Simple Span Bridge Loading Based on Weight in Motion Data

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Abstract. Over Dimension Over Load (ODOL) vehicle is claimed to be the cause of a number of fatal accidents and damage to road infrastructure in Indonesia and has become a serious issue for roads and bridges maintenance. Over loaded vehicles can result in damage to the bridge, reduced bridge capacity and can even result in collapse of the bridge. Therefore the characteristics of the actual vehicle load need to be known and compared to the bridge design load according to the bridge design code and standard. In this paper, an analysis is carried out on the actual traffic load data obtained from the measurement results using Weight in Motion (WIM) in Kaligawe, Semarang, Indonesia. Monte Carlo simulation is used to simulate the arrival of the vehicle. The results of vehicle load simulation are then applied to a simple span bridge with a span of 30, 40, 50 m. The bending moment and shear force obtained due to actual load compared to the magnitude of the bending moment and shear by applying Indonesia Bridge Loading Standard. The results show that 43 percent of vehicles are overloaded. The bending moment and shear force caused by actual load is less than the design bending moment and shear force for 30 m, 40 m and 50 m bridge span.

Keywords: Monte Carlo simulation, simple span bridge, traffic load, weight in motion

1. Introduction

The highway bridge is a public infrastructure that must continue to function in serving traffic passing on it. Therefore the bridge must be designed to be able to withstand the traffic loads and such load should be considered in the design process. Traffic passing on the bridge varies greatly from light vehicles to heavy vehicles, it can be a single vehicle or it can also be a motorcade. For Highway Bridge in Indonesia, the Ministry of Public Works requires that the designed load shall refers to a predetermined load design standard. Currently the bridge loading guidelines refer to the Indonesian National Standard Number 1725, (2016), Loading for Bridges [1].

In the road bridge loading guidelines, traffic loads are modeled as distributed loads and line loads which are expected to represent the effect of the maximum traffic load using the bridge. The vehicle load in this regulation is an idealization of the actual vehicle load. The modeling of the traffic load along with dead load, environmental load and implementation load are loads that must be taken into account in bridge design.

The actual load of vehicles using roads or bridges is very random both in size and volume. For bridge design, the magnitude of vehicle load becomes a very important aspect. Therefore weighting
the traffic vehicle is become important. Vehicle weight measurement technology has been around for a long time. The conventional vehicle load measurement technology that is commonly used is a static weighbridge which requires the vehicle to be stopped first and then weighed statically. This of course can disrupt the smooth flow of traffic for roads with heavy traffic. The use of static weigh bridges is less efficient, therefore the new development of vehicle weighting technology that can directly determine the load when the vehicle passes the load sensor on the vehicle is expected. The weigh in motion (WIM) is the latest technology to measure the weight of vehicles without having to stop the vehicle, [2][3][4].

This study will utilize the weight in motion data in term of weight and volume of actual vehicles at national road and compare the effects of actual loads as measured by the WIM with the effects of design loads in accordance with highway bridge regulations in Indonesia.

The purpose of this study is to simulate actual vehicle load from WIM data into traffic loads on bridges and to compare the effects of loads in the form of moments and shear due to actual traffic based on WIM data with the bridge design load according to SNI 1725: 2016 on simple span steel bridges with the span lengths of 30m, 40m and 50m.

2. Methodology

The methodology of this research are as follow

a. The WIM data for this study is measured at the Kaligawe Bridge Semarang on the Pantura line by the Road and Bridge Research and Development Center of the Ministry of Public Works and Public Housing for 7 days from 1 - 7 November 2018.

b. After filtering the WIM data, the Monte Carlo simulation is used to obtain the frequency and the order of the types of vehicles passing the bridge.

c. 3-dimensional Finite Element Method model of the bridge is developed for this study for bridge span of 30m, 40m and 50m.

d. The moments and shear according to SNI 1725: 2016 is calculated by applying the design load to the finite element model of the bridge for spans of 30m, 40m, and 50m.

e. The combination of traffic loads from WIM data simulation is applied to the bridge structure model for bridge span of 30m, 40m, and 50m.

f. The Maximum Shear and Moment Force on the Bridge Girder due to the design load and due the load resulting from the simulated WIM data will be compared and analyzed.

3. Characteristic of Traffic based on WIM Data

The characteristics of the number of vehicles for each vehicle class is presented in Figure 1. It can be seen that the largest number of vehicles is group 30, namely the type of two-axle car with the number of vehicles of 2296.
The characteristics of the maximum axle load, the percentage of overloaded vehicle and the percentage of overload for each vehicle class can be seen in Figure 2, Figure 3 and Figure 4.

**Figure 1.** Number of Vehicle for Each Vehicle Class

It can be seen that the largest axle load is 18 tons in vehicle class 40, a two-axle type of truck. While the smallest axle load is 2.61 tonnes in vehicle class 30, vehicle that carries goods.
Based on Figure 3 and Figure 4, it can be seen that the percentage of the number of overloaded vehicles ranges from 0 - 100%. Meanwhile, the percentage of overload ranged from 14 - 84%.

4. Simulation of WIM Data Traffic Load

The analysis results of the cumulative probability and random number intervals for each vehicle class is presented in Table 1.
Table 1. Cumulative probability and random number interval for each variable

| No | Vehicle Class | Frequency | Probability Density Function (PDF) | Cumulative Density Function (CDF) | Tag Number |
|----|---------------|-----------|-----------------------------------|----------------------------------|------------|
| 1  | 20            | 28        | 0.0045                            | 0.0045                           | 0.0000 - 0.0045|
| 2  | 30            | 2296      | 0.3728                            | 0.3774                           | 0.0045 - 0.3774|
| 3  | 40            | 698       | 0.1133                            | 0.4907                           | 0.3774 - 0.4907|
| 4  | 50            | 4         | 0.0006                            | 0.4914                           | 0.4907 - 0.4914|
| 5  | 51            | 1635      | 0.2655                            | 0.7569                           | 0.4914 - 0.7569|
| 6  | 57            | 24        | 0.0039                            | 0.7608                           | 0.7569 - 0.7608|
| 7  | 58            | 9         | 0.0015                            | 0.7623                           | 0.7608 - 0.7623|
| 8  | 59            | 12        | 0.0019                            | 0.7642                           | 0.7623 - 0.7642|
| 9  | 60            | 4         | 0.0006                            | 0.7649                           | 0.7642 - 0.7649|
| 10 | 61            | 76        | 0.0123                            | 0.7772                           | 0.7649 - 0.7772|
| 11 | 62            | 696       | 0.1130                            | 0.8902                           | 0.7772 - 0.8902|
| 12 | 63            | 33        | 0.0054                            | 0.8956                           | 0.8902 - 0.8956|
| 13 | 70            | 7         | 0.0011                            | 0.8967                           | 0.8956 - 0.8967|
| 14 | 71            | 1         | 0.0002                            | 0.8969                           | 0.8967 - 0.8969|
| 15 | 100           | 55        | 0.0089                            | 0.9058                           | 0.8969 - 0.9058|
| 16 | 101           | 74        | 0.0120                            | 0.9178                           | 0.9058 - 0.9178|
| 17 | 102           | 449       | 0.0729                            | 0.9907                           | 0.9178 - 0.9907|
| 18 | 111           | 13        | 0.0021                            | 0.9929                           | 0.9907 - 0.9929|
| 19 | 112           | 1         | 0.0002                            | 0.9930                           | 0.9929 - 0.9930|
| 20 | 120           | 43        | 0.0070                            | 1.0000                           | 0.9930 - 1.0000|

Based on the results of the compatibility hypothesis (goodness of fit) of the Chi-Square test method, the appropriate distribution type is the Weibull (3P) distribution. By using the Weibull (3P) distribution type, a random number of 50 experiments was carried out, then simulated simply by selecting a random number from a table of random numbers. The order of the simulation results with a random number of 50 trials for bridge with span of 30 m is presented in Table 2.
Table 2. The Order of the Simulation Results for Bridge with Span of 30 m

| No | Random Number | Vehicle Class | Combination |
|----|---------------|---------------|-------------|
| 1  | 0.1326        | 30            | 1           |
| 2  | 0.2267        | 30            | 2           |
| 3  | 0.1464        | 30            | 3           |
| 4  | 0.1914        | 30            | 4           |
| 5  | 0.0609        | 65            | 5           |
| 6  | 0.4752        | 51            | 6           |
| 7  | 0.3184        | 30            | 7           |
| 8  | 0.3202        | 30            | 8           |
| 9  | 0.9611        | 103           | 9           |
| 10 | 0.2658        | 30            |             |
| 11 | 0.0473        | 65            |             |
| 12 | 0.6297        | 30            |             |
| 13 | 0.7647        | 51            |             |
| 14 | 0.1999        | 65            |             |
| 15 | 0.3780        | 30            |             |
| 16 | 0.3138        | 30            |             |
| 17 | 0.3732        | 30            |             |
| 18 | 0.0378        | 67            |             |
| 19 | 0.4257        | 30            |             |
| 20 | 0.7091        | 51            |             |
| 21 | 0.4204        | 30            |             |
| 22 | 0.4700        | 51            |             |
| 23 | 0.3084        | 30            |             |
| 24 | 0.4653        | 30            |             |
| 25 | 0.7389        | 51            |             |
| 26 | 0.6148        | 51            |             |
| 27 | 0.0181        | 30            |             |
| 28 | 0.8117        | 51            |             |
| 29 | 0.0541        | 30            |             |
| 30 | 0.4904        | 25            |             |
| 31 | 0.0897        | 51            |             |

Based on the table above, the vehicle class 30 and 51 are frequently found in a simulation result. This is in accordance with the probability values for vehicle class 30 and 51, which are 37.28% and 26.55%. The simulation results above will be used to form several load combinations on a 30 m bridge span. As a sample, combination no 17 for bridge with the span of 30 meters is presented in Figure 5.

Figure 5 Combination Vehicle no 17 at bridge with the span of 30 meters

Similar process is applied for bridge with spans of 40 m and 50 m. A sample of Combination for bridge with span of 40 m and 50 m are presented in Figures 6 and 7.
5. 3-Dimensional Finite Element Model of the Bridge

The bridge is composite steel girder bridge with a span of 30 m, 40 m and 50 m with 9 m width. The cross section of the bridge is presented in Figure 8.

At first, the standard traffic load of the Indonesian bridge SNI 1725: 2016 will be applied to the finite element model of the bridge to determine the maximum bending moment and maximum shear force. The second analysis is by applying the load for each Combination which come from the WIM data to determine the maximum bending moment and maximum shear force. The maximum values of bending moment and shear force from those 2 loading then compared.
Figure 9 Finite Element Model, Bending Moment Diagram, Shear Diagram for Combination no 17 at bridge with the span of 30 meters

Figure 10 Finite Element Model, Bending Moment Diagram, Shear Diagram for Bridge Loading based on SNI 1725:2016 at bridge with the span of 30 meters

Similar process is applied for bridge with spans of 40 m and 50 m

6. **Ratio of Maximum Bending Moment and Maximum Shear Force**

The result of analysis is presented in Table 3 and Figure 11
### Table 3 Maximum Bending Moment and Maximum Shear

| Bridge Span | Live Load Forces | WIM data (t-m) | SNI 1725:2016 (t-m) |
|-------------|------------------|----------------|---------------------|
| 30 m        | Max. Bending Moment | 112.52 | 133.25 |
|             | Max. Shear Force    | 21.98  | 24.91  |
| 40 m        | Max. Bending Moment | 197.73 | 211.82 |
|             | Max. Shear Force    | 28.79  | 29.9   |
| 50 m        | Max. Bending Moment | 287.18 | 307.51 |
|             | Max. Shear Force    | 33.87  | 36.71  |

**Figure 11.** Ratio of Maximum Bending Moment and Maximum Shear Force

Based on Table 3 and Figure 9, it can see that the actual traffic load obtained from the WIM data of the Kaligawe Semarang Bridge produces a bending moment and shear force that is lower than the standard load of SNI 1725: 2016, where the bending moment ratio value and the maximum shear force at bridges of 0.93 and 0.96.

### 7. Conclusion and Recommendation

Based on the research results, the following conclusions can be drawn:

a. Based on the axle load characteristics of the vehicle, class 40, which is the type of two-axle truck vehicle, has the largest axle load value of 18 tons with an overload percentage of 80%.

b. Based on the results of the 3D analysis of the bridge structure, it can be concluded that the actual traffic load of the WIM data of the Kaligawe Bridge Semarang produces bending moments and shear forces that are lower than the standard loads of SNI 1725: 2016 on a steel composite bridge with a span of 30 m, 40 m and 50 m.

It is advisable to conduct research for different types of bridges and also by using WIM data obtained at other measurement locations.
References

[1] Standar Nasional Indonesia Nomor 1725, (2016), Pembebanan untuk Jembatan, Badan Standardisasi Nasional, Jakarta.

[2] Standar PUPR PD 15 – 2018 – D. (2019), Pengukuran Beban Kendaraan dengan Weight In Motion (WIM) Bridge, Kementrian Pekerjaan Umum Dan Perumahan Rakyat, Jakarta

[3] Nugraha, W. dan Gatot S. 2018. Uji Coba Model Fisik Sistem Bridge Weigh In Motion Sederhana Pada Jembatan Gelagar Baja Komposit. Jurnal Jalan-Jembatan. 35 (1): 1-15

[4] Nugraha, W. dan Hardono, S. (2015), Evaluasi Reliabilitas Jembatan Standar Tipe Komposit Menggunakan Data Hasil Pengukuran Beban Kendaraan Bergerak, Widyariset, 1, 11-20.