Remaining Life of Flexible Pavement at Pulang Pisau – Pangkoh Road, Central Kalimantan

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Abstract

The condition of the road pavement is an important aspect in terms of determining road maintenance and repair activities. In order to evaluate the condition of the road pavement, it is first necessary to determine the type of damage, the cause, and the extent of the damage that has occurred. Construction of a road that is not accompanied by good maintenance will cause various kinds of problems. Many district/city road pavements in Central Kalimantan have suffered damage as a result of repeated traffic loads, in line with increasing economic growth in these areas, including one of them on the Pulang Pisau – Pangkoh Road Section as far as ± 57.5 Km which is located in Pulang Pisau Regency, Central Kalimantan Province. So that on this road research will be carried out on the remaining existing road services to be able to provide alternative solutions for handling existing road problems and also budget plans. The method used in this study is using a FWD (Falling Weight Deflextometer) to determine the condition of the road structure. In addition, to find out how to handle it, this study used the 2017 Pavement Design Manual. Comprehensive road survey vehicles typically consist of a FWD mounted on a heavy truck together with a ground-penetrating radar and impact attenuator. The results obtained from this study are the remaining life of the Pulang Pisau – Pangkoh road section of 17% x UR (about 3-4 years). For its handling, it uses a flexible pavement overlay which was previously covered with selected fill and requires a cost of Rp. 243.905.730.000,- or Rp. 6.097.643.250,- per Km.

Keywords

Remaining life, road pavement, FWD, road maintenance, traffic

INTRODUCTION

The development of a region is closely tied to the role of infrastructure. Roads and bridges serve as connecting facilities between different areas, catering to various user needs. Central Kalimantan Province is one of the provinces in Indonesia, consisting of 13 regencies and one city, with a total road and bridge infrastructure spanning 1,272.08 kilometers.

The condition of road pavement is a critical aspect when determining road maintenance and repair activities [1]. To assess the condition of road pavement, it is essential to first determine the types of damage, their causes, and the extent of damage that has occurred [2]. Many roads in the regencies and cities of Central Kalimantan experience damage due to repeated traffic loads, in tandem with the economic growth in these regions. One such example is the Pulang Pisau - Pangkoh Road, which stretches approximately 57.5 kilometers in Pulang Pisau Regency, Central Kalimantan Province.

The quality of existing and planned roads must adhere to applicable standards and regulations. The primary requirements for good roads are strength, smoothness, waterproofing, durability, and cost-effectiveness over their planned lifespan. To determine the causes of pavement damage, testing can be conducted through traffic counting surveys and deflection testing using a Falling Weight Deflectometer (FWD) device [3]. In pavement thickness design, methods like Bina Marga Revision on June 2017 and AASHTO 1993 can be employed. Evaluation of pavement layer thickness structure can be carried out using the Cumulative Equivalent Single Axle (CESA) method and following the Road Pavement Design Manual 2013.
The research aims to assess road service levels, evaluate the pavement structure, and provide alternative solutions for road issues, which includes producing Detailed Engineering Designs and Budget Plans. This research pertains specifically to the Pulang Pisau - Pangkoh Road in Pulang Pisau Regency, Central Kalimantan Province. Furthermore, the study will explore the remaining life of this road and suggest measures for its maintenance. Through research, utilizing tools such as the Falling Weight Deflectometer (FWD) and the 2017 Road Pavement Design Manual, an approach to address the road section's issues will be developed.

LITERATURE REVIEW

Central Kalimantan Province is one of Indonesia's regions, comprising 13 districts and 1 city, with a total road and bridge infrastructure spanning 1,272.08 kilometers, distributed across these 13 districts and 1 city. This underscores the integral role of infrastructure in regional development. Roads and bridges serve as crucial links between various regions, catering to diverse user needs. Due to the varying usage demands, these roadways often endure significant wear and tear, posing disruptions and potential hazards to road users.

The condition of road pavement is a pivotal aspect when determining road maintenance and repair activities. To assess road pavement conditions, it is essential to identify the types of damage, their causes, and the extent of deterioration. Many road pavements in the districts and city of Central Kalimantan experience damage primarily due to repeated traffic loads, in line with the region's economic growth, including one such instance on the Pulang Pisau – Pangkoh Road, spanning approximately 57.5 kilometers in Pulang Pisau District, Central Kalimantan Province.

Road pavements are categorized into two main types: flexible pavement and rigid pavement. Flexible pavement consists of thin surface layers built on top of a base course, which, in turn, rests on a sub-base course [4]. These three layers lie above the compacted sub-grade layer of natural soil. Conversely, rigid pavement is constructed using a mix of concrete, and it may or may not have a foundation layer between the pavement and the natural soil. The key distinction between the two lies in the load distribution across their layers . Rigid pavements exhibit high stiffness and elastic modulus, resulting in a widespread load distribution. The structural capacity of rigid pavements primarily derives from the pavement structure itself, with the subgrade playing a minor role. In contrast, flexible pavements distribute loads all the way to the subgrade, with the top layer's material quality and thickness being crucial factors influencing their strength.

Frequent early road pavement damage can often be linked to several specific factors. These errors include the choice of asphalt type, asphalt content, voids within the mixture, and the mixing or compaction temperature. Asphalt, as the binding material for road aggregates, plays a significant role in the quality and quantity of road pavement. Insufficient asphalt layer thickness or asphalt content in the mixture can lead to premature asphalt hardening. As a result, it's essential to ensure the right choice of asphalt and its quantity in the mixture, as well as proper compaction and mixing temperatures to mitigate early pavement damage [5].

According to the Directorate General of Highways in Indonesia, road damage can be categorized into various types, including cracking, distortion, surface defects, abrasion, rutting, and settlement at the utility installation or bridge abutment locations. Recognizing these types of damage and their underlying causes is crucial for effective road maintenance and ensuring the longevity of road infrastructure. Proper material selection, construction practices, and maintenance procedures are essential to mitigate these issues and enhance the durability of road pavements.

The performance of road pavement structures can be generally assessed in two ways, through functional evaluation and structural evaluation. Functional evaluation focuses on assessing the condition of the pavement, particularly issues that impact the comfort and safety of road users. On the other hand, structural evaluation aims to assess damages to one or more pavement components that might render the pavement incapable of carrying traffic loads. In functional evaluation, the pavement's serviceability is often determined using the Serviceability Index in relation to cumulative traffic loads. In contrast, structural evaluation involves assessing the pavement's serviceability through the Structural Capacity concerning cumulative traffic loads, as depicted in Figure 1.

Non-Destructive Testing (NDT) is a method utilized for both functional and structural evaluations by gathering data on the existing pavement structure without causing any harm to its condition [6]. For functional evaluation, methods such as the International Roughness Index (IRI) and surface condition data are used to assess the pavement's performance. Meanwhile, for structural evaluation, data on pavement deflection is collected using a Falling Weight Deflectometer (FWD) to gauge the structural capacity [7]. These non-destructive techniques enable engineers to assess the quality and condition of road pavements, facilitating more effective maintenance and repair decisions to ensure the longevity of road infrastructure.

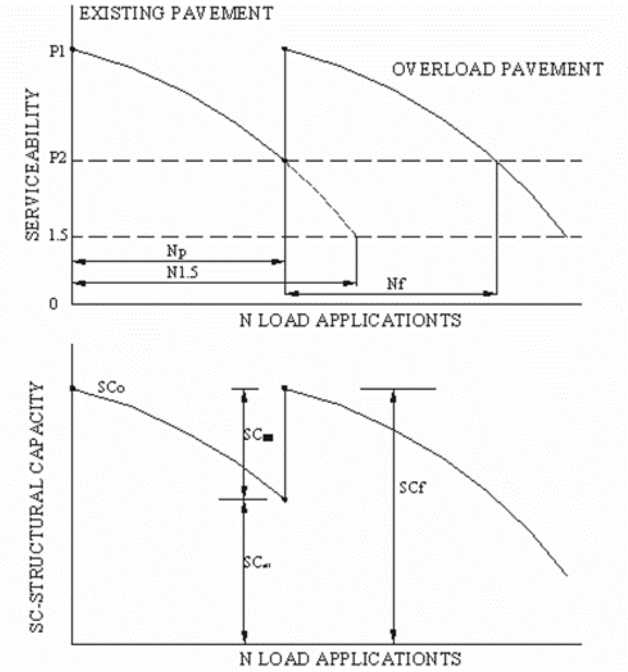

Figure 1 The decline in service level and structural capacity concerning cumulative vehicle loads (source: AASHTO, 1993)

A. INTERNATIONAL ROUGHNESS INDEX (IRI)

Roughness is a representation of the longitudinal profile of road pavement, where, in the context of highways, it reflects the level of driving comfort. The cumulative value of this roughness is expressed in terms of the IRI (International Roughness Index), which is the cumulative length of ups and downs in the pavement surface per unit length, typically measured in meters of roughness per kilometer of road (m/km). The IRI values, developed by Sayers, Gillespie, and Peterson in 1986, vary depending on the pavement's age and speed, as shown in Figure 2 [8].

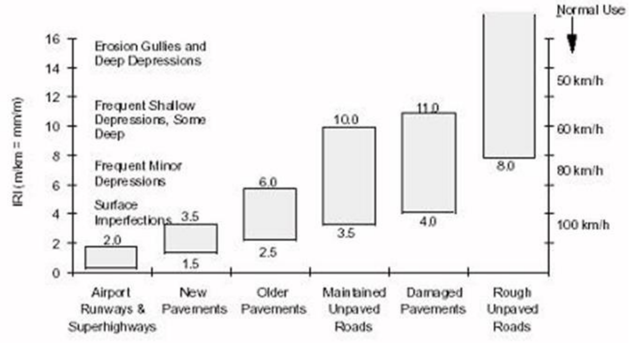

Figure 2 IRI Values for various Pavements and Speeds (source: Sayers, Gillespie & Peterson, 1986)

According to AASHTO, functional damage refers to damage that can negatively impact road users, influenced by two key parameters: surface friction, determined by assessing aggregate wear on the pavement surface, and surface roughness, quantified by the International Roughness Index (IRI) [9]. Bina Marga suggests that the IRI value can be ascertained through visual inspections, estimating the Road Condition Index or assessing road roughness condition based on visual surface evaluations conducted by surveyors, as outlined in Table 1. This IRI value, obtained through visual inspections to estimate road surface roughness, is also useful for evaluating the road surface condition, as indicated in Table 2.

Table 1 Estimated IRI Value Based on RCI Value

Road Condition Assessed Visually	RCI Value	Estimated IRI Value	Description
Cannot be passed	0-2	17 - 24	Very Bad
Many potholes throughout the pavement area	2 -3	12 - 17	Poor-Bad
Damaged, wavy, many potholes	3 - 4	9 - 12	Fair-Poor
Slightly damaged, few potholes, surface not smooth	4 - 5	7 - 9	Good-Fair
Few potholes, and the road surface is slightly uneven	5 -6	5 - 7	Good-Fair
Good	6 - 7	3 - 5	Good
Very good, generally smooth	7 - 8	2 - 3	Very Good
Very smooth and regular	8 -10	0 - 2	Very Good

Table 2 Assessment of Road Condition Based on IRI Value

IRI Value	Description
< 4	Good
4 - 8	Fair
8 - 12	Poor
> 12	Bad

B. SURFACE DISTRESS INDEX (SDI)

In the visual inspection approach, data is collected from various distress parameters, encompassing total distress area, average distress width, the number of potholes, and the depth of vehicle wheel ruts. These parameters are measured using the Road Condition Survey (RCS) form, tailored to pavement types (asphalt or gravel/dirt roads) and divided into 100-meter segments for each road stretch [10]. The results obtained from this survey are then subjected to calculations employing assessment standards stipulated by Bina Marga, as illustrated in Table 3. These computations yield a Surface Distress Index (SDI), and this SDI value is subsequently cross-referenced with Table 4, which outlines road condition assessments based on SDI values, to determine the road's condition for the assessed road segment [11].

Table 3 The calculation steps for SDI value according to bina marga

SDI Value Based on Total Cracked Area		SDI Value Based on Average Crack Width	
CRITERIA	(1)	CRITERIA	(2)
< 10 %	5	< 1 mm	(1)
(10 - 30) %	20	1-3 mm	(1)
> 30 %	40	> 3 mm	(1) x 2
SDI Value Based on the Number of Potholes		SDI Value Based on the Average Depth of Wheel Rut	
CRITERIA	(3)	CRITERIA	(4)
< 10 /Km	(2) + 15	< 1 Cm	(3) + 2,5
10-50 /Km	(2) + 75	1-3 Cm	(3) + 10
> 50 /Km	(2) + 225	> 3 Cm	(3) + 20

Table 4 Road condition assessment based on SDI value

Road Condition	**SDI**
Good	< 50
Fair	50 - 100
Slightly Damaged	100 - 150
Severely Damaged	> 150

C. MODULUS RESILIENT (MR)

Every pavement material, including asphalt mixtures and subgrade soil, possesses a "stiffness" value or a resilient modulus. In Indonesia, the resilient modulus of asphalt mixtures falls within a specific range, which depends on factors such as temperature, time of loading, and the additives used in the mixture. The magnitude of the resilient modulus of asphalt mixtures can be measured using the UMATTA instrument or calculated using the SHELL equation [12].

$$E_1 = S_{bit}\left(1+\frac{257{,}4\text{-}2{,}5\ \mathrm{VMA}}{\mathrm{n(VMA\text{-}3)}}\right)^n \qquad (1)$$

$$n = 0{,}83\ Log\left(\frac{4 \times 10^{10}}{\mathrm{Sbit}}\right) \qquad (2)$$

The value of Sbit can be obtained from the Van der Poel nomogram.

$$M_R = C.\frac{0{,}24\ \mathrm{P}}{\mathrm{d_r\ .\ r}} \qquad (3)$$

Where:
MR = Modulus Resilient (psi)
P = Weight (lbs)
dr = The deflection measured at distance "r" (inch)
r = The radius concerning deflection (inch)
C = Adjusment Factor (Cmax = 0,33)

Table 5 The VDF value according to The MDP for the year 2017

Vehicle Type	Volume	Category	Axle Configuration	Total Load	Axle Load (tons)		VDF
					Front	Rear	
Sedan, Jeep, Station Wagon	768.00	2	1.1	2,00	1,00	1,00	0,0005
Pick-up, Combi 2-Axle	5,940.00	3	1.2	8,30	2,82	5,48	0,1791
Truck, Micro Bus, Delivery Vehicle	4,236.00	4	1.2	8,30	2,82	5,48	0,1791
Small Bus	192.00	5a	1.2	8,30	2,82	5,48	0,1791
Large Bus	0	5b	1.2	9,00	3,06	5,94	0,2686
2-Axle Light Truck	2,580.00	6a	1.2L	8,30	2,82	5,48	0,1791
2-Axle Heavy Truck	396.00	6b	1.2H	18,20	6,19	12,01	90,819
Medium 3-Axle	336.00	7a	1.2.2	25,00	6,25	18,75	53,322
2-Axle Trailer & 2-Axle Semi-Trailer Truck	0	7b	1.2+2.2	31,40	14,44	16,96	46,694
4-Axle or more, Articulated Truck	0	7c1	1.2+2	26,20	15,46	10,74	43,934
Semi-Trailer Truck	0	7c2	1.2+2.2.2	42,00	19,32	22,68	192,668

Table 6 Remaining life of The Pulang Pisau - Pangkoh road section

Section	Direction	Segment	Distance (Km)	SNo	Wexc.	Wfailure	RL	CF	Sneff-1
				2020	ESAL	ESAL	%	AASHTO	Sno*CF
Pulang Pisau-Pankoh	A	8.400 - 14.800	6.400	1,75	10,289	12,407	17.07	0,75	1,3125
Pulang Pisau-Pankoh	A	23.200 - 27.600	4.400	1,75	8,106	9,774	17.08	0,75	1,3125
Pulang Pisau-Pankoh	A	31.200 - 39.600	8.400	1,75	9,341	11,264	17.09	0,75	1,3125

D. BUDGET ESTIMATE PLAN

The Budgetary Plan (often referred to as "begrooting") for a building or project is the estimation of the costs required for materials, labor, and other expenses related to the construction or execution of the building or project. It includes cost calculations for every aspect of the project to determine the total expenditure needed to complete it [13]. The budgetary plan involves detailed planning and construction procedures, as well as cost calculations based on the specifications (bestek) for the building. The estimated costs in this budget cover all expenditures related to the specified requirements. The budgetary plan must be calculated carefully and accurately, taking into account variations in material prices and labor wages in different regions. The total cost is the result of calculating the work volume with the corresponding unit prices. In general, it can be summarized as follows.

$$BQ = \Sigma\ Volume\ x\ Unit\ Price\ of\ Work \qquad (4)$$

METHODOLOGY

This research is a type of quantitative descriptive study with the aim of analyzing a specific condition to serve as a reference for future applications, following established scientific principles and theories. The research is conducted in the Central Kalimantan Province, Indonesia, specifically on the Pulang Pisau - Pangkoh road segment within Pulang Pisau Regency. Data collection involves visual surveys and secondary data related to the research subject, which is the aforementioned road.

The research data consists of primary and secondary data. Secondary data is sourced from various entities, including the Central Kalimantan Public Works and Spatial Planning Agency, the Central Kalimantan Central Bureau of Statistics, and relevant government agencies. The research methodology employs a descriptive approach and combines a literature review method to identify pertinent information from literature related to energy efficiency in buildings. Data collection includes journal titles, researcher names, research methods used, and published research results.In the context of the overall research, data analysis is crucial to comprehend the concept of energy-efficient building applications. This process adheres to Radolph's recommendations, acknowledging the significant role of literature review in providing a framework, linking previous findings with new ones, and providing context for the research. The literature review stages encompass formulating problems, collecting data, evaluating data, analyzing information, and presenting findings publicly. The results of the data analysis are used to formulate conclusions that describe the road treatment concept, particularly within the Central Kalimantan Province

RESULTS AND DISCUSSIONS

In this chapter, researchers present and analyze the data they have gathered, discussing the key findings that emerged during the research process. The results presented in this chapter encompass observations, experiments, or analyses that are relevant to the research questions, often supported by graphs, tables, or other visual aids. The discussion delves into the implications of the research findings, connecting them to existing theories and explaining their significance within the research context. Researchers also identify the study's limitations and provide recommendations for future research. Calculation of the VDF according to MDP for the year 2017 can be seen in Table 5.

A. REMAINING LIFE ANALYSIS

Remaining life is calculated using the following equation:

$$RL = 100 \text{ x } [1-\frac{Np}{N1,5}] \qquad (5)$$

Where:
RL = Remaining Life (%)
N_p = Total Traffic to date (18-Kip ESAL)
N1,5 = Total Traffic to pavement failure (18-Kip ESAL)
N2,5 = Total Traffic to pavement critical (18-Kip ESAL)

The results of calculating the remaining service life of The Pulang Pisau - Pangkoh Road Section can be seen in the Table 6.

B. COST ANALYSIS

After identifying the types of activities required for each assessed segment, the next step is to conduct a cost analysis aimed at providing cost estimates for each segment of the road section. These cost estimates will aid in forecasting the budget needed for each fiscal year. In this study, the types of maintenance activities requiring cost estimation are as follows.

Table 7 Unit prices of materials

Material	Unit	Unit Price (Rp)
AC-WC	Ton	2.590.800
AC-BC	Ton	2.449.800
Markings	M^2	351.000
Absorptive Layer	M^2	30.850
Selected Fill	M^3	647.500

Table 7 explains the unit price of material. Based on the design thickness obtained, the cost estimate for the flexible pavement can be seen in Table 8.

Table 8 Budget Plan

Material	Unit	Volume	Unit Price (Rp)	Total (Rp)
AC-WC	Ton	43.200	2.590.800	111.922.560.000
AC-BC	Ton	32.400	2.449.800	79.373.520.000
Markings	M^2	19.150	351.000	6.721.650.000
Absorptive Layer	M^2	480.000	30.850	14.808.000.000
Selected Fill	M^3	48.000	647.500	31.080.000.000
Total				243.905.730.000

CONCLUSIONS

Based on the analysis conducted and considering the issues presented in this research, several key points can be concluded. Firstly, the remaining service life of the Pulang Pisau – Pangkoh road segment is estimated to be around 3-4 years, which is equivalent to approximately 17% x UR. Next, to calculate the remaining service life of the pavement, the initial step is to assess the current traffic, followed by traffic when the pavement is damaged, and traffic when the road reaches congested/critical conditions. Finally, to address this issue, it is necessary to perform an overlay of flexible pavement, which initially requires the spreading of selected fill material, with a total cost of Rp. 243,905,730,000,- or approximately Rp. 6,097,643,250.00 per kilometer.

For future researchers, it is recommended to explore alternative designs and materials that can enhance the durability and rigidity of a structure. Additionally, a more in-depth analysis of the subgrade conditions, which will serve as the foundation for the project, is advised. These steps will contribute to the long-term performance and sustainability of the infrastructure, making it a cost-effective and reliable choice.

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