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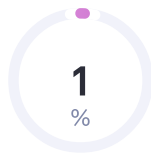
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5

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1

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 dominated³ by heavy vehicles. Consequently, road damage often occurs. Every year, road improvements are always made⁴. The results of the road condition survey in stage 1 and stage 2 survey⁵ found that the ravelling⁶ 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 708848⁷, 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 concluded⁸ 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.

Introduction

The main transportation problem in Indonesia is a huge⁹ 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 handled¹⁰ immediately, it will lead to higher investment and maintenance costs.

Road damage is generally caused¹¹ 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. This¹² can be illustrated¹³ in Figure 1.

Figure 1. Distribution of Vehicle Wheel Loads

The principle of road pavement planning are:

a. The principle¹⁴ of repetitive load

Road pavement planning is not based on the largest¹⁵ 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 principle¹⁶ of fatigue¹⁷ due to the burden¹⁸ 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 weight²¹ is higher, the²² faster the road fatigue process will be.

The pavement structure is planned²³ 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 distributed²⁴ 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].

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,²⁵ 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 is²⁶ the area of the road surface that is damaged²⁷ against the total area of the road being reviewed.²⁸ 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 survey²⁹ 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 done³⁰ by statistical tests using the Wilcoxon Signed Ranks Test and paired T-test with a significance level of $p = 0,05$.

In this study, two statistical tests were conducted,³¹ namely the Wilcoxon Signed Ranks Test and the Paired T-test. The hypotheses for the Wilcoxon Signed Ranks Test are:

H0: EAL value (vehicle load) does not affect road damage.

H1: EAL value (vehicle load) affects road damage.

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

If $p > \alpha$, then H_0 is rejected.

If $p < \alpha$, then H_1 is accepted.

Where : $\alpha = 0,05$

105 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 twice³², before being treated and after being treated. Two samples are paired to
106 see whether there are differences or not³³, 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:

107 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 TValue with tCritical³⁴.

- If P Value³⁵ $>$ t Critical, then H_0 is rejected.

- If P Value³⁶ $<$ t Critical, then H_0 is accepted

Discussion

Road damage data obtained from the survey, which is divided³⁷ into two stages, namely:

- Phase 1 survey, conducted on April 22, 2019.

- Phase 2 survey, conducted³⁸ on July 31, 2019.

Vehicle volume surveys are conducted³⁹ on Tuesday, Wednesday, and Thursday.

The survey was carried out on May 14-16, 2019 and⁴⁰ 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:

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

With: NK = Damage Value

C = Multiplier Factor

The results of the survey 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

Ravelling⁴⁸

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 1⁴⁹. The assessment of road damage in survey 2⁵⁰ was the same as survey 1⁵¹. In survey 2, STA 1+100 - STA 1+500 suffered the most significant damage⁵² with a damage value of 1269. Ravelling⁵³ became the type of damage the biggest⁵⁴ road with a value⁵⁵ of 1068. The results of survey 2⁵⁶ can be seen in table 2⁵⁷.

TABLE II. DAMAGE VALUE OF SURVEY RESULTS 2

Type of Damage

Multi-plier⁴³ 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

Ravelling⁵⁸

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 be⁵⁹
calculated⁶⁰ with the following formula 2.

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

The results of calculating the percentage⁶¹ of road damage values for each type can be seen⁶² in Table 4 and Figure 2.

TABLE IV. PERCENTAGE OF ROAD DAMAGE

Type of Damage

Percentage⁶³ (%)

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

Ravelling⁶⁴

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. ⁶⁵ This is not a mistake, but because the damage value from alligator cracking, profile distortion, ⁶⁶ ravelling, and transverse crack has a much higher increase in damage percentage. From table 4, the rate of road damage can ⁶⁷ be drawn as ⁶⁸ shown in figure 2.

Figure 2. Comparison of Percentage of Road Damage

In table 4 and ⁶⁹figure 2, the most significant type of damage is ⁷⁰ravelling, while ⁷¹transverse track is the smallest type of ⁷²damage. The cause of ⁷³ravelling 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 ⁷⁴is reduced [13][14]. Another quite important cause ⁷⁵is cracked that ⁷⁶is not immediately repaired. If this cracking left untreated will cause ⁷⁷greater damage and damage to the road foundation. Traffic counting data consists of traffic data that passes through Taman Road Sidoarjo. The survey ⁷⁸was conducted from May 14-16, 2019 and ⁷⁹May 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 ⁸⁰is divided into four segments. Traffic counting survey results can ⁸¹be 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 volume⁸² of 36234 vehicles⁸³. Still, this type of vehicle does not affect road damage. This⁸⁴ 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 damage⁸⁵, it is analyzed using the Wilcoxon Signed Ranks Test and Paired T-test. From the Wilcoxon Signed Ranks Test, p Value⁸⁶ = 0,01 < α = 0,05. This⁸⁷ indicates that H0 is rejected⁸⁸, and H1 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-tail⁸⁹

0,001687

t Critical one-tail

2,82889

P value (T) two-tail⁹⁰

0,002275

t Critical two-tail

4,2271

From Table 6 the results of statistical tests using Paired T-test obtained $P = 0,001687$ $t = 2,82889$. This⁹¹ shows that H_0 was rejected⁹², 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).⁹³⁹⁴

Conclusion

From the results of the study, several conclusions can be drawn⁹⁵, namely:

a. The types of damage that occur in Taman Sidoarjo road are potholes, ravelling⁹⁶, alligator cracking, profile distortion, block cracking, transverse crack, longitudinal cracking, rutting. The most dominant type of damage is ravelling⁹⁷. 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 damage⁹⁸ 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 greater⁹⁹.

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. This¹⁰⁰ means that the heavier the vehicle load, the greater¹⁰¹ the chance of road damage.

Acknowledgment

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%Leave it blank for Publications Department to complete%

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1.	Investigations vol	Improper Formatting	Correctness
2.	, vol	Punctuation in Compound/Complex Sentences	Correctness
3.	is dominated	Passive Voice Misuse	Clarity
4.	are always made	Passive Voice Misuse	Clarity
5.	survey → study, investigation, poll, review	Word Choice	Engagement
6.	ravelling → raveling	Mixed Dialects of English	Correctness
7.	708848,	Punctuation in Compound/Complex Sentences	Correctness
8.	was concluded	Passive Voice Misuse	Clarity
9.	huge → vast, massive	Word Choice	Engagement
10.	is not handled	Passive Voice Misuse	Clarity
11.	is generally caused	Passive Voice Misuse	Clarity
12.	This	Intricate Text	Clarity
13.	be illustrated	Passive Voice Misuse	Clarity
14.	principle → law, policy	Word Choice	Engagement
15.	largest → most significant, most extensive, most considerable, most substantial	Word Choice	Engagement
16.	principle → law, policy	Word Choice	Engagement
17.	fatigue → exhaustion	Word Choice	Engagement
18.	burden → weight, charge, difficulty, trouble	Word Choice	Engagement

19.	<i>is exceeded</i>	Passive Voice Misuse	Clarity
20.	exceeded → surpassed	Word Choice	Engagement
21.	weight → pressure	Word Choice	Engagement
22.	,the → ; the	Punctuation in Compound/Complex Sentences	Correctness
23.	<i>is planned</i>	Passive Voice Misuse	Clarity
24.	<i>are distributed</i>	Passive Voice Misuse	Clarity
25.	pavement → roadway	Word Choice	Engagement
26.	is → in	Confused Words	Correctness
27.	<i>is damaged</i>	Passive Voice Misuse	Clarity
28.	<i>being reviewed</i>	Passive Voice Misuse	Clarity
29.	survey → study	Word Choice	Engagement
30.	<i>is done</i>	Passive Voice Misuse	Clarity
31.	<i>were conducted</i>	Passive Voice Misuse	Clarity
32.	twice,	Punctuation in Compound/Complex Sentences	Correctness
33.	not,	Comma Misuse within Clauses	Correctness
34.	tCritical → critical	Misspelled Words	Correctness
35.	PValue → P-Value	Misspelled Words	Correctness
36.	PValue → P-Value	Misspelled Words	Correctness
37.	<i>is divided</i>	Passive Voice Misuse	Clarity

38.	conducted → held	Word Choice	Engagement
39.	are conducted	Passive Voice Misuse	Clarity
40.	, and	Punctuation in Compound/Complex Sentences	Correctness
41.	<i>The results of the survey 1 in the form of the number and dimensions of damage by the type of road damage.</i>	Wordy Sentences	Clarity
42.	is then multiplied	Passive Voice Misuse	Clarity
43.	multiplier; Multi-plier	Text Inconsistencies	Correctness
44.	1 → one	Improper Formatting	Correctness
45.	be seen	Passive Voice Misuse	Clarity
46.	In survey → In survey	Improper Formatting	Correctness
47.	ravelling → raveling	Mixed Dialects of English	Correctness
48.	Ravelling → Raveling	Mixed Dialects of English	Correctness
49.	survey → study, review	Word Choice	Engagement
50.	survey → study, review	Word Choice	Engagement
51.	survey → study, review	Word Choice	Engagement
52.	damage → blow, injury	Word Choice	Engagement
53.	Ravelling → Raveling	Mixed Dialects of English	Correctness
54.	biggest → most significant, most prominent	Word Choice	Engagement
55.	a value → an amount	Word Choice	Engagement
56.	2 → two	Improper Formatting	Correctness

57.	<i>be seen</i>	Passive Voice Misuse	Clarity
58.	Ravelling → Raveling	Mixed Dialects of English	Correctness
59.	<i>To find out the percentage of damage that occurs from each type</i>	Misplaced Words or Phrases	Correctness
60.	<i>be calculated</i>	Passive Voice Misuse	Clarity
61.	percentage → rate	Word Choice	Engagement
62.	<i>be seen</i>	Passive Voice Misuse	Clarity
63.	Percentage → Rate	Word Choice	Engagement
64.	Ravelling → Raveling	Mixed Dialects of English	Correctness
65.	<i>This</i>	Intricate Text	Clarity
66.	ravelling → raveling	Mixed Dialects of English	Correctness
67.	<i>be drawn</i>	Passive Voice Misuse	Clarity
68.	<i>, as</i>	Punctuation in Compound/Complex Sentences	Correctness
69.	figure → number	Word Choice	Engagement
70.	ravelling → raveling	Mixed Dialects of English	Correctness
71.	<i>the transverse, or a transverse</i>	Determiner Use (a/an/the/this, etc.)	Correctness
72.	damage → injury	Word Choice	Engagement
73.	ravelling → raveling	Mixed Dialects of English	Correctness
74.	<i>is reduced</i>	Passive Voice Misuse	Clarity
75.	<i>is cracked</i>	Passive Voice Misuse	Clarity
76.	<i>is not immediately repaired</i>	Passive Voice Misuse	Clarity

77.	greater → more significant, more considerable	Word Choice	Engagement
78.	<i>was conducted</i>	Passive Voice Misuse	Clarity
79.	, and	Punctuation in Compound/Complex Sentences	Correctness
80.	<i>is divided</i>	Passive Voice Misuse	Clarity
81.	<i>be seen</i>	Passive Voice Misuse	Clarity
82.	volume → amount, capacity, size	Word Choice	Engagement
83.	vehicles → cars	Word Choice	Engagement
84.	<i>This</i>	Intricate Text	Clarity
85.	<i>To determine whether there is an effect of the EAL value with road damage</i>	Misplaced Words or Phrases	Correctness
86.	p-Value → p-Value	Misspelled Words	Correctness
87.	<i>This</i>	Intricate Text	Clarity
88.	<i>is rejected</i>	Passive Voice Misuse	Clarity
89.	P-value → P-value	Misspelled Words	Correctness
90.	P-value → P-value	Misspelled Words	Correctness
91.	<i>This</i>	Intricate Text	Clarity
92.	<i>was rejected</i>	Passive Voice Misuse	Clarity
93.	<i>was concluded</i>	Passive Voice Misuse	Clarity
94.	<i>From the Paired T-test, it was concluded that there are differences before and after treatment (through the load for 99 days).</i>	Wordy Sentences	Clarity

95.	<i>be drawn</i>	Passive Voice Misuse	Clarity
96.	ravelling → raveling	Mixed Dialects of English	Correctness
97.	ravelling → raveling	Mixed Dialects of English	Correctness
98.	damage → cost	Word Choice	Engagement
99.	greater → higher	Word Choice	Engagement
100.	<i>This</i>	Intricate Text	Clarity
101.	greater → higher	Word Choice	Engagement
102.	Yisa → Yes	Misspelled Words	Correctness
103.	years,	Punctuation in Compound/Complex Sentences	Correctness
104.	<i>International Journal of Science and Engineering Investigations, Volume</i>	Study on Melt Flow Length in Injection Molding Process ... http://www.ijsei.com/papers/ijsei-66517-10.pdf	Originality
105.	<i>To find out the difference before and after the</i>	The effect of mirror therapy on the gait of chronic stroke ... http://www.scopemed.org/?mno=296484	Originality
106.	<i>to see whether there is an effect of</i>	For instance prison study to see whether there is an ... https://www.coursehero.com/file/p56uatq/For-instance-prison-study-to-see-whether-there-is-an-effect-of-nutrition-low/	Originality
107.	<i>H0: There is no difference before and after</i>	a What is the appropriate t test Your answer repeated ... https://www.coursehero.com/file/pm0619g/a-What-is-the-appropriate-t-test-Your-answer-repeated-measures-t-test-2b-State/	Originality

108. *He has been teaching for 20 years, in* Roberto Sabbadini | Gonzaga University
<https://www.gonzaga.edu/gonzaga-in-florence/about-us/faculty/roberto-sabbadini> Originality