The Use of International Roughness Index and Structural Number for Rehabilitation and Maintenance Policy of Local Highway

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Abstract. Rehabilitation and maintenance of road performed by technical agencies at the local government in Indonesia, are generally not based on the assessment of road conditions. The value of the structural and functional condition of the pavement is not counted on carefully. As a result, road rehabilitation and maintenance patterns tend to be similar, repetitive and improper. International Roughness Index (IRI) is a parameter for assessing the functional condition of the pavement while the Structural Number (SN) is a parameter for assessing the structural condition of the pavement. Measuring road conditions by using Roadroid applications on smartphones can provide an efficient way, scalable, and low cost to the highway authority to collect road condition data. This study was conducted to determine the conditions of the road both functionally and structurally. Results of research conducted, pavement functionally in a good condition with the acquisition of IRI value of less than 4. Structural pavement conditions indicate that the value of Structural Number Effective (SN_{eff}) is less than the value of the Structural Number Future (SN_f), thus the structural condition of the road segments has not been able to serve traffic with a design life of 20 years. Prediction of IRI value obtained to determine the type of road maintenance is functionally performed when the value of IRI exceeds the value of 4 with an overlay of material HRS WC 30 mm. Structurally road maintenance carried out various scenarios, the phased construction and direct construction. The type of material and thickness of pavement on a phased construction scenario for the design life of 15-20 years and direct construction gives better results than the phased construction scenarios for the design life of 5-20 years and 10-20 years.

1. Introduction

Handling of the flexible pavement maintenance should be done through measurable criteria for achieving the goals set. International Roughness Index is a parameter to determine the functional pavement conditions, whereas the structural condition of pavement was obtained from the value of the Structural Number [1]. SN is used to determine the structural capacity of the pavement, whether it is able to withstand traffic loads up to design life.

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The measuring road roughness with smart phone can provide an efficient, scalable, and cost-effective way for road organizations delivers road condition data.Application web-based GIS it can use powerful filtering techniques as the IRI for road maintenance decision support [2]. Roadroid can help the road network asset management by offering a cheaper solution to monitor and report road conditions [3].

The scenario of handling and maintaining roads to serve the traffic load during the design life, using indicators IRI predicted through an empirical equation Patterson (1987) [4]. The structural condition of pavement over the design life was obtained by comparing the value SN_{eff} with SN_f. The results of the comparison value of SN_{eff} and SN_f produce overlay requirements necessary to serve the traffic load during the design life.

The results of assessment road functional and structural condition, were analyzed to determine the selection of the type of road maintenance is the thickness of an overlay and a mixture of asphalt used.

2. Experimental

2.1. Functional Condition of Pavement

Obtaining the average value of IRI on each road segment is analyzed based on the provisions of Bina Marga (Ministry of Public Work and Housing. Republic of Indonesia), as shown in Table 1.

Table 1. Classification of road condition level

Road Condition	IRI
Good	<4
Fair	4-8
Poor	8-12
Bad	>12

IRI values obtained from the application Roadroid, simulated to obtain predictions IRI or the rate of road roughness. Prediction IRI is used to determine the functional condition of the road during the design life [4]. Equations to determine the evolution of pavement roughness are presented in Paterson(1987), namely:

$$\mathrm{RI_t} = (\mathrm{RI_0} + 725\ (1 + \mathrm{SNC})^{-5} \times \mathrm{NE_t}) \times e^{0.0153t} \qquad (1)$$

WhereRI_t is roughness at time, *m/km*;

RI_0 – roughnes at t=0, *m/km*;

NE_t – cumulative equivalent standard axle loadingsuntil time *t* (10^6 ESA $lane^{-1}$);

SNC – StructureNumber Capacity, given by:

$$\mathrm{SNC} = (1/24{,}4) \times \Sigma \mathrm{a_i h_i} + \mathrm{SN_{SG}} \qquad (2)$$

Where SNC is Structural Number Capacity;

a_i – the strength coefficient of the i^{th} layer as defined;

h_i – thethickness of the i^{th} layer provided that the sum of thicknesses $h_i$is not greaterthan 700 mm

SN_{SG} is the modified structural number contribution of the subgrade, given by:

$$\mathrm{SN_{SG}} = 3{,}51 logCBR - 0{,}85(logCBR)^2 - 1{,}43 \qquad (3)$$

CBR is the California Bearing Ratio of the subgrade at in situ conditions of moisture and density [5].

2.2. Structural Condition of Pavement

Pavement structural condition assessment in this study was analyzed by using the method of Bina Marga (2002 and 2013). The value of the existing structural pavement conditions is determined by using the equation of Bina Marga adopted from the AASHTO method [6].

$$SN = a_1D_1 + a_2D_2 + a_3D_3 \quad (4)$$

Where SNis Structural Number;

$a_{1,2,3}$ – the strength coefficient;
$D_{1,2,3}$ – the thickness of layers, *inch*.

The value of the strength coefficient (a) used is the actual condition of pavement materials, so that the SN values is equal to the value of Structural Number Effective (SN_{eff}). The next phase is to determine values Structural Number Future (SN_f) obtained using the equation:

$$\log_{10} W_{18} = Z_R\, So + 9.36\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{Po - Pt}{Po - Pf}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32\log_{10} Mr - 8.07 \quad (5)$$

Where$W_{18}$is predicted number by 18-kip equivalent single axle load applications;

Z_R – standard normal deviate;
S_0 – combined standard error of the traffic prediction and performance prediction;
ΔPSI – difference between the initial design serviceability index, P_0, and the design terminal serviceability index, P_t;
MR – resilient modulus, *psi*.

2.3. Functionally Overlay

The use of overlay materials to repair Roughness (IRI), as shown in Table 2 [7].

Table 2. Overlay thickness to roughness repair

IRI (m/km)	Minimum Overlay Thickness *(mm)*	Materials
4	30	HRS-WC
5	45	AC-WC
6	50	AC-WC
7	55	AC-WC
8	60	AC-BC

HRS: Hot Rolled Sheet-Wearing Course
AC-WC: Asphalt Concrete-Wearing Course
AC-BC: Asphalt Concrete-Binder Course

2.4. Structured Overlay

Calculation of thickness layers to overlay (H_{OL}), using the equation:

$$H_{OL} = \frac{SN_{OL}}{a_{OL}} - \frac{SN_f - SN_{eff}}{a_{OL}} \quad (6)$$

Where H_{OL} is overlay thickness, *inch*;

SN_{OL} – Structural Number to overlay;
a_{OL} – the strength coefficient of the overlay layer;
SN_f – Structural Number Future;
SN_{eff} – Structural Number Effective;

The type of material and thickness overlay of asphalt mixture used to maintenance and rehabilitation of pavement, as shown Table 3 [8].

Table 3. The type of material and thickness of the asphalt mix

Minimum Thickness (mm)	Materials
30	HRS-WC
35	HRS-Base
40	AC-WC
60	AC-BC
75	AC-Base

3. Results and Discussion

3.1. Pavement Condition

3.1.1. Functional Condition

Assessment of road performance are functionally obtained from the result of survey by using the Roadroid application of the Android smartphone to get the value of IRI. The results measurement of road roughness as shown in Table 5, and the predictive value of IRI in the design life of 20 years as shown in Table 4.

Table 4. IRI prediction during the design life

Years	IRI of road segment (*m/km*)									
	I		II		III		IV		V	
	WR	R	WR	R	WR	R	WR	R	WR	R
1	2.12	2.12	1.9	1.9	1.93	1.93	1.79	1.79	2.2	2.2
2	2.31	2.31	2.03	2.03	2.02	2.02	1.89	1.89	2.34	2.34
3	2.52	2.52	2.18	2.18	2.12	2.12	2	2	2.5	2.5
4	2.76	2.76	2.35	2.35	2.22	2.22	2.13	2.13	2.67	2.67
5	3.02	3.02	2.53	2.53	2.34	2.34	2.26	2.26	2.86	2.86
6	3.3	3.3	2.72	2.72	2.46	2.46	2.41	2.41	3.07	3.07
7	3.62	3.62	2.94	2.94	2.60	2.6	2.57	2.57	3.3	3.3
8	3.98	3.98	3.19	3.19	2.76	2.76	2.75	2.75	3.56	3.56
9	4.37	**4.37**	3.46	3.46	2.92	2.92	2.94	2.94	3.84	3.84
10	4.81	2.4	3.75	3.75	3.11	3.11	3.16	3.16	4.15	**4.15**
11	5.3	2.66	4.08	**4.08**	3.31	3.31	3.4	3.4	4.5	2.13
12	5.83	2.95	4.45	2.28	3.53	3.53	3.67	3.67	4.88	2.33
13	6.43	3.27	4.85	2.5	3.77	3.77	3.96	3.96	5.31	2.56
14	7.1	3.63	5.3	2.74	4.04	**4.04**	4.29	**4.29**	5.78	2.81
15	7.84	**4.03**	5.8	3.01	4.34	2.08	4.64	2.34	6.3	3.09
16	8.66	3.01	6.36	3.31	4.67	2.25	5.04	2.55	6.88	3.39
17	9.57	3.31	6.97	3.65	5.03	2.44	5.48	2.78	7.52	3.74
18	10.58	3.64	7.65	**4.02**	5.44	2.65	5.97	3.03	8.23	**4.12**
19	11.71	**4.01**	8.41	3	5.88	2.88	6.51	3.32	9.01	2.99
20	12.96	3.13	9.24	3.28	6.37	3.13	7.11	3.63	9.89	3.27

NR : Without Rehabilitation
R : Rehabilitation

Table 5. IRI value of road segment

Road Segment	IRI	Condition
I. Kertijayan-Bligo	1.95	Good
II. Bligo-Podo	1.78	Good
III. Podo-Surabayan	1.85	Good
IV. Surabayan-Sedayu	1.7	Good
V. Sedayu-Karanganyar	2.07	Good

3.1.2. Structural Condition

The data is required to determine the value Structural Number Effective (SN_{eff}) on the existing pavement is the thickness of layer pavement (D) and value of the strength coefficient (a).The result of the calculation of Structural Number Effective (SN_{eff}), as shown in Table 6.

Table 6. Structural Number effective (SN_{eff})

Road Segment	Strength coefficient				Thickness of layer (*inch*)				SN_{eff}
	$a_{1'}$	$a_{1''}$	a_2	a_3	$D_{1'}$	$D_{1''}$	D_2	D_3	
I. Kertijayan-Bligo	0.3	0.25	0.13	0.1	1.18	2.62	2.76	7.87	**2.16**
II. Bligo-Podo	0.3	0.25	0.15	0.12	1.18	2.95	3.15	9.84	**2.75**
III. Podo-Surabayan	0.35	0.3	0.17	0.14	1.18	2.23	2.76	10.24	**2.98**
IV. Surabayan-Sedayu	0.35	0.3	0.17	0.13	1.18	2.43	4.4	7.87	**2.91**
V. Sedayu-Karanganyar	0.3	0.25	0.15	0.12	1.18	2.85	4.82	7.87	**2.74**

To determine the value of the Structural Number Future (SN_f) using the equations (5). The variables required to determine the value of the Structural Number Future (SN_f) are: Traffic forecasts of future (W_{18}/CESA), reliability, Overall standard deviation (S_0), initial design serviceability index (IP_0), design terminal serviceability index (IP_t), Design serviceability loss ($\Delta PSI = IP_0 - IP_t$) and resilient modulus (MR) of sub grade.

The Calculation of SN_f used some of the scenarios values Cumulative Equivalent Standard Axle Loadings(W_{18}) by using equation (2). The value of CESA/W_{18} and SN_f for all segments of the road with a design life (DL) of various scenarios, as shown in Table 7.

Table 7. CESA/W_{18} and Structural Number Future (SN_f)

Segment Number	W_{18}/CESA				SN_f			
	DL=5	DL=10	DL=15	DL=20	DL=5	DL=10	DL=15	DL=20
I	2,967,406	7,648,204	15,031,715	26,678,496	2.72	3.14	3.48	3.79
II	2,967,406	7,648,204	15,031,715	26,678,496	2.75	3.17	3.51	3.82
III	1,870,627	4,821,362	9,475,864	16,817,895	2.72	3.15	3.48	3.79
IV	2,338,284	6,026,703	11,844,830	21,022,369	2.71	3.14	3.47	3.78
V	2,338,284	6,026,703	11,844,830	21,022,369	2.8	3.24	3.58	3.89

Structural conditions during the design life of the pavement can be determined by calculating the difference between the value of the Structural Number Future (SN_f) with Structural Number Effective (SN_{eff}). If the Structural Number Effective (SN_{eff}) value greater than or equal to the Structural Number Future (SN_f) shows pavement in good condition, if on the contrary it is necessary to overlay structurally. The type of road rehabilitation and maintenance structurally as shown in Table 8 and Table 9.

Table 8. Calculation of Overlay

Segment Number	$(SN_f - SN_{eff})$				a_{OL}	Overlay thickness (cm)			
	DL=5	DL=10	DL=15	DL=20		DL=5	DL=10	DL=15	DL=20
I	0.56	0.99	1.32	1.63	0.4	**3.57**	**6.27**	**8.4**	**10.35**
II	0	0.43	0.77	1.08	0.4	**0**	**2.72**	**4.87**	**6.84**
III	-0.26	0.16	0.5	0.81	0.4	**-1.67**	**1.03**	**3.17**	**5.12**
IV	-0.2	0.22	0.56	0.87	0.4	**-1.28**	**1.42**	**3.55**	**5.5**
V	0.06	0.5	0.84	1.16	0.4	**0.4**	**3.17**	**5.35**	**7.35**

Table 9. Overlay Materials

Segment Number	Overlay thickness (cm)				Material of asphalt mixture			
	DL=5	DL=10	DL=15	DL=20	DL=5	DL=10	DL=15	DL=20
I	4	7	9	(9+3)	AC-WC	AC-BC	AC-BC	(AC-Base +HRS WC)
II	0	3	5	7	-	AC-WC	AC-WC	AC-BC
III	0	3	3	6	-	HRS-WC	HRS-Base	AC-BC
IV	0	3	4	6	-	HRS-WC	AC-WC	AC-BC
V	3	3,5	6	8	HRS-WC	HRS-Base	AC-BC	AC-BC

4. Conclusions
The simulation of IRI predictions, can determine a time plan of road rehabilitation and maintenance are functional. Layers thickness and material of asphalt mixture can be determined from the results predictions IRI in accordance with the method of Bina Marga. Road maintenance is structurally obtained from the value SN, SN_{OL} value is required to determine the thickness of the overlay and the selection of appropriate materials. So that the pavement is able to serve traffic load in the design life. Selection of road maintenance is structurally preferable, because it takes into account the capacity of the pavement, sub grade conditions and traffic load during the design life.

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