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Safety Study of Steel Structure of Weighbridge I Girder Against Hauling Trailer

Ryan Zulfikar[1] , Rusandi Noor[1*]
[1] Program Studi Teknik Sipil, Fakultas Sains dan Teknologi, Universitas Muhammadiyah Kalimantan Timur, Jl Juanda No 15, Samarinda, Kalimantan Timur, Indonesia 75131

* Corresponding Email: rn903@umkt.ac.id

Abstract – Weighbridges play a vital role in coal mining operations. This study aims to calculate the stress range and fatigue life of steel bridge girder cross-sections. Using the numerical simulation method with the CSI Bridge V22 application, the maximum axial force of 197 kN and the minimum axial force of -74 kN were obtained. The axial force is determined from the first 3 spans of the bridge with a span length of 4 m. The span length of the weighbridge is 80 m. From the calculation, the maximum stress of 40.11 MPa and the minimum stress of -15.06 MPa were obtained, resulting in a stress range of 55.16 MPa. The nominal bending moment strength of the beam was found to be 0.56. This modeling allows the simulation of dynamic loads from a 400-tonne SDT truck (semi-trailer door tipper) passing over the bridge so that accurate stress range data can be obtained. Fatigue analysis was carried out using the Basquin equation using the constant C = 1x1012 and exponent m = 3, receiving a fatigue life of 0.006 (6.01x106) cycles assuming 30-40 hauling trucks passing over the weighbridge. The results of calculations and simulations obtained longitudinal and transverse profile dimensions of IWF 1000x520x18x31.

Keywords: Stress range, fatigue life, weighbridge

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1. Introduction

Weighbridges are heavyweight industrial scales installed with concrete foundations or placed on flat ground and used to weigh the weight of trucks and their cargo. By utilizing a weighbridge, the process of weighing vehicles and coal trucks either when they are empty or full of cargo, can be easily done [1].

The mention of the weighbridge is because the construction is in the form of a bridge consisting of 2 (two) long I-Beam main girders and 6 (six) child girders with transverse beams along the beam that binds the right and left girders and is covered with a plate on its surface. The weighbridge rests on 42 (forty-two) load cells to function as load sensors [2].

Coal mining always strives to increase coal production every year. One of the efforts made is to increase the carrying capacity of the Semi Trailer Door Tipper (SDT) or hauling trailer from 170 tons to 255 tons. The weighbridge currently used is a permanent type weighbridge with a maximum weighing capacity of 255 tons [3].

The existence of this bridge is very important for coal mining, so the feasibility and ability of this bridge need to be closely monitored. One way of monitoring can be done by analyzing the fatigue life of the bridge. The 80-meter-long weighbridge may be subjected to various stresses from hauling trailer vehicles. Therefore, an in-depth understanding of its structural response to vehicle movements is important to ensure the structural integrity of the bridge [4].

Hauling trailers or door-tipper semi-trailers (SDTs) often carry heavy loads and generate significant dynamic forces when crossing weighbridges. Rapid movement, uneven loading, and vibration forces from the vehicle can substantially affect the dynamic response of the bridge [5].

Understanding the parameters and characteristics of bridge dynamic modes based on the measured dynamic response when the bridge is in operational condition is very important information. This information can provide an in-depth assessment of the bridge's condition and assist in making decisions regarding whether the bridge is still suitable for optimal use [6].

Before being operated, vehicle load tests need to be carried out to ensure that the bridge can function optimally and safely and deal with the loads that occur during its use [7].

Bridge maintenance and repair has received significant attention as its service life increases [8].

Therefore, the use of CSI Bridge V22 software is important in conducting structural analysis of weighbridges. By inputting appropriate parameters, such as bridge geometry, construction materials, and vehicle load profiles, simulations can provide valuable insights into bridge stability and reliability [9].

in planning a bridge construction, it is necessary to consider vibration aspects to ensure user safety and comfort. Steel frame bridges are an attractive alternative for bridges with long spans [10].

the fatigue life of the bridge to determine the eligibility requirements of the bridge theoretically and experimentally [11].

the natural frequency on the weighbridge refers to the natural frequency of vibrations or oscillations that occur in the bridge structure when a load is applied to the bridge. This natural frequency is influenced by various factors such as the shape, size, material, and construction of the bridge [12].

the relationship between the natural frequency of the weighbridge and the hauling trailer is that the vibration generated by the trailer movement can cause the bridge to vibrate at a frequency that matches the natural frequency of the bridge. If the vibration frequency of the trailer is close to or matches the natural frequency of the bridge, a phenomenon called resonance can occur [13].

Resonance is a condition in which external vibrations (vibrations from the trailer) match the natural frequency of the bridge, which can cause vibration amplification and magnify adverse effects on the bridge structure [14].

all objects that have mass and elasticity are capable of vibrating. The magnitude of the natural frequency of a material that vibrates transversely is strongly influenced by the modulus of elasticity of the material, dimensions/geometry (cross-sectional area, length), density, and the action force acting on the material [15].

in one structural element there will be several different frequency values, this is due to the difference in frequency values in each mode. The greater the mode number, the greater the natural frequency value [16].

In this study, the loading methods used did not follow the standards set by the relevant authorities. This can include the use of loads that exceed or fall short of the regulated provisions, as well as the application of loading techniques that do not comply with generally accepted guidelines in construction.

SNI 03-1729-2002, This standard provides guidelines for the planning of full-walled plate beams (girder plates), including structural design requirements, dimensions, and calculation methods that must be considered to ensure the safety and reliability of bridge structures using girder plates [17].

The purpose of this study was to determine the characteristics of fatigue fracture propagation rates in structural components subjected to maximum forces on steel arch bridges and to determine the fatigue life of structural components subjected to excessive loads [18].

In recognizing the limitations of previous research, it was found that most previous studies focused on bridge supervision and maintenance, which may not fully consider complex structural dynamics [19].

Some studies may also lack attention to the integration of the latest technologies, such as natural frequency analysis, in the monitoring and maintenance process. Recent data and facts show that the use of natural frequency analysis can provide a deeper understanding of the structural performance of bridges, allowing the identification of previously overlooked limitations [20].

2. Methodology

2.*1 Research Procedures*

This stage provides an overview of the initial steps to the end of the preparation of the final project. The stages start from the starting stage, data collection, data analysis, bridge detail planning, CSI Bridge V22 software planning, and design drawings.

Data Collection Techniques

In this case, data collection is carried out by taking data from the office of PT Ganda Alam Makmur in the form of images of existing data structures that have been processed again.

The guidelines used in the preparation of the Final Project entitled "Safety Study of the Weighbridge I Girder Steel Structure Against Hauling Trailer" are:

1. Data of 51 meters weighbridge of PT Ganda Alam Makmur
2. SNI 03-1729-2002, on the Planning of Full-Walled Plate Beams (Girder Plates).

Data collection is the first step taken in structural planning which generally consists of::

1. General description of the building
2. Calculation analysis method and design of construction structures such as superstructure.
3. Determine the working load

Picture of Weighbridge

Figures 2.1 and 2.2 show the design of the weighbridge modeling results in AutoCAD 2021 software.

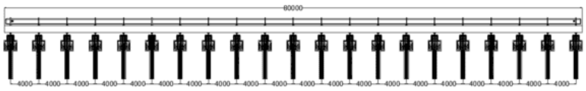

Figure 2. 1 Weighbridge longitudinal section

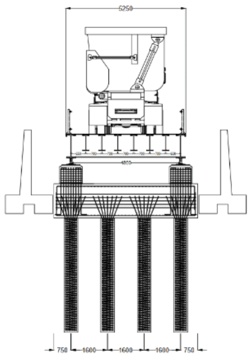

Figure 2. 2 Weighbridge cross-section

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Bridge Implementation Method

The implementation of this steel frame bridge installation uses the Load Resistance Factor and Design (L.R.F.D) method. The Load Resistance Factor and Design (L.R.F.D) method is a method in building planning that takes into account the load factor and material resistance factor.

Design Modeling Stage

In the modeling process, the design of the weighbridge must comply with the applicable criteria and standards. With a span of 80 meters and a bridge width of 5 meters, the structural modeling steps of the bridge will be analyzed in detail.

1) In this study, modeling was carried out using CSI Bridge V22 software.

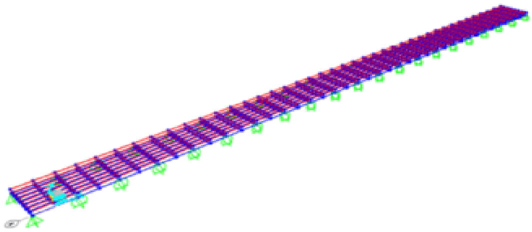
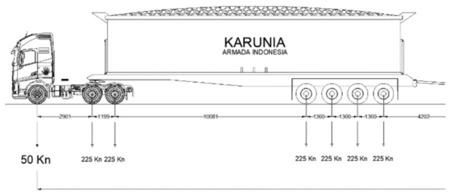
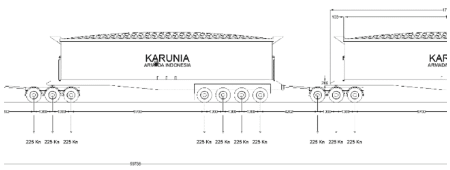


Figure 2.4 CSI Bridge V22 display.

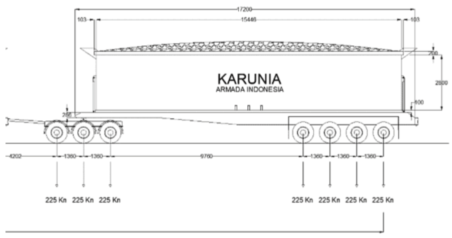
2) After modeling the bridge structure using CSI Bridge V22, the next step is to determine the material and type of steel profile to be used for each part of the bridge.
3) After determining the material and type of steel profile for the bridge structure, the next step is to enter the loads that have been capitalized into the CSI Bridge V22 software.
   - Dead load
   - Live load



(a)



(b)



(c)

Figure 2.4 (a), (b), and (c) Hauling trailer size details

4) At this stage, the CSI Bridge V22 user will create a live load model involving moving loads from vehicle loads using the moving load feature.
5) The next step after entering the individual loads into the bridge structure model in the CSI Bridge V22 software is to determine the loading combination.
6) Checking the bridge structure model in CSI Bridge V22 software is an important stage in the structural design and analysis process.
7) After checking and validating the bridge structure model that has been made in the CSI Bridge V22 software, the next step is to run the structural analysis. This process is carried out by performing a "Run Analysis" on the model that has been prepared.
8) In the bridge retrofitting stage, CSI Bridge V22 users took various measures such as replacing weak structural elements and enlarging the dimensions of certain elements by using stronger steel.
9) After performing the initial structural analysis on the bridge model in CSI Bridge V22, the next step is to re-run the analysis to obtain the structural reinforcement analysis results.

3. Results and Discussion

3.1. Bridge Technical Data

1) Bridge general data
   1) Bridge Type: Weighbridge
   2) Bridge Width: 4.8 meters
   3) Span: 80 meters
   4) Floor Plate Thickness: 60 mm
2) Bridge Material Data
   1) Steel Quality: BJ 50
3) Design Standard Reference

The following is a standard reference in the design analysis of this weighbridge structure.

a. SNI 03-1729-2002, on ‘Planning of Full-Walled Plate Beams (Girder Plates)’.

e-ISSN: 2723-3944

3.2. Bridge Steel Structure Design

Data-data:

Mu max = 4078331000 kN/m
Vu max = 8560000000 kN/m
Used BJ – 50, fu = 500 MPa
fy = 290 MPa

Calculations

Determine the height of a full-walled plate beam:

h = L/10
= 1000/10
= 100 cm

h = L/12
= 1000/12
= 83,33 cm

A maximum height of 100 cm is used

Suppose a flange thickness of 3.1 cm is taken, then the height of the web is:

h = h – 2 tf
= 100 - 2 (3,1)
= 93,8 cm

To determine the thickness of the web, the limit values h/*tw* can be used:

1. To fulfill the requirements of a full-walled plate beam, the

$$\frac{h}{t_w} \geq \frac{2550}{\sqrt{fy}} = \frac{2550}{\sqrt{290}} = 149{,}741$$

$$t_w \leq h/149{,}741 = 93{,}8/149{,}741 = 0{,}6264\ cm$$

2. To a/h ≤ 1,5:

$$\frac{h}{t_w} \leq \frac{5250}{\sqrt{fy}} = \frac{5250}{\sqrt{290}} = 308{,}291$$

$$t_w \geq 93{,}8/308{,}291 = 0{,}3043$$

3. To a/h > 1,5:

$$\frac{h}{t_w} \leq \frac{95000}{\sqrt{f_{yf}(f_{yf} + 115)}} = \frac{95000}{\sqrt{290\ (290 + 115)}} = 277{,}2025$$

$$t_w \geq 93{,}8/277{,}2025 = 0{,}3384$$

Using a web size of 1.8 cm x 93.8 cm to determine the flange size:

$$A_f = \frac{M_u}{0{,}9\,.h.f_y} - \frac{A_w}{6}$$

$$A_f = \frac{407{,}83x10^7}{0{,}9\ x\ 938\ x\ 290} - \frac{8\ x\ 938}{6} = 15407{,}83\ \text{mm}^2 = 154{,}1\ \text{cm}^2$$

The self-weight of the beam can now be calculated:

Extensive web = 1,8 x 93,8 = 168,8 cm^2

Extensive flens = 2 (154,1) = 308,2 cm^2

Total = 477 cm^2

Self weight of the beam = $\frac{477}{10000} x7{,}85 = 0{,}3744$ ton/m = 0,37 ton/m

The value of the bending moment caused by the beam's weight is:

$$M_u = 407{,}83 + \frac{(1{,}2\ x\ 0{,}37).18^2}{8} = 425{,}81\ \text{kg}$$

(The numbers listed in brackets on the moment and latitude plane images indicate the magnitude of the lateral force and bending moment which includes the self-weight of the beam).

After recalculating the bending moment, the flange area is calculated once again :

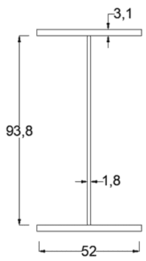
$$A_f = \frac{425{,}81\ x\ 10^7}{0{,}9\ x\ 938\ x\ 290} - \frac{8\ x\ 938}{6} = 16142{,}25\ \text{mm}^2 = 161{,}4\ \text{cm}^2$$

If the flange thickness remains 3.1 cm as before, then the flange width will be :

$$b_f = \frac{A_f}{t_f} = \frac{161{,}4}{3{,}1} = 52{,}0645\ \text{cm} \approx 52\ \text{cm}$$

Tried flange size 3,1 cm x 52 cm

Calculate the moment of inertia of the cross-section concerning the bending axis:



$$I_x = \frac{1{,}8\ x\ 93{,}8^3}{12} + 2(3{,}1)(50)(80{,}5)^2$$

= 2213026,651 cm^4

And cross-sectional modulus:

$$S_x = \frac{I_x}{d/2} = \frac{2213026{,}651}{82{,}5}$$

= 26824,57 cm^3

Since the beam is continuously laterally restrained, it is not necessary to check the lateral torsional buckling stress to limit the local buckling stress at the compressive flange :

$$\lambda_G = \frac{b_f}{2.t_f} = \frac{52}{2\ x\ 3{,}1} = 8{,}39$$

$$\lambda_p = 0{,}38\sqrt{(E/f_y)} = 0{,}38\sqrt{\frac{200000}{290}} = 9{,}98$$

$\lambda_G < \lambda_p$ so $f_{cr} = f_y = 290$ MPa

Furthermore, the coefficient Kg for beams with full-walled plates was also calculated :

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$$K_g = 1 - \left[\frac{a_r}{1200 + 300.\,a_r}\right]\left[\frac{h}{t_w} - \frac{2550}{\sqrt{f_y}}\right]$$

By:

$$a_r = \frac{A_w}{A_f} = \frac{1{,}8\ x\ 93{,}8}{3{,}1\ x\ 52} = 1{,}0474$$

$$\frac{h}{t_w} = \frac{93.8}{1{,}8} = 52{,}11$$

$$K_g = 1 - \left[\frac{1{,}0474}{1200 + (300\ x\ 1{,}0474)}\right]\left[52{,}11 - \frac{2550}{\sqrt{290}}\right] = 1{,}0675$$

Hence the nominal bending moment strength of the beam:

$M_n = K_g.S.f_{cr}$ = 1,0675 (26824,10^3) (290) = 830,4 ton/m

ϕ. M_n = 0,9 (830,4) = 747,4 ton m > 425,81 ton/m **OK**

Count the distance between vertical stiffeners!

Shear resistance at the end of the panel (does not take into account the influence of tensile forces):

$$\phi\ V_n = \phi\ (0{,}6.A_w.f_{yw}.C_v)$$

$$C_v = \frac{\phi.V_n}{\phi.0{,}6.A_w.f_{yw}} = \frac{8{,}536}{0{,}9\ x\ 0{,}6\ x\ 8\ x\ 938\ x\ 290} = 7{,}3$$

From Equation. 10.25: (assume C_v is within the elastic region)

$$C_v = 1{,}5.\frac{k_n.E}{f_y}.\frac{1}{(h/t_w)^2}$$

$$k_n = \frac{C_v.f_y.(h/t_w)^2}{1{,}5.\,E} = \frac{7{,}3\ x\ 290\ x\ 52{,}11^2}{1{,}5\ x\ 200000} = 19{,}16204$$

$$a/h = \sqrt{\frac{2}{K_n - 2}} = \sqrt{\frac{2}{19{,}16204 - 2}} = 0{,}34$$

a = 0,61.h = 0,34 (93,8) = 31,89 cm = 32 cm from the end of the beam

Confirm again the sliding stability of the end panels with the corresponding numbers.

a = 32 cm:

$$k_n = 2 + \frac{2}{(32/93{,}8)^2} = 19{,}1845$$

$$1{,}37\ .\sqrt{\frac{k_n E}{f_y}} = 1{,}37\ .\sqrt{\frac{19{,}1845\ x\ 200000}{290}} = 157{,}5839 > h/t_w\ \ (= 52{,}11)$$

Nominal shear strength for end panels:

$$V_n = \frac{0{,}9.A_w.k_n.E}{(h/t_w)^2} = \frac{0{,}9\ x\ 8\ x\ 938\ x\ 19{,}1845\ x\ 200000}{52{,}11^2} = 954{,}28\ \text{ton}$$

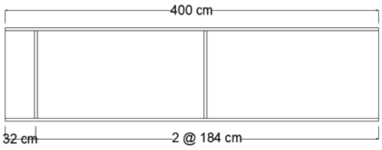
$\phi.V_n$ = 0,9 (954,28) = 858,85 ton > 8,536 ton **OK**

For center panels, the influence of the tensile field can be calculated if:

$$a/h > \left[\frac{260}{h/t_w}\right]^2 = 1{,}75$$

a/h = 1,6 → a = 1,6 (93,8) = 150,1 cm *(max)*

To obtain uniform spacing of the vertical stiffeners, the remaining length between the end vertical stiffeners and the center of the span of the full-walled plate beam should be divided equally. In this example, 2 panels are planned as shown in the figure below:



$$a = \frac{\frac{1}{2}L - \text{a ujung}}{\sum \text{panel}} = \frac{400 - 32}{2} = 184\ \text{cm}$$

Ratio a/h = 184 / 93,8 = 1,9616

$$k_n = 2 + \frac{2}{(a/h)^2} = 2 + \frac{2}{(1{,}9616)^2} = 2{,}5198$$

$$1{,}37\ .\sqrt{\frac{k_n.E}{f_y}} = 1{,}37\ .\sqrt{\frac{2{,}5198\ x\ 200000}{290}} = 57{,}1 > h/t_w (= 52{,}11)$$

Then C_v is taken from equation 10.25:

$$C_v = 1{,}5\frac{k_n.E}{f_y}.\frac{1}{(h/t_w)^2} = 1{,}5\frac{2{,}5198\ x\ 200000}{290}.\frac{1}{52{,}11^2} = 0{,}960$$

Nominal shear strength of full-walled plate beams considering the influence of tensile field:

$$V_n = 0{,}6.f_y.A_w.\left[C_v + \frac{1 - C_v}{1{,}15\sqrt{1 + (a/h)^2}}\right]$$

$$= 0{,}6(290)(8)(938)\left[0{,}960 + \frac{1 - 0{,}960}{1{,}15\sqrt{1 + 1{,}9616^2}}\right]$$

= 127,41 ton

ϕV_n = 0,9 (127,41) = 114,669 ton > 8,560 ton **OK**

The next step is to design the vertical stiffeners. The cross-section of the vertical stiffener is determined based on three criteria:

1. Minimum area
1. Minimum moment of inertia
2. Maximum width to thickness ratio to thickness ratio.

$$A_{s\ min} = 0{,}5.A_w.D.(1 - C_v).\left[\frac{a}{h} - \frac{(a/h)^2}{\sqrt{1 + (a/h)^2}}\right]$$

$$= 0{,}5(8)(938)(1)(1 - 0{,}960)\left[1{,}9616 - \frac{1{,}9616^2}{\sqrt{1 + 1{,}9616^2}}\right]$$

= 32,15 cm^2

From equation 10.70

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$$I_{s\ min} = j.a.t_w{}^3$$

Dengan : $j = \frac{2{,}5}{(a/h)^2} - 2 = \frac{2{,}5}{1{,}9616^2} - 2 = -1{,}350 < 0{,}5 \rightarrow j = 0{,}5$

$$I_s = 0{,}5(184)(1{,}8)^3 = 560{,}54\ \text{cm}^4$$

The maximum value of b_s/t_s is: $0{,}56\sqrt{\frac{E}{f_y}} = 14{,}7063$

It was tried to use vertical stiffeners with a size of 1.8 cm x 12 cm, so that:

$A_s = 2(1{,}8)(12) = 43{,}2\ \text{cm}^2 > 32{,}15\ \ \text{cm}^2$ **<u>OK</u>**

$I_s = \ \Sigma(I_o + A.d^2) = \frac{1}{12}(1{,}8)(12)^3 + (1{,}8)(12).\left(\frac{12}{2} + \frac{1{,}8}{2}\right)^2$

$= 1287{,}576\ \text{cm}^4 > 536{,}54\ \text{cm}^4$ **<u>OK</u>**

$b_s/t_s = \frac{12}{1{,}8} = 6{,}67 < \ 14{,}7063$ **<u>OK</u>**

3.3. Weighbridge Design Modeling

Dimensions of the Upper Structure of the Bridge

The dimensions of the superstructure of the weighbridge using IWF 1000x520x18x31 profiles were selected for their strength and stability in withstanding loads. These profile size inputs were entered in the CSI Bridge V22 program.

Bridge Floor Plate Dimensions

The weighbridge floor plate uses a 60 mm thick steel plate to ensure strength and resistance to the load of hauling trailers that often pass by. Details of the floor plate size were entered in the CSI Bridge V22 program.

Support/Restraint

A bridge uses roller-joint support to transmit load forces and improve measurement accuracy by allowing horizontal movement of the vehicle. Meanwhile, roll pedestals on weighbridges are emphasized more than joint pedestals because the lateral tilt allowed by the roll allows the vehicle to move horizontally without compromising measurement accuracy.

Vehicle Load Input

At this stage is the input of vehicle loads that include dynamic loads generated by hauling SDT-type trailers (semi-trailer door tipper) across the bridge. This includes analyzing the weight of different vehicles, and the load distribution that affects the performance of the bridge during normal use. The following application of vehicle load input is shown in Figures 3.1 and 3.2 below.

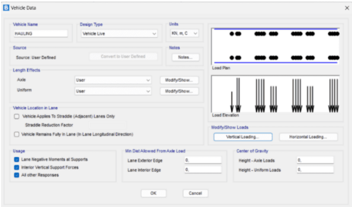

Figure 3. 1 Vehicle data

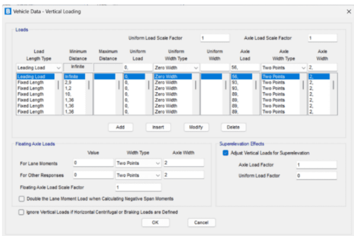

Figure 3. 2 vehicle load input

Vehicle Lane Input

The lane or traffic lane on a bridge determines the load borne by the bridge from passing vehicles, including their weight and speed. This definition is crucial in the design and analysis of bridge structures to ensure safety and efficiency in bearing vehicle loads without damage or performance degradation. The steps to apply vehicle lane input can be found in Figures 3.3, 3.4, and 3.5.

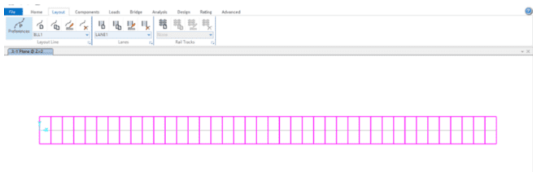

Figure 3. 3 Input Preferences

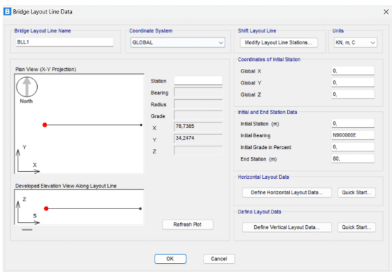

Figure 3. 4 Input bridge layout line data

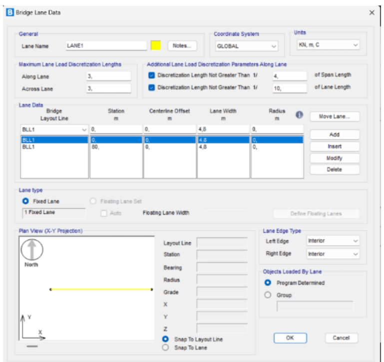

Figure 3. 5 Input bridge lane data

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Vehicle Speed Input on Load Pattern

The speed of haulage vehicles crossing the bridge has been set at 5 km/h or equivalent to 1.4 m/s. This speed was chosen based on special considerations related to operational conditions at the study site. The use of this speed allows for the collection of accurate data regarding the impact of vehicle speed on the bridge structure and overall system performance. The procedure for inputting vehicle speeds can be found in Figure 3.6.

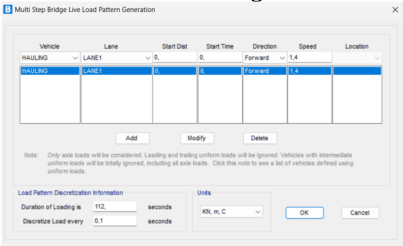

Figure 3. 6 Vehicle speed input

Vehicle Design Hauling Trailer Across the Bridge

Modeling hauling trailers in the CSI Bridge V22 program must consider various factors such as dynamic loads, proper load distribution, and structural interaction with the bridge to produce accurate and representative simulations. Here are some views of the vehicle shown in Figures 3.7, 3.8, and 3.9 below.

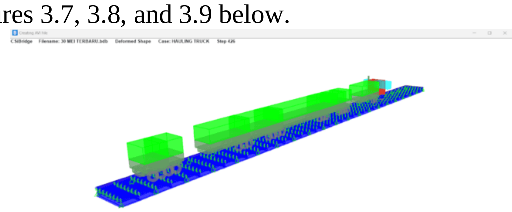

Figure 3. 7 A hauling trailer crosses the weighbridge

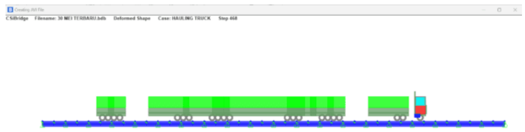

Figure 3. 8 Side view of hauling trailer crossing the weighbridge

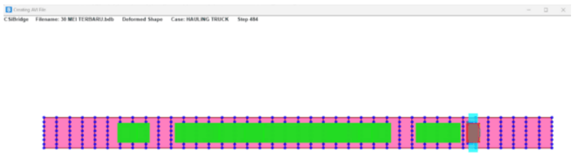

Figure 3. 9 Top views of hauling trailer crossing the weighbridge

3.4. Bridge Structure Analysis Results with CSI Bridge V22.

In this section, we will briefly describe the forces arising from the applied plan loads.

Moment Force

From the results of the analyses carried out using the CSI Bridge V22 software, data were obtained regarding the magnitude of the maximum moment that occurred on span 1 (one) and span 2 (two) of the weighbridge. This data is illustrated in detail in Figures 3.10, 3.11, 3.12, 3.13, 3.14, and 3.15 below. The figures show the moment distribution at various points along the span, providing a clear visual representation of the areas experiencing the highest moments.

1. Moment at span 1

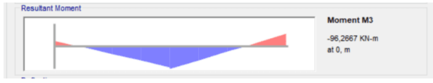

Figure 3. 10 Maximum moments of span 1 at the left end

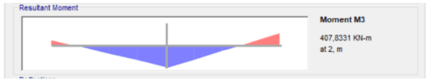

Figure 3. 11 Maximum moment of span 1 at span center

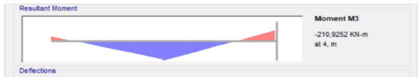

Figure 3. 12 Maximum moments of span 1 at the right end

Based on the analyses conducted, it was found that the maximum moment forces arising due to the maximum load were -96.2667 kN at the left end of span 1, 407.8331 kN at the center of the span, and -210.9252 kN at the right end.

2. Moment at span 2

Figure 3. 13 Maximum moments of span 2 at the left end

Figure 3. 14 Maximum moment of span 2 at span center

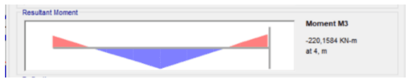

Figure 3. 15 Maximum moments of span 2 at the right end

The analysis results show that the maximum moment forces arising from the maximum load on span 2 are -194.485 kN at the left end, 352.0961 kN at the center of the span, and -220.1584 kN at the right end.

Axial Force

From the results of the analyses carried out with the CSI Bridge V22 software, data were obtained on the magnitude of the maximum axial force that occurred due to the hauling trailer on span 1 (one) and span 2 (two) of the weighbridge. This data is illustrated in detail in Figures 3.16, 3.17, 3.18, 3.19, 3.20, and 3.21 below. The figures show the axial forces at three points along the span, providing a clear visual representation of the areas experiencing the highest axial forces.

1. Axial Force at span 1

e-ISSN: 2723-3944

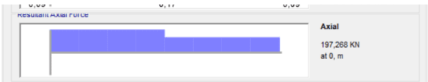

Figure 3. 16 Maximum axial force of span 1 at left end

Figure 3. 17 Maximum axial force of span 1 at span center

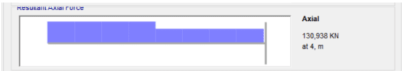

Figure 3. 18 Maximum axial force of span 1 at right end

Based on the analyses conducted, it was found that the maximum axial forces arising from the maximum load were 197.268 kN at the left end of span 1, 197.268 kN at the center of the span, and 130.938 kN at the right end.

2. Axial Force at span 2

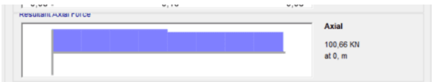

Figure 3. 19 Maximum axial force of span 2 at left end

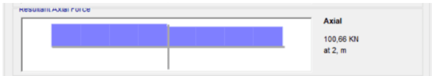

Figure 3. 20 Maximum axial force of span 2 at span center

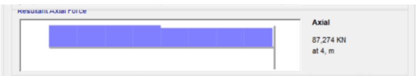

Figure 3. 21 Maximum axial force of span 2 at right end

Based on the analyses conducted, the results show that the maximum axial forces that occur due to the maximum load are 100.66 kN at the left end of span 2, 100.66 kN at the center of the span, and 87.247 kN at the right end.

Mid-span Maximum Deflection

The maximum deflection of the weighbridge was found to be 0.6 mm at the center of the span, indicating the highest load point that affects the stability and overall strength of the weighbridge. This phenomenon occurs because the hauling trailer-type SDT (semi-trailer door tipper) vehicle crossing the weighbridge produces the largest deflection, resulting in maximum deformation. The following are the results of the deflection analysis displayed in the CSI Bridge V22 program as shown in Figure 3.22 below.

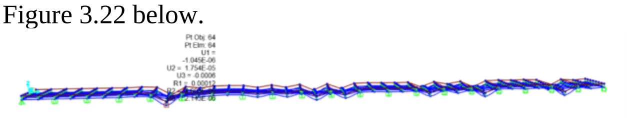

Figure 3. 22 Maximum deflection result of the bridge

Shear Force

The results of the analysis using CSI Bridge V22 software showed that the maximum shear force generated by the SDT (semi-trailer door tipper) hauling trailer when crossing the weighbridge was 315.764 kN. This detail is presented in illustration figure 3.23 below.

Figure 3. 23 Maximum shear force results in the CSI Bridge program

Check the Safety of the Bridge Structure

After a thorough inspection using the CSI Bridge V22 software, the weighbridge was found to be safe against the hauling load of a 400-tonne SDT (semi-trailer door tipper) type trailer. Analyses performed with the software included a detailed evaluation of the material strength, load capacity, and pressure distribution on the bridge. The load difference on the floor plate occurs due to the repeated movement of the wheels. Each time the wheels move and pass over the floor plates, the dynamic load received by the plates changes, causing stress variations at various points.

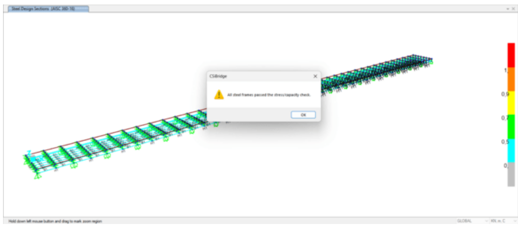

Figure 3. 24 Check the safety of the structure

Bridge Floor Plate Safety Check

Initially assuming an 18 mm thick steel plate with a yield stress (fy) of 290 MPa, it was found that the stresses exceeded the yield limit and the specified allowable stress. To solve this problem, the floor plate was reinforced by thickening it to 60 mm. The aim is to ensure that the steel plate can safely withstand the hauling load of a 400-tonne SDT (semi-trailer door tipper) type trailer, without exceeding the allowable stress limit. The safety results of the floor plate from the simulation using CSI Bridge V22 software can be seen in Figure 3.25 below.

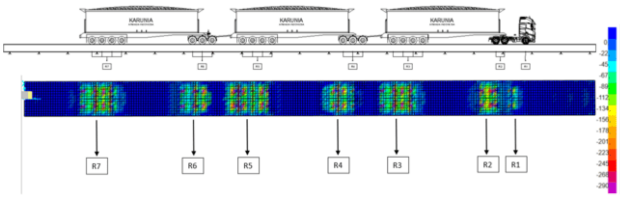

Figure 3. 25 Check floor plate safety

Check Stress Areas

1. Area Stress Step 100

   Based on the results of the analysis that has been carried out, it is obtained that the largest floor plate stress value at Step 100 is -275.92 Mpa with object area 1 fulfilling 95%. It can be concluded that at Step 100, the floor plate is safe because the floor plate does not exceed the yield limit and allowable stress of 290 MPa.

e-ISSN: 2723-3944

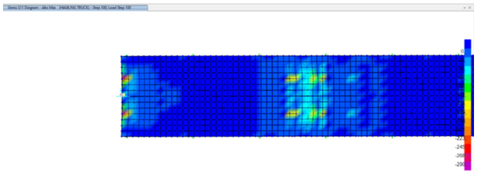

Figure 3. 26 Area stress step 100

1. Area Stress Step 500

Based on the results of the analysis that has been carried out, it is found that the largest floor plate stress value at Step 500 is -212.65 Mpa with an object area of 7 fulfilling 73%. It can be concluded that at Step 500, the floor plate is safe because the floor plate does not exceed the yield limit and allowable stress of 290 MPa.

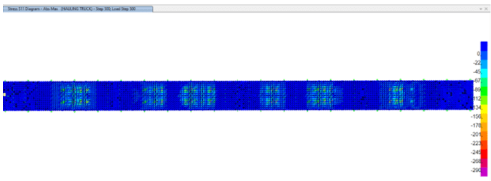

Figure 3. 27 Area stress step 500

4. Conclusions and Suggestions

4.1. Conclusion

Based on the results of calculations and analyses that have been carried out on the data presented above, the following important conclusions can be drawn :

1. The design of the 80-meter span weighbridge is safe against the load of hauling trailer type SDT (semi-trailer door tipper) vehicles and from the results of running analysis using the CSI Bridge V22 program obtained :
   a. The maximum moment force of 407.8331 kN at the center of span 1 and 352.0961 kN at the center of span 2, indicates a significant value in the structural analysis at the center of the two spans.
   b. The maximum axial force of 197.268 kN at the center of span 1 and 100.66 kN at the center of span 2, showed significant values in the structural analysis at the center of the two spans.
   c. The maximum deflection at the center of the bridge span was found to be 0.6 mm.
   d. The simulation and modeling results show that the bridge can withstand the load of SDT-type hauling trailers effectively and efficiently, making it safe and reliable for coal mining purposes.
   e. The analysis results show that the largest floor plate stress value at Step 100 is -275.92 MPa with an object area of 1 fulfilling 95%. This indicates that at Step 100, the floor plate is safe because it does not exceed the yield limit and permit stress of 290 MPa.
2. The results of the calculation obtained the dimensions of the IWF 1000x520x18x31 longitudinal profile and IWF 1000x520x18x31 transverse girder.

4.2. Suggestion

1. For future research, it is necessary to conduct more in-depth planning related to the lower structure of weighbridges that use steel frames. This includes detailed analyses of the foundations and the most suitable materials to ensure the strength and durability of the structure. In addition, it is also important to consider environmental and geographical aspects that may affect the performance of the weighbridge.
2. It is necessary to perform analyses using Midas Civil Software to obtain accurate data on the distribution and amount of loads acting on the bridge. This analysis will provide a detailed comparison so that we can better understand how loads are distributed and affect the bridge structure.

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