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Measurement of Geometric Variations of a Railway Truss Bridge (Case Study: BH77 Railway Bridge)

Anindhya Mustika L^{1*}, Pariatmono¹, Erlangga Rizqi F¹, Mawardi Amin¹, Resmi Bestari M¹, Dimas Aryo S¹, Mulyadi Sinung H², Dwi Agus P², Wimpie Agoeng N. A², Thiya Fiantika², Emeraldal Insani. N. S. P. J. D. S. P²

¹*Civil Engineering Post-Graduate Program, Faculty of Engineering, Mercu Buana University, West Jakarta, 11650, Indonesia,*

²*National Research and Innovation Agency - BRIN, Jakarta 10340, Indonesia*

*Correspondence email: anindhyamustika@gmail.com

ABSTRACTS

Monitoring the condition of the railway track on a regular basis needs to be carried out regularly to minimize risk. One of the causes of the decrease in the strength of the bridge structure can be caused by changes in cross-sectional dimensions. The existing dimensions of the bridge structure need to be known because they will affect the steel frame profile area, where the steel frame area will affect the size or the small value of the deflection and stress of the bridge structure. The dimensions of the frame need to be seriously considered so that the stress and deflection values of the bridge structure remain constant. This research was conducted at the BH 77 Railway Bridge in Tegineng, Tanjungkarang-Martapura, Lampung, which uses a type frame configuration warren truss. This location was chosen to fit the research that was also conducted by *Badan Riset dan Inovasi Nasional* (National Research and Innovation Agency of Indonesia). Based on the measurement of the dimensions of the bridge truss that has been carried out, the results show that there is a difference in the value of the circumference of each rod with the standard deviation for each similar profile. The biggest difference in the circumference of the truss is the profile of H beam, 113 and 115 rods with dimensions of 340×300×15×18, the initial circumference value is 1,280 mm, and after the measurement is 1,289.42 mm with a standard deviation value of 0.91 mm. while for the smallest difference, namely the H beam profile, rod 110 with dimensions of 340×310×39×21, the initial circumference value is 1,300 mm and after the measurement is 1,300.33 mm with a standard deviation value of 0.24 mm.

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INTRODUCTION

Regulation number 23/2007 of the Republic of Indonesia states that trains are modes of transportation that have special characteristics and advantages, such as saving energy and use of space [1]. Trains have higher safety and lower level of pollution and therefore more efficient than other land transportation modes, especially for long distances as well as for areas with heavy traffic. The regulation also mentions that rail transportation has priority for on-land traffic, which means other means of transportation should give ways for trains to pass by. The advantages of the train need to be utilized in an effort to develop an integrated transportation system at an affordable cost.

By considering the high amount of capital needed to develop a railway transportation network, it is necessary to monitor the condition of the railway infrastructure regularly to minimize the risk of damage that may occur and keep railway transportation in service. To do so, the monitoring should be backed-up by related research activities.

In order to encourage research-based sustainable development, the government of Indonesia established the National Research Priority on Railway Transportation (*Program Riset Nasional Perkeretaapian, PRN Perkeretaapian*) with *Badan Riset dan Inovasi Nasional* (BRIN) as the coordinator. The main program on this PRN *Perkeretaapian* is developing a Structural Health Monitoring System (SHMS) of railway bridges to monitor and evaluate railway bridge structures and assist decision-makers in developing bridge maintenance programs [2]. It should be carefully noted that the bridge geometric measurement taken in the present study was not part of the inspection program mentioned in [3] or [4]. It is rather related to developing the pilot project of SHMS for railway bridge in Indonesia as mentioned in [2]

SHMS was intended to monitor the occurrence of accidents considering the age of the bridge, which is old and its condition has begun to deteriorate. In this case, the Research and Innovation Center of the Sumatran Institute of Railways Technology was involved in the implementation of the railway research, especially in Sumatra [5] and in collaboration with several universities, one of which is Mercu Buana University. This research was conducted to measure the dimensions of the existing steel structure frame.

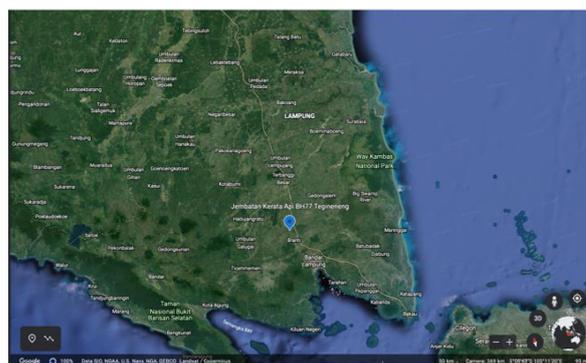
The steel truss bridge is chosen as it is very common, especially for medium span. A similar study was previously undertaken for utilizing truss as roof structures [6].

The current dimensions of a bridge structure need to be known because it will affect the area of the steel frame profile, where the steel frame area will affect the size or the small value of the deflection and stress of the bridge structure. So, the dimensions of the frame need to be seriously considered so that the stress and deflection values of the bridge structure are kept under

control. This research was conducted at the BH 77 Railway Bridge in Tegeneng, Tanjungkarang-Martapura, Lampung. The location of the railway bridge is presented in **Figure 1**. This location was chosen to fit the research criteria that was also conducted by *Badan Riset dan Inovasi Nasional* (National Research and Innovation Agency of Indonesia) [7]. The railway truss bridge is a Warren configuration. The steel frame bridge used is the WF profiles and the angled profiles, which are known based on the results of the direct inspection in the field. **Figure 2** shows the bridge and its surrounding environment.

LITERATURE STUDY

In the construction of railroad tracks, it is often found terrain that has high elevation differences such as valleys and hills, uneven ground contours, and also the presence of rivers, lakes, irrigation canals and swamps. There are conditions in which railway crossings have slopes greater than determining ramps. Therefore, various methods are developed to make rail slopes within safe thresholds by constructing bridges to overcome the problem of steep ramps.



(a) Map of Lampung province.



(b) Location Details of the BH77 Tegeneng Bridge.

Figure 1. Location of the BH77 Tegeneng Bridge [8].



Figure 2. The BH 77 Tegineneng railway bridge perspective.

Designing these bridges starts from the railway tracks, free bridge space until loading is applied on the bridge and adjustment of the trains that cross the bridge [9]. This leads to the need for bridges to be made as a liaison between the tracks. One commonly used railway bridge is the steel truss bridge, such as the BH77 Bridge, which is a special review in this paper. A steel frame railway bridge is a steel bridge that serves to accommodate the traffic load of trains that pass on the surface of the bridge floor [10]. Based on the Minister of Transportation regulation number 60 of 2012 on Railway Technical Requirements, the steel bridge type is generally divided into four groups [3] as presented in **Table 1**.

Table 1. Types of Steel Bridge [10].

Type	Girder	Frame
Wall	Wall girder	Wall frame
Possession /Deck	Rib Girder/deck	Rib truss/desck

Nuranita [10] performed an analysis of a closed steel frame railroad bridge based on the draft technical requirements. The bridge is described with detailed components. Description of the steel bridge truss components is presented in **Figure 3**.

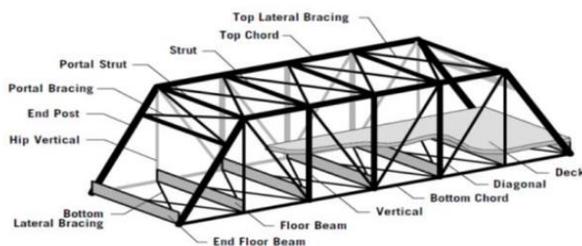


Figure 3. Details of Steel Frame Bridge [10].

Each structure will inevitably experience a decrease in capacity, which is directly proportional to the age of the structure, one of which is the bridge structure. The decrease in the capacity of the bridge structure is caused by internal and external factors. Internal factor referred to is a decrease in the capacity of the structure caused by a decrease in the quality of the material itself. In the steel

frame structure, the quality of the steel material will experience a decrease in stress caused by resistance/fatigue caused by repeated and continuous loads in a certain period and time. As a result of this load, the ultimate stress of the steel material will decrease.

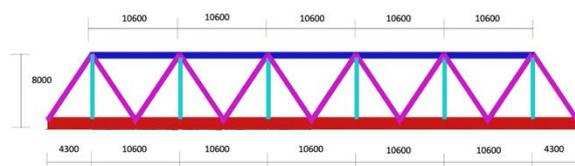
The decrease in the capacity of the structure can also be caused by external factors. External factors can occur as a result of vehicle collisions that result in changes in the shape of the elements. In addition, the influence of weather can also cause corrosion, as well as the effect of vibration resulting in loosening of the bolts in the connection. In Bridge Inspection Guidelines No. 005-01 P/BM/2011, there are nine major damages to the truss bridge structure resulting in a decrease in capacity [4]. The nine bridge deteriorations are mostly caused by rusty conditions of the unprotective system, broken/clogged members, cracks, vibrations, and changes in shape and deflection.

In the case of the BH77 railway bridge structure, the damage that affects the reduced capacity cross-section, namely vibration and changes in dimensions (shape) originally due to the age of the bridge. In order to initiate the implementation of this SHMS, Purnomo et al. (2021) conducted research on the implementation of SHMS for the railway bridge. The aim of the research is to know the related permit threshold deflection and vibration of the railway bridge by analyzing the strength of the attached profile to the workforce, especially the live load on the bridge [2]. The simulation results were used to determine the placement point of the SHMS sensors to be used on the BH77 bridge. In this study, only configuration data was available, but there was no truss dimension data for the bridge structure.

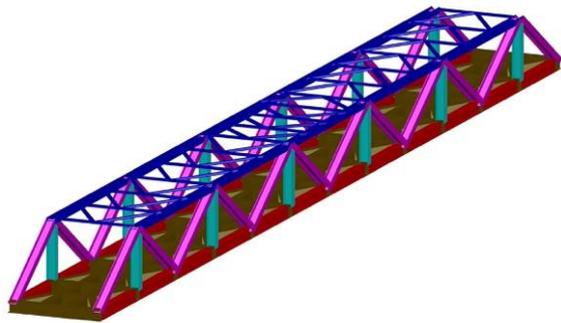
Aritenang (2021) explained that currently, SHMS has been widely applied on various types of highway bridges, but not much further research performed on the railway bridge [11]. Therefore, this research was carried out on the BH77 Tegineneng Lampung Railway Bridge by applying SHMS in order to see the health condition of the railway bridge via the signal sensors installed.

RESEARCH METHODOLOGY

This research was conducted on the existing steel Railway Bridge BH77, in Tegineneng, Tanjungkarang-Martapura Crossing, Lampung. This railway bridge are warren type steel frame configuration. In reference to as built drawing, the railway bridge has a vertical height of 8 m, a lower span of 61.6 m, an upper span of 53 m, and a width of 4.8 m with detailed drawings as shown in **Figure 4**.



(a) Side view.



(b) 3D perspective view.

Figure 4. The railway bridge of the case study.

Initially, the technique used in this research was to conduct a literature study on previous research related to the BH77 bridge. Following the literature study, preparation of the field survey was conducted. Finally, a field survey by measuring the dimensions of each truss bridge was carried out. **Figure 5** illustrate the flow of research activities.

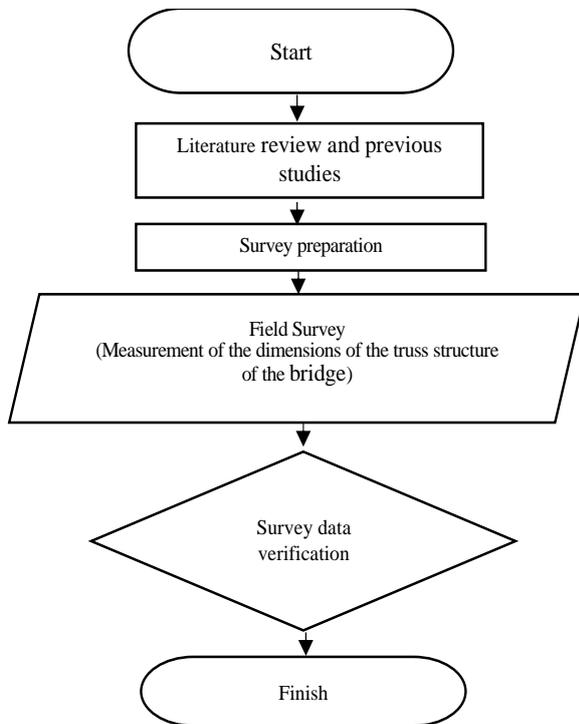


Figure 5. Research Flowchart.

RESULTS AND DISCUSSION

Research Results

Field measurements were performed in order to obtain the dimensions of the railway bridge members. **Figure 6** shows dimension measurement activities in the field. Measurements were done by grouping four

measurements, namely the bottom length, upper length, the height of the bridge and the width of the bridge, respectively. Measurements were carried out by comparing the original dimensions according to the as-built drawings and current measurements in the field. Comparison bridge detail dimension is presented in **Table 2**. It can be noticed that bridge dimensions have been changed. This elongation may be caused by loading and exposure to continuous sunlight. In order to avoid structural deterioration, continuous maintenance is required. Therefore, it is necessary to monitor the health of the bridge structure so that bridge maintenance mitigation can be carried out regularly.

In bridge measurement activities, the results obtained will be one of the determining factors for the strength of the bridge based on the maximum load that can be carried. So that when there is a decrease or change in the dimensions of the bridge beam when an analysis is carried out on the strength of the structure, it should not be less than what is permitted.



Figure 6. Dimension measurements activities.

If the value of the strength of the bridge structure generated based on calculations using the current dimensional data is very small or does not meet the safety requirements, then the existing dimensions of the bridge beam need to be reconstructed. The other alternative that can be applied is reducing the maximum amount of load that passes through the bridge.

One of the analyses that can be used to determine the strength of the bridge structure due to the influence of the load is deflection. The value of the deflection of a structure is influenced by the cross-sectional area of the truss. If there is a slight change in the dimensions of the truss will affect the area of the truss, so the value of the bridge deflection will be smaller. This is one of the basics of the importance of regular maintenance of the existing condition of the bridge structure.

Table 2. Bridge Frame Configuration.

No	Bridge Detail	Initial Dimension (meters)	Current Dimension (meters)
1.	Bottom Length	61.6	61.8
2.	Upper Length	53.0	53.2

3.	Bridge Height	8.0	8.1
4.	Bridge Width	4.8	4.92

Based on the results of measurements of the truss that have been carried out, there are many values of the circumference of the truss that has a value greater than the stated value based on as-built drawing with a standard deviation that varies in each variation of its dimensions.

All member frames were also measured. Dimensions of all members are tabulated in **Table 3**. The biggest

difference in the circumference of the truss is the profile of H beam, 113 and 115 frames with dimensions of 340×300×15×18. The initial circumference value is 1280 mm, and the current measurement is 1289.42 mm with a standard deviation value of 0.91 mm, while for the smallest difference, namely the H beam profile, frame 110 with dimensions of 340×310×39×21, the initial circumference value is 1300 mm. The current measurement is 1300.33 mm with a standard deviation value of 0.24 mm.

Table 3. Results of Measurement of the Dimensions of All Members.

No	Profile	Truss Number	Dimension (mm)	Initial Mean Value	Around (mm)	
					Measurement Mean	Result Standard Deviation
1	HR	1, 2, 3, 4, 5, 9, 10, 11, 12	690×300×27×14,5	1980	1989.02	2.11
2	HR	21	152×160×6×9	624	629.25	0.66
3	HR	95, 96, 97	133×140×8,5×5,5	546	549.8	0.49
4	HR	98, 99, 100, 101	133×140×8,5×5,5	546	549.9	0.78
5	C	36, 37, 38, 39, 40, 41, 42, 43, 50, 51, 52, 53, 54, 55, 56	680×160×30×30	1680	1683.2	3.29
6	C	64, 65, 66, 67, 70, 71, 72, 73, 89, 90, 91, 92	490×170×35×35	1320	1320.6	0.82
7	H	13, 14	680×320×40×25	2000	2004.23	1.81
8	H	103	340×420×35×20	1520	1523.17	4.04
9	H	105	340×350×35×20	1380	1380.92	0.60
10	H	107	340×420×30×20	1520	1523.33	2.71
11	H	109	340×300×21,5×12	1280	1288.33	0.55
12	H	110	340×310×39×21	1300	1300.33	0.24
13	H	111	330×300×16,5×9,5	1260	1266.42	0.60
14	H	113, 115	340×300×15×18	1280	1289.42	0.91
15	Equal Angel	29, 32, 34, 35	120×120×12	417	418.91	2.00

Discussions

The circumference of the truss that has a value greater than the stated value based on as-built drawing happens because the bridge frame has been painted several times to avoid corrosion of the steel structure. With varying measurement results obtained, it is necessary to do structural modeling to include wide variations cross-section so that the minimum strength of the bridge structure can be determined. The strength of the railway bridge might be affected by changes in the cross-sectional area.

CONCLUSION

From the results of the measurements of the BH77 railway bridge, the facts are obtained and are presented as follows:

By comparing the as-built drawing dimensions with the existing detail dimension, it can be concluded that the railway bridge has been experienced in elongation of the dimension. This elongation may be caused by loading and exposure to continuous sunlight. In addition, the railway bridge frame has been painted several times to avoid corrosion of the steel structure.

Structural deterioration possibly would happen in the future. Therefore, monitoring and evaluation should be performed regularly to avoid structural collapse.

Structural modelling should be carried out to understand the minimum strength capacity of the railway bridge.

AUTHOR INFORMATION

Corresponding Authors

Email: anindhyamustika@gmail.com

Phone: +62 81319126914

Email: pariatmono@mercubuana.ac.id

Phone: +62 81317463462

Author Contributions

The authors contributed equally to this work. The authors declare that there is no conflict of interest regarding the publication of this paper. The authors confirmed that the paper was free of plagiarism.

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