

# Experimental and analytical assessment of 60 m steel truss bridge

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**Abstract.** The experimental test was conducted on a new 60 m Steel Truss Bridge at Lumajang East Java. The Purpose of the test to observe the actual condition of the bridge before use for regular traffic. The static and dynamic loading test were applied. For static loading 63% of live load was applied. Several test instruments were installed to record all data during testing. Seven stages of loading were performed during static loading test. The structural analysis also performed as comparison with the experimental result. The experimental test and analytical study showed that the Steel Truss Bridge provides good performance refers to current Indonesian code.

## 1 Introduction

The bridges are essential since the failure of a bridge can disrupt the regular traffic, with the result that causes economic loss and inconvenience to the community. It is prominent that particular attention is performed to the inspection of bridges as part of the management within the road system. The objective of bridge inspection is to ensure the safety of public and protection of the capital investment in bridges. Data for Bridge Inspections is utilized to plan maintenance, rehabilitation, strengthening and replacement of the bridge. Directorate General Highways Ministry of Public Works of Republic Indonesia has developed Bridge Management System (BMS) to enable bridge activities to be planned, executed and monitored under the overall policy. The activities involved in BMS are from inspections, planning, programming and design through to construction and maintenance.

East Java Provincial Government built Kalimujur Bridge to provide an alternative route between Lumajang city and Jember city. This bridge is crossing mujur river Lumajang. The bridge consists of four approach bridges and one main bridge. The approach bridges are steel truss bridges with a span of 60m while the main bridge is the arch steel bridge with a span of 128 m. The construction processes were ended in 2016. Before the bridge used for regular traffic, the loading test and structural assessment were conducted to observe the actual condition of the bridge structure. This inspection only performed at one Approach Bridge near Lumajang City. The requirement for inspection, investigation, and loading test

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were based on BMS[1, 2], Directorate General Higways[3] and AASHTO[4] since the objective of bridge loading test is to obtain the actual load capacity of the bridge and guarantee safety services below the traffic load. The loading test that applied on bridge structure should not create any damage or failure of the bridge. During the loading test, any damage such as cracking or spalling on concrete should not occur. The maximum bridge deflection and stress or strain on structural members should be a control on the permissible range.

Several researchers [5-6] have been conducted structural assessment and load testing in concrete and steel bridges. Old and historical bridges dominated all cases study that reported. On this study, the Kalimujur bridge was tested before opened for regular traffic. The loading procedure includes static and dynamic loading test. The loading test results were compared with the result from structural analysis to provide a comprehensive report.

## 2 Experimental program

### 2.1 Bridge design

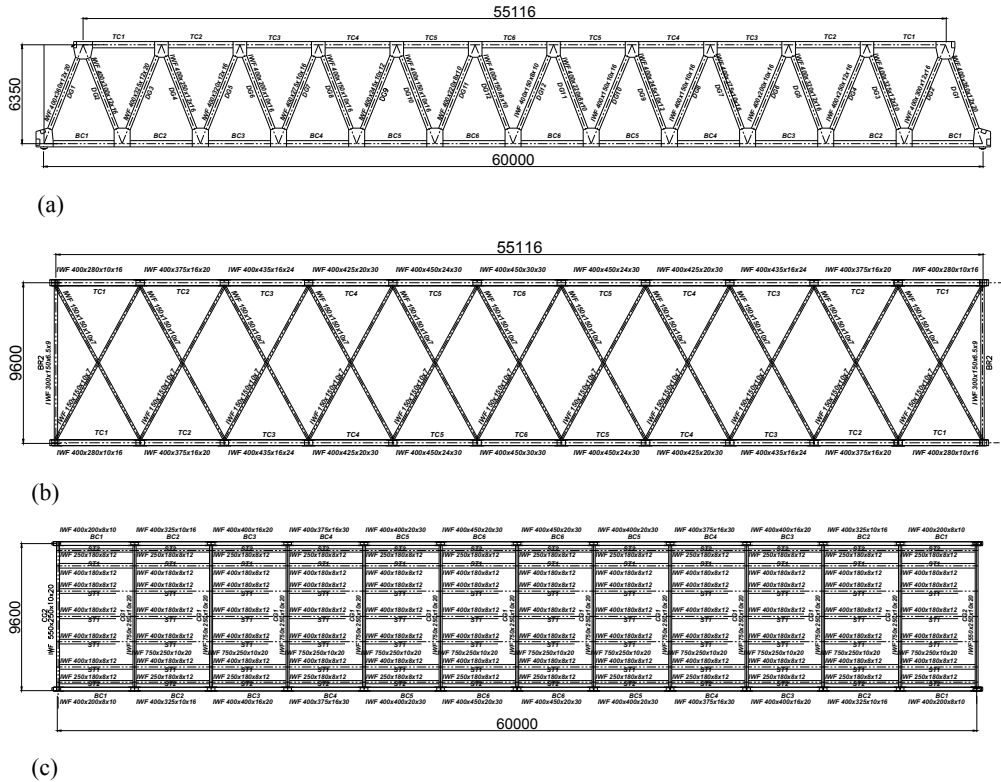


**Fig. 1.** The approach bridge of Kalimujur Bridges.

The approach bridges of Kalimujur Bridges were Truss Steel Bridge with a span of 60 m. The bridge plant-top chord bracing, plant bottom chord bracing and elevation can be seen in Fig. 1. The IWF steel profiles are utilized for the bridge. The bottom chords, diagonal and upper chord uses IWF 400 (Fig. 2). The IWF 250 and IWF 400 are applied for the stringers. The upper bracing and floor beam utilize IWF 150 and IWF 750, respectively. The bridge was designed with ss400 and SM490YB steel (Table 1).

**Table 1.** Specification of steel materials.

Notation	Yield strength (MPa)			Tensile strength (MPa)
	Thickness of rolled Steel			
	< 16 mm	16 mm to 40 mm	> 40 mm	
Ss 400	245 min	245 min	215 min	400 to 510
SM 490YB	365 min	365 min	336 min	490 to 610

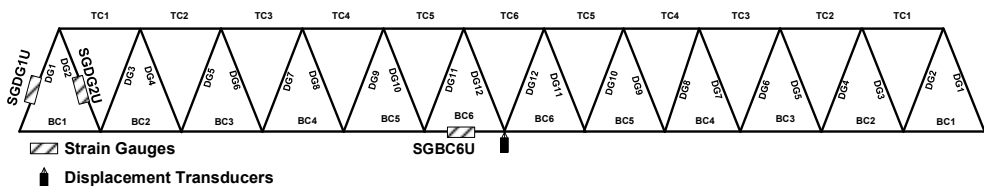


**Fig. 2.** The steel truss of Kalimujur bridge (a) Elevation; (b) Plant-top chord bracing (b) Plant-bottom chord caption.

The ss 400 steel has minimum yield strength range from 215 MPa to 245 and tensile strength range from 400 MPa to 510 MPa. The SM 490YB steel has minimum yield strength range from 335 MPa to 365 MPa and tensile strength from 490 to 610 MPa. The SM 490YB steel is the material specification for IWF 250, IWF 400, IWF 750, and Plate gusset. The ss 400 steel is the material specification for IWF 150 and Plate tell. The compressive strength specification for concrete deck bridge is 30 MPa.

**2.2 Test instruments**

The loading tests consisted of static loading test and dynamic loading test. Several instruments were used to monitor the bridge during the loading test. The instrument such as strain gauge, displacement transducers, data logger and the total station was used to observe the bridge in the course of static loading test (Fig. 3).

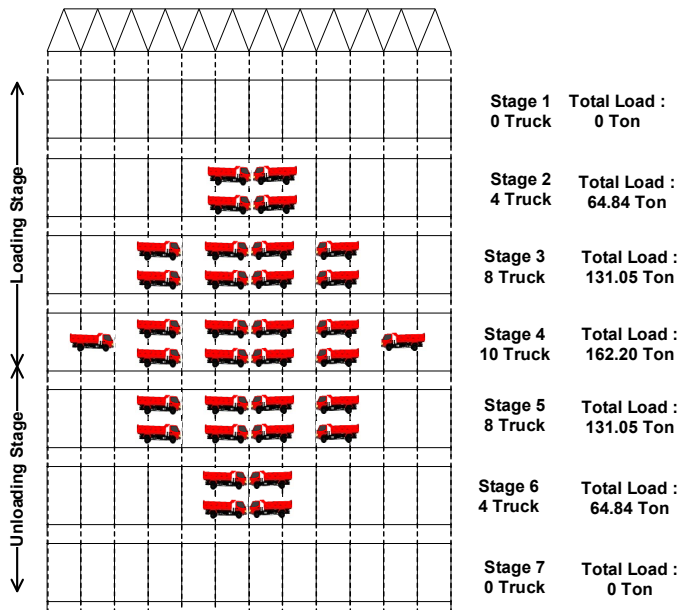


**Fig. 3.** Test Instrumentation (strain gauges and displacement transducers).

Six strain gauges were installed on the bridge to measure the strain on the structural elements that predicted to receive highest stress distribution. Three displacement transducers were set up in the middle span of the bridge to measure the actual displacement for each loading stage during static loading test. The reading measurement during static loading test was recorded in the data logger. The total station was used to monitor the deformation that occurred in bottom chord joints. The acceleration transducer was used to observe the bridge frequency during dynamic loading test. All reading measurement from dynamic loading test also recorded in the data logger.

### 2.3 Load test procedure

The type of loading test that applied is static and dynamic loading test. Before conducting static loading test, determination of total static load should be carefully estimated in order not to cause any damage to the bridge. The bridge must show linear respond to the whole static load applied. If the bridge exhibits non-linear behavior, the loading test must be terminated. The design of the total static load is based on uniform distribution load (UDL) for the bridge [7]. Since the span and width of the bridge are 60 m and 7 m respectively, the total of UDL load is 0.675 ton/m<sup>2</sup> or 253.125 ton. Since the total static load must not cause damage or failure to the bridge, only 63% (160 ton) of whole UDL load that applied for testing. This design load estimation also had taken into account deformation calculation through structural analysis. The total actual load that applied during static loading test was 162.2 ton. This whole actual load was higher 1.3% than total design load for static loading test. The actual total static load was divided into ten two-axle dump truck with a gross weight of each vehicle were ranged from 15 tons to 17 tons. The recording of dump truck gross weights were conducted at Mutiara Halim Company. Four loading stage and three unloading stage were applied during static loading test. The value of loading during static loading test for each stage are shown in Fig. 4. In each stage of the static loading test, the measurement of deformation and strain were recorded.



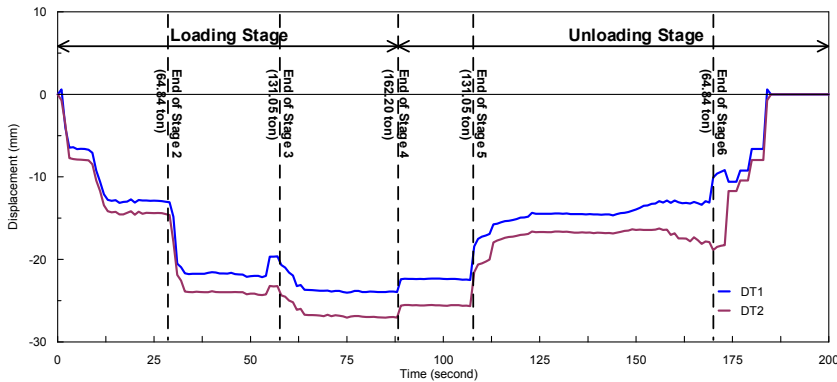
**Fig. 4.** Loading stage for static loading test.

The dynamic loading test procedure was conducted by measure the vibration on the bridge that caused by truck motion on speed range from 30-40 km/h. When truck crossover a bridge, the vertical acceleration on the bridge were recorded with acceleration transducer and data logger. The actual bridge frequency will be compared with a natural frequency that estimated from structure analysis. The actual bridge frequency is higher than expected frequency means that actual stiffness of bridge is higher than calculated in structural analysis and vice versa.

### 3 Results and discussion

#### 3.1 Load-displacement relationship and visual inspection

The data load-displacement relationship for each stage of the loading test is shown in Fig. 5 and Table 2. In the Fig. 5 two displacement reading from each transducer are presented. DT1 and DT2 are nomenclatures of each displacement transducers.



**Fig. 5.** Displacement reading from transducers during static loading test.

**Table 2.** Load-displacement relationship of static loading test.

Stage	Load (ton)	DT1 (mm)	DT2 (mm)	Total station (mm)
2	64.84	13.08	13.90	26.60
3	131.05	23.10	25.98	35.60
4	162.20	23.96	27.06	37.40
5	131.05	22.89	25.78	35.49
6	64.84	13.11	13.80	26.45

Note: DT1: Displacement Transducer 1, DT2: Displacement Transducer 2.

In Table 2 the reading data from transducers and total station are compared. The displacement reading from total station showed higher displacement than displacement reading from transducers. The bridge showed a linear response from the loading stage until the end of the unloading stage.

Each loading stage visual inspection was conducted to observe any damage that may occur in the bridge structure. From stage 2 with total load 64.84 ton until end stage 4 with total load 162.20 ton, the structure did not show any damage. All steel profile on bottom chords, upper chords, diagonals, floor beams, and stringers were on good condition. The steel profile did not exhibit tension failure or buckling. The connection of each element of the bridge structure was not shown any joint failure.

### 3.2 Strain reading

The strain gauges instrument were installed in element DG1S (IWF 400x360x12x20), DG2S (IWF 400x300x12x16) and BC6S (IWF 400x450x20x30). Element DG2S, BC6S were predicted to receive higher tensile stress than other elements, while the element DG1S was estimated to resist highest compressive stress. Fig. 6 exhibited the strain reading from DG1S, DG2S, and BC6S. From stage 2 to end of stage 6 these elements did not reach the tensile or compression yielding strain. The maximum stress at peak load (stage 4, total load 162.20 ton) that occurred at DG1S, DG2S, and BC6S was 23.40 MPa, 25.40 MPa, and 29.00 MPa, respectively. The elastic behavior that shown from these elements conformed the elastic response of bridge during static loading test.

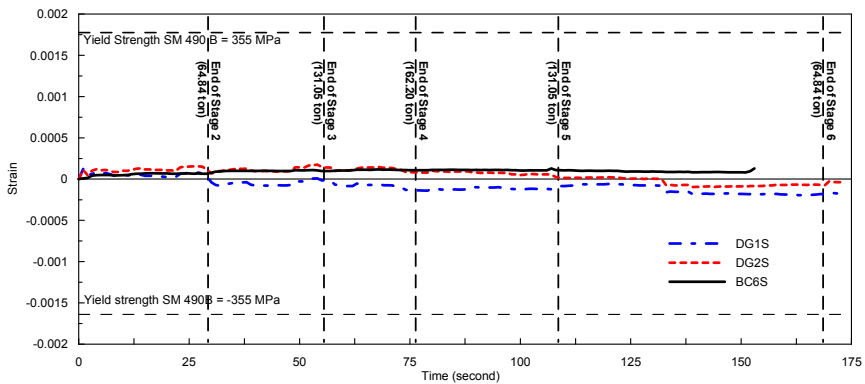


Fig. 6. Strain reading during static loading test.

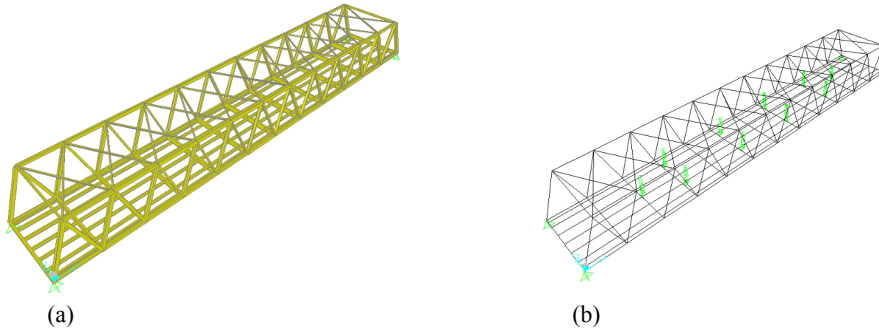
### 3.3 Dynamic testing

Dynamic loading test was performed by recorded the vertical acceleration that occurred due to the motion of two axle dump truck with medium speed (30-40 km/h). The vertical acceleration was measured by an acceleration transducer and recorded in the data logger. In OrdeTo obtain the bridge frequency, the acceleration data were processed using Fast Fourier Transformation (FFT) method. From the FFT method showed that the bridge frequency was 1.46 Hz.

## 4 Structural analysis

All data that reported from the loading test can provide a significant amount of useful information. However, it is important to realize that all data can be influenced by a large number of factors, some of which may not be reliable at higher load level. It is essential to validate the measured response through analysis and determines the critical response throughout the entire structure. A three-dimensional finite element of the bridge was described, and the procedures of the static and dynamic loading test were approached in the

modeling and analysis procedure. The truss members, stringers and floor beams were modeled used 3-D frame elements. The bridge concrete floor deck was represented as a load that applied to stringers. At the bridge supports, the boundary conditions were modeled as a hinge and rolled as support. The loading on the model was represented by placing point load with a load value of the gross weight of two axle dump truck. The bridge model and positions of point load were corresponding with the placement of the truck during static loading load (Fig. 8).



**Fig. 7.** (a) Generate display of bridge model; (b) truck load applied on bridge model.

**Table 3.** Comparison  $\Delta_{actual}/\Delta_{prediction}$  for each loading stage.

Stage	Load (ton)	$\Delta_{actual}$ (mm)	$\Delta_{prediction}$ (mm)	$\Delta_{actual}/\Delta_{prediction}$
2	64.84	26.60	27.60	0.96
3	131.05	35.60	35.60	1.00
4	162.20	37.40	38.26	0.97
5	131.05	35.49	35.60	0.99
6	64.84	26.45	27.60	0.96

The comparison data that obtain from structure modeling and loading test showed a similar result. The actual deformation data that recorded was taken from total station. Since this deformation data was more conservative that deformation is reading from displacement transducers. The ratio actual deformation to deformation prediction that attain from analysis for each stage were range from 0.96 to 1.00 (Table 3). This deformation comparison showed similar value.

**Table 4.** Stress comparison between actual and prediction at peak applied load.

Element	$\sigma_{actual}$ (MPa)	$\sigma_{prediction}$ (MPa)	$\sigma_{actual}/\sigma_{analysis}$
DG1S(IWF400x360x12x20)	23.40	32.70	0.72
DG2S (IWF400x300x12x16)	25.40	44.92	0.57
BC6S (IWF400x450x20x30).	29.00	51.03	0.57

The stress result from structural analysis exhibited element DG1S, DG2S and BC6S were not reached yield condition. The comparison stress at peak applied load showed that

the actual stress that occurred in DG1S, DG2S, and BC6S were lower than predicted in structural analysis (Table 4). It means that the stiffness of bridge was higher than structural analysis. In order to obtain the natural frequency of the bridge, the modal analysis was performed. The report showed that the natural vertical frequency that occurred on the bridge was 0.61 Hz. This result was lower than the vertical frequency that recorded (1.47 Hz). Similar to the stress comparison result, the bridge at actual condition provide higher stiffness than analysis.

## 5 Conclusions

This study investigated and performed loading test on approach bridge of Kalimujur bridge. Static and dynamic load were applied. The loading test results were also compared with numerical analysis. Important conclusions are summarized as follows.

Seven stages on static loading test were performed with peak applied force was 63% of UDL. Visual inspections were conducted in each load stage, and no damage occurred during static loading test. The bridge showed elastic behavior and the recorded stress at elements that installed with strain gauges were conformed with a similar response. The measurement of bridge displacement at peak applied load showed that the actual displacement does not exceed the deformation limit that specified in Indonesian Bridge Code. The dynamic load test was also conducted. 2) The test results were evaluated with numerical analysis. The recorded deformations from static loading test were lower than the deformation that estimated from structural analysis. The recorded stress from the experimental result also showed lower stress than stress that calculated in the structural analysis. The natural frequency from the structural analysis showed lower valued than frequency recorded during the dynamic load test. All these results showed that the actual bridge exhibited more stiffness than predicted from the analysis. The overall evaluation of the approach bridge of Kalimujur bridges showed that this bridge is safe to service regular traffic.

## References

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