

Linear Analysis for Performance Evaluation of Twin Suspension Bridge's Upper Structure (Case Study: Barito Bridge, Barito Kuala Regency)

Kamil Al Kahfi Sobina¹, Ade Yuniati Pratiwi²

*Civil Engineering, Faculty of Engineering Lambung Mangkurat University
Jl. Jenderal Achmad Yani Km 35,5 Banjarbaru, Kalimantan Selatan – 70714
E-mail: ¹kahfisobina@gmail.com; ²ade.pratiwi@ulm.ac.id*

ABSTRACT

Linear analysis using MIDAS CIVIL 2022 GEN V1.2 software was used to evaluate the overall performance and stability of the Barito Bridge structure. This analysis aims to ensure that the structural design meets applicable technical standards and safety aspects. Some of the main parameters analyzed include the self-weight of the structure, the maximum deflection value, the deformed shape, and the internal forces on the main structural elements. Based on the analysis, the self-weight of the structure is 37,150 kN. The framing system consists of clamps on the pylon and main cable, rollers on the saddle, and joints on the deck. The maximum sprung reaction occurred at node 14 amounting to 7,806.47 kN. The maximum displacement generated was recorded at the left Top Chord (TC) of 449.454 mm, the right Top Chord (TC) of 478.175 mm, the left Botom Chord (BC) of 450.694 mm, the right Botom Chord (BC) of 492.333 mm. The analysis results show that the structure is able to withstand the working load with deformation and internal forces that are still within the safe limit of L/800 of 525.625 mm.

Keywords : Linear Analysis, Structural Stability, Suspension Bridge, Deflection Target, Structural Performance

1. INTRODUCTION

The Barito Bridge is a vital construction that connects the west and east banks of the Barito River, as well as connecting South and Central Kalimantan via the Trans Kalimantan Road. The bridge is 1,082 m long, crossing the Barito River and Bakut Island. It consists of a 902m main bridge, 180m approaches, and two suspension bridges of 420.5m each. This bridge design reduces foundation costs and provides traffic-free space. The foundation uses 1.016 m reinforced concrete piles. The superstructure is made of galvanized steel frame and the grade K-350 will be borne by the structure.

Based on the Center for Road and Bridge Research and Development in 2011, explains that condition evaluation is carried out to determine the level of decline in structural conditions caused by structural changes. These changes can be in the form of structural damage that occurs over time (such as corrosion and fatigue), loading (such as increasing traffic loads), accidents, and increasing the age of bridge workers.

This research aims to evaluate the structural capacity through a linear analysis approach, in order to obtain a comparison between the calculated structural capacity and the resulting displacement due to the loading combination based on LRFD Bridge design specifications 9th Edition using MIDAS CIVIL GEN V1.2 software.

2. THEORITICAL FOUNDATION

Suspension Bridge with Stiffeners

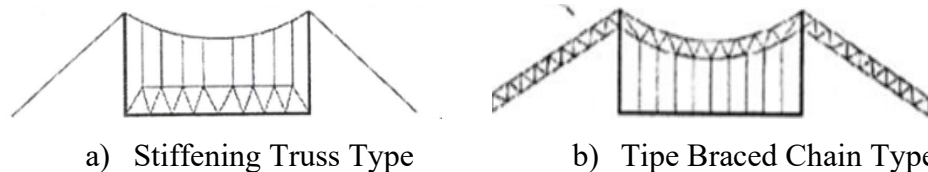
A bridge with stiffeners is a type of suspension bridge where one part of the structure has a straight section that functions to support the traffic floor (deck). The deck on this type of suspension bridge is usually a frame structure. In the calculation of the overall structure, the load from the bridge floor is supported jointly by cables and stiffening girders based on the principle of deflection compatibility (cooperation between cables and decks in supporting deflection). Suspension bridges with stiffeners have two basic general forms, namely:

a) Stiffening truss type

In this type of bridge has a rigid or stiffened part, namely on the straight supporting part of the bridge floor (deck) which is connected to the main cable with a hanger.

b) Braced chain type

In this type, the part that is stiffened or stiffened is the part that serves as the main cable.



Type of Suspension Bridge with Stiffeners

Figure 1. Barito Bridge Structure Components

(Source: Supriyadi dan Muntohar, 2007)

The structural components of the suspension bridge are the stiffening truss and are shown as shown in **Figure 2.** below.



Figure 2. Barito Bridge Structure components

(Source : Personal Documentation)

Load Combination

In this research, the loading used is based on AASHTO LRFD 2020 9th edition. The loading factors are shown in Table 1 :

Table 1. Loading based on AASHTO LRFD 2020 9th edition.

No	Load	AASHTO LRFD 2020 9th edition On the front axle, 35.5 kN, On the rear axle with a distance of 4-9 m is 142 kN.
1	Truck Load “T”	9,3 kPa
2	Uniformly Distributed “D” Load (BTR)	80 kN/m
3	Lane Load “D” centered line (BGT)	3,6 kPa
4	Pedestrian Load (TP)	2670 kN
5	Vehicle Impact Load (TC)	142 kN
6	Fatigue load	AASHTO LRFD 2020 9th edition

Stiffener Structure

The stiffening structure based on Permen PU No. 02/SE/M/2010 includes cables, I-profiles, and trusses.

The inertia of the stiffener girder for the truss-shaped stiffener structure can be calculated by equation (1): For truss-shaped stiffener structures, the inertia of the stiffener girder is calculated by equation (1) :

$$I = A_{bta} \cdot (d_{ta})^2 + A_{btb} \cdot (d_{tb})^2 \quad (1)$$

Description :

I = girder inertia (mm⁴)

Ab_{ta} = top edge bar area (mm²)

Ab_{tb} = bottom edge bar area (mm²)

d_{ta} = distance from girder mass center to top edge (mm)

d_{tb} = distance from girder mass center to bottom edge (mm)

Deflection Target

The deflection due to live load as shown in **Error! Reference source not found.** with an even load acting on one quarter of the main span, is calculated based on the load sharing between the stiffening girder by $(1-\alpha)$ and the main cable by (α) :

$$\Delta' = \frac{5(1-\alpha)PL^4}{12288EI} \quad (2)$$

$$\Delta = \frac{\alpha \left(\frac{P}{8}\right)}{w + \alpha \left(\frac{P}{2}\right)} d \quad (3)$$

Description :

Δ' = lendutan gelagar pengaku pada seperempat bentang (m)

Δ = lendutan kabel pada seperempat bentang (m)

α = fraksi beban yang menunjukkan proporsi beban hidup yang ditahan oleh kabel, yang besarnya diperoleh dari $\Delta' = \Delta$

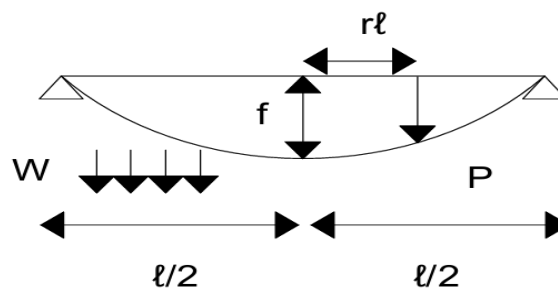


Figure 3. Live load centered on cable

(Source : Irawan et al, 2011)

1. METHODS

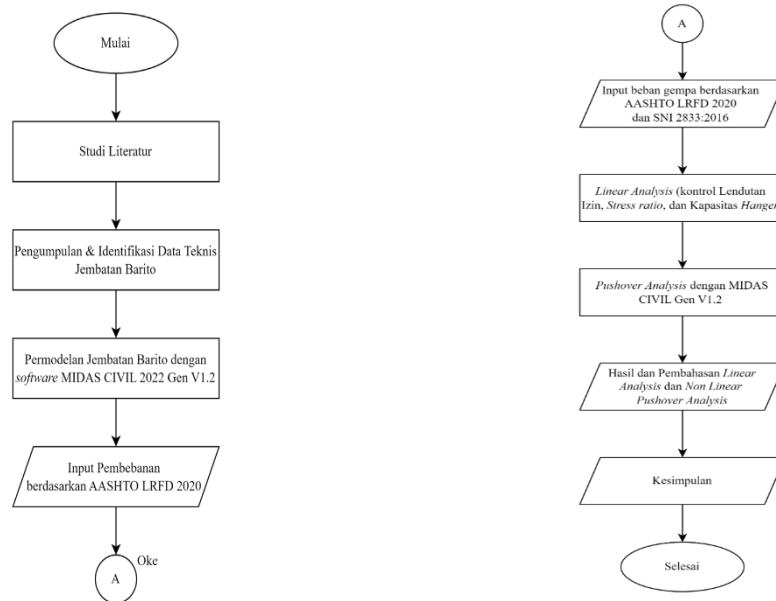


Figure 4. Research flowchart

Figure 4 This research begins with a literature study stage to obtain the theoretical basis and references related to the evaluation of the performance of suspension bridge structures, especially the Barito Bridge. Furthermore, the collection and identification of technical data for the Barito Bridge which includes geometric information, materials, and structural systems. The next stage is modeling the bridge structure using MIDAS CIVIL 2022 GEN V1.2 software, then continued with loading input based on the AASHTO LRFD 2020 9th edition standard and earthquake loads entered according to the provisions of SNI 2833: 2016.

4. RESULTS AND DISCUSSION

Self Weight of Structure

SECTION NAME	ID	MATERIAL TYPE	NAME	DENSITY	LENGTH	PAINT AREA INNER	PAINT AREA OUTER	WEIGHT
Cable	1	U Cable		8.107e+01	1.773e+03	0.000e+00	1.465e+03	7.807e+03
Hanger	2	U Hanger		7.709e+01	1.502e+03	0.000e+00	1.887e+02	1.455e+02
Deck	3	C Deck		2.356e+01	4.230e+02	0.000e+00	1.006e+04	2.216e+04
Pylon Bracing	4	U Pylon		7.698e+01	1.347e+02	1.316e+02	1.371e+02	6.826e+01
Bottom Bracing (BB)	5	S Baja		7.709e+01	1.182e+03	7.655e+02	8.130e+02	3.894e+02
Bottom Chord (BC)	5	S Baja		7.709e+01	8.461e+02	0.000e+00	1.899e+03	1.416e+03
Cross Girder (CG)	5	S Baja		7.709e+01	1.574e+03	0.000e+00	3.731e+03	2.003e+03
Diagonal Chord (DC)	5	S Baja		7.709e+01	1.083e+03	0.000e+00	1.933e+03	9.474e+02
Diagonal Chord CTD (	5	S Baja		7.709e+01	2.007e+03	0.000e+00	7.225e+02	2.129e+02
Stringer (ST)	5	S Baja		7.709e+01	1.692e+03	0.000e+00	2.423e+03	1.050e+03
Top Bracing (TB)	5	S Baja		7.709e+01	1.032e+03	0.000e+00	7.428e+02	3.321e+02
Top Chord (TC)	5	S Baja		7.709e+01	8.461e+02	0.000e+00	1.591e+03	6.066e+02
Vertical Chord (VC)	5	S Baja		7.709e+01	1.040e+01	0.000e+00	1.647e+01	9.685e+00
SUMMATION :					1.410e+04	8.971e+02	2.572e+04	3.715e+04

Figure 5. Bill of Material Jembatan Barito, Kabupaten Barito Kuala

Based on the results of the Bill of materials, the weight of the barito bridge structure W_t is 37,150 kN, or 3,715 tons.

Deformed Shape

Based on the results of the analysis generated by the loading combination. Barito Bridge has a deformed shape in the x direction and y direction as shown in Figure 6.

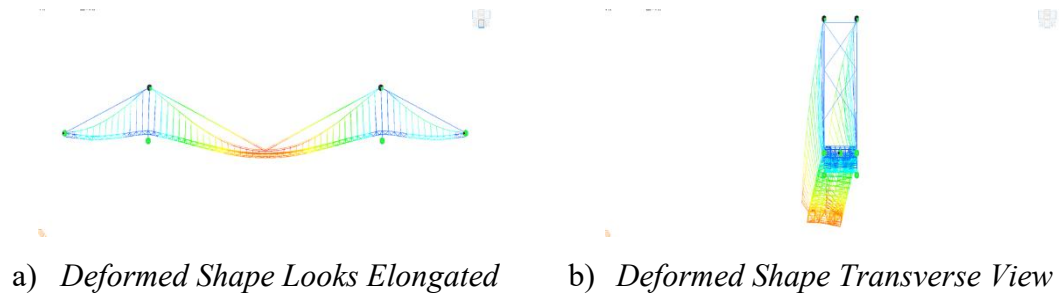


Figure 6. Deformed Shape of Barito Bridge

Placement Reaction

Barito Bridge has a movement reaction on the Pylon and Main Cable, namely pinch, Saddle using rollers, and Deck using joints. With the results of the maximum movement reaction located at Node 14 with a Dynamic Strong load (Truck) of 7,806.47 kN.

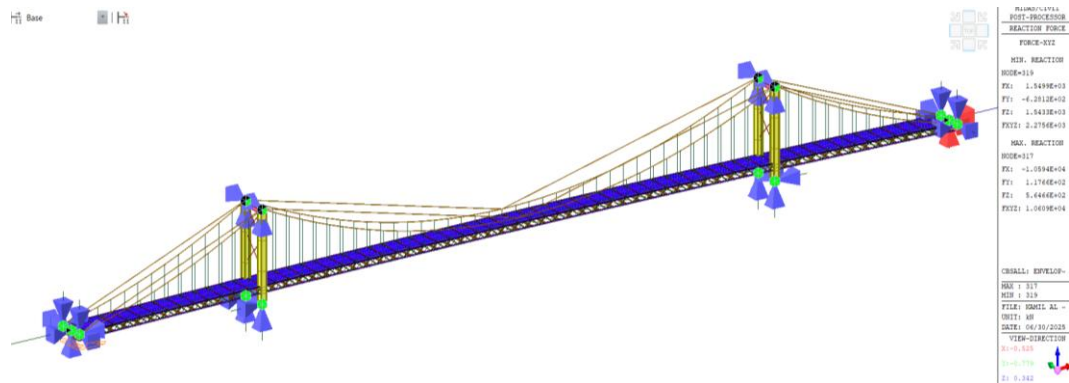
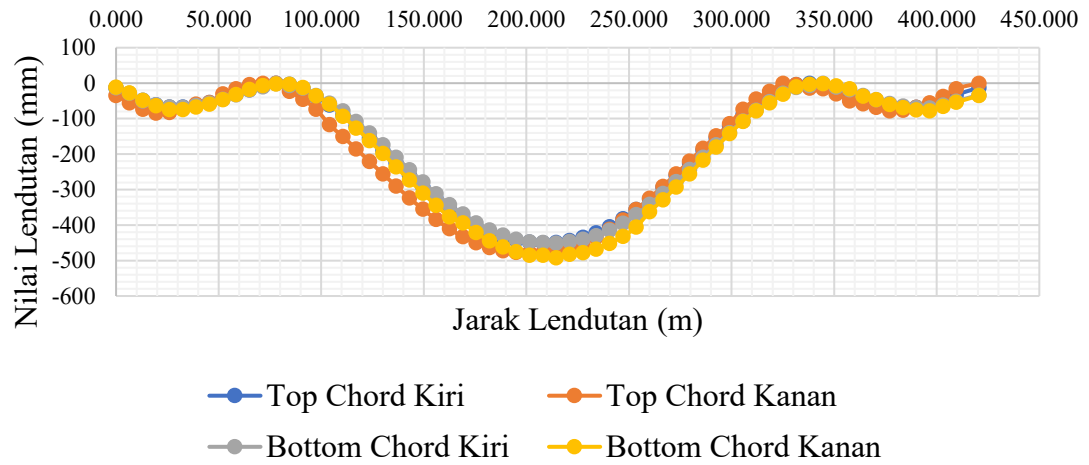


Figure 7. Placement Reaction Result

Displacement

After the model and loading are complete, perform analysis on the MIDAS CIVIL 2022 GEN V1.2 program with the following results. In order to know the value of deflection in each combination, the review is done at one point with the largest deflection at node 1044 with the review done on Top Chord Left, Top Chord Right, Bottom Chord Left, Bottom Chord Right with the following results: Bottom Chord Right with the following results:



Gambar 1. Recapitulation of Deflection Values on Longitudinal Girders

The largest deflection values that occur in the longitudinal girder in the 5 Truck Strong Combination (Dynamic) based on AAASHTO LRFD 2020 are 449.45 mm, 478.17 mm, 450.69 mm, and 492.33 mm at mid-span.

Deflection Control

Based on the results of the internal force and displacement. Then, deflection control is carried out to determine the capacity of the Barito Bridge, with the following calculations:

$$\begin{aligned}
 \text{Control} &= 492,33 < \frac{L}{800} \\
 &= 492,33 < \frac{L}{800} \\
 &= 492,33 < \frac{420.500}{800} \\
 &= 492,33 < 525,625 \text{ (Eligible)}
 \end{aligned}$$

Based on the provisions with L is the length of the span, so the deflection on the Barito Bridge meets the allowable deflection of 492.33 mm < 525.625 mm.

2. CONCLUSION

Based on the results of the analysis, the following conclusions can be drawn:

1. The total weight of the Barito Bridge structure obtained in the MIDAS CIVIL GEN V.1.2 software is 3,715 tons with a vibration period (T) of 4.

2. Meanwhile, based on the deflection control results, the maximum deflection value is 492.33 mm which is still below the permit limit of 525.625 mm, so the structure is declared safe and meets the permit deflection.
3. Based on the results of linear analysis due to earthquake loads, the displacement value in the maximum X direction at node 1276 is 0.481 mm and the displacement in the maximum y direction at node 1276 is 7.62 mm.

REFERENCES

- AASHTO, 2020. *LRFD Bridge design specifications 9th Edition*. American Association Of State Highway And Transportation Officials (AASHTO).
- Badan Standardisasi Nasional Indonesia, 2016. *Pembebanan untuk Jembatan*. , pp. 1-63
- Badan Standardisasi Nasional Indonesia, 2016. *Perencanaan Jembatan Terhadap Beban Gempa*, pp. 1–60.
- Chen, W. F., dan Duan, L. (2014). *Bridge Engineering Handbook, 2nd edition Superstructure design*. CRC Press, pp. 1-716.
- Kementerian Pekerjaan Umum, 2010. Surat Edaran Menteri Pekerjaan Umum No. 02/SE/M/2010 tentang Pemberlakuan Pedoman Perencanaan dan Pelaksanaan Konstruksi Jembatan Gantung Untuk Pejalan Kaki.
- Kementerian Pekerjaan Umum (2011). Surat Edaran Menteri Pekerjaan Umum No. No.005/02/P//BM/2011 tentang Pedoman Pemeliharaan Rutin Jembatan Suspensi.
- Pusat Litbang Jalan dan Jembatan, 2011. *Perencanaan Teknis Jembatan Gantung*, pp. 1-88
- Pusat Litbang Jalan dan Jembatan, 2011. *SISTEM MONITORING KESEHATAN STRUKTUR-PENILAIAN KONDISI DAN KRITERIA PERALATAN MONITORING*, pp. 1-74
- Supriyadi, B. dan Muntohar, A.S, 2007. *Jembatan (Edisi Pertama)*, pp. 1–244.
- Suarjana, M., & Budiharto, P. (2023). *Evaluasi Kinerja Struktur Jembatan Kabel Pancang Pasupati Bandung*. Jurnal Teknik Sipil, pp. 367-378.