final stage of structural performance evaluation, the self-weight of each steel truss bridge type was analyzed to complete the comparison of DCR, deflection, support reactions, and overall efficiency. The comparison of structural weight for each truss type is presented in the following table 13.

Table 13. Comparison of Steel Truss Bridge Structural Weight

Truss Type	Steel Truss Weight – Local (kN)	Steel Truss Weight – SNI 2833:2016 (kN)
Warren	3000.8	3000.8
Pratt	3070.2	3070.2
Howe	3239.2	3239.2

The structural weight results show that the Warren Truss has the lightest self-weight, followed by the Pratt Truss, while the Howe Truss has the highest structural weight. This difference is influenced by the variation in internal force distribution, which governs the required member sizes in each truss configuration.

Discussion of Structural Performance

The superior performance of the Warren Truss can be explained from a structural mechanics perspective. The triangular configuration of the Warren Truss enables a more uniform distribution of axial forces throughout the structure. Under applied loads, tensile and compressive forces are alternately transferred through diagonal members, reducing force concentration in specific elements. This mechanism allows the structure to achieve a balanced stress distribution and more efficient utilization of member capacity, which is reflected in the lower DCR values and reduced structural weight obtained in this study.

In contrast, the Howe Truss exhibited the largest structural weight and deflection among the evaluated configurations. This behavior is associated with the dominance of compressive forces in the diagonal members. Compression members are generally more susceptible to buckling than tension members, requiring larger cross-sectional areas to satisfy design requirements. Consequently, the Howe Truss requires more material and exhibits lower structural efficiency. The increased member sizes also contribute to higher self-weight, which subsequently increases support reactions and structural deflection.

The Pratt Truss demonstrated intermediate behavior between the Warren and Howe configurations. Since its diagonal members primarily resist tensile forces, the risk of buckling is lower than that of the Howe Truss. However, the force distribution is not as balanced as that of the Warren Truss, resulting in slightly higher structural weight and support reactions.

These findings are consistent with previous studies. Handayani et al., 2022 reported that Warren Truss configurations generally provide more efficient force distribution and lower structural demand compared with Pratt and Howe Trusses. Similarly, Putri & Nindyawati, 2024 found that Warren-type configurations exhibit favorable structural efficiency due to their balanced load transfer mechanism. The present study extends these findings by incorporating support reaction evaluation and comparing the influence of site-specific seismic parameters with seismic parameters based on SNI 2833:2016.

From a practical design perspective, the results suggest that Warren Truss can be considered a preferred alternative for steel truss bridges with a 60 m span. In addition to providing adequate strength and serviceability performance, the configuration offers improved material efficiency and lower support reactions, which may contribute to more economical foundation design and overall construction costs.

Determination of the Optimum Truss Type

The selection of the optimum truss type is based on structural performance comparisons, including the DCR value, maximum deflection, support reactions, and structural weight. These parameters are used to evaluate the safety and efficiency of each truss type. The comparison results are presented in Table 14.

Table 14. Structural Performance Comparison

Parameter	Warren (Local)	Warren (SNI 2833:2016)	Pratt (Local)	Pratt (SNI 2833:2016)	Howe (Local)	Howe (SNI 2833:2016)
Maximum DCR	0.989	0.970	0.994	0.984	0.990	0.975
Maximum Deflection (mm)	66.14	66.14	67.26	67.26	71.22	71.22
Support Reaction (Fz max, kN)	5174.4	5174.4	5180.1	5180.1	5237.9	5237.9
Structural Weight (kN)	3000.8		3239.2		3239.2	

Based on the results, all truss types satisfy the safety requirement (DCR ≤ 1.0). The Warren truss shows the lowest DCR values (0.989 for local earthquake; 0.970 for SNI 2833:2016), indicating more efficient member utilization compared to Pratt and Howe trusses. Local earthquake loading generally produces slightly higher DCR values than SNI loading. For deflection, the Warren truss yields the smallest value (66.14 mm), followed by Pratt (67.26 mm) and Howe (71.22 mm). No variation is observed between local and SNI seismic cases, indicating that deflection is mainly governed by gravity loads. Support reactions (Fz) are relatively similar across all truss types, ranging from 5174.4 kN to 5237.9 kN, and are not significantly affected by load variations. This suggests similar foundation demand for all configurations. In terms of structural weight, the Warren truss is the lightest (3000.8 kN), followed by Pratt (3070.2 kN) and Howe (3239.2 kN), indicating better material efficiency. Overall, seismic load variations do not significantly alter the performance trend. Based on all parameters, the Warren truss is identified as the most optimal configuration due to its safe design, lowest deflection, and lightest structural weight.

CONCLUSION

Based on the analysis and discussion of three steel truss bridge types, namely Warren Truss, Pratt Truss, and Howe Truss with a 60 m span, it can be concluded that all structures satisfy the strength requirement after optimization, with DCR values ≤ 1.0, while deflection values remain within allowable limits. Differences in structural performance are influenced by truss configuration, which affects internal force distribution, material efficiency, and support reactions. The variation between local and SNI 2833:2016 seismic data also indicates differences in structural response, where local seismic input produces a more representative condition of actual site behavior. Among the three configurations, the Warren Truss demonstrates the best overall performance, characterized by the most efficient material usage (lowest structural weight), the most favorable DCR values, relatively small deflection, and more stable reaction distribution. Therefore, the Warren Truss is identified as the most optimal and efficient alternative for the design of a 60 m span steel truss bridge.

REFERENCES

Adryana, V. N., & Suprapto, B. (2016). Studi Perencanaan Struktur Jembatan Rangka Baja Pada Jembatan Toduku Halmahera Barat. Jurnal Universitas Islam Malang, V O L . 6, 208–215. Chrome-Extension://Efaidnbmnnnibpcajpcglclefindmkaj/Https://Media.Neliti.Com/Media/Publications/484701-None-87a4a85f.Pdf?Utm_Source=Chatgpt.Com

Badan Standardisasi Nasional Indonesia. (2016a). Pembebanan Untuk Jembatan, Sni 1725:2016. In Badan Standardisasi Nasional Indonesia.

Badan Standardisasi Nasional Indonesia. (2016b). Perencanaan Jembatan Terhadap Beban Gempa, Sni 2833:2016. In Badan Standardisasi Nasional.

Fahmi, F. A., Rasidi, N., & Rahman, A. (2024). Perencanaan Struktur Jembatan Rangka Baja Tipe Warren Menggunakan Software Untuk Jembatan Tambang Desa Buntaran Kabupaten Tulungagung. Jurnal Online Skripsi, 5(1), 139–145. Http://Jos-Mrk.Polinema.Ac.Id/

Handayani, Musbar, & Mahyar, H. (2022). Analisis Perbandingan Kinerja Jembatan Rangka Baja Tipe Warren, Pratt Dan Howe. Jurnal Teknik Sipil, 14(2), 97–100. Https://E-Jurnal.Pnl.Ac.Id/Portal/Article/View/2937/2840?Utm_Source=Chatgpt.Com

Kadir, H., Ashad, H., & Zaifuddin. (2021). Studi Model Struktur Rangka Baja Jembatan. Journal Of Applied Civil And Environmental Engineering, 1(2), 28–35. Http://Jurnal.Poliupg.Ac.Id/Index.Php/Jacee

Purwanto, H., & Hariadi, G. (2018). Analisis Perbandingan Jembatan Tipe Parker Dan Tipe Warren Dengan Bentang 50 Meter. Jurnal Deformasi, Volume 3-, 10–18. Https://Doi.Org/10.31851/Deformasi.V3i1.1963

Putri, N. M., & Nindyawati. (2024). Analisis Pengaruh Tipe Rangka Warren, Pratt, Howe Dan K-Truss Terhadap Efisiensi Jembatan Rangka Baja Bentang 80 M. Jurnal Inovasi Teknologi Dan Edukasi Teknik, 4(5). Https://Doi.Org/10.17977/Um068.V4.I5.2024.1

R.C Hibbeler. (2012). Stuctural Analysis (P. Education, Ed.; 8th Ed.).

Santoso, A. N., & Sumaidi. (2021). Perbandingan Rangka Jembatan Tipe Warren Dan Tipe Pratt Pada Jembatan Brantas. 13, 70–75.

Sari, W., Delitriana, A., & Gunadi, R. (2025). Literature Review: The Influence Of Truss Configuration And Height On Steel Truss Bridges Based On Deflection And Structural Weight. Jurnal Teknik Sipil, 25(2), 1956–1967. Https://Doi.Org/10.26418/Jts.V25i2.91399

Shinde, V. R., Patil, A. S., & Mahadik, U. A. (2021). Comparative Analysis Of Truss Bridges. International Journal Of Engineering Research & Technology (Ijert), 10(01), 434–436. Https://Www.Ijert.Org/Comparative-Analysis-Of-Truss-Bridges