Study of Road Surface Damage due to Rainwater Puddles using the Pavement Condition Index

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DOI: 10.22178/pos.84-8

LCC Subject Category: L7-991

Received 21.07.2022
Accepted 25.08.2022
Published online 31.08.2022

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Abstract. Damage to the road surface will cause many losses that users can feel directly. One of the factors that influence the damage is waterlogging. In Mataram City, several roads experience inundation and water runoff when it rains, such as Jalan Swasembada Kekalik and Jalan Kesra Raya Perumnas. The impact on road construction is a change in the shape of the road surface layer, which causes road service performance to decline. So, it needs to be analyzed to determine the damage to the pavement structure in several segments, both flooded and not. The method used to carry out road damage analysis is the method (Pavement Condition Index) PCI. Surveying road conditions in the field collected data. The PCI value is obtained after calculating the parameters, namely: density, deduct value (DV), total deduct value (TDV), and corrected deduct value (CDV). The results showed that the types and average values of damage to Jalan Swasembada Kekalik were: subsidence (6.22%), edge cracks (3.22%), vertical downhill road edges (8.22%), patches (4.25 %), holes (1%), grain release (27.33%). The average value of the Pavement Condition Index (PCI) for each segment is 36.33%, which is at a lousy level (Poor). In comparison, on Jalan Kesra Raya Perumnas, the PCI value is 82.5%, which is at a reasonable level (Good) evidence that the inundated section has a worse condition than the unflooded section is seen in the Jalan Swasembada Kekalik section, where the inundated area has a poor to poor condition. In contrast, the unflooded team has a very good to perfect condition. For the Jalan Kesra Raya Perumnas section, although in flooded areas, the road conditions are less than those that are not flooded, overall, the roads are in good to perfect condition. By looking at the conditions on each lane, it is necessary to deal damage to several road segments immediately to have a decent performance in serving traffic.

Keywords: Road Damage; Pavement Condition Index; Puddles.

INTRODUCTION

The components that cause road damage are increased traffic loads, inadequate drainage systems and asphalt pavement materials. Other causes are climate, unstable soil conditions, and planning and execution of work that is not by specifications [1]. Road damage is not caused by one factor alone but can be a combination of several interrelated causes [11].

Factors causing road damage, in general, are increased traffic volume loads, poor drainage systems, poor pavement construction material properties, weather, unstable soil conditions, very thin pavement layer planning, and inappropriate work implementation processes with specifications [5, 10, 12].

Drainage channels not functioning properly lead to puddles on the road surface. Other things that cause inundation are changes in land function and reduced catchment areas [7]. Empirical observations show that the dominant pool of water above the road surface occurs because of the road drainage system. This is due to the lack of integration with the spatial water system of the area around the road and uncontrolled spatial planning. Water in this puddle enters through the pores of the pavement surface so that it can damage the asphalt bond [9].

Several road segments in Mataram City experience inundation and water runoff when it rains. These areas include Kekalik (Jalan Swasembada) and Perumnas (Jalan Kesra Raya). The condition of the road shows that there are puddles in several segments during the rain and persist after the rain has stopped. The impact on road pavement is a change in the shape of the road surface layer in the form of potholes, rutting, cracks, ravelling, and edge scouring. This causes road service performance to decline. According to [6], waterlogging causes the pavement base to be entirely or partially saturated in the road drainage system.

The damage that occurred in the segment that experienced inundation appeared to be more severe than that which was only inundated when it rained. The effect of inundation on road damage can be determined by comparing the analysis results of road damage analysis on the flooded (submerged) and the un-submerged segments. Several methods can be used to analyze road damage, including the Pavement Condition Index (PCI). PCI is a road pavement condition assessment system based on the type and level of damage that occurs and can be used as a reference in maintenance efforts. Identify the type of damage, the severity of the injury, and its size based on the observations during the visual condition survey [8].

It is necessary to study the effect of inundation on road surface damage by looking at the conditions on two roads (Jalan Swasembada Kekalik and Jalan Kesra Raya Perumnas). The purpose of the study was to determine the damage to several road segments in the inundated and unflooded sections when it rains using the PCI method. Based on the results of the analysis, it can be seen the condition of the road surface, whether it is in a state of failure, good to perfect. This is needed to provide recommendations for handling, so that road conditions are feasible to serve traffic.

Types of Pavement Damage [2], divided into 19 damages, namely:
1) Crocodile Cracking (Alligator Cracking)
2) Overweight (Bleeding)
3) Block Cracking
4) Basin (Bumb and Sags)
5) Curly (Corrugation)
6) Depression
7) Edge Cracking
8) Joint Reflec Cracking
9) Vertical Downhill Edge (Lane/Shoulder Drop Off)
10) Longitudinal Crack /Transverse Cracking)
11) Patching (Patching end Utility Cut Patching)
12) Wearing Aggregate (Polished Aggregate)
13) Pothole
14) Damaged Railroad Crossing (Railroad Crossing)
15) Groove (Rutting)
16) Sungkur (Shoving)
17) Broken Slip (Slippage Cracking)
18) Swelling (Swell)
19) Grain Release (Weathering/Raveling).

Pavement Condition Index (PCI) is the level of the condition of the pavement surface and the size in terms of road capability, which refers to the state and damage to the pavement surface. PCI is a numerical index whose value ranges from 0 to 100. A value of 0 indicates the pavement is in a failed condition, and a weight of 100 means that the pavement is still perfect. This PCI is based on the results of a visual condition survey. The type of damage, the extent of the damage, and its size are identified when surveying the condition. PCI was developed to provide an index of pavement structural integrity and surface operational conditions. Damage information obtained as part of the PCI condition survey includes information on the causes of the damage and whether the damage is load-related or climate-related.

In the PCI method, the severity of pavement damage is a function of 3 main factors: a) Type of damage, b) The severity of the damage, and c) The amount or density of the damage. The PCI method only provides information on pavement conditions when the survey is conducted but cannot provide a predictive picture in the future. However, by conducting periodic condition surveys, information on pavement conditions can help predict future performance. In addition, it can also be used as input for more detailed measurements.

Theoretical basis

Determination of Pavement Condition Index Value. PCI values are obtained in the following order: a) determine the density, b) determine the deduct value, c) determine the total deduct value, d) find the value of q, e) find the correct deduct value (CDV), f) calculate Pavement Condition Index (PCI) value.

Density. Density is the percentage of the total area or length of one type of damage to the size or total length of the measured road section. Thus, the damage density can be expressed in equations 1 or 2.

$$Density = \frac{Ad}{As} \times 100, \quad (1)$$

$$Density = \frac{Ld}{As} \times 100, \quad (2)$$

Where Ad – total area of damage type for each level of damage (m^2), Ld – full length of damage type for each level of damage (m), As – total area of segment unit (m^2).

Deduct Value. Deduct value is a deduction value for each type of damage obtained from the curve (Figure 1) of the relationship between density and severity level of damage.

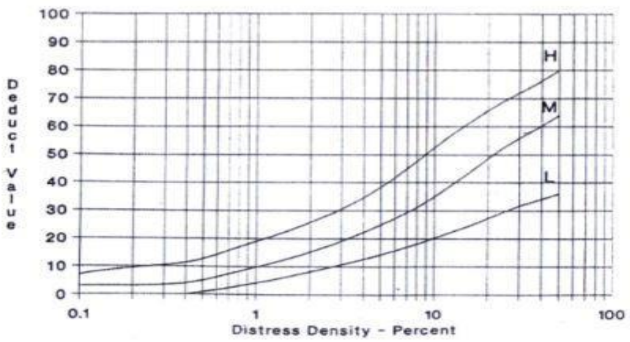

Figure 1 – Graph of deducting value (deduct value)

Total Deduct Value. Total Deduct Value (TDV) is the full value of the individual deduct value for each type of damage and the damage level in a research unit (Table 1).

Table 1 – TDV Nilai value

STA	Deduct Value (DV)					TDV
0+*** to 0+***	13	23	18	27	42	123

Finding the value of q. The requirement to determine the value of q is determined by the sum of the individual deduct values greater than 5 in each road segment under study (Table 2). For example, if there are five values of DV>5, then q=5.

Table 2 – *q* value

STA	Deduct Value (DV)						q
0+*** to 0+***	13>5	23>5	18>5	27>5	42>5	4<5	5

Finding the Correct Deduct Value. The Correct Deduct Value (CDV) value can be found after the q, and TDV values are obtained (see points c and d using the curve in Figure 2.

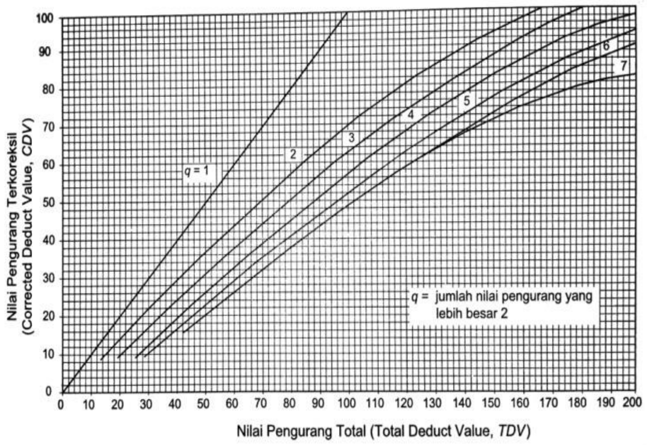

Figure 2 – CDV Graphics

Calculating PCI Nilai Value. The PCI value is obtained using equation 3, using the CDV value.

$$PCI = 100 - CDV, \quad (3)$$

The overall pavement PCI value is N. The overall PCI value on a particular road pavement segment is researched using equation 4 [4].

$$PCI_f = \sum_{i=1}^{N} PCI, \quad (4)$$

where PCI_f – Average PCI value of all research segments; PCI – PCI for each sample unit or research unit; N – number of sample units.

The condition of road damage based on PCI values can be seen in Table 3.

Table 3 – PCI Value Magnitude

PCI value	Condition
0–10	Failed
11–25	Very bad (very poor)
26–40	Bad (poor)
41–55	Medium (fair)
56–70	Good (good)
71–85	Very good (very good)
86–100	Perfect (excellent)

Repair Method. According to the practical instructions for routine maintenance of roads UPR.02.1 of 1992, the Director General of Highways has several methods of handling that can be done, among others: Met Handling ode 2 (P2) and Handling Method 5 (P5). Handling Method 2 (P2) is Local Sealing, while Handling Method 5 (P5) is Hole Patching [3].

Method (P2) (Local Sealing), performed on damage: Cracking lines (cracking) and Crocodile skin cracking (alligator cracking). The handling steps are cleaning the area to be handled, marking the square in the place to be dealt, spraying 1.5 kg/m^2 emulsion asphalt on the marked area until evenly distributed, spreading coarse sand or fine aggregate and levelling when using fine aggregate compacted with a light compactor [3].

Method (P5) Hole Patching can be done on damage: rutting Edge cracking, Holes (potholes), Deformation (deformation). Handling steps: making square marks on the area to be treated with paint or chalk, digging the road layer in the area that has been marked square until it reaches a solid layer, compacting the bottom of the excavation, filling the dug hole with substitute material (aggregate foundation layer or cold asphalt mix), consolidating layer by layer, and applying local asphalt over the last layer [3].

METHODS

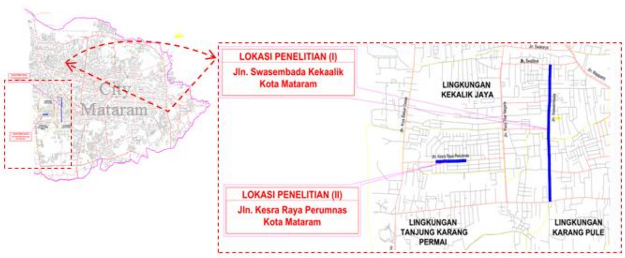

Figure 3 – Research areas

Research Stages. The research stages include 1) the Research preparation stage, 2) the Data collection survey stage, and 3) the analysis of road damage data and discussion of the results.

The preparation stage is a series of activities before starting data collection and processing. This stage is carried out by preparing a plan to obtain efficiency and effectiveness of time and work. At this stage, preliminary observations are also carried out to get a general picture of identifying and formulating problems in the field. This preparatory stage includes 1) Study of literature/literature from the latest publications related to research; 2) Listing agencies and institutions that can be used as data sources; 3) Determining data needs, data collection methods and personnel needs in the field as well as data analysis methods and discussion of results.

Survey phase of direct visual data collection at the study site on the condition of road damage. The survey location is Section Mataram Self-Sufficiency Street and Perumnas Kesra Raya Street. The survey focuses on the current problems and the state of the damaged pavement under study. The data used to determine the level of road damage is in the form of data on the length, width, area, and depth of each type of damage. The tools used include stationery, roll meter, camera, and motor spray paint. At the same time, the materials used at the data collection stage are the first step after the preparation stage in the critical evaluation and planning process. Because from here, the problem can be determined, and a series of determining alternative problem solving is taken. The data needed include primary data and secondary data. The data analysis is carried out by finding the value of road conditions and knowing how to handle them, including maintenance or rehabilitation.

The analysis and discussion stage is carried out after the data is collected using the PCI method. The analysis results in PCI values are used to determine the level of damage and appropriate repair plans/recommendations. Besides that, there is also a discussion about the effect of the inundated and not flooded parts.

RESULTS AND DISCUSSION

Data on road conditions and damage. Based on the survey results, the condition and road damage on the Kekalik Self-Sufficiency Road and Perumnas Kesra Raya Road can be seen in Table 4.

Determine the Deduct Value (DV). The analysis is carried out for each segment on each segment. For example, the analysis used segments STA 0+100 to 0+150 Self-Sufficiency of Kekalik. In Table 4, it can be seen that the total value of each level of damage is: Side of the vertical descending road = 29 m; Patch= 22.5 m; Grain release= 39 m; Edge crack= 8 m; Amblas= 20 m.

Table 4 – Values of damage area of two road sections

Airfield asphalt pavement sketch: condition survey data sheet for the sample unit		Length: 50 m
1. Crocodile crack (m^2) 2. Overweight (m^2) 3. Checkered Crack (m^2) 4. Basin (m^2) 5. Curly (m^2) 6. Amblas (m^2) 7. Edge Cracks (m^2) 8. Joint Crack (m^2)	9. Sidewalk Downhill Vertical (m^2) 10. Longitudinal / Transverse Crack (m^2) 11. Patches (m^2) 12. Aggregate Wear (m^2) 13. Hole (count) 14. Rail Intersection (m^2) 15. Groove (m^2) 16. Sungkur (m^2)	17. Broken Slip (m^2) 18. Inflated Head (m^2) 19. Grain Release (m^2)

STA	Kekalik Self-Sufficiency Road Section					Perumnas Raya Welfare Road Section			
	Quantity, m					Quantity, m			
	19					12			
0+000 to 0+050	12					12			
Total	12					12			
0+050 to 0+100	Quantity, m					Quantity, m			
	9	11	19						
	15	2	20						
			4						
			5						
Total	15	2	29						
0+100 to 0+150	Quantity, m					Quantity, m			
	6	7	9	11	19	1	6	7	19
	20	8	2	15	20	2	7	10	8
			5	4.5	4				
			7	1.5	15				
			12	1.5					
			3						
Total	20	8	29	22.5	39	2	7	10	8
0+150 to 0+200	Quantity, m					Quantity, m			
	11	13 (counts)	19			1	6	12	
	3	1	10			4	4	15	
Total	3	1	10			4	4	15	
0+200 to 0+250	Quantity, m					Quantity, m			
	6	7	19			11	12	19	
	10	7	8			2	40	7	
Total	10	7	8			2	40	7	
0+250 to 0+300	Quantity, m					Quantity, m			
	13 (counts)	19				12	19		
	2	10				12	8		
Total	2	10				12	8		

Calculating density. Density is calculated by equation 3, as follows:

Side of the road down vertically = 29/(6×50)×100 = 9.67 %

Patches = 22.5/(6×50)×100 = 7.75 %

Grain release = 39/(6×50)×100 = 13 %

Edge Crack=8/(6×50)×100 = 2.67 %

Sink = 20/(6×50)×100 = 6.67 %

Deduct value is the reduction value for each type of damage obtained from the graph. Deduct Value (DV) STA 0+100 to 0+150 on Jalan Swasembada Kekalik can be seen in Figure 4.

Finding the maximum corrected subtraction (CDV). The CDV value in the STA segment 0+100 to 0+150 on the Jalan Swasembada Kekalik section is q = 5 (there are 5 DV values > 5), see Table 5 the CDV value = 65.

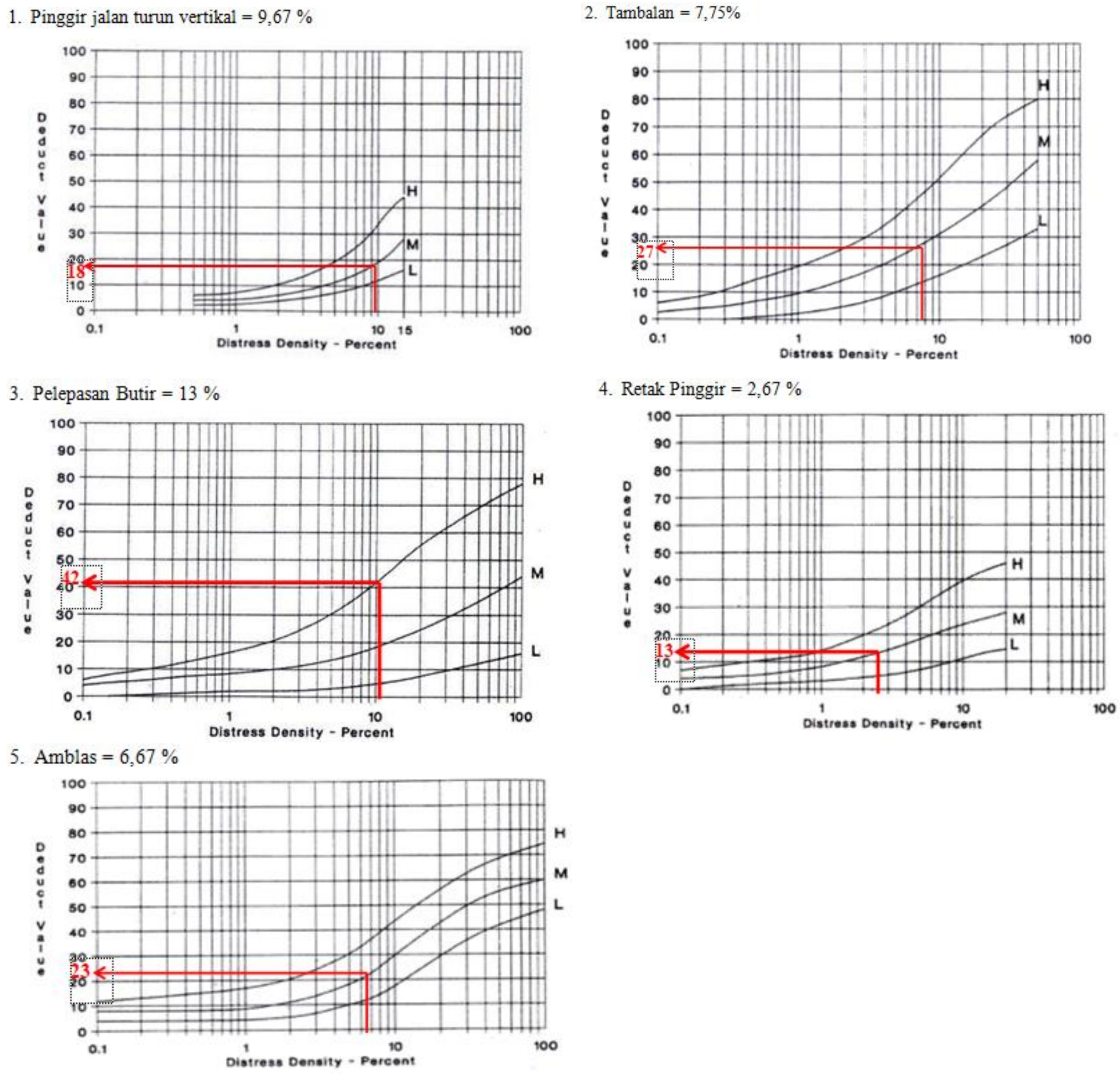

Figure 4

Table 5 – STA CDV value 0+100 to 0+150 Jalan Swasembada Kekalik

STA	Deduct Value (DV)						Total	q	CDV
0+100 to 0+150	13	23	18	27	42		123	5	65

Calculating PCI. After the CDV value on the Jalan Swasembada section with STA 0+100 to 0+150 is obtained, the PCI value is obtained by equation 3.

PCI value = 100–65 = 35.

Furthermore, the PCI values for all segments on Jalan Swasembada Kekalik and Jalan Kesra Raya Perumnas can be seen in Tables 5, 6.

Road Conditions and Recommendations for Handling. Based on the analysis that has been carried out above, the value of the pavement condition for six segments of two roads is obtained, which is calculated using the following formula: *PCIs = 100 – CDV.* The results are shown in Table 7.

The average PCI value of the number of 6 segments that have been calculated on the Swasembada Kekalik road section is the following value 36.33 %

From the average PCI value of each segment shown in Table 7, the classification of damage to the pavement structure in each part can be seen, so it can be seen that the average PCI value on the Kekalik Swasembada road section is 36.33% which is a lousy level (Poor). The average PCI value on the Perumnas Kesra Raya road section is 82.5%, which is reasonable (Good).

Table 5 – PCI value of each segment on Jalan Swasembada Kekalik

STA	Damage Type	Damage Class, m	Size(m/m²)	Density (%)	DVD	CDV	PCI
0+000s / d0+050	Grain release	19	12	4.00	12		
					12	12	88
0+050s / d0+100	Sidewalk down vertical	9	15	5.00	7		
	Patches	11	2	0.67	8		
	Grain release	19	29	9.67	18		
					33	19	81
0+100s / d0+150	Sink	6	6.67	2.22	13		
	Edge crack	7	2.67	0.89	23		
	Sidewalk down vertical	9	9.67	3.22	18		
	Patches	11	7.75	2.58	27		
	Grain release	19	13	4.33	42		
					123	65	35
0+150s / d0+200	Patches	11	3	1.00	10		
	Hole, count	13	1	0.33	35		
	Grain Release	19	10	3.33	15		
					60	48	52
0+200s / d0+250	Sink	6	12	4.00	18		
	Edge crack	7	7	2.33	12		
	Grain release	19	8	2.67	10		
					40	26	74
0+250s / d0+300	Hole, count	13	2	0.67	52		
	Grain release	19	10	3.33	15		
					67	48	52

Table 6 – The PCI value of each segment on the Jalan Kesra Raya Perumnas section

STA	Damage Type	Damage Class, m	Size(m/m²)	Density (%)	DVD	CDV	PCI
0+000s / d0+050	Aggregate Wear	12	12	4.00	2		
					2	0	100
0+050s / d0+100	Crocodile crack	1	2	0.67	19		
	Edge crack	7	10	3.33	17		
	Grain release	19	8	2.67	12		
					48	30	70
0+100s / d0+150	Sink	6	7	2.33	8		
	Aggregate Wear	12	20	6.67	4		
	Grain release	19	10	3.33	17		
					29	22	78
0+150s / d0+200	Crocodile crack	1	4	1.33	24		
	Sink	6	4	1.33	8		
	Aggregate Wear	12	15	5.00	4		
					36	27	73
0+200s / d0+250	Patches	11	2	0.67	8		
	Aggregate Wear	12	40	13.33	9		
	Grain release	19	7	2.33	10		
					27	14	86
0+250s / d0+300	Aggregate wear	12	12	4.00	2		
	Grain release	19	8	2.67	12		
					14	12	88

Table 7 – Comparison of the PCI values of flooded and unflooded roads

STA	Kekalik Self-Sufficiency Road Section			Perumnas Raya Welfare Road Section		
	PCI value	Road Status	Damage rate	PCI value	Road Status	Damage Rate
0+000 to 0+050	88	Not flooded	Perfect	100	Not flooded	Perfect
0+050 to 0+100	81	Not flooded	Very good	70	Flooded	Well
0+100 to 0+150	35	Flooded	Bad	78	Not flooded	Very good
0+150 to 0+200	52	Flooded	Currently	73	Flooded	Very good
0+200 to 0+250	74	Not flooded	Very good	86	Not flooded	Perfect
0+250 to 0+300	52	Flooded	Currently	88	Not flooded	Perfect

Based on the above conditions, then by the instructions/regulations of Binamrga [3], it is recommended that the appropriate type of treatment is treatment method 2 (P2)local asphalt sealing (Local Sealing), handling method 5 (P5) Hole Patching on the Jalan Swasembada Kekalik section. In contrast, for the Jalan Kesra Raya Perumnas section, it is recommended to only use handling method 2 (P2).

CONCLUSIONS

The average Pavement Condition Index (PCI) on Jalan Swasembada Kekalik is 36.33%, which is at a poor level with the lowest PCI segment value of 35%. While on the Jalan Kesra Raya Perumnas section, 82.5% is reasonable, with the lowest PCI segment value of 70%. The method of maintenance and repair of damage to the road pavement structure on the Jalan Swasembada Kekalik section is the P2 and P5 Repair method. In contrast, the P2 method is used in the Jalan Kesra Raya Perumnas section.

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