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Analysis of the Damage of Rigid Pavement Road by Using Pavement Condition Index (PCI)

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Abstract

Bogasari Road, which is located in Citeureup sub-district, Bogor Regency, within the PT Indocement Tunggal Prakarsa industrial area, is a road that uses rigid pavement. The road is always passed by heavily loaded vehicles that affect road pavement conditions and the level of comfort and safety for road users. The study's purpose is to determine the average daily traffic volume, determine the value of conditions in the rigid pavement, and provide input to relevant agencies in terms of solutions and road repair costs. The method used in the analysis is the Pavement Condition Index (PCI). The study shows the average daily traffic of 2,883 vehicles/hour/day and the average pavement condition value of 66.57 with a good rating, or in good condition. It also provides a method of repair by functional means.

Keywords: PCI, Bogasari Road, rigid pavement.

1. Introduction

Roads have an essential role in life, including smoothing the distribution of goods and services. Road infrastructure that is burdened by high and repetitive traffic volume will decrease quality, as is the case with Bogasari road that uses rigid pavement. The road, which is located within the PT Indocement Tunggal Prakarsa industrial area, is most burdened by heavy vehicles. Currently, the Bogasari road has experienced significant damage, as seen from the appearance of several cracks, both small and even severe. So far, the handling of the damage on the Bogasari Road Section is only limited to maintenance, namely by functional repairs on damaged road surfaces. The handling is considered not entirely appropriate because the improvement efforts undertaken cannot last long according to the age of the plan. Therefore, it is necessary to conduct a more in-depth study of the Bogasari Road Section. Some data are required to find out the level of damage, such as the average daily traffic that passes through the road. The researcher has surveyed to identify the condition of the level of damage on the road surface to provide appropriate repair solutions for handling the damage that occurred.

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1.1. Construction of Concrete Road

Concrete road construction is a pavement that uses cement as a binder so that it has a relatively high stiffness level, especially when compared to asphalt pavement [1]. The modulus of elasticity of concrete construction is about ten times that of asphalt pavement modulus of elasticity.

In Indonesia, several types of concrete construction are commonly used, namely:

a) Jointed unreinforced concrete pavement
b) Jointed reinforced concrete pavement.
c) Continuously reinforced concrete pavement
d) Prestressed concrete pavement
e) Fiber-reinforced concrete pavement

1.2. Road Damage

According to ASTM D6433 [2], in calculating the value of road conditions using the Pavement Condition Index (PCI) method, the types of damage in rigid pavement consist of blow up, corner crack, divided slab, durability cracking, faulting, joint seal damage, shoulder drop-off, linear cracking, small patching, large patching, polished aggregate, popouts, pumping, punchout, railroad crossing, scaling, shrinkage cracks, spalling corners, and spalling joints.

1.3. Pavement Condition Index (PCI)

Pavement Condition Index is an evaluation system of road pavement condition based on the type, level, and the extent of damage that occurs. It can be used as a reference for maintenance efforts [3][4]. The PCI value has a range of 0-100 with criteria 0-10 (failed), 10-25 (very poor), 25-40 (poor), 40-55 (fair), 55-70 (good), 70-85 (very good) and 85-100 (excellent). The level of damage consists of low severity level (L), medium severity level (M), and high severity level (H).

(1) Level of Damage (density)

Damage rate is the percentage of the amount of a type of damage to the number of slabs in a sample unit.

$$Density = \frac{Ad}{As} x100\%$$

with:
Ad : the total type of damage for each level of damage
As : number of slab sample units

(2) Deduct value

Deduct value is the reduction value for each type of damage obtained from the relationship curve between density and deduct value.

(3) Total deduct value (TDV)

TDV is the total value of the individual deduct value for each type of damage and the level of damage that exists in a sample unit.

(4) Allowable maximum deduct value

Before the TDV and CDV values are determined, the deduct value needs to be checked to find out whether the value can be used in further calculations. The value of m can be calculated using the equation:

$$m = 1+ 9/98 (100 – HDVi)$$

with:
m : correction value for deduct value
HDVi : the highest deduct value in one sample unit.

(5) Corrected deduct value (CDV)

Corrected deduct value (CDV) is obtained from the relationship curve between TDV and CDV by selecting the curve of the curve based on the number of individual deduct values that have a value higher than two, which is also called the q value.

If the CDV value is known, the PCI value for each unit can be determined by the formula:

$$PCI(s) = 100 – CDV$$

with:

PCI(s) : PCI value for each unit
CDV : CDV for each unit

For overall PCI values:

$$PCI = \frac{\sum PCI(s)}{N}$$

with:

PCI : Overall pavement PCI value
PCI(s) : PCI value for each unit
N : number of units

From the PCI value for each study unit, it can be seen the quality of the pavement layers of segment units based on certain conditions, by looking at the figure 1.

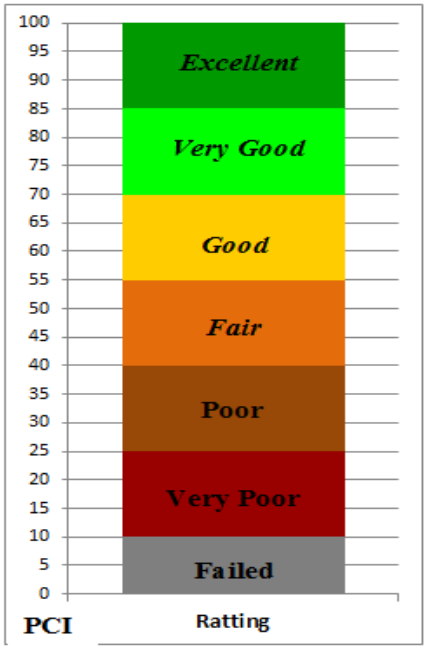

Figure 1 Graph of PCI values

1.4. Handling Method

The types of handling Portland cement concrete pavement damage is grouped in several rigid pavement maintenances, with models of handling, in general, can be seen in the figure 2.

No	Types of Damage	Repair Method								
		Protection		Correction						
		PPK-1	PPK-2	PPK-3	PPK-4	PPK-5	PPK-6	PPK-7	PPK-8	PPK-9
I	Deformation									
	1. Depression				V					V
	2. Faulting				V					V
	3. Pumping					V				V
	4. Rocking					V				V
II	Crack									
	1. Block crack	V							V	
	2. Corner crack	V							V	
	3. Diagonal crack	V							V	
	4. Longitudinal	V							V	
	5. Tranverse	V							V	
	6. Meandering	V								V
III	Joint seal defect		**V**							
IV	Spalling			**V**				**V**		
V	Edge drop off	**V**			**V**					
VI	Damage to the surface texture									
	1. Scalling							V		
	2. Polished aggregate						V	V		
VII	Pathole			**V**						
VIII	Inadequate surface drainage						**V**	**V**		

Figure 2 Handling Table
Source : Portland Cement Concrete Road Pavement [4]

Notes:
PPK-1: Crack filling
PPK-2: Joint sealing
PPK-3: Patching
PPK-4: Leveling
PPK-5: Grouting
PPK-6: Grooving
PPK-7: Thin surfacing
PPK-8: Local Reconstruction
PPK-9: Reconstruction

2. Methodology

All figures should be numbered with Arabic numerals (1, 2, ..., n). All photographs, schemes, graphs and diagrams are to be referred to as figures. Line drawings should be good quality scans or true electronic output. Low-quality scans

are not acceptable. Figures must be embedded into the text and not supplied separately.

3. Result and Discussion

3.1. Road Geometric

Bogasari Road is divided into two lines and four lanes with a width of 3.5 m each. The object of research carried out on Jalan Bogasari is only on one line, which is the direction from the Major Oking Highway (arterial road) to the PT Indocement area, with a total length of 1400 m (1.4 km). The road is divided into 14 research segments with a size of 7 m x 100 m each, which is divided again into several slabs. In this study, slab distribution refers to ASTM D6344 Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys, which is a maximum of 20 slabs per sample segment/unit.

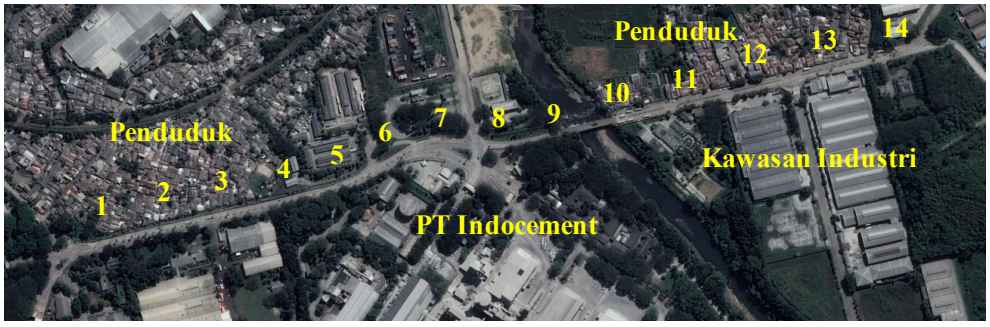

Figure 3 Bogasari Street Layout

Table 2 Research Location Segmentation

Code	Description
1	Segment 1 (STA 0+900 – 1+000)
2	Segment 2 (STA 1+000 – 1+100)
3	Segment 3 (STA 1+100 – 1+200)
4	Segment 4 (STA 1+200 – 1+300)
5	Segment 5 (STA 1+300 – 1+400)
6	Segment 6 (STA 1+400 – 1+500)
7	Segment 7 (STA 1+500 – 1+600)
8	Segment 8 (STA 1+600 – 1+700)
9	Segment 9 (STA 1+700 – 1+800)
10	Segment 10 (STA 1+800 – 1+900)
11	Segment 11 (STA 1+900 – 2+000)
12	Segment 12 (STA 2+000 – 2+100)
13	Segment 13 (STA 2+100 – 2+200)
14	Segment 14 (STA 2+200 – 2+300)

3.2. Traffic Volume

In the study, traffic volume is obtained from the results of a field survey conducted for three days, with a period of two hours in the morning, afternoon, and evening.

3.3. Assessment of Road Conditions

There are several types of damage found in the assessment in sample units of 0 + 900 to 1 + 000 including:

Five low levels of corner crack damage, one medium durability cracking damage, one low level of settlement or faulting damage, six medium joint seal damage, and a linear cracking.

3.3.1. Calculate the level of damage (density)

$$\text{Density} = Ad/As \times 100 \quad \text{or} \quad \text{Density} = Ld/As \times 100$$

with:

Ad = the total type of damage for each type of damage
As = the number of slabs in 1 segment (20 slabs)

Corner crack (L)

$$= \frac{5}{20} \times 100 = 25$$

Durability crack (M)

$$= \frac{1}{20} \times 100 = 5$$

Settlement/faulting (L)

$$= \frac{1}{20} \times 100 = 5$$

Joint seal damage (M)

$$= \frac{6}{20} \times 100 = 30$$

Linear cracking (H)

$$= \frac{8}{20} \times 100 = 40$$

Large fillings (M)

$$= \frac{6}{20} \times 100 = 30$$

Table 3 Type and Level of Damage

Type of damage	Damage level	*Density*
Corner crack	H	25
Durability crack	H	5
Settlement/faulting	L	5
Joint seal damage	M	30
Linear cracking	H	40
Large fillings	M	30

Source: Researchers

3.3.2. Determination of Deduct Value

Each type of damage is plotted to the graph, based on the level of damage, to find the deduct value after the density value is obtained.

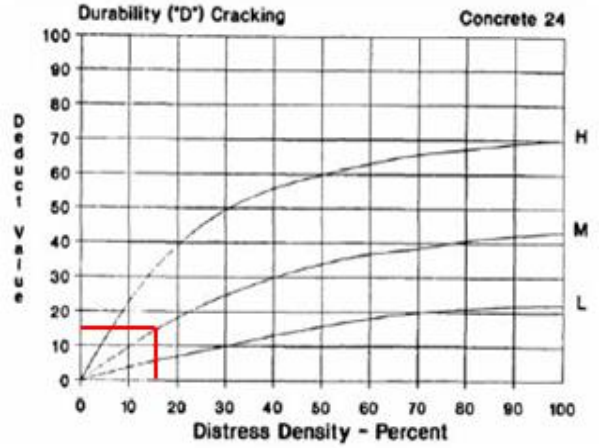

Figure 4 Deduct Value Graph

The relationship between density and deduct value for the type of durability crack damage.

Table 4 The relationship between the type of damage

Type of damage	Damage Level	*Density*	*Deduct Value*
Corner crack	L	25	20
Durability crack	M	5	5,5
Settlement/faulting	L	5	4
Joint seal damage	M	30	9
Linear cracking	H	40	40
Large fillings	M	30	20

Source: Researchers

3.3.3. Determination of Total Deduct Value

The subtraction value (DV) used in the calculation is DV, whose value is higher than two (for paved roads).

Determine the number of deductions allowed:

Mi = $1 + (9/98) * (100 - HDVi)$
Mi = $1 + (9/98) * (100 - 40) = \mathbf{6,50}$ > 6 (6 is DV)

3.3.4. Determination of the maximum corrected deduction value (CDV)

Determine the subtraction value (DV) whose value is greater than two. In the deduct value table with values of DV: 40; 20; 20; 9; 5.5; 4, the DV with a value greater than 2 is 6 digits, so q = 6.

Determine the total deduction value (TDV) by adding all deduction values (DV). Then, determine the CDV of q and the TDV by using the correction values of the curves for the concrete pavement. Iterate until getting q = 1, by reducing the DV values that are greater than 2, which are changed to 2.

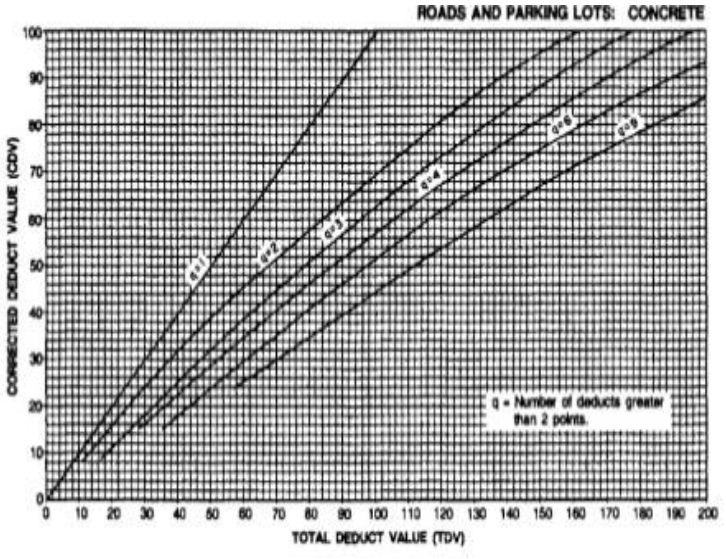

Figure 5 Graph of CDV Curve

Table 5 Deduct Value

No	Deduct Value						TDV	q	CDV
1	40	20	20	9	5.5	4	98.5	6	46
2	40	20	20	9	5.5	2	98.5	5	48
3	40	20	20	9	2	2	93	4	49.5
4	40	20	20	2	2	2	86	3	**50**
5	40	20	2	2	2	2	68	2	**50**
6	40	2	2	2	2	2	50	1	**50**
7									
8									
9									
10									

Note:

Source: Researchers

3.3.5. Calculation of PCI(s)

PCI (s) $= 100 - CDV\ max = 100 - 50 = \mathbf{50}$ … (*Fair*)

The road conditions of Bogasari-Citeureup Sta 0 + 900 to 2 + 300. Based on calculations using the Pavement Condition Index (PCI) method, the average condition values for each segment are obtained.

Table 6 Pavement Conditions Value

Segment	Pavement Conditions Value	Description
1	50	Fair
2	56	Good
3	55	Good
4	80	Very Good
5	67	Good
6	44	Fair
7	42	Fair
8	48	Fair

Segment	Pavement Conditions Value	Description
9	93	Excellent
10	97	Excellent
11	74	Very Good
12	80	Very Good
13	76	Very Good
14	70	Very Good
Average of PCI	66.57	Good

3.4. Handling of Damage

Pavement conditions that have been damaged should be immediately repaired. The repair method used must be following the type and level of damage to improve the condition of the road pavement. Functional handling is handling carried out at a low to moderate level of damage, which considers the type of damage, such as longitudinal crack damage with a width of damage <5 mm, angle cracking, and damage to the connection filler.

The handling methods for each type and the volume of damage that must be repaired are in the following table:

Table 7 Type and Level of Damage

Type and level of damage		Handling
Corner crack	L M	Cracks are cleaned and then filled with asphalt to all depths
Durability crack	L M	
Linear cracking	L	
Settlement/faulting	L M	Fractures are sharpened, or graded layers of concrete mortar and crack crackers are provided.
Joint seal damage	L M H	Replacement of connection cover material
Small/large fillings	L M	The filling is dismantled and the bottom foundation layer is solidified again and then filled again.
Slippery aggregate		Small grooves are made to make the surface rough.
Crushed	L	Patching in all depths.

Source: Researchers

Structural repairs are carried out at medium level of damage to high. The damage has reached the structure that makes the inability of the pavement to withstand the burden. For this reason, it is necessary to improve the structure of the road, one of which is by doing the reconstruction method based on the location of damage for each segment.

4. Conclusion and Suggestions

4.1. Conclusions

1. Survey results show that the highest average daily traffic volume is on Monday with 2,883 vehicles/hour/ day.
2. Based on survey results and data processing, an average pavement condition value is 66.57, with a Good rating. Whereas the pavement value for each segment is 50 for 1st segment (Fair), 56 for 2nd segment (Good), 55 for 3rd segment (Good), 80 for 4th segment (Very Good), 67 for 5th segment (Good), 44 for 6th segment (Fair), 42 for 7th segment (Fair), 48 for 8th segment (Fair), 93 for 9th segment (Excellent), 97 for 10th segment

(Excellent), 74 for 11th segment (Very Good), 80 for 12th segment (Very Good), 76 for 13th segment (Very Good), and 70 for 14th segment (Good), respectively.

3. Based on the analysis of the damage that occurred in the field, we get two methods of repair, namely functional repairs for low damage and reconstruction repair for heavy damage.

4.2. Recommendations

1. It is necessary to take corrective action on the damaged units immediately, so it does not cause more damage.
2. Serious supervision needs to be done during the implementation of road repairs so that repairs carried out can last according to the age of the plan and following the recommended specifications based on calculations.

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