



# Comparison of Warren Type Steel Truss Bridge Planning with Truss Bridge Standard No. 07/BM/2005 (Case Study: Tabang Penjalin Bridge Construction Project)

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**Abstract.** Good transportation facilities will make it easier for an existing area to develop further. In order for traffic to flow smoothly and not be hampered, the condition of the infrastructure must always be treated and maintained. Until now, the guidelines used for steel truss bridges are Guideline No: 07/BM/2005 issued by the Public Works Department, Directorate General of Highways. Purposes to this study to redesign the superstructure of a warren type steel truss bridge and compare the results of the bridge planning with standard truss bridge No. 07/BM/2005. This bridge is a new alternative that will function as a means of connecting Tabang District - Kembang Janggut District, Kutai Kartanegara Regency. The planned steel truss bridge is 60 meters long and 9 meters wide. The method used in bridge planning is the LRFD (Load and Resistance Factor Design) method based on the concept of probability which uses statistical characteristics of resistance and load. The regulations used to design this warren type steel truss bridge are the Indonesian National Standard (SNI) 1725:2016 and RSNI T-03-2005 regulations. The stages in planning a truss bridge are analysis of the bridge's longitudinal girders, analysis of the bridge's transverse girders, and analysis of the main frame structure. From the results of the analysis of the design of the bridge's upper structure, the steel profile used in the longitudinal girder is HB 400.400.20.35, the transverse girder profile is IWF 900.300.18.34, the main steel frame profile is HB 400.400.45.70, and the wind tie profile is HB 250.250.14.14.

**Keywords:** Frame Steel, Truss Bridge, Warren.

## 1 Introduction

The Kutai Kartanegara Regency Government, through the Dinas Pekerjaan Umum (PU) Kutai Kartanegara, is rebuilding the braided bridge that connects Tabang sub-district with Kembang Janggut sub-district. The name of the project being handled is the Construction of the Tabang Penjalin Bridge. The construction of this bridge aims to replace the previous bridge, because previously there was a composite steel girder type

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bridge with a span of 15 meters that connected Tabang sub-district with Kembang Janggut sub-district in Kukar district, but due to the overflow of the Belayan River in 2020, it resulted in the bridge being scouring which ultimately destroyed the long pen-jalin bridge.

In this way, it is necessary to construct a suitable bridge according to applicable regulations and compare the planning results with the applicable bridge standards, namely truss bridge standard No. 07/BM/2005. Apart from that, to increase community accessibility, a bridge with a 60-meter-long steel frame structure and road improvements are planned to minimize the overflow of the Belayan River. Therefore, this research aims to redesign the Long Penjalin Bridge using a warren type steel frame structure. A 60-meter span steel truss bridge was used to minimize the impact of river overflows and make the construction process easier.

A bridge is a construction that functions to connect two sections of road that are separated by an obstacle with a lower surface [1]. Bridges are useful for assisting daily activities, therefore the bridge to be built must be appropriate and meet the requirements for stiffness, deflection and resistance to working loads [2]. Bridge design must be based on applicable regulations, procedures, codes and provisions. This is intended to guarantee the level of safety, feasibility and savings that may still be acceptable in structural planning [3]. The LRFD provisions are considered to meet the requirements if the necessary strength,  $R_u$  is smaller than the design strength,  $\phi R_n$  where  $\phi$  is a resistance factor whose value varies depending on the action behavior of the component under consideration [4]. A good design or plan will pay attention to economic factors in terms of funding sources for the implementation of the bridge after it has been planned. Choosing the type of superstructure, determining the number and length of spans and so on will determine how much it costs to build the bridge [5].

The purpose of this research is to redesign the superstructure of the warren type steel truss bridge and to compare the results of bridge planning with standard truss bridge No. 07/BM/2005.

## 2 Methods

### 2.1 Location

This research takes a case study of the Penjalin Tabang Bridge Construction Project, Kutai Kartanegara. The research location can be seen in Fig. 1.

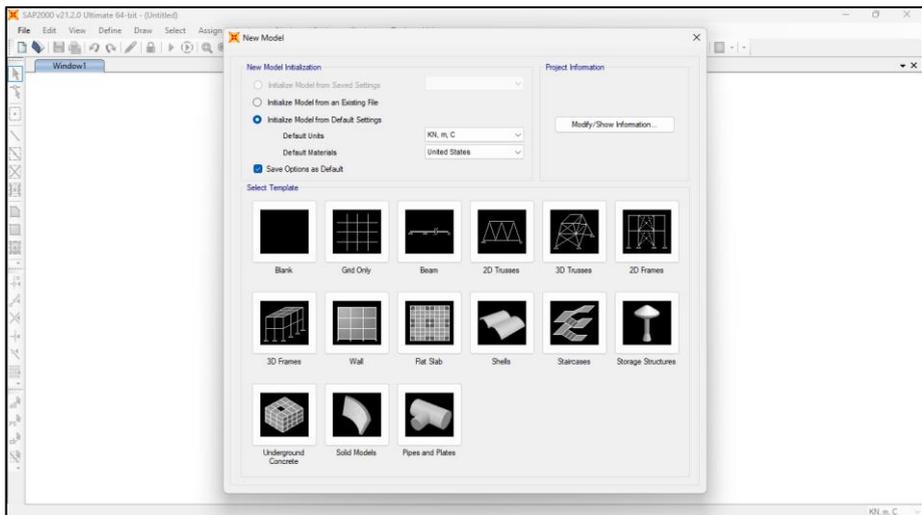
### 2.2 Load and Resistance Factor Design (LRFD) Method

LRFD is a specification issued by AISC (America's State of Steel Construction) for the design of steel construction, based on the resistance of the ultimate strength method (Plastic Method). LRFD provides a more specific comparison between load  $Q$  and resistance  $R_n$  [6]. LRFD provisions are considered to meet the requirements if the necessary strength,  $R_u$  is smaller than the design strength,  $\phi R_n$  where  $\phi$  is a resistance factor whose value varies depending on the action behavior of the component under consideration. So, the basic concept of the LRFD provisions is  $R_u \leq \phi R_n$ .



**Fig. 1.** Research Location (Google Earth, 2023)

## 2.3 SAP2000 Software



**Fig. 2.** Initial appearance of SAP2000 software

SAP2000 is software used to analyze building structures and has been used widely throughout the world. This program is the result of research and development by a team led by Professor Edward L. Wilson from the University of California for more than 25 years.

SAP2000 can make concrete structure calculations easier because it is equipped with completely integrated features and modules for the design of steel structures and

reinforced concrete structures. Thus, this application makes it easy for users to create, analyze and modify planned structural models using the same user interface

**2.4 Bina Marga Truss Bridge Standard No. 07/BM/2005**

The Bina Marga standard bridge is a bridge that is designed typically according to loading regulations in Indonesia, which refers to the Bina Marga standard drawing guidelines No.07/BM/2005. This type of bridge uses steel structural elements in the form of IWF and H-Beam for the frame structural elements and girder structural elements. The construction steel components in this bridge are made from steel that meets the quality SM490 BJ 55, and high quality bolts, namely JIS B1180 Grade 8.8. The largest steel profiles used on class A bridges with a span of 60 m can be seen in the Table 1.

The main principle underlying the use of trusses as the main load bearer is the arrangement of elements into a triangular configuration which produces a stable shape. In a stable structure, the deformation that occurs is relatively small, and bending will not occur as long as external forces are at the node points.

**Table 1.** Bina Marga Steel Profile for the A60 Bridge [7]

	Upper Bar	HB 400.400.32.32
	Lower Bar	HB 400.400.16.28
	Diagonal Bar	HB 400.400.16.32
Profile	Longitudinal Girder	IWF 450.200.9.16
	Transverse Girder	IWF 750.350.12.25 IWF 900 350.12.19
	Wind Bond	IWF 150.150.6.9 IWF 300.200.12.19

**2.5 Bridge Loading based on SNI 1726:2016**

Loading is one of the most important elements in designing bridge structures. According to SNI 1725-2016, there are 3 loads used to design the loads on bridges. Namely permanent burden, traffic burden, and environmental action [8, 9]

1. Permanent Expenses

- Own Weight (MS)

Self-weight is the weight of the part and other structural elements that it carries, including in this case the weight of materials and bridge parts which are structural elements.

- Additional/Utility Dead Load (MA)

Additional dead load is the weight of all materials that form a load on the bridge which are non-structural elements, and the amount can change during the life of the bridge [9].

## 2. Traffic Load

- Lane Load (D)

The "D" lane load consists of an evenly distributed load (BTR) combined with a line load (BGT) as shown in Fig. 3.

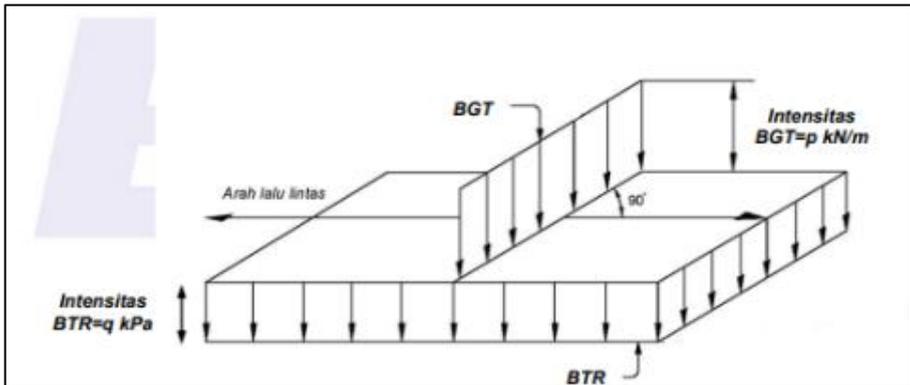


Fig. 3. Load of Lane "D" [8]

Lane loads are divided into 2, namely evenly distributed loads (BTR) and vertical line loads (BGT). The evenly distributed load (BTR) has an intensity of  $q$  kPa with the quantity  $q$  depending on the total length of the load  $L$ , namely as follows:

$$\text{If } L \leq 30 \text{ meters, } q = 9.0 \text{ kPa} \quad (1)$$

$$\text{If } L > 30 \text{ meters, } q = 9.0 (0.5 + 15/L) \text{ kPa} \quad (2)$$

where  $q$  is the uniformly distributed load intensity (BTR) in the longitudinal direction of the bridge (kPa), and  $L$  is the total length of the bridge under load (meters). The concentrated line load (BGT) with intensity  $p$  kN/m must be placed perpendicular to the direction of traffic on the bridge. The intensity  $p$  is 49.0 kN/m.

- Truck Load (T)

"T" truck loads cannot be used in conjunction with "D" loads. The "T" truck load consists of a semi-trailer truck which has an axle arrangement and weight as shown in Fig. 2. The distance between the 2 axles can be varied from 4.0 m to 9.0 m.

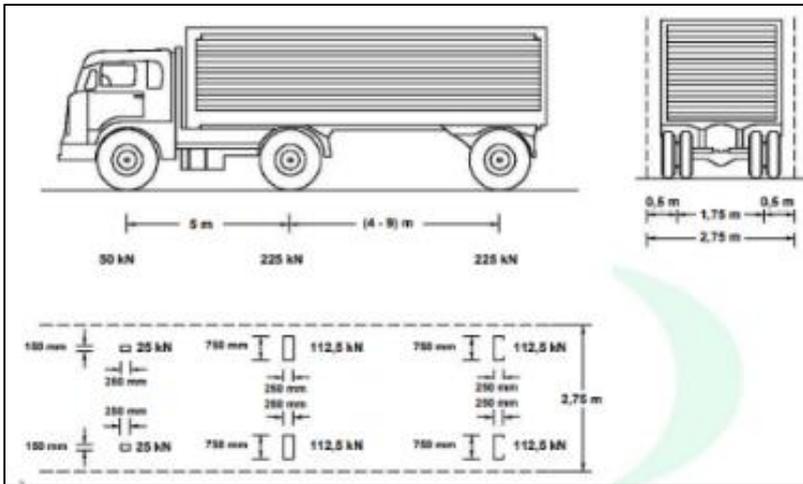


Fig. 4. Truck Loading “T” (500kN) [8]

- Dynamic Load Factor (FBD)

Dynamic load factor (FBD) is the result of interactions between moving vehicles. The amount of FBD depends on the fundamental frequency of the vehicle suspension.

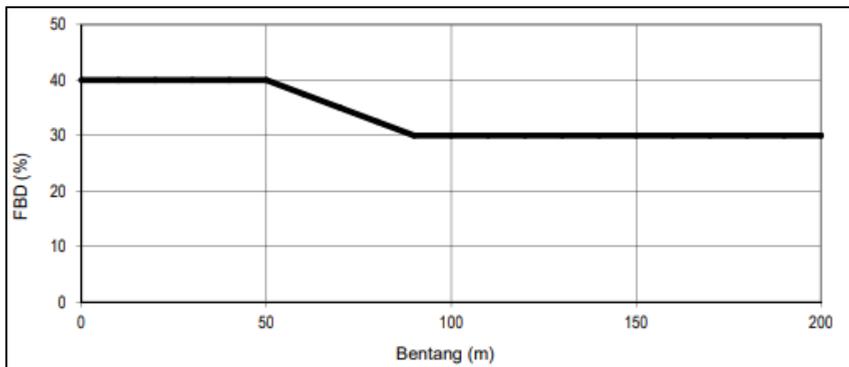


Fig. 5. Dynamic load factor [8]

- Brake Force (TB)

In SNI 1725:2016 Loading Standards for Bridges, the brake force is taken as the largest of the following conditions [8].

- 25% of design truck axle weight
- 5% of the planned truck weight plus evenly distributed lane load. The brake force is applied to all planned lanes that are loaded and contain traffic.

- Pedestrian Load (TP)

Pavement structures that are more than 600 mm in size must be planned to carry pedestrian loads with an intensity value of 5 kN/m<sup>2</sup> [9].

3. Environmental Action

- Horizontal Wind Pressure

The wind pressure determined in this article is assumed to be caused by design winds with a basic speed (VB) of 90 to 126 km/hour. For bridges or bridge sections with an elevation higher than 10,000 mm above ground level or water level, the design wind speed, VDZ, must be calculated using the following equation:

$$V_{DZ} = 2,5 V_0 \left( \frac{V_{10}}{V_B} \right) In \left( \frac{Z}{Z_0} \right) \tag{3}$$

where V<sub>DZ</sub> is the design wind speed at the design elevation, Z (km/hour), V<sub>10</sub> is the wind speed at an elevation of 10,000 mm (km/hour), VB is the design wind speed, namely 90 to 126 km/hour at an elevation of 10,000 mm, Z is the elevation of the structure is measured from the ground surface or from the water surface (Z > 10,000 mm), V<sub>0</sub> is the wind friction speed, which is a meteorological characteristic, for various types of surfaces upstream of the bridge (km/hour), and Z<sub>0</sub> is the friction length upstream of the bridge, which is a meteorological characteristic.

**Table 2.** V<sub>0</sub> and Z<sub>0</sub> values for various variations in upstream surface conditions [8]

Upper building components	Compressive wind (Mpa)	Suction wind (Mpa)
Frames, columns and arches	0.0024	0.0012
Beam	0.0024	N/A
Flat surface	0.0019	N/A

In addition, there is a provision that the total force of the wind load must not be taken to be less than 4.4 kN/mm in the compression plane and 2.2 kN/mm in the suction plane in frame and arch structures and must not be less than 4.4 kN/mm for beams or girders.

- Vehicle Wind Load (EWL)

The value of the vehicle's wind load is 1.46 N/mm perpendicular and works 1.8 m above the road surface [9].

4. Load Factor and Load Combination

Based on SNI 1725:2016, there are load combinations in designing bridge structures [8]. The following loading combinations used can be seen in the Table 3 [9].

**Table 3.** Loading Combinations and Load Factors [8]

<i>Boundary State</i>	<i>MS MA TT TD</i>		<i>EU</i>	<i>EW<sub>s</sub></i>	<i>EW<sub>L</sub></i>	<i>BF</i>	<i>EU<sub>n</sub></i>	<i>TG</i>	<i>ES</i>	<i>Use either</i>		
	<i>TA PR</i>	<i>TB TR</i>								<i>EQ</i>	<i>TC</i>	<i>TV</i>
	<i>PL SH</i>	<i>TP</i>										
Kuat I	$\gamma_p$	1.8	1.00	-	-	1.00	0.50/1.20	$\gamma_{TG}$	$\gamma_{ES}$	-	-	-
Kuat II	$\gamma_p$	1.4	1.00	-	-	1	0.50/1.20	$\gamma_{TG}$	$\gamma_{ES}$	-	-	-
Kuat III	$\gamma_p$	-	1.00	1.40	-	1	0.50/1.20	$\gamma_{TG}$	$\gamma_{ES}$	-	-	-
Kuat IV	$\gamma_p$	-	1.00	-	-	1	0.50/1.20	-	-	-	-	-
Kuat V	$\gamma_p$	-	1.00	0.40	1.00	1	0.50/1.20	$\gamma_{TG}$	$\gamma_{ES}$	-	-	-
Extreme I	$\gamma_p$	$\gamma_{EQ}$	1.00	-	-	1	-	-	-	1.0	-	-
Extreme II	$\gamma_p$	0.50	1.00	-	-	1	-	-	-	-	1.0	1.0
Daya layan I	1.00	1.00	1.00	0.30	1.00	1	1.00/1.20	$\gamma_{TG}$	$\gamma_{ES}$	-	-	-
Daya layan II	1.00	1.30	1.00	-	-	1	1.00/1.20	-	-	-	-	-
Daya layan III	1.00	0.80	1.00	-	-	1.00	1.00/1.20	$\gamma_{TG}$	$\gamma_{ES}$	-	-	-
Daya layan IV	1.00	-	1.00	0.70	-	1.00	1.00/1.20	-	1.00	-	-	-
Fatik (TD dan TR)	-	0.75	-	-	-	-	-	-	-	-	-	-

**2.6 Flexible Structural Components**

Placing the load perpendicularly will cause the rod to bend, this is called a bending mechanism. If a rod that is given a load returns to its original condition, then this behavior is called elastic. A structural element component analyzed using the plastic method must meet the following requirements [8]:

- Compact Cross Section
- Meets the bending strength of the web plate
- Satisfies the condition  $L \leq L_p$ , where L is the span length between two adjacent lateral restraints
- Fulfills the condition  $M_u \leq \phi M_n$ , where  $M_u$  is the ultimate bending moment and  $M_n$  is the nominal bending strength

The concrete on the bridge floor is supported by the main girder with its wings. To make steel and concrete into one homogeneous unit, a shear connector is provided so that the steel and concrete can jointly withstand the forces that arise [10].

**2.7 Compressive Structural Components**

1. Compressive Strength Requirements

A structural component that experiences concentric compression forces due to factored loads must meet the following requirements [11].

$$P_u \leq \phi P_n \tag{4}$$

where  $P_u$  is the ultimate compressive strength, and  $P_n$  is the nominal compressive strength of the compressive structure

2. Slimness

- The slenderness of the cross-sectional elements, (Table 5)

$$< \lambda_r \tag{5}$$

- The slimness of the components of the press structure,

$$\lambda = Lk / r \leq 140 \tag{6}$$

The slenderness value of the cross-sectional elements can be seen in Table 4 below [11].

**Table 4.** Comparison of Maximum Width Against Thickness [8]

Element Type	$\lambda$	Maximum Width to Thickness Ratio	
		$\lambda_p$ (compact)	$\lambda_r$ (not compact)
Wing Plat	$\frac{b}{t}$	170	370
I-Beam	$\frac{h}{tw}$	$\sqrt{F_y}$	$\sqrt{F_y - Fr}$
Body Plat	$\frac{h}{tw}$	1680	2550
		$\sqrt{F_y}$	$\sqrt{F_y}$

3. Nominal compressive strength due to flexural buckling

Nominal compressive strength is calculated using the following formula [11].

$$P_n = (0.66^{\lambda c^2}) \times A_g \times F_y \text{ for } \lambda c \leq 1.5 \tag{7}$$

$$P_n = (0.88^{\lambda c^2}) \times A_g \times F_y \text{ for } \lambda c \geq 1.5 \tag{8}$$

$$\lambda c = \frac{Lk}{r \times \pi} \times \sqrt{\frac{F_y}{E}} \tag{9}$$

$$Lk = kc \times L \tag{10}$$

where  $A_g$  is the gross cross-sectional area of the steel profile ( $\text{mm}^2$ ),  $F_y$  is the yield stress of steel (MPa),  $\lambda c$  is the slenderness parameter,  $kc$  is the effective length factor (mm),  $E$  is the elastic modulus of the steel material ( $\text{N}/\text{mm}^2$ ).

## 2.8 Tensile Structural Components

### 1. Tensile Strength Requirements

Structural components that bear factored axial tensile forces must meet [11]:

$$P_u \leq \phi P_n \quad (11)$$

where  $P_u$  is the ultimate tensile strength,  $P_n$  is the nominal tensile strength of the tensile structure whose value is taken from the lowest value of the equation below:

- Nominal tensile strength is based on yielding at the gross cross section

$$P_n = F_y \cdot A_g \quad (12)$$

- Nominal tensile strength based on fracture in the effective cross section

$$P_n = A_e \cdot F_u \quad (13)$$

where  $A_g$  is the gross cross-sectional area of the steel profile ( $\text{mm}^2$ ),  $A_e$  is the effective cross-sectional area of the steel profile ( $\text{mm}^2$ ),  $F_u$  is the ultimate stress of steel ( $\text{N}/\text{mm}^2$ ),  $F_y$  is the yield stress of steel ( $\text{N}/\text{mm}^2$ ).

### 2. Effective Cross Section

The effective cross-sectional area of a structural component is determined by the following equation [11]:

$$A_e = A_{nt} \times U \quad (14)$$

where  $A_{nt}$  is the net cross-sectional area of the steel profile ( $\text{mm}^2$ ),  $U$  is the reduction factor  $= 1 - (x/L) \leq 0.90$ ,  $x$  is the eccentricity of the joint (mm), and  $L$  is the length of the joint in the direction of the tensile force (mm)

$$A_{nt} = A_g - (n \times d \times tf) \quad (15)$$

where  $A_g$  is the gross cross-sectional area of the steel profile ( $\text{mm}^2$ ),  $tf$  is the thickness of the steel profile flange (mm),  $d$  is the diameter of the bolt hole (mm),  $n$  is the number of holes in one cutting line.

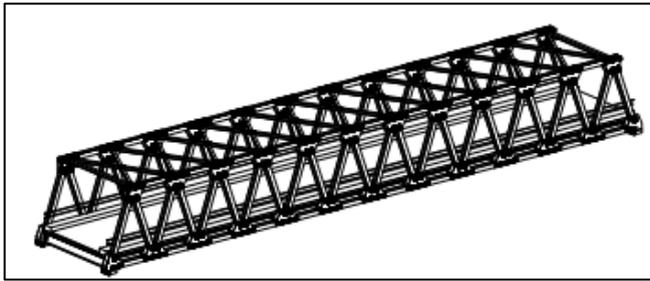
## 3 Results

### 3.1 Preliminary Design

In the construction of the Long Penjalin bridge, initial design planning was carried out in the form of assumptions that could be used, however, if after checking the stability,

robustness, safety, suitability and comfort of the construction, the construction did not meet then the design had to be changed [9]. Steel profile data used:

- Longitudinal girder = HB 400.400.20.35
- Transverse girder = IWF 900.300.18.34
- Main frame = HB 400.400.45.70
- Wind bond = HB 250.250.14.14

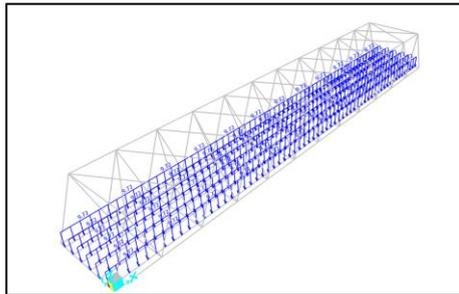


**Fig. 6.** Dimensional Preliminary Design View

### 3.2 Bridge Loading

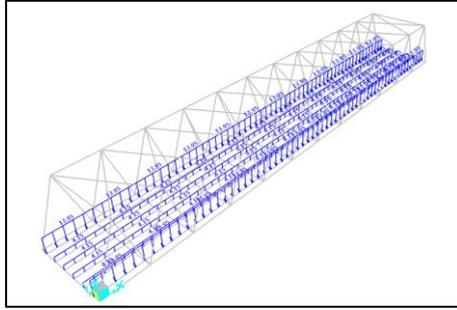
Planning of bridge structural components must be based primarily on planning methods based on ultimate limits which must meet safety criteria for all types of internal forces in all bridge structural components [10]. The loading of the Long Penjalin bridge was calculated based on SNI 1725:2016 and then analyzed using SAP2000 software.

- Self-dead load (MS) = 9.72 kN/m



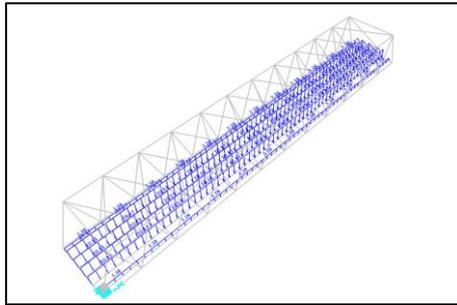
**Fig. 7.** Dead load

- Additional dead load (MA) = 16.15 kN/m



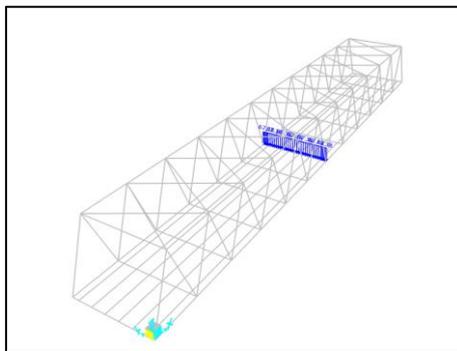
**Fig. 8.** Additional dead load

- Evenly distributed load (BTR) = 10,125 kN/m



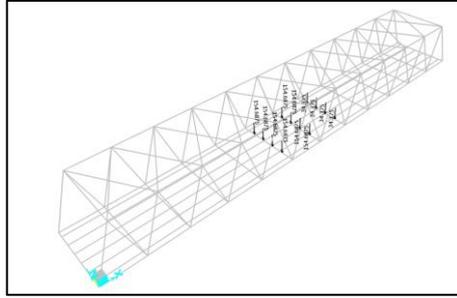
**Fig. 9.** Load is evenly distributed

- Vertical load (BGT) = 67,375 kN/m



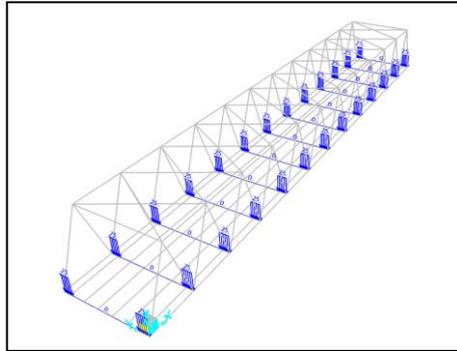
**Fig. 10.** Vertical line load

- Truck load (TT) TR1 = 34.375 kN, TR2 = 154.6875 kN, TR3 = 154.6875 kN



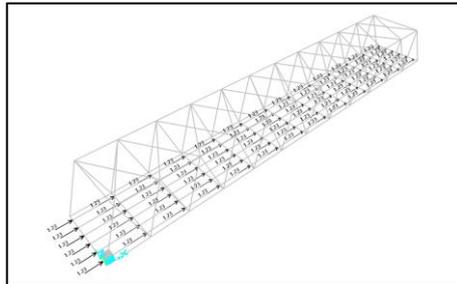
**Fig. 11.** Truck Load

- Pedestrian load (TP) = 25 kN/m



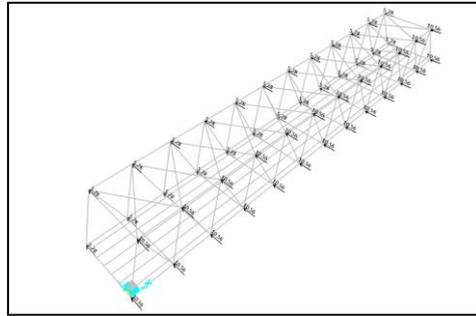
**Fig. 12.** Pedestrian load

- Brake force (TB) = 2.14 kN/joint



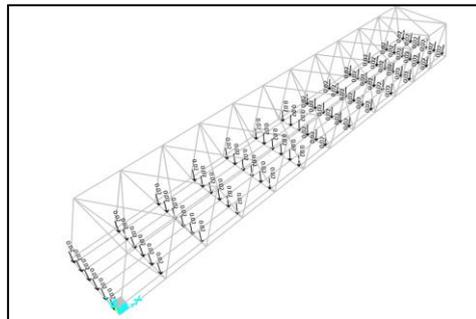
**Fig. 13.** Brake force

- Structure wind load (EWS)
- Compressive wind = 10.56kN/joint
- Suction wind = 5.28 kN/joint



**Fig. 14.** Structure wind load

- Vehicle wind load (EWL) = 0.0193 kN/m per joint



**Fig. 15.** Vehicle wind load

The results of the structural analysis of the main bridge frame can be seen in Table 5.

**Table 5.** Structural Analysis Results

Steel Profile	Axial (Pu)		Shear (Vu)	Moment (Mu)
Upper Bar	-242.64	-13,676.774		
Diagonal Bar	6,028.461	-6,110.091		
Lower Bar	9,632.762	80.068		
Wind Bond	13.449	-25.661		
Longitudinal Girder			194.875	208.6836
Transverse Girder			1,158.347	2,560.3882

### 3.3 Design of Composite Longitudinal Girder (Stringer)

The longitudinal beam is the main beam that carries the load from the vehicle floor and the load from vehicles passing through the bridge and then these loads are distributed to the foundation [1]. Longitudinal girder planning data:

- Longitudinal girder profile = HB400.400.20.35
- Steel quality = BJ37
- Concrete quality = 30 MPa
- Length of girder = 5 m
- Distance between girders = 1.5 m
- Number of girders = 6 pieces
- Floor plate thickness = 270 mm
- Specific gravity of reinforced concrete = 24 kN/m<sup>3</sup>
- Specific gravity of steel = 78.5 kN/m<sup>3</sup>

#### 1. Slide and Ultimate Moment

Moment and shear values in longitudinal girders (stringers).

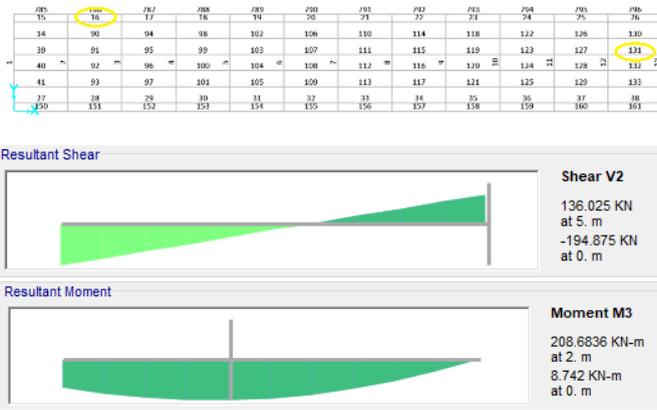


Fig. 16. Maximum Stringer Force

#### 2. Review of Shear

- Vertical stiffeners

$$a/h > 3$$

$$15,924 > 3$$

- Control the thickness of the web plate

$$(h/t_w) \leq 3.57 \sqrt{\frac{E}{f_y}}$$

$$15.7 \leq 103.057$$

- Hold plan slide

$$(h/tw) \leq 1.1 \sqrt{\frac{K_n \times E}{f_y}}$$

$15.7 \leq 71.0047$ , then the shear review is calculated using plastic shear calculations.

$$\phi_s V_n = 0.9 \times 0.6 \times F_y \times A_w = 813.888 \text{ kN}$$

$$V_u = 194.875 \text{ kN}$$

Longitudinal girders are safe against sliding.

### 3. A Review of Bending

- Effective width (bE)

The effective width is taken to be 1,500 mm

- Balance equation  $T = C$

The force on the fiber is attracted,

$$T = A_s \times F_y = 8,656,800 \text{ N}$$

The force on the compressed fiber,

$$C = 0.85 \times f_c' \times b_E = 38,250 \text{ N}$$

- Location of the neutral axis of the composite girder

$$a = \frac{A_s \times f_y}{0.85 \times f_c' \times b_E} = 226.322 \text{ mm} < t_p = 270 \text{ mm}$$

So the neutral axis is located on the concrete floor plate.

- Prisoner of the moment of plan

$$M_n = f_y \times A_s \times \left( \frac{d}{2} + t_p - \frac{a}{2} \right) = 3.210.28 \text{ kNm}$$

$$\phi M_n = 2.889.25 \text{ kNm}$$

$$M_u = 208.89 \text{ kNm}$$

Longitudinal girders are safe against bending.

### 4. Shear and Bending Interactions

$$\frac{M_u}{\phi_f M_n} + 0.625 \times \frac{V_u}{\phi_s V_n} < 1.375$$

$$0.2219 < 1.375$$

### 5. Shear Connector

The shear force that occurs between the concrete plate and the steel profile must be borne by a number of shear connectors, so that slip does not occur during service life [12]. Shear connectors are used to resist slippage that occurs at the interface between concrete and steel beams with a length when installed that is not less than 4 times the diameter. A325 quality shear connectors with a diameter of 24 mm are used.

- Shear Connector Strength ( $Q_n$ )

$$Q_{n1} = 0.5 \times A_c \times \sqrt{f_c' \times E_c} = 198.78 \text{ kN}$$

$$Q_{n2} = A_c \times F_u = 167.384 \text{ kN}$$

The smallest value is used, namely 167,384 kN

- Nominal shear strength ( $V_n$ )

$$V_{n1} = A_g \times F_y = 8,656.8 \text{ kN}$$

$$V_{n2} = 0.85 \times F_c' \times t_p \times bE = 10,327.5 \text{ kN}$$

The smallest value is used, namely 8,656.8 kN

- Number of Shear Connectors

$$n = V_n / Q_n = 51,718 \text{ pieces} \approx 60 \text{ pieces}$$

$$S = L / ((0.5 \times (n + 1))) = 82.6446 \text{ mm} \approx 82 \text{ mm}$$

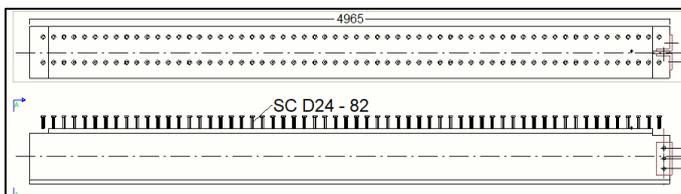


Fig. 17. Detail of Composite Longitudinal Girder

### 3.4 Transverse Girder Planning (Cross Girder)

Transverse girder planning data:

- Longitudinal girder profile using IWF 900.300.18.34
- Steel quality = BJ55
- Girder length = 9 m

- Distance between transverse girders = 5 m
- Distance between longitudinal girders = 1.5 m

1. Slide and Ultimate Moment

Moment and shear values in the cross girder.



Fig. 18. Maximum cross girder force

1. Review of Shear

- Control the thickness of the web plate

$$(h/tw) \leq 3.57 \sqrt{(E/fy)}$$

$$46.8889 \leq 78.8481$$

- Design shear resistance

$$(h/tw) \leq 1.1 \sqrt{((K_n \times E)/fy)}$$

46,889 ≤ 54,325, then the shear review is calculated using plastic shear calculations.

$$\phi_s V_n = 0.9 \times 0.6 \times F_y \times A_w = 3,363.51 \text{ kN}$$

$$V_u = 1,158.347 \text{ kN}$$

Transverse girders are safe against sliding.

2. A Review of Bending

- Cross-sectional plastic modulus

$$Z_x = 15,426,328 \text{ mm}^3$$

- Plastic limit moment and bending limit moment

Plastic limit moment ( $M_p$ ) =  $Z_x \times F_y = 6,324,794 \text{ kNm}$

Bending limit moment ( $M_r$ ) =  $S_x \times (F_y - F_r) = 3.706 \text{ kNm}$

- Local bending

Wing slenderness  $\lambda_f < \lambda_p$ , and body slenderness  $\lambda_w < \lambda_r$ . So, the profile is included in the non-slim profile and includes a perfectly plastic cross-section.

- Lateral torsion bending

Plastic length limit ( $L_p$ ) =  $1.76 \times r_y \times \sqrt{(E/F_y)} = 2,549.996 \text{ mm}$

Includes perfect plastic cross section.

- Lateral torsion bending

Plastic length limit ( $L_p$ ) =  $1.76 \times r_y \times \sqrt{(E/F_y)} = 2,549.996 \text{ mm}$

Includes perfect plastic cross section.

- Prisoner of the moment of plan

$$M_n = M_p = 6,324.794 \text{ kNm}$$

$$\phi M_n = 5,692.315 \text{ kNm}$$

$$M_u = 2,560,388 \text{ kNm}$$

Transverse girders are safe against bending.

### 3. Shear and Bending Interactions

$$\frac{M_u}{\phi_f M_n} + 0.625 \times \frac{V_u}{\phi_s V_n} < 1.375$$

$$0.665 < 1.375$$

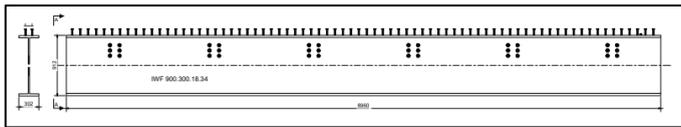


Fig. 19. Detail of transverse girder

### 3.5 Compression Bar Design

- Maximum compressive axial force

Maximum compressive force on the compression member.

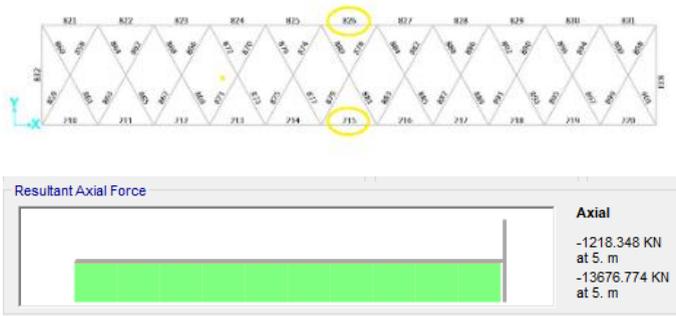


Fig. 20. Maximum pressure member force

- Profile cross-sectional slenderness  
 $\lambda_f < \lambda_r$ , the profile is classified as compact
- Compression structure slenderness parameters

$\lambda_c = L \times k_c \times \sqrt{\frac{F_y}{E}} = 0.497 \leq 1.5$ , then the nominal compressive force is calculated using equation 1 according to RSNI T-03-2005 [13].

- Design pressure force

$$\phi R_n = 0.85 \times (0.66^{\lambda_c^2}) \times A_g \times F_y = 14,179.409 \text{ kN}$$

$$P_u = 13,676.774 \text{ kN}$$

Because  $\phi R_n > P_u$ , the profile is safe against compression.

### 3.6 Tensile Rod Planning

- Maximum tensile axial force

Maximum tensile force on the pull rod.



Fig. 21. Maximum tension rod force Bolt diameter

- The diameter of the bolt used is 33 mm.

Number and spacing of bolts

- The number of bolts used is 48, 24, and 8.

Distance between bolts:  $3 \times db \approx 100 \text{ mm}$

Bolt to edge distance:  $1.25 \times db \approx 50 \text{ mm}$

- Tensile strength based on yield

Tensile strength at melting condition:  $16,634.16 \text{ kN} \geq 9,632.762 \text{ kN}$

Tensile strength based on fracture

- Tensile strength of fracture conditions:

$18,428.964 \text{ kN} \geq 9,632.762 \text{ kN}$

Because  $\phi R_n > P_u$ , the profile is safe against tension.

## 4 Discussion

Modeling was carried out using the SAP2000 Auxiliary Program. In this modeling, geometric and material data are used in accordance with the preliminary design of a warren type steel frame bridge. The warren type is more economical because it uses more efficient materials. Additionally, truss bridges can support heavier loads over longer distances by using shorter elements. Truss bridges are generally made of steel, with a basic shape in the form of a triangle [14].

The longitudinal girder on the Long Penjalin bridge uses the HB 400.400.20.35 profile and is planned as a composite structure with a maximum shear force value of 194.875 kN and a maximum moment of 208.69 kNm. A review of the shear shows that the longitudinal girder meets the web plate thickness requirements and is included in the plastic shear condition with a shear resistance of 813,888 kN. A review of bending for composite structures was carried out using a plastic analysis approach and a bending resistance of 2,889.25 kNm was obtained. For shear connections at zero moment to maximum moment, 120 33 mm diameters are used in 1 girder.

The transverse girder on the Long Penjalin bridge uses the IWF 900.300.18.34 profile with a maximum shear force value of 1,158,347 kN and a maximum moment of 2,560,388 kNm. A review of the shear shows that the transverse girder meets the web plate thickness requirements and is included in the plastic shear condition with a shear resistance of 3,363.51 kN. A review of bending was carried out using a plastic analysis approach and a bending resistance of 5,692,315 kNm was obtained.

The main steel frame of the bridge uses the HB 400.400.45.70 profile, and the wind ties use the HB 250.250.14.14 profile. Planning for steel frames and wind ties based on RSNI T-03-2005 includes analysis of compressed and tensile members [8]. The maximum compressive force value is 13,676,774 kN and the maximum tensile force is 9,632,762 kN. Analysis of the compressive rod shows that the profile used is a compact

profile and the slenderness parameter is included in equation 1, so that the design compressive force is 13,676,774 kN. The tensile rod analysis was calculated based on the fracture condition and yield condition, so that the smallest design tensile force was obtained, namely, 16,634.16 kN.

Based on the loads acting on the bridge and the strength of the profile used, the bridge meets the requirements and is strong enough to withstand the load for a steel frame bridge with a span of 60 meters.

## 5 Conclusions

Based on the analysis and design calculations that have been carried out, the following results can be concluded that the steel profile used in the main steel frame of the bridge is IWF 400.400.45.70 with steel quality BJ37. The steel profile used in the bridge wind ties is IWF 250.250.14.14 with steel quality BJ37. The steel profile used in the bridge's longitudinal girders (stringers) is IWF 400.400.20.35 with steel quality BJ37. The steel profile used in the cross girder of the bridge is IWF 900.300.18.34 with steel quality BJ55.

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