International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-4, February 2020

The Correlation between Drainage Condition and Pavement Performance

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Abstract*: One of the things that cause rapid destruction the pavement that is due to lack of maintenance of the road drainage system. Road drainage system serves to dry the pavement or water flow in order as quickly as possible out of the road surface and then flowed through the channel next to the final disposal. Road deterioration will interfere with the comfort and safety of the vehicle and affects the performance and quality of the pavement structure. Pavement condition index (PCI) is one of the pavement performance assessment methods used to evaluate the condition of the pavement. This research is aimed to identify and analyze the shape of influence of drainage conditions to damage the road surface pavement structures PCI method with the territory of reviews Jakarta Province. The method used is a field research with primary data in the form of survey of road damage that will be evaluated by the method of PCI and carried out analysis of the effect of drainage analysis method experimental design factorial of the components of the condition of drainage channels, the existence of the water surface pavement, and the value of PCI as the value of damage pavement. Based on the research results obtained using Design of Experiments main factors that greatly influence the surface damage is a factor pavement drainage channel conditions and then factor the value of PCI and the last is a factor of the condition of the surface water. The entire region of reviews is dominated by the value of PCI "good" and the type of maintenance that dominates is "routine maintenance".

***Index Terms*: road deterioration, drainage condition, surface water, PCI, factorial analysis.**

I. INTRODUCTION

There are three factors that affect the quality of road, namely the construction of roads, drainage condition of the road surface and the surrounding area, and the use of the road is overloaded. Overload can cause the load of each vehicle axle to exceed the specified standard set (Hadiwardoyo, Sumabrata, & Berawi, 2012)(Tawalare & Raju, 2016). Damage to pavement can be caused by the burden of excessive traffic, soil conditions the base (subgrade) unstable, condition of the foundation soil is not good, the material of the pavement structure and poor processing, a decline due to the construction of utilities under the pavement, asphalt content in the mix too much, tiredness (fatigue) from the pavement, the environmental conditions (temperature and high rainfall), as well as poor drainage (Mia, Henning, & Costello, 2015). One of the things that cause rapid damage to road pavement that is caused by lack of maintenance of drainage systems. The road was built without a good drainage system has a speed faster damage, so its pavement design life will be shorter than the road built with good drainage structures. Good drainage should be able to avoid problems-problems or damage to roads caused by the effects of weather and traffic load. Water drainage factor is the main enemy of the asphalt road as the water pooled on the surface will soak into the pores and damage the asphalt bond that undermines the foundations of the road.

This paper describes the effect of drainage in the research area of flexible pavement damage surface structures that are reviewed by the scope of the research conducted in Jakarta. With the classification of collector roads and assess damage caused only by water or exacerbated by water. Determination of drainage and surface water conditions seen purely based functional. Previous research related to the effects of drainage conditions damage the surface of flexible pavement structure has a lot to do. Update drainage accordance with the experiments have been conducted Mia Muhammad NU aims to: (1) Preventing moisture captured in the shoulder of the road and road profile; (2) Remove stagnant moisture on the surface, near the edge of the seal; (3) Increase the pavement life cycle through sub-surface drainage improvements; (4) Reducing the risk of premature failure through shear and permanent deformation due to the moisture in the formation of the sidewalk; (5) Preventing pump and blistering effect in the surface layers mainly in the piece or pieces of the box part by lowering the ground water level; and (6) improve the efficiency of the existing drainage action through the installation and replacement of pavement and the existing channels, the channel sub-soil and manhole (Chen, Dong, Zhu, & Huang, 2016)(Islam & Buttlar, 2012).

II. LITERATURE STUDY

A. Data Collection

This study was conducted aiming to obtain results that match the intended target, through which the research will be obtained from the data that can then be used in the processing and analysis of data to get the expected results, the correlation of surface damage the structure of the flexible pavement with good drainage and the presence of surface water that flooded when it rains.

Revised Manuscript Received on February 28, 2020.
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Data retrieval begins by reviewing the roads in the region of reviews randomly with respect to some criteria, which is a type of flexible pavement, road class iii (collector), drainage channels open, not include roads with bends, inclines / derivative and intersection, and heavy vehicles are very rare the road passes. The criteria are selected to facilitate the categorization to achieve the research objectives.

The data collection was done by using the inventory of flexible pavement structures in Jakarta, then saw, assessment and categorization of the condition of the drainage around the area of damage to the road surface and surface water conditions moments after the rain. After categorizing is finished, then the observation of damage to the road surface and measuring the extent of damage.

The survey was conducted with a stroll along the road which are reviewed and observed good any damage caused to the road surface and drainage. There are 32 research sites were observed and are spread over 5 areas in Jakarta (Shahin, 1994). Then the qualitative data obtained will be processed based on the statistical approach to library literature manual and stats processing program.

B. Pavement Condition Index

Pavement condition assessment system based on the type and level of damage to roads that occurred in the study using the PCI method. Surveying the damage done to identify damage that occurred on the pavement. The results are used to determine the level of damage to roads and then make an analysis of the effect of its drainage. Identifying the damage intended to determine the types of distress, distress area and distress classification (Iskandar, Hadiwardoyo, Sumabrata, & Fitriasari, 2018).

This type of damage of the sample was measured to what extent, and the results of the survey examined in this study refer to the literature. Further examination and assessment at the destination location by considering Table 1 as a reference to assess the damage, and are grouped into several categories. Measurements were taken at the level of the damage below the depth of damage to the road surface and drainage. From the results of the monitoring and investigation in the field can be obtained data for a review of the location 32 as shown in Table 1.

Table 1: Table of drainage conditions, puddles and PCI values

No	PCI	Drainage Condition	Puddles
1	95.6	Good	exist
2	84	Moderate	exist
3	92	good	exist
4	83	good	exist
5	98	good	exist
6	86	moderate	no exist
7	75	moderate	exist
8	88	good	no exist
9	85	good	exist
10	79	good	exist
11	87.6	moderate	exist
12	76.4	moderate	exist
13	79.5	moderate	no exist
14	78	moderate	no exist
15	72.5	moderate	no exist
16	90.2	moderate	exist
17	79	moderate	exist
18	91	good	no exist
19	98	moderate	exist
20	94	good	no exist
21	85	good	no exist
22	94.2	good	no exist
23	93.9	good	no exist
24	91.7	moderate	no exist
25	85	good	no exist
26	98	good	no exist
27	90	good	no exist
28	86	good	no exist
29	84	good	no exist
30	82.5	good	no exist
31	82	good	no exist
32	98	moderate	exist

| No | PCI | Drainage Condition | Puddles |

C. Rating Evaluation Road Drainage

The categorization used in this study are based on common sense and are intended to be easy to use. It describes three categories of evaluation: drainage channel conditions (fig.1 and fig.2), surface water conditions (fig.3 and fig.4) and the condition of the degree of damage (table 2) (Shah, Jain, Tiwari, & Jain, 2013)(Kathleen T Hall, 2003). Categorization has subcategories which describe the condition of research location. Each category is illustrated by a series of photographs and a few explanations. It is unlikely that all the damage will be described.

Fig. 1. Picture of drainage good condition

Fig. 1 describe the flow of water to function properly and there is no trash.

Fig. 2. Picture of drainage moderate condition

Retrieval Number: C8413019320 /2020©BEIESP
DOI: 10.35940/ijitee.C8413.029420
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
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Fig. 2 describe the flow of water to function properly and there is a bit rubbish

Fig 3. Picture of drainage with puddles condition

Fig 3. Describe there are puddles on roadside.

Fig. 4. Picture of puddles condition

Table 2: Categorization Value PCI

PCI Classification	PCI Score
Good	100 - 85
Satisfactory	85 - 70

III. ANALYSIS AND DISCUSSION

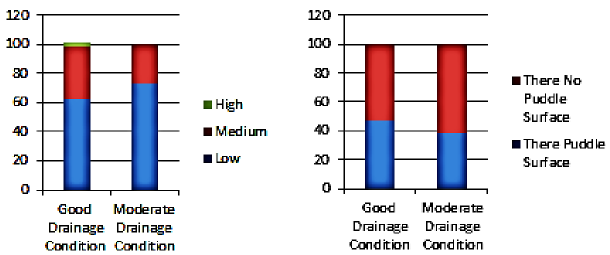

Fig. 5. (left). Distribution of the extent of damage is based on the condition of drainage (right) the distribution of surface water conditions based on the condition of drainage

Fig 5 (left) describe the damage to the light level (low) most widely produced by the two drainage conditions, reaching 62 and 73 percent. Good drainage conditions and is producing damage which entirely within the light levels. Fig 5 (right) illustrates the condition there are no puddles pavement surface is more prevalent in both drainage with a percentage of 53 and 62 percent.

A. Data Processing with Factor Analysis

In the study, researchers used three factors, A (drainage channel conditions), B (surface water conditions), and C (Score PCI), with the level of each level as follows:
Drainage Channel Condition (A); A1 = Drainage Channel Condition Good, A2 = Drainage Channel Conditions Medium
Surface Water Condition (B); B1 = There Puddles Surface, B2 = N Puddles Surface
PCI value (C); C1 = The Good PCI (100-85), C2 = Value PCI Satisfactory (84-70)
And the three-factor model of analysis of variance, to the effect (influence) remains:

Ho : $\tau_i = 0$ — $H_1 : \tau_i \neq 0$
Ho : $\beta_j = 0$ — $H_1 : \beta_j \neq 0$ No major influence

Ho : $e_{ke} = 0$ — $H_1 : w_{k.} \neq 0$
Ho : $\tau_i\ \beta_j = 0$ — $H_1 : \tau_i\ \beta_j \neq 0$
Ho : $\tau_i\ \gamma_k = 0$ — $H_1 : \tau_i\ \gamma_k \neq 0$ There is no interaction effect

Ho : $\beta_j\ \gamma_k = 0$ — $H_1 : \beta_j\ \gamma_k \neq 0$
Ho : $\tau_i\ \beta_j\ \gamma_k = 0$ — $H_1 : \tau_i\ \beta_j\ \gamma_k \neq 0$

The initial hypothesis (Ho) no main effect (A, B, C) and the effect of interactions (AB, AC, BC, and ABC) real (significant).

B. Construction Design of Experiments

The result of the calculation of the value of PCI (C) is then performed factorial analysis 23 by a factor of surface water conditions (B) and the condition of the drainage channel (A) to determine the effect of the third factor of the level of damage to roads. The experiments were performed using the three causal factors (A, B, and C) with r repeatability (r = 3) and each experiment contains all the combined treatment of factor levels a, b, and c it will be easier to put them together in a factorial design.

Survey results produced in this study contained 32 samples, but untu in experimental design calculation only takes 24 samples. This is done because the 32 samples did not happen even distribution of the results of surveys to fill in every block of code, so that only the replication 3 that can be used with a sample of 24. Here is a 4:13 table construction design of experiments for this study.

Table 3: Construction Design of Experiments

PCI Score		Surface Water Conditions (B)			
		Exist Puddles		No Puddles	
		Drainage Channel Conditions (A)			
		Good	Moderate	Good	Moderate
PCI (C)	Good	87.6	98	90	94.2
		95.6	98	93.9	86
		92	90.2	98	91.7
	Statis factory	83	75	82.5	78
		85	84	84	72.5
		79	76.4	85	79.5

C. Factor Analysis 2^3

Factorial design was used to examine two or more independent variables factor in experimental situations.

Table 4: Yates method for determining contrast

Treatment	Responses	Column 1	Column 2	Column 3 contrast	JK
1	275.2	522.2	1055.6	2079.1	180,110.7
A	247	533.4	1023.5	-151.3	953.82
B	281.9	521.6	-58.6	-8.5	3.01
Ab	251.5	501.9	-92.7	6.7	1.87
C	286.2	-28.2	11.2	-32.1	42.93
Ac	235.4	-30.4	-19.7	-34.1	48.45
bc	271.9	-50.8	-2.2	-30.9	39.78
abc	230	-41.9	8.9	11.1	5.13

Table 5: List of ANOVA experimental design results

Sources of variation	dk	JK	KT	F count	P value
average treatment	1	180,110.70	180,110.70		
A	1	953.82	953.82	64.69	0.000
B	1	3.01	3.01	0.20	0.657
AB	1	1.87	1.87	0.13	0.726
C	1	42.93	42.93	2.91	0.103
AC	1	48.45	48.45	3.29	0.089
BC	1	39.78	39.78	2.70	0.12
ABC	1	5.13	5.13	0.35	0.563
error	16	235.91	14.74		
total	24	181,441.61	-	-	

Based on the findings of analysis of variance table, the can that concluded:

- Factors Drainage Channel Condition (A) With A P value which states that the value of F = 64.69 chance at P = 0.000 for a review UNABLE reject Ho: $\tau i = 0$
- Water Surface Condition Factor (B) With A P value which states that the value of F = 0.20 chance at P = 0.657 for a review CAN reject Ho: $\beta j = 0$
- Factor PCI value (C) With A P value which states that the value of F = 2.91 chance at P = 0.103 for a review Unable reject Ho: $\gamma k = 0$

On findings above calculation factor with P-value analysis of can concluded that the most influential factor is the main A (drainage conditions channels) and C (Rated PCI) and the last one in is B (surface air condition). Interaction of the most influential is the AC (line drainage condition and PCI value), and BC (air surface condition and PCI value), and ABC (line drainage condition, air condition the surface, and Value PCI) and the last in the AB (drainage condition canals and the surface condition of the air).

D. *Fractional Effects Analysis* 2_{IV}^{4-1}

The calculation of the value of securities is done by half-reaction analysis. Calculation half this reaction would give a great depiction of the effect to the change in the reaction block. Every fractional factorial contains full factorials in fewer factors. Fraction one-half will project into a full factorial in any k-1 from the original factor.

For the main fractions, note that in contrast to estimate the main effect A is the same as the contrast is used to estimate the interaction BC. This phenomenon is called aliasing and it occurs in all fractional design. Alliances can be found directly from a column in the table + and - signs. Here are the results of research experiments that fill half the value of the block anava the reaction is presented in table 7.

Table 6: Block ANOVA half fractions with a value of experimental results

		Surface water conditions (B)			
		Exist puddles		No puddles	
		Drainage Channel Conditions (A)			
	Good	Good			
PCI Score	Good	(-1) = 275.2	C = 286.2	B = 281.9	BC = 271.9
	Satisfactory	A = 247	AC = 235	AB = 252	ABC = 230

The main effect aliate by the interaction of three factors: AI = A2BCD = BCD, BI = AB2CD = ACD, CI = ABC2D = ABD, and DI = ABCD2 = ABC, the interaction of two factors interact with each other, AB.I = A2B2CD = CD, AC. I = BD, AD.I = BC. Thus only seven effects can be estimated, namely A, B, C, D, AB, AC, and AD. This is in line with the number of observations of 8, so only 7 effects can be estimated. With the value of the experimental results in Table 6, then do the work half-reaction analysis with 8 treatment combination.

Table 7: Observations Experimental Results with design 2_{IV}^{4-1}

Treat ments	Basic Design A	B	C	D = ABC	Combination Treatment	Y
1	-	-	-	-	1	275.2
2	+	-	-	+	ad	247
3	-	+	-	+	bd	281.9
4	+	+	-	-	ab	251.5
5	-	-	+	+	cd	286.2
6	+	-	+	-	ac	235.4
7	-	+	+	-	bc	271.9
8	+	+	+	+	abcd	230

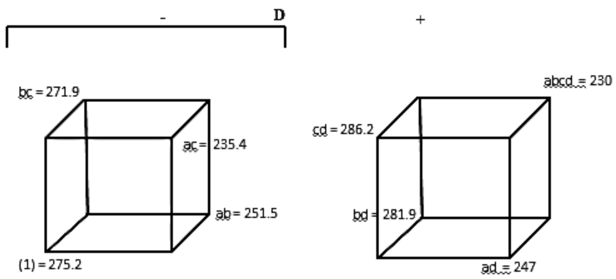

Figure 6. Geometric Main Effects

Table 8: Geometric Main Effects

No.	Basic Design A	B	C	ABC	Y	Estimated Effect A	B	C	D	AB	AC	BC
1	-1	-1	-1	-1	275.2	-275.2	-275.2	-275.2	-275.2	275.2	275.2	275.2
2	1	-1	-1	1	247	247	-247	-247	247	-247	-247	247
3	-1	1	-1	1	281.9	-281.9	281.9	-281.9	281.9	-281.9	281.9	-281.9
4	1	1	-1	-1	252	251.5	251.5	-251.5	-251.5	251.5	-251.5	-251.5
5	-1	-1	1	1	286.2	-286.2	-286.2	286.2	286.2	286.2	-286.2	-286.2
6	1	-1	1	-1	235	235.4	-235.4	235.4	-235.4	-235.4	235.4	-235.4
7	-1	1	1	-1	271.9	-271.9	271.9	271.9	-271.9	-271.9	-271.9	271.9
8	1	1	1	1	230	230	230	230	230	230	230	230
						-37.825	**-2.125**	**-8.025**	**2.775**	**1.675**	**-8.525**	**-7.725**

Table 9. Table captions should be placed above the table

Probe	Alias structure
ℓ_A = -37.825	$\ell_A \rightarrow$ A +BCD
ℓ_B = -2.125	$\ell_B \rightarrow$ B +ACD
ℓ_C = -8.025	$\ell_C \rightarrow$ C +ABD
ℓ_D = 2.775	$\ell_D \rightarrow$ D +ABC
ℓ_{AB} = 1.675	$\ell_{AB} \rightarrow$ AB +CD
ℓ_{AC} = -8.525	$\ell_{AC} \rightarrow$ AC +BD
ℓ_{AD} = -7.725	$\ell_{BC} \rightarrow$ BC +BC

Retrieval Number: C8413019320 /2020©BEIESP
DOI: 10.35940/ijitee.C8413.029420
Journal Website: www.ijitee.org

Published By:
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In Table 9 it appears that the main effect Factor A, C, and D is quite large.
If A, C and D main effect is large enough, it is logical to conclude that the two interaction alias chains AC + BD and AD + BC have a big effect because of the interaction AC and AD are also significant. In other words, if A, C and D significantly, then the significant interaction is AC and AD.

IV. CONCLUSION

The results of the analysis and discussion that has been conducted in this study on the effect of drainage on the road surface damage with flexible pavement structure, can be summed up as follows:

The five regions of reviews are dominated by good drainage conditions, the conditions there are no puddles on the surface of the pavement and the level of damage to low.

The type of damage occurring in this study consisted of nine types of damage to the road surface, with the most dominant type of surface pavement damage being slightly longitudinal Cracking and dominating were slippage crack.

Based on road pavement condition assessment system by the method of Pavement Condition Index (PCI), the five regions of reviews is dominated by the PCI score "Good" and the type of maintenance that dominates is "routine maintance".

Based on calculations using ANOVA statistical method, which states that the factors that most influence the road surface damage to the structure is a flexible pavement with a drainage channel conditions F_{count} 64.69. While the factors affecting the surface water slightly F_{count} 0.2.

From the analysis factorial design effect running Minitab 24-1 result obtained Regression Equation: Y = 259.9 - 18.91 C - 1063 B - 4013 A + 0.8375 AC - 4,262 BC - 3,863 1,388 AB + ABC with A = the value of PCI, B = condition surface water, and C = the condition of the drainage channel.

There is the influence of drainage conditions to damage the road surface with a form where the better drainage conditions, the level of damage to the surface of the pavement which generated the smaller the value of PCI higher the contrary, the poor drainage conditions, the level of damage produced the greater the value of PCI lower,

There is the influence of drainage conditions damage the road surface with the form in which the conditions for better drainage, the level of damage produced less of the type that has a damage level is getting low, otherwise the worse the condition of drainage so extensive damage produced greater with the type that has a degree of damage higher.

From the research that has been done is suggested that further research be done by considering factors of rainfall, the slope of the road, and the road grade and increase the number of samples with a variety of factors the severity of damage to the surface enough so that further research could represent a larger population.

ACKNOWLEDGMENT

The authors are grateful to the Direktorat Riset dan Pengabdian Masyarakat (DRPM) Universitas Indonesia for the financial support provided to this study through grant PITTA 2016. The authors wish to thank the reviewers for their valuable comments and suggestions.

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