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# Amay Bridge Assessment in Busang District, East Kutai Regency

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***Abstract*—*The assessment of the Amay Bridge, located in the PT. HPM – SAWA area in Busang District, East Kutai Regency, Indonesia, was conducted to evaluate and analyze the condition of the bridge. Built in 2021, the Amay Bridge is a composite structure combining a steel frame and girder system, with a total span of 120 meters and a width of 5.5 meters. The bridge serves as a transportation route for delivering oil palm plantation products to the processing plant. The assessment began with situational and dimensional measurements, as well as the evaluation of the bridge's geometry. Additionally, material testing was conducted, including hammer tests, rebar scanning, and ultrasonic thickness measurements. The results of these tests provided essential data for structural analysis using the SAP2000 software. Deflection measurements and static load tests were also carried out to determine the deflection occurring on the bridge. Based on structural analysis and load testing, the deflection was found to remain within the allowable limit (<L/800). However, the stress ratio approached the maximum limit of 1, with a recorded value of 0.950. Preventive measures, such as limiting vehicle volume, load, and speed, are recommended to ensure the bridge's continued safe, reliable, and secure operation.*

***Keywords*— *Bridge Assessment, Bridge Deflection, Stress Ratio.*

## I. INTRODUCTION

The Amay Bridge was constructed over a river in the PT. HPM – SAWA area, located in Busang District, East Kutai Regency (Fig. 1). This bridge features a span of 120 meters (30 m girder + 60 m steel truss + 30 m girder) and a width of 5.5 meters. Built in 2021, it functions as a transportation route for palm oil plantation products to the processing plant. Observations of swaying during crossings and instances of deflection prompted a structural strength evaluation to ensure the bridge's safety and performance.

Fig. 1. Amai Bridge.

The Amay bridge assessment began with a field survey, measuring the dimensions and geometry of the bridge. Material quality tests and static load tests were also conducted. Data collected from these measurements and tests were used in structural analysis performed with SAP2000. From the results of the measurements, static loading test, and structural analysis, the bridge deflection value was obtained as a basis for determining solutions to the condition of the Amay bridge which swayed when passed.

## II. LITERATURE REVIEW

Bridges can be defined as a construction designed to cross natural obstacles such as rivers, valleys, or cliffs. The main purpose of building a bridge is to connect two points separated by the obstacle, thus allowing easier and faster access for humans, vehicles, and goods. Bridges can be built with various materials, such as wood, iron, steel, concrete, or a combination of several type of materials.

According to the Bridge Management System (BMS), bridges should be assessed at least once a year. One of the checks that must be carried out is a load test. There are several methods of bridge load testing, one of which is a static load test. The purpose of a static load test is to obtain the amount of deflection and strain of the bridge structure in a measurable and controlled manner (Setiati & Surviyanti, 2013).

A bridge characterizes two different types of deformation, namely long-term movement caused by the foundation, bridge deck and strain pressure and short-term movement caused by wind, temperature, tide, earthquake, and traffic. Unlike long-term bridge deformation that cannot return to its original shape, short-term bridge deformation is called deflection. It is called deflection because the deformed object will return to its original position and shape if released from all its loads (Meng, 2002). According to Nawy (2010), deflection or what is often called deflection, is caused because the beam section is given a load. Deflection depends on the load (w) and the length of the beam span (L) and is inversely proportional to the stiffness of the beam. Stiffness is based on the type of material used, namely the modulus of elasticity (E) and the magnitude of the cross-section, namely the moment of inertia (I). Deflection is a function of the span length, placement, or support, type of loading and the bending stiffness EI of the element.

Based on RSNI T-03-2005 concerning Steel Structure Planning for Bridges, the deflection allowable limit is calculated using (1):

$$\Delta = L/800 \qquad (1)$$

With:

L = the length of the bridge span

The allowable deflection limit becomes the bridge tolerance limit from the results of the deflection measurement in the bridge load test.

## III. Research Methodology

In general, the research method used is described in the following steps:

### A. Data Collection

1) *Bridge Dimension and Geometric Measurement using:*
   - Total station
   - Sigmatee
   - Measuring tape

2) *Bridge Material Testing*
   - Hammer test, to determine the quality characteristics of concrete on the bridge section made of concrete.
   - Sigmate, to determine the location and position of reinforcing steel in concrete construction.
   - Ultrasonic thickness gauge, to determine the thickness of steel material

3) *Bridge Deflection Measurement using Static Load*
   - Zero load condition
   - Gradual loading condition

### B. Structural Analyze

Structural modeling and bridge loading simulation based on material test data using SAP2000.

### C. Conclusions and Suggestions

Structural modeling and bridge loading simulation based on material test data using SAP2000.

## IV. Research Results And Explanation

### A. Material Testing

1) *Hammer Test, conducted on floor slabs and bridge girders with a total of 19 test points.*

Fig. 3. Hammer test execution on bridge floor slab.

Results of 19 points hammer test shown in table 1.

TABLE I. Hammer test results.

| Point No. | Hammer Test | | Concrete Age (Day) | Concrete Quality |
|---|---|---|---|---|
| | MPa | kg/cm$^2$ | | |
| G I | 40.485 | 412.825 | +28 | K300 |
| PII | 33.160 | 338.134 | +28 | K300 |
| GIV | 31.989 | 326.190 | +28 | K300 |
| ABII | 45.273 | 461.651 | +28 | K300 |
| PIV | 41.339 | 421.534 | +28 | K300 |
| ABII | 39.057 | 398.263 | +28 | K300 |
| GII | 33.460 | 341.187 | +28 | K300 |
| GIII | 36.707 | 374.298 | +28 | K300 |
| GIV | 36.805 | 375.299 | +28 | K300 |
| GV | 39.623 | 404.032 | +28 | K300 |
| PI | 38.052 | 388.018 | +28 | K300 |
| GVII | 42.403 | 432.383 | +28 | K300 |
| GVIII | 42.296 | 431.287 | +28 | K300 |
| ABIV | 36.886 | 376.127 | +28 | K300 |
| PIII | 37.281 | 380.153 | +28 | K300 |
| GIX | 34.520 | 352.003 | +28 | K300 |
| GX | 39.755 | 405.385 | +28 | K300 |
| GXI | 36.060 | 367.707 | +28 | K300 |

From the Hammer Test, it was found that the quality of the bridge concrete was f'c = 25 MPa or equivalent to K300.

2) *Measurement of Situation, Geometry and Dimension of Bridge Elements.*

a. Measurement using total station, sigmate, roll meter and Ultrasonic Thickness Gauge

Fig. 4. Bridge situation and geometry measurement using total station.

Fig. 5. Measurement of steel profile using sigmate.



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Fig. 6. Measurement of steel profile using ultrasonic thickness gauge.

The results of the bridge element dimension measurements are shown in the following table of (2) and (3).

TABLE 2. Steel profiles of steel truss bridge.

| No. | Type | Dimension | Quantity (pcs) | Distance between girders (m) |
|---|---|---|---|---|
| 1 | Longitudinal girder (GM) | WF 350x350x13,38x14,84 | 48 | 1.5 |
| 2 | Transversal girder (GMT) | WF 450x200x9x16 | 13 | 5.0 |
| 3 | Diagonal truss frame (BSD) | WF 350x350x13,38x14,84 | 48 | |
| 4 | Upper truss frame (BSA) | WF 350x350x13,38x14,84 | 22 | |
| 5 | Lower truss frame (BSB) | WF 350x270x9,09x13,01 | 24 | |
| 6 | Wind ties (BIA) | WF 125x125x6,5x9 | 22 | |

TABLE 3. Steel profiles of girder bridge.

| No. | Type | Dimension | Quantity (pcs) | Distance between girders (m) |
|---|---|---|---|---|
| 1 | Longitudinal girder (GM) | WF 1400x325x11,4x21,2 | 3 | 2 |
| 2 | Horizontal bracing (L1) | L 70x70x7 | 7 | 4.5 – 5 |
| 3 | Diagonal bracing (L2) | L 60x60x6 | 7 | 4.5 – 5 |

*B. Deflection with Structural Analysis*

The bridge loading consists of self-weight, additional dead loads, and live loads. The self-weight includes the deck slab, steel truss, longitudinal girders, and cross girders of the bridge. Additional dead loads consist of concrete sidewalk loads, while live loads include a truck load weighing 10.50 tons. The structural analysis was performed twice: once for the girder bridge and once for the truss bridge. The assumptions and limitations applied in the analysis are as follows:

- The three-dimensional modeling of the bridge structure was conducted using SAP2000 software.
- Steel truss elements, longitudinal girders, cross girders, and bracing were modeled as frame elements, while the deck slab was modeled as an area element.
- Bridge supports were modeled as hinge-roller connections.
- Dead loads include the self-weight, additional dead loads, and other supporting elements.

The permissible deflection limits (Δ) for the truss bridge with a span of 60 m and the girder bridge with a span of 30 m are as follows:

Δ Girder bridge = 3000/800 = 3.75 mm
Δ Truss bridge = 6000/800 = 7.50 mm

1) *Girder Bridge*

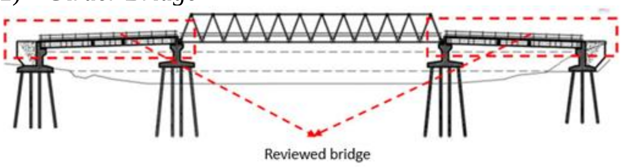


Fig. 7. Layout of girder bridge.

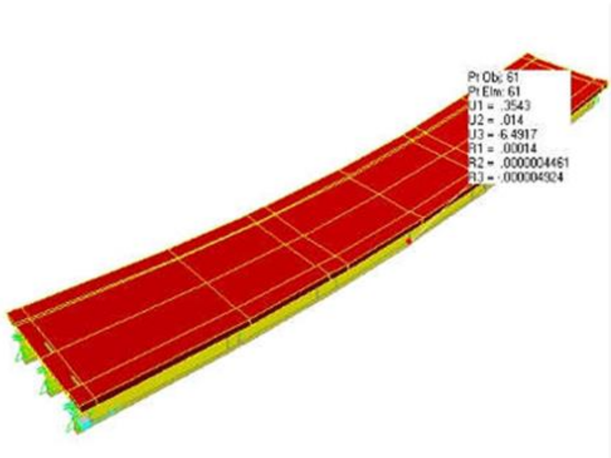


Fig. 8. Deflection at condition R4 load 3 trucks = 6.49 cm.

TABLE 4. Deflection value of girder bridge.

| No. | Condition | Load Combination | Run Result (Frame Ratio) | Maximum Deflection (cm) | Deflection (cm) | Correction to Chamber (cm) | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | R1: Existing (No load) | 1.2D | 0.671 | 3.88 | 4.64 | - | chamber |
| 2 | R2: 1 truck load | 1.2D+1.6L | 0.795 | 3.88 | 5.41 | 0.77 | |
| 3 | R3: 3 trucks load | 1.2D+1.6L | 0.888 | 3.88 | 6.12 | 1.48 | |
| 4 | R4: 4 trucks load | 1.2D+2L | 0.950 | 3.88 | 6.49 | 1.85 | |

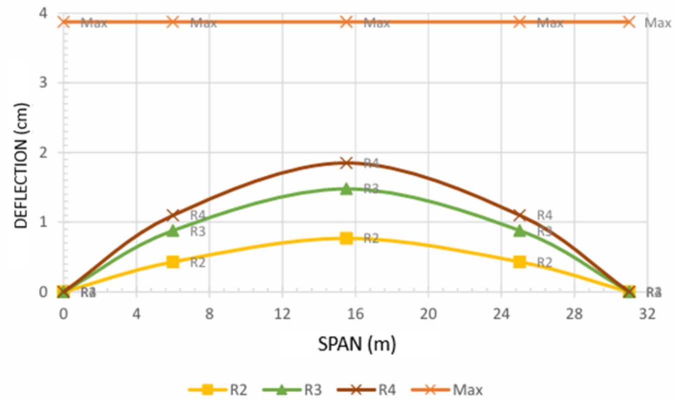

Fig. 9. Deflection graph of girder bridge.

2) *Steel Truss Bridge*

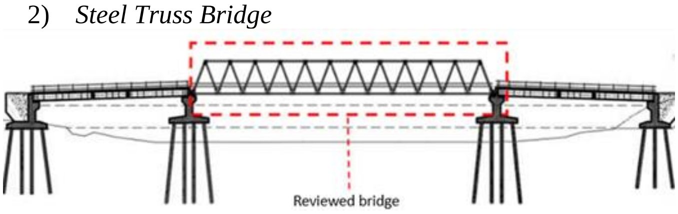

Fig 10. Layout of steel truss bridge.

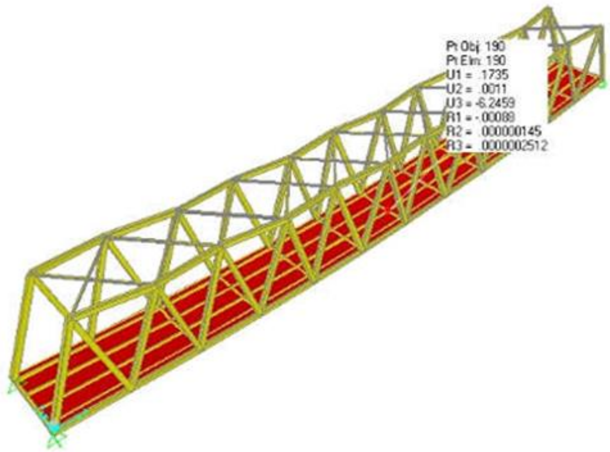

Fig. 11. Deflection at condition R4 load 3 trucks = 6.24 cm.

TABLE 5. Deflection value of steel truss bridge.

| No. | Condition | Load Combination | Run Result (Frame Ratio) | Allowed Deflection (cm) | Bridge Deflection (cm) |
|---|---|---|---|---|---|
| 1 | R1: Existing (No load) | 1.2D | 0.547 | 7.50 | 5.28 |
| 2 | R2: 1 truck load | 1.2D+1.6L | 0.600 | 7.50 | 5.76 |
| 3 | R3: 3 trucks load | 1.2D+1.6L | 0.628 | 7.50 | 6.05 |
| 4 | R4: 4 trucks load | 1.2D+2L | 0.647 | 7.50 | 6.24 |

From Table 4 and Table 5 also Figure 9 and Figure 12 it is obtained that the greater the load acting on the bridge, the greater the deflection that occurs. The maximum deflection occurs in the middle of the span, which is 6.49 cm on the girder bridge and 6.24 on the frame bridge.

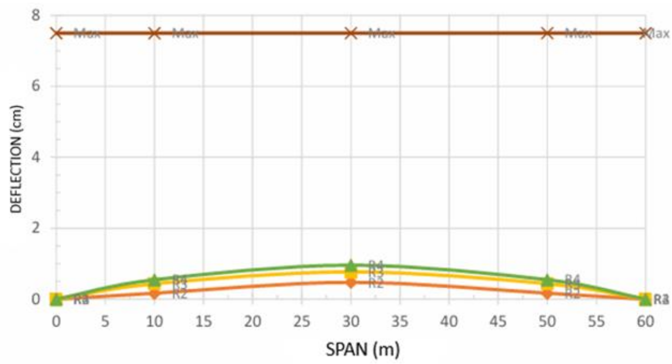

Fig. 12. Deflection graph of steel truss bridge.

### C. *Deflection with Static Loading Test*

Static loading test was conducted using 3 (three) trucks each loaded with a weight of 10.5 tons. Trucks were distributed to a number of points to represent the actual traffic load passing through the bridge. Static loading test began with the bridge in a condition without truck load. Furthermore, the addition of truck loads was given gradually from 1 (one) truck to 3 (three) trucks running in tandem, as shown in the following image.


Fig. 13. Illustration of a load of 3 trucks @ 10.5 tons on the girder bridge.

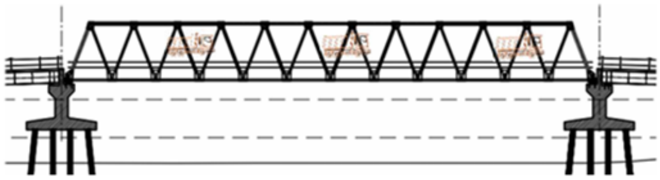
Fig. 14. Illustration of a load of 3 trucks @ 10.5 tons on the steel truss bridge.

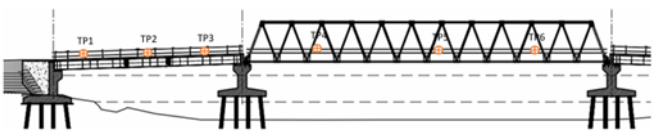

Fig. 15. Observation point locations on the bridge.

Optical leveling measurements using a total station tool begin with reading the backsight marker placed at point TP2. The next leveling measurement is to each monitoring point. The deflection value is obtained from the difference in distance between the position when the bridge is unloaded and when the bridge is loaded with a truck. The amount of deflection that occurs on the girder bridge and the frame bridge is presented in Table 6 and Table 7 as follows.

TABLE 6. Deflection measurement results of girder bridge.

| No. | Description | UTM-WGS-84 (50-5) | | | Code | Deflection (cm) | Remarks |
|---|---|---|---|---|---|---|---|
| | | x | y | z | | | |
| **Monitoring point 1** | | | | | | | |
| 1 | Girder 1 | 85359.232 | 455956.339 | 30.064 | BREM.1.B.0 | 1.5 | 0 Load |
| 2 | Girder 1 | 85359.232 | 455956.346 | 30.049 | BREM.1.B.1 | | Load of 1 Truck |
| | | | | | | | |
| 1 | Girder 1 | 85359.232 | 455956.339 | 30.064 | BREM.1.B.0 | 2.1 | 0 Load |
| 2 | Girder 1 | 85359.222 | 455956.343 | 30.043 | BREM.1.B.2 | | Load of 2 Trucks |
| | | | | | | | |
| 1 | Girder 1 | 85359.232 | 455956.339 | 30.064 | BREM.1.B.0 | 2.4 | 0 Load |
| 2 | Girder 1 | 85359.223 | 455956.344 | 30.040 | BREM.1.B.3 | | Load of 3 Trucks |
| | | | | | | | |
| **Monitoring point 2** | | | | | | | |
| 1 | Girder 2 | 85346.050 | 455946.119 | 30.089 | BREM.2.B.0 | 2.4 | 0 Load |
| 2 | Girder 2 | 85346.052 | 455946.123 | 30.065 | BREM.2.B.1 | | Load of 1 Truck |
| | | | | | | | |
| 1 | Girder 2 | 85346.050 | 455946.119 | 30.089 | BREM.2.B.0 | 2.8 | 0 Load |
| 2 | Girder 2 | 85346.048 | 455946.114 | 30.061 | BREM.2.B.2 | | Load of 2 Trucks |
| | | | | | | | |
| 1 | Girder 2 | 85346.050 | 455946.119 | 30.089 | BREM.2.B.0 | 2.2 | 0 Load |
| 2 | Girder 2 | 85346.047 | 455946.116 | 30.067 | BREM.2.B.3 | | Load of 3 Trucks |
| | | | | | | | |
| **Monitoring point 3** | | | | | | | |
| 1 | Girder 3 | 85346.049 | 455946.120 | 30.089 | BREM.1.B.0 | 1.7 | 0 Load |
| 2 | Girder 3 | 85346.052 | 455937.662 | 30.072 | BREM.3.B.1 | | Load of 1 Truck |
| | | | | | | | |
| 1 | Girder 3 | 85346.049 | 455946.120 | 30.089 | BREM.1.B.0 | 2.5 | 0 Load |
| 2 | Girder 3 | 85335.558 | 455937.661 | 30.064 | BREM.3.B.2 | | Load of 2 Trucks |
| | | | | | | | |
| 1 | Girder 3 | 85346.049 | 455946.120 | 30.089 | BREM.1.B.0 | 1.8 | 0 Load |
| 2 | Girder 3 | 85335.557 | 455937.661 | 30.071 | BREM.3.B.3 | | Load of 3 Trucks |

TABLE 7. Deflection measurement results of steel truss bridge.

| No. | Description | UTM-WGS-84 (50-5) | | | Code | Deflection (cm) | Remarks |
|---|---|---|---|---|---|---|---|
| | | x | y | z | | | |
| **Monitoring point 1** | | | | | | | |
| 1 | Steel 1 | 85334.880 | 455935.975 | 30.748 | BAJA.1.B.0 | 0.95 | 0 Load |
| 2 | Steel 1 | 85334.881 | 455935.976 | 30.653 | BAJA.1.B.3 | | Load of 3 Trucks |
| | | | | | | | |
| **Monitoring point 2** | | | | | | | |
| 1 | Steel 2 | 85313.101 | 455918.959 | 31.002 | BAJA.2.B.0 | 1.1 | 0 Load |
| 2 | Steel 2 | 85313.108 | 455918.957 | 30.892 | BAJA.2.B.3 | | Load of 3 Trucks |
| | | | | | | | |
| **Monitoring point 3** | | | | | | | |
| 1 | Steel 3 | 85288.004 | 455899.125 | 30.772 | BAJA.3.B.0 | 0.93 | 0 Load |
| 2 | Steel 3 | 85288.017 | 455899.115 | 30.679 | BAJA.3.B.3 | | Load of 3 Trucks |

## V. CONCLUSION

From this research, it can be concluded that:

1. The maximum deflection of the girder bridge from structural analysis using SAP2000 occurs at the mid-span when three trucks cross the bridge. The maximum deflection is 1.85 cm, which is less than the allowable deflection of 3.75 mm.
2. The maximum deflection of the truss bridge from structural analysis using SAP2000 occurs at the mid-span when three trucks cross the bridge. The maximum deflection is 6.49 mm, which is less than the allowable deflection of 7.50 mm.
3. The maximum deflection of the girder bridge from static loading test occurs at the mid-span when two trucks cross the bridge. The maximum deflection is 2.8 mm, which is less than the allowable deflection of 3.75 mm.
4. The maximum deflection of the truss bridge from static loading test occurs at the mid-span when three trucks cross the bridge. The maximum deflection is 11 mm, which exceeds the allowable deflection of 7.50 mm.
5. The deflection observed in the girder section of the Amay Bridge is within safe limits, whereas the deflection in the truss section exceeds the allowable deflection.

## VI. RECOMMENDATION

1. The Amay Bridge can still be passed but it is necessary to limit the volume, loads, and speed of vehicles so that the deflection and stress ratio do not increase further.
2. Reinforcement can be done on the frame section, for example by providing external prestressing without support rods and external prestressing with support rods.

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