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The effect of load position to the accuracy of deflection measured with LVDT sensor in I-girder bridge

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Abstract. Serviceability of a bridge will decrease based on the function of time. Most likely due to the cyclic load from the traffic. The indicators which can be measured to determine the serviceability is the deflection of the girder. In this research, the PCI-Girder and vehicle load are analyzed by using the finite element method (Midas/Civil) Program. For comparison, the running vehicle test to the bridge has been conducted where the bridge deflections are measured using LVDT sensors on PCI-Girder Bridge. To find the effect of vehicle distance to the LVDV position, the running vehicle goes through on several lanes. The finite element program (Midas/Civil) gives relatively similar result to the measured deflection using LVDT sensors. However, when the vehicle load is situated far from the sensor, the result from both analysis showed significant differences.

Keywords: PCI-Girder, Deflection, vehicle Load, LVDT sensor

1. Introduction

The serviceability of the bridges will decreased from time to time. The main reason of this decreasing function is because of the cyclic load which occurred on the girder due to the vehicle. Parameters that can be monitored and measured on site to determine the serviceability of the bridge are the deflection and rotation angle which caused by the weight of the vehicle. To determine the value of the deflection and rotation angle, modeling was undertaken using finite element method approach and then compare with filed measurement using running vehicle. Comparative evaluation for this case have been done before. The Bridge in Szczercowska performed testing in the field and analyzed by using finite element analysis. And the result, the testing in the field has a smaller value than the finite element analysis modeling [4-5]. The important parameters to determine deflection on girder are vehicle load and velocity. These parameters caused the increase in the value of the stress and deflection, and the testing result in the field is higher than the predicted results of analysis methods [3]. Study indicated that the reason of the experimental deflection values greater than the theoretical results is due to the difference in stiffness of the material at the time of the test so that the lack of uniformity of the material used as assumed in the theoretical calculations [6].

Theoretical calculation of deflection and rotation angle in bridge composed by several girders has been studied. Yan Yu (2013) mentioned in his paper related to theoretical calculation in calculating deflection and rotation angle using Hooke's elasticity Law where its coefficients are related to the stiffness characteristics of the material. It is widely acknowledged that the unknown parameters EI of the deflection curve can be calculated through measuring the slope of the curve, which is angle value. Then, the deflection curve equation and the deflection along the girder are obtained [7].

This paper emphasis the analysis deflection and angle rotation by using finite element modeling. The software tools for this analysis is Midas/Civil program by compute the geometry of bridge, material, and configuration of the tendon. After that the PCI- Girder Bridge is given running vehicle load. The result of FEM then compare with the results of filed load testing. In situ measurement will be performed using LVDT sensors and tilt meter where each sensor generates the values of deflection and rotation angle of the girder as function of time or vehicle position. These measured values will be compared with finite element analysis. The comparison will be done by considering the geometry of the bridge and the position of vehicle load to represent the real conditions on the field.

2. Methodology

2.1 Research Methodology

The bridge parameters are collected from the design document and site measurement, an dwill be used to develop the 3D FEM model of the bridge. Since the vehicle load run slowly, the Running vehicle is assumed a static load with different location at different time acting on the bridge deck. Before the test begun, the weight of each tire of the vehicle must be measured first

The value of deflection and angle of rotation the bridge obtained from FEM Model, then compare to the deflection and rotation angle produced on test equipment in the field test, and then all the data is processed and analyzed. The comparison of deflection and rotation angle from FEM model and the theoretical results will be presented in the form of graphs deflection and rotation angle value against the imposition of the vehicle on the bridge.

2.2 Object Research

The research object of this study PC I-girder bridge with span length of the bridge ± 22 meters, width 21.5 meters, and has 10 Girder with a distance of 2 meters between Girder. Further details regarding the bridge can be seen in the figure 1:

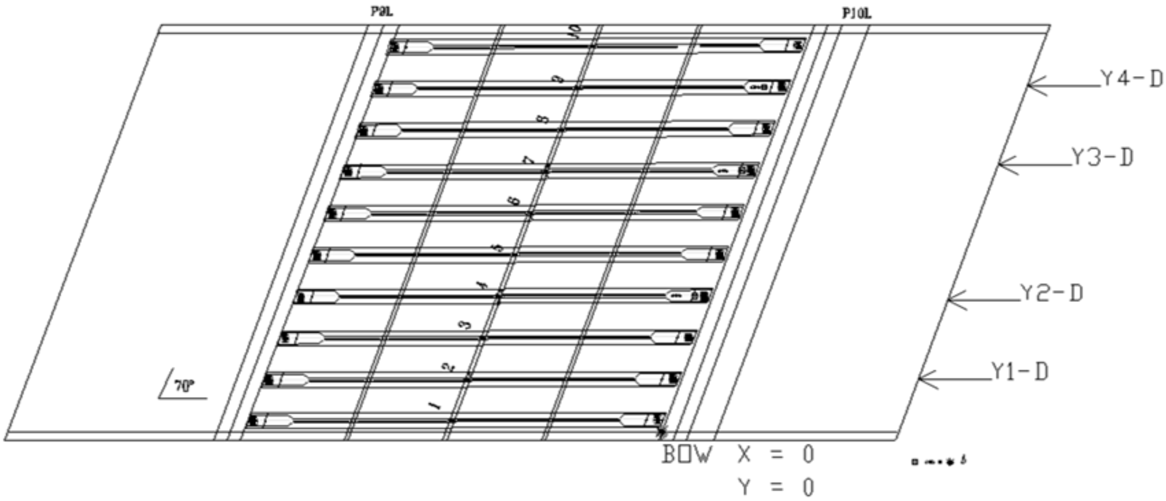

Figure 1. Transverse direction of the bridge

The general specifications of the bridge structure are as indicated in Table 1:

Table 1. The general specification of bridge

Item	The values
Number of Girder	10
Span length	23 meters
Skew Angle	20° from the direction perpendicular
Width of the Bridge	24.35 m/23.46 m
Slab Thickness	20 cm
Moment Inertia of Girder (composite)	214 250 221 825 mm^4
Modulus of Elasticity of Girder	33000 MPa

3. Result and Discussion

3.1 The Position Sensor LVDT and Vehicle Load (Truck Load)

A truck with two axles is used as running vehicle. Vehicle load was placed at four locations of the lateral direction (Y-axis). The Linear Variable Differential Transformer testing (LVDT) sensor installed in girder 4 (LV9583), girder 5 (LV9582) and girder 6 (LV9580). Whereas the tilt meter sensor are installed in girder 4 (T2031), girder 7 (T2034), and girder 9 (T2033). The illustration of vehicle load placement in lateral direction and sensor position are presented in Figure 2.

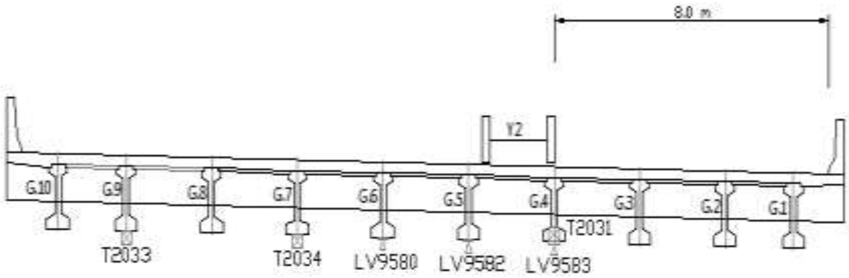

Figure 2. The placement of the load y2 = 8 m (left side axles)

Position of the truck for this study are presented in figure 3. The vehicle comprises of 2 axles, with 2 point load in each axle.

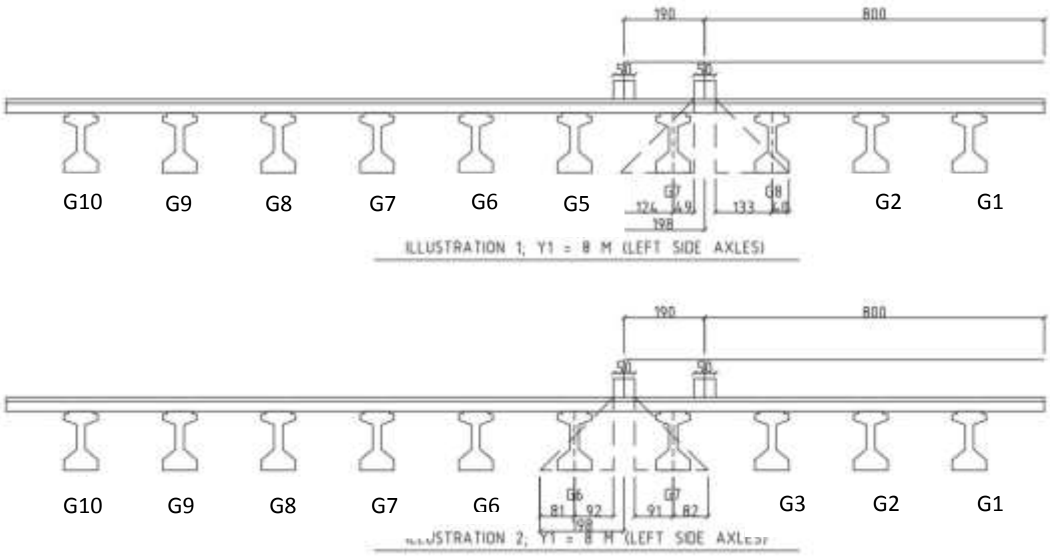

Figure 3. The ilustration distibution load Y2 = 8 m (left side axles)

For analytical calculation, the loading will be modeled as a concentrated load to the front axle as a starting point of reference. The truck load will moving along the bridge in x direction. The formula deflection (y) using principle of unit load method is mentioned below:

$$y(x) = \int_0^l \frac{M.m}{E.I} dx \qquad (1)$$

Where, y(x) is a deflection, M : moment due to external Load, m : momen due to 1 unit, E : modulus of elasticity, I : moment of inertia

Modeling of the load will be described in the following table.

Table 2. Position X load on axis direction

Load Position on axis direction	The position of Front axle load the vehicle of Point[0,0] (m)	Front axle load vehicles (kN)	Rear axle load vehicles (kN)
X1	1.0975	70	0
X2	5.3675	70	200
X3	5.4875	70	200
X4	9.7575	70	200
X5	10.975	70	200
X6	15.245	70	200
X7	16.4625	70	200
X8	20.7325	70	200
X9	20.8525	70	200
X10	25.1225	0	200

Distance of the sensor to the truck load is based on Figure 4 and their values is presented in Table 3

Table 3. The distance of influence vehicle load in girder 4, 5 and 6 due to load Y2

Number girder	Distance of influence due to vehicle load (mm)	Front axle load vehicles (kN)	Rear axle load vehicles (kN)
Girder 4	116	16.789	47.97
Girder 5	92	10.339	29.54
Girder 6	81	7.159	20.45

3.2 Deflection

The values deflection due to vehicle load from LVDT sensor is compared with deflection value from FEM, and unit load method as shown in table 4 and Figure 4, 5 and 6

Table 4. Comparison of deflection due to vehicle load Y2

Vehicle Load Y2										
Load	The position of Front axle load the vehicle of Point [0.0] (m)	Deflection (mm)								
		Girder 4			Girder 5			Girder 6		
		Midas (DZ)	Sensor LVDT	Unit Load	Midas (DZ)	Sensor LVDT	Unit Load	Midas (DZ)	Sensor LVDT	Unit Load

Y2-1	1.0975	-0.016	-0.002	-0.071	-0.015	-0.002	-0.044	-0.011	0,000	-0.030
Y2-2	5.3675	-0.230	-0.104	-0.945	-0.214	-0.081	-0.582	-0.163	-0.053	-0.403
Y2-3	5.4875	-0.246	-0.111	-0.971	-0.229	-0.087	-0.598	-0.175	-0.056	-0.414
Y2-4	9.7575	-0.920	-0.759	-1.845	-0.841	-0.536	-1.136	-0.611	-0.330	-0.787
Y2-5	10.975	-1.106	-0.999	-1.955	-1.004	-0.690	-1.204	-0.718	-0.418	-0.833
Y2-6	15.245	-1.379	-1.449	-1.818	-1.223	-0.914	-1.119	-0.836	-0.538	-0.775
Y2-7	16.4625	-1.258	-1.359	-1.641	-1.131	-0.858	-1.011	-0.787	-0.504	-0.700
Y2-8	20.7325	-0.566	-0.411	-0.697	-0.526	-0.262	-0.396	-0.397	-0.159	-0.274
Y2-9	20.8525	-0.546	-0.382	-0.666	-0.507	-0.241	-0.379	-0.384	-0.147	-0.262
Y2-10	25.1225	-0.045	-0.019	-0.216	-0.042	-0.005	-0.078	-0.033	-0.012	-0.054

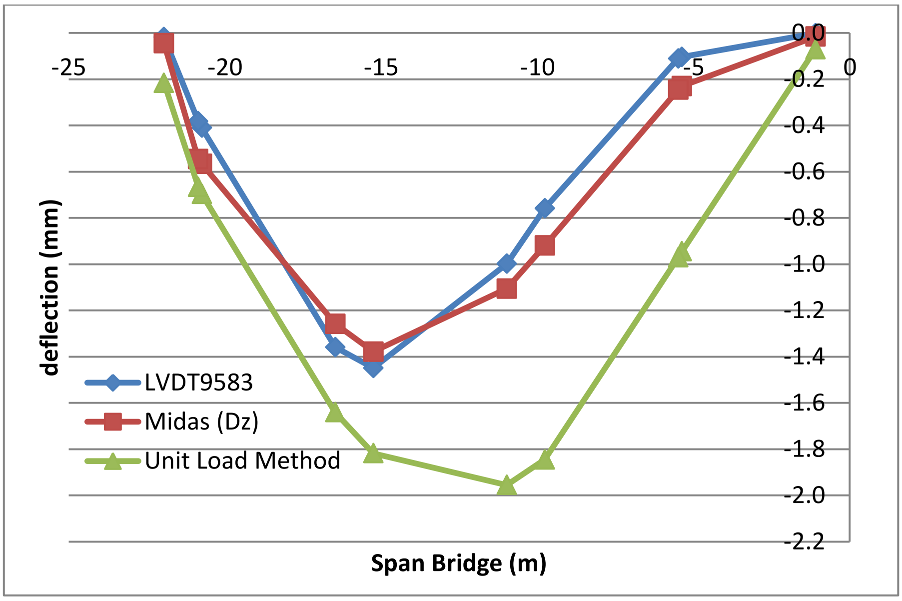

Figure 4. The deflection on girder 4

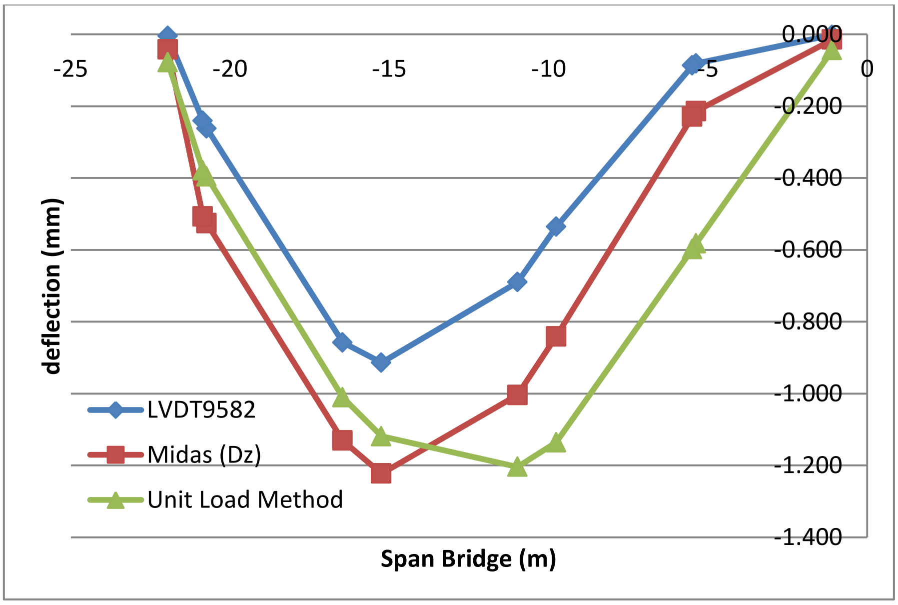

Figure 5. The deflection on girder 5

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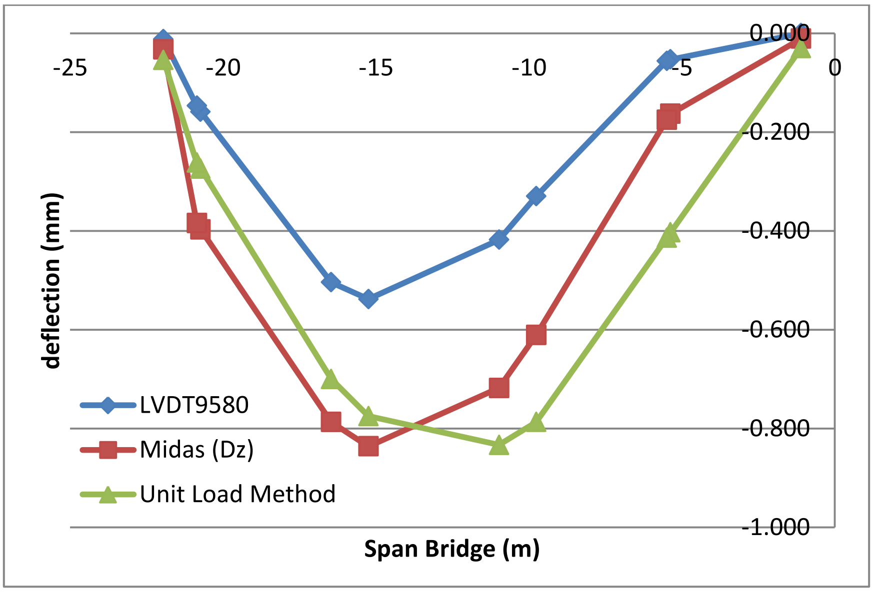

Figure 6. The deflection on girder 6

Based on figure 4,5, and 6, the deflection values from unit load method gives the biggest value. In the unit load method approach, a girder is modeled as a single girder with composite girder behavior, then a vehicle load which are given in accordance the distribution of loads that occur on each girder. Whereas, using FEM, the bridges is modeled as multi girder and each girder connecting with the diaphragm element. This model can increase the value of stiffness in the girder bridge.

In Figure 5 and 6, the deflection values generated by the sensor on girder 5 is not similar with the FEM modelling. At girder 6, there is a significant difference values of deflection between the FEM modelling and LVDT sensor. From the results of figure 4, 5, and 6, it can be concluded that when the sensor location is far from the vehicle load, it will obtain a deflection which is less represent the actual deflection in the transverse direction.

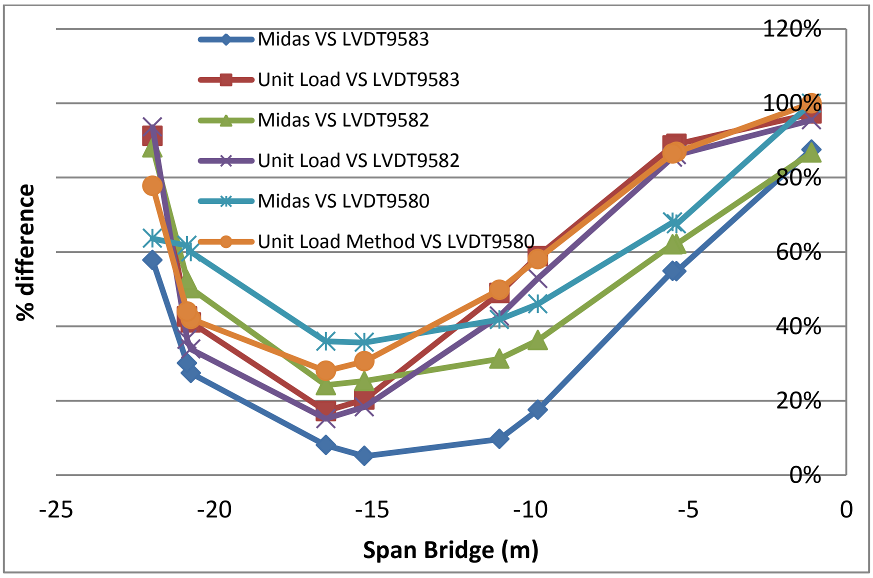

Figure 7. Comparison the difference a values of deflection midas/civil, unit load method towards to LVDT sensor

From figure 7, it shows that the percentage difference in deflection is below 10%, it occurs in comparison between LVDT9583 sensor and Midas/Civil in girder 4. And this value only occurred when the position of the vehicle load within range distance around 10 to 16 m in transverse direction of the bridge. Therefore, it can be concluded that the sensor has maximum function when the load position is close to the position of the sensor installation.

4. Conclusion

This study obtained several conclusions, among others:

- The unit load method obtains a larger deflection value compared to the Midas/civil and LVDT sensor. Because the girder bridge is modeled with a single bridge and without the diaphragm in calculation. This result is not representing the actual values because it is a conservative calculation, however this method can be used as a comparative data for the results from LVDT sensor.
- The calculation using the Midas/civil program, with modeling as multi girder and each girder connecting with the diaphragm produces a deflection that has similarities with the LVDT9583 sensor, especially in girder 4.
- The values of deflection with the program Midas/Civil indicates that the results are relatively similar and close to the results of LVDT sensor when the position of vehicle load and LVDT sensor adjacent.

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