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Effect of Axle Overload on Road Damage

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Abstract- Taman Road at Sidoarjo City is an arterial road, as a link between the cities of Surabaya, Sidoarjo, Krian, and Mojokerto. The volume of vehicles is very high and is dominated by heavy vehicles. Consequently, road damage often occurs. Every year, road improvements are always made. The results of the road condition survey in stage 1 and stage 2 survey found that the ravelling type of damage was the most damage type in the amount of 21.02%. The most significant Equivalent Axle Load (EAL) value obtained from heavy vehicles was 708848, so that the most significant percentage of the cause of road damage was heavy vehicles by 92.54%. The next causes of road damage were medium vehicles at 7.35% and light vehicles at 0.12%. From the results of the Wilcoxon Signed Ranks Test and the Paired T-test, it was concluded that the EAL values affect road damage. The higher the EAL value, the higher the vehicle load. If the carrying capacity of the road is not able to carry the burden of the vehicle, it will cause damage.

Keywords- *Vehicle Load, Equivalent Axle Load, Road Damage, Ravelling*

I. INTRODUCTION

The main transportation problem in Indonesia is a huge number of vehicles growing. Limited funds for road maintenance and construction make more complicate transportation problems [1]. Whereas to develop an area and improve the economy of the community, adequate transportation facilities are needed [2][3]. The growth of public transport vehicles and private vehicles, if not accompanied by improvements in transportation facilities, will cause inconvenience and congestion for road users and will disrupt the regional economy.

Taman Road Sidoarjo is the main road that connects Surabaya, Sidoarjo, Krian, and Mojokerto. The volume of vehicles on Taman Road Sidoarjo is very high due to:

1. There are many factories along the road.
2. There are dense settlements.
3. There are many housing estates along this route.
4. It is the main route from Surabaya-Sidoarjo- Mojokerto.

The increasing volume of vehicles on Taman Road Sidoarjo due to changes in land use along this road. Changes in land use resulted in reasonably substantial road damage. Many small and heavy vehicles pass this road. Common types of damage roads are profile distortion, alligator cracking, potholes, longitudinal cracking, and rutting [4]. The damage endangers road users, such as traffic jams, accidents, and disrupting economic activities [5]. If the road damage is not handled immediately, it will lead to higher investment and maintenance costs.

Road damage is generally caused by pavement coating material, water that comes from rain, unstable soil conditions, climate or weather, and excessive vehicle volume [6][7]. In this study, road damage is only analyzed from the excess vehicle volume, because in Taman Road Sidoarjo, many heavy vehicles pass through it.

The principle in road pavement planning is how to spread vehicle wheel loads to the subgrade so that the subgrade can bear the loads. In other words, the stress caused by the wheel load of the vehicle when it reaches the subgrade must be smaller than the subgrade stress. The ground will experience compressive stress due to vehicle wheel loads. This can be illustrated in Figure 1.

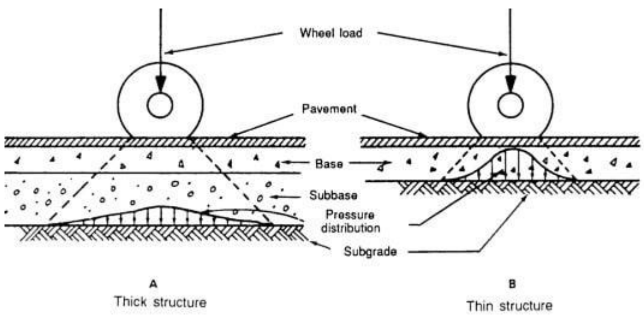

Figure 1. Distribution of Vehicle Wheel Loads

The principle of road pavement planning are:

A. *The principle of repetitive load*

Road pavement planning is not based on the largest vehicle load that passes, but on the accumulation of vehicle loads that are planned to pass through the road.

B. The principle of fatigue due to burden

The principle of fatigue due to the burden is the asphalt road will suffer permanent damage due to the design load that exceeds the fatigue limit of the mixture of road materials so that at this stage, the age of pavement is exceeded. The more weight a vehicle passes, the fatigue will quickly occur. Moreover, the repetitive weight is higher, the faster the road fatigue process will be.

The pavement structure is planned by assuming that the road will experience several repetitions of vehicle loads in the Standard Axle Load (SAL) unit of 18,000 lbs or 8,16 tons for Single Axle Dual Wheel. The vehicle axle configuration in the pavement calculation needs to be transformed first into the Equivalent Standard Axle Load (ESAL), whose forces are distributed at each pavement layer [8]. Each type of vehicle has different axle wheels, including a single axis, double axis, and triple axis. Each axis has a Damage Factor (DF). DF or Equivalent Axle Load (EAL) of a vehicle axle load is the number of single-axis trails weighing 18,000 lbs or 8,16 tons resulting in the same pavement damage if the axis of the vehicle in question crosses once on a road section. Analysis of road damage due to overloading has consequences for the Damage Factor Cost and Design Cost [9].

II. METHODOLOGY

Visual recording aims to record as complete as possible damage that occurs, such as: regarding the width of the pavement, the type of pavement, gradients, intersections, traffic signs. Visual inspection can be done by driving, walking, depending on the situation. Surveyors must understand the characteristics of each type of damage. Road damage is the area of the road surface that is damaged against the total area of the road being reviewed. The stages of data collection and processing are as follows:

a. First, a literature study is conducted to determine the types of road damage.

b. Road geometry surveys include road length and width.

c. Road damage condition survey by calculating area and amount according to the damage type.

d. Road damage documentation. This documentation is needed to determine the damage during the first survey and the second survey.

e. The survey was conducted twice at 99-day intervals.

f. Calculate the increase in the value of road damage from survey data 1 and survey data 2.

g. Traffic counting survey to find out the volume of vehicles every day that cross this road.

h. Observation of the effect of EAL values on-road damage is done by statistical tests using the Wilcoxon Signed Ranks Test and paired T-test with a significance level of $p \leq 0{,}05$.

In this study, two statistical tests were conducted, namely the Wilcoxon Signed Ranks Test and the Paired T-test. The hypotheses for the Wilcoxon Signed Ranks Test are:

H_0: EAL value (vehicle load) does not affect road damage.

H_1: EAL value (vehicle load) affects road damage.

Decision making on the Wilcoxon Signed Ranks Test by comparing probability (p_{Value}) with α [10][11].

- If $p > \alpha$, then H_0 is rejected.
- If $p < \alpha$, then H_1 is accepted.

Where : $\alpha = 0{,}05$

To find out the difference before and after the treatment (through the load for 99 days), the Paired T-test was performed [12]. So the sample was observed twice, before being treated and after being treated. Two samples are paired to see whether there are differences or not, or to be able to see whether there is an effect of treatment on the sample results or not. The hypothesis of Paired T-Test is:

H_0: There is no difference before and after treatment

H_1: There are differences before and after treatment

Decision making on Paired T-test statistical tests by comparing T_{Value} with $t_{Critical}$.

If $P_{Value} > t_{Critical}$, then H_0 is rejected.

If $P_{Value} < t_{Critical}$, then H_0 is accepted

III. DISCUSSION

Road damage data obtained from the survey, which is divided into two stages, namely:

- Phase 1 survey, conducted on April 22, 2019.
- Phase 2 survey, conducted on July 31, 2019.

Vehicle volume surveys are conducted on Tuesday, Wednesday, and Thursday. The survey was carried out on May 14-16, 2019 and May 21-23, 2019. The results of the survey 1 in the form of the number and dimensions of damage by the type of road damage. This damage condition is then multiplied by a multiplier factor like the following equation:

$$NK = \sum \text{Damage Condition} \times C \quad (1)$$

With: NK = Damage Value

C = Multiplier Factor

The results of the survey 1 can be seen in table 1. In survey 1, the greatest damage occurred at STA 1+000 - STA 1+500, with a value of 747. The most dominant type of damage was ravelling with a value of 606.

TABLE I. THE RESULTS OF THE VALUE OF ROAD DAMAGE IN SURVEY 1

Type of Damage	Multi-plier Factor	STA					Total Damage Value
		0+000 - 0+500	0+500 - 1+000	1+000 - 1+500	1+500 - 2+000	2+000 - 2+500	
Potholes	6	84	78	96	84	120	462
Alligator Cracking	2	72	68	88	106	84	418
Profile Distortion	2	76	106	134	90	84	490
Raveling	2	74	118	184	136	94	606
Transverse Crack	1	6	6	12	13	12	49
Longitudinal Cracking	1	46	66	80	61	44	297
Block Cracking	1	57	84	80	52	47	320
Rutting	1	38	68	73	53	42	274
Flushing	0,25	0	0	0	0	0	0
Edge Distortion	0,25	0	0	0	0	0	0
Damage Value		453	594	747	595	527	2916

Source: Research result

Survey 2 was carried out with a time interval of 99 days from survey 1. The assessment of road damage in survey 2 was the same as survey 1. In survey 2, STA 1+100 - STA 1+500 suffered the most significant damage with a damage value of 1269. Ravelling became the type of damage the biggest road with a value of 1068. The results of survey 2 can be seen in table 2.

TABLE II. DAMAGE VALUE OF SURVEY RESULTS 2

Type of Damage	Multi-plier Factor	STA					Total Damage Value
		0+000 - 0+500	0+500 - 1+000	1+000 - 1+500	1+500 - 2+000	2+000 - 2+500	
Potholes	6	108	144	168	120	150	690
Alligator Cracking	2	106	156	202	186	136	786
Profile Distortion	2	122	222	212	206	152	914
Ravelling	2	140	248	282	242	156	1068
Transverse Crack	1	8	11	21	26	21	87
Longitudinal Cracking	1	65	113	137	105	90	510
Block Cracking	1	84	124	132	95	94	529
Rutting	1	54	97	115	103	82	451
Flushing	0,25	0	0	0	0	0	0
Edge Distortion	0,25	0	0	0	0	0	0
Damage Value		687	1115	1269	1083	881	5035

Source: Research result

In Table 2, there was an increase in the value of road damage in Taman Road Sidoarjo. The biggest increase in damage occurs to:

STA 1 + 000 - STA 1 + 500:

a) In survey 1, the value of road damage = 747

b) In survey 2, the value of road damage = 1269

c) During the 99 day interval, the increase in damage value is:

= Survey 2 - Survey 1

= 1269 – 747

= 522

For calculations of increasing the value of damage to roads can be seen in Table 3.

TABLE III. INCREASING THE VALUE OF ROAD DAMAGE IN TAMAN ROAD SIDOARJO

Road Damage Value	STA				
	0+000 - 0+500	0+500 - 1+000	1+000 - 1+500	1+500 - 2+000	2+000 - 2+500
Road Damage Value Stage 1	453	594	747	595	527
Road Damage Value Stage 2	687	1115	1269	1083	881
Increased Value of Road Damage	234	521	522	488	354
Total Increase in Road Damage Value	2119				

Source: Research result

To find out the percentage of damage that occurs from each type, it can be calculated with the following formula 2.

$$Percentage\ of\ Road\ Damage = \frac{The\ Damage\ Value\ of\ Each\ Type}{Total\ Damage\ Value}\ x\ 100\% \quad (2)$$

The results of calculating the percentage of road damage values for each type can be seen in Table 4 and Figure 2.

TABLE IV. PERCENTAGE OF ROAD DAMAGE

Type of Damage	Percentage (%)		
	Survey 1	Survey 2	Average
Potholes	15.84	13.70	14.78
Alligator Cracking	14.33	15.61	14.94
Profile Distortion	16.80	18.15	17.45
Ravelling	20.78	21.21	21.02
Transverse Crack	1.68	1.73	1.71
Longitudinal Cracking	10.19	10.13	10.17
Block Cracking	10.97	10.51	10.76
Rutting	9.40	8.96	9.16

Source: Research result

In table 4, it looks like there are irregularities, namely potholes, longitudinal cracking, block cracking, there is a decrease in the percentage of damage. This is not a mistake, but because the damage value from alligator cracking, profile distortion, ravelling, and transverse crack has a much higher increase in damage percentage. From table 4, the rate of road damage can be drawn as shown in figure 2.

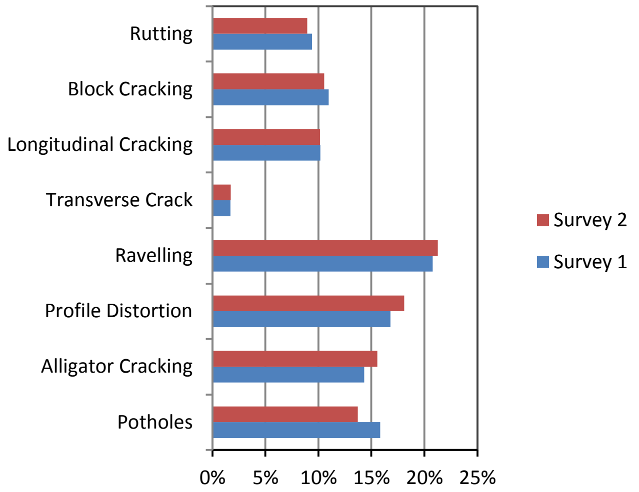

Figure 2. Comparison of Percentage of Road Damage

In table 4 and figure 2, the most significant type of damage is ravelling, while transverse track is the smallest type of damage. The cause of ravelling is a mixture of layers of material that is ugly, so it is easy to peel. Another reason is poor drainage that results in flooding. As a result of flooding, the binding capacity between asphalt and aggregate is reduced [13][14]. Another quite important cause is cracked that is not immediately repaired. If this cracking left untreated will cause greater damage and damage to the road foundation.

Traffic counting data consists of traffic data that passes through Taman Road Sidoarjo. The survey was conducted from May 14-16, 2019 and May 21-23, 2019, from 06.00 WIB until 18.00 WIB. Every 15 minutes recorded to get more accurate results. To make it easier to collect traffic counting data, Taman Road is divided into four segments. Traffic counting survey results can be seen in table 5.

TABLE V. AVERAGE PERCENTAGE OF VEHICLES CAUSED DAMAGE

Information	MC	LV	MV	HV
Vehicle Volume	36234	22407	1860	1172
E	0	0,0004	0,306	6,1179
Interval	99	99	99	99
EAL	0	887	56347	708848
Total	767082			
% Causes of Road Damage	0	0,12	7,35	92,54

Source: Research result

From the results of the calculation of the traffic volume in table 5, the types of vehicles that mostly pass through the Taman Road are motorcycles (MV) with an average daily volume of 36234 vehicles. Still, this type of vehicle does not affect road damage. This is due to the motorcycle having a little load or no equivalent value. Meanwhile, heavy vehicles (HV), although the average daily volume is only 1172 vehicles, affect road damage. The EAL value of heavy vehicles is 708848, so the percentage of causes of road damage is heavy vehicles at 92.54%.

To determine whether there is an effect of the EAL value with road damage, it is analyzed using the Wilcoxon Signed Ranks Test and Paired T-test. From the Wilcoxon Signed Ranks Test, $p_{\text{Value}} = 0{,}01 < \alpha = 0{,}05$. This indicates that H_0 is rejected, and H_1 is accepted, meaning that the value of EAL (vehicle load) affects road damage. The greater the EAL value of a vehicle, the greater the damage it causes.

The results of the Paired T-test results obtained in table 6.

TABLE VI. T-TEST RESULTS: PAIRED TWO SAMPLE FOR MEANS

T-test: Paired Two Sample for Means	
Mean	919554,4611
Variance	8046611235
Observations	2
Pearson Correlation	0,862
Hypothesized Mean Difference	0
df	2
t Stat	17,756
P value (T) one-tail	0,001687
t Critical one-tail	2,82889
P value (T) two-tail	0,002275
t Critical two-tail	4,2271

From Table 6 the results of statistical tests using Paired T-test obtained $P = 0{,}001687 \leq t = 2{,}82889$. This shows that H_0 was rejected, and H_1 was accepted. From the Paired T-test, it was concluded that there are differences before and after treatment (through the load for 99 days).

IV. CONCLUSION

From the results of the study, several conclusions can be drawn, namely:

a) The types of damage that occur in Taman Sidoarjo road are potholes, ravelling, alligator cracking, profile distortion, block cracking, transverse crack, longitudinal cracking, rutting. The most dominant type of damage is ravelling. The highest value of road damage occurred at STA 1+000 - STA 1+500, with a damage value of 522.

b) The type of vehicle that significantly affects the damage is heavy vehicles, especially 2-axle trucks. Even though the volume of heavy vehicles is the least, but because the EAL value is the biggest, the level of damage caused is also greater.

c) From the results of the Wilcoxon Signed Ranks Test and Paired T-test shows that the EAL value affects the damage to the road. This means that the heavier the vehicle load, the greater the chance of road damage.

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REFERENCES

[1] N. Khafian, "The Efforts of Handling Transportation Problems in DKI Jakarta Through Sustainable Transportation Policy," *Bisnis Birokrasi J.*, vol. 20, no. 3, pp. 2011–2014, 2014.

[2] B. Srinivasu, A. Professor, and P. Srinivasa Rao, "Infrastructure Development and Economic growth: Prospects and Perspective," *J. Bus. Manag. Soc. Sci. Res.*, vol. 2, no. 1, pp. 2319–5614, 2013

[3] E. A. Olamigoke and A. A. Emmanuel, "The Role of Road Transportation in Local Economic Development : A Focus on Nigeria Transportation System," vol. 3, no. 6, pp. 46–54, 2013.

[4] E. A. Olamigoke and A. A. Emmanuel, "The Role of Road Transportation in Local Economic Development : A Focus on Nigeria Transportation System," vol. 3, no. 6, pp. 46–54, 2013.

[5] E. A. Olamigoke and A. A. Emmanuel, "The Role of Road Transportation in Local Economic Development : A Focus on Nigeria Transportation System," vol. 3, no. 6, pp. 46–54, 2013.

[6] S. Ibnu and U. Nugroho, "Road Damage Analysis of Kalianak Road Surabaya," *Adv. Sci. Lett.*, vol. 23, no. 12, pp. 12295–12299, 2018.

[7] A. Mohammed, S. Y. Umar, D. Samson, and T. Y. Ahmad, "The Effect of Pavement Condition on Traffic Safety: A Case Study of Some Federal Roads in Bauchi State," *IOSR J. Mech. Civ. Eng.*, vol. 12, no. 03, pp. 139–146, 2016.

[8] F. Sarie, M. Bisri, A. Wicaksono, and R. Effendi, "Types of Road Pavement Damage for Road on Peatland, A Study Case in Palangka Raya, Central Kalimantan, Indonesia," *IOSR J. Environ. Sci. Toxicol. Food Technol.*, vol. 9, no. 12, pp. 53–59, 2015.

[9] Z. Shehu, N. Elma, I. R. Endut, and G. D. Holt, "Factors influencing road infrastructure damage in Malaysia," *Infrastruct. Asset Manag.*, vol. 1, no. 2, pp. 42–52, 2014.

[10] M. Raheel *et al.*, "Impact of axle overload, asphalt pavement thickness and subgrade modulus on load equivalency factor using modified ESALs equation," *Cogent Eng.*, vol. 5, no. 1, pp. 1–12, 2018.

[11] J. C. Pais, S. I. R. Amorim, and M. J. C. Minhoto, "Impact of traffic overload on road pavement performance," *J. Transp. Eng.*, vol. 139, no. 9, pp. 873–879, 2013.

[12] I. C. Anaene Oyeka and G. U. Ebuh, "Modified Wilcoxon Signed-Rank Test," *Open J. Stat.*, vol. 02, no. 02, pp. 172–176, 2012.

[13] T. K. Kim, "Statistic and Probability," no. Table 2, 2015.

[14] A. O. Yisa, G. Lazhi, and D. Paul, "Bad Drainage and Its Effects on Road Pavement Conditions in Nigeria," *Civ. Environ. Res.*, vol. 3, no. 10, pp. 7–16, 2013.

[15] M. R. Keymanesh, H. Ziari, A. Nasrollahtabar, and D. Kamrankho, "Correlation Between Aggregate to Aggregate Contact and Mechanical Properties of HMA Mixture," Civ. Eng. Urban Plan. An Int. J., vol. 3, no. 3, pp. 29–35, 2016.

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