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Review of pavement thickness and road damage using an empirical approach

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Abstract: Road damage can be attributed to several factors, including high traffic volume, excessive vehicle loads, subgrade bearing capacity, and climatic conditions. Common. methods for road pavement planning include the Road Note 31 method, AASHTO 1993, Component Analysis, and the 2017 Pavement Design Manual. This study aims to review pavement thickness and identify the damage levels on the Palingi-Lansilowo road in Konawe Islands Regency.
The analysis results indicate that 50% of the road pavement falls into the Severely Damaged category, while the remaining 50% is classified as Moderately Damaged. The dominant causes of road damage are climatic factors and subgrade bearing capacity. The pavement thickness determined using the Component Analysis method includes subbase course of Class C Sand and Gravel (15 cm), base course of Class C Crushed Stone (15 cm), and surface course of Asphalt Concrete (5 cm). This review is based on traffic survey results from 2023. Therefore, it is recommended to reassess the road condition and pavement thickness in the next 10 years, considering urban development and traffic growth rate.

Keywords. road pavement, road damage level.

1. Introduction

One of the transportation infrastructures crucial for supporting the progress and development of a region is roads. Roads serve as land transportation infrastructure, facilitating the accessibility and mobility of people and goods. Land transportation is vital for enabling economic activities and cultural exchanges between regions in Indonesia. Well-maintained road conditions enhance population mobility, fostering smoother economic activities and other social engagements [1]. Conversely, damaged road infrastructure impedes traffic flow, highlighting the necessity for regular road maintenance to improve transportation services [2].

As demands evolve over time, roads must adapt to meet increasing service levels. This is exemplified by the road connecting Palingi and Lansilowo, which has seen growing traffic over the years, reflecting ongoing economic activities. Traffic congestion and suboptimal subgrade conditions are suspected causes of functional road deterioration along the Palingi-Lansilowo road in Konawe Islands Regency. According to Amakye at all (2022) [3], reinforcing the subgrade with cement and lime as binders can reduce pavement thickness.

The Component Analysis Method is an empirical method commonly used for planning district and city road pavements. This method considers a wide range of factors, ensuring that proper construction of road pavements can achieve safe, comfortable, and efficient land transportation, provided the planning adheres to applicable guidelines.

Initial field observations reveal structural damage to the pavement layers of the Palingi-Lansilowo road. Therefore, to contribute to scholarly knowledge, this study reanalyzes the pavement thickness structure and materials used on the Palingi-Lansilowo road using the Component Analysis Method, incorporating the latest traffic data from 2023. The Surface Distress Index (SDI) method is employed to identify the extent of road damage.

2. Materials and methods

A road encompasses all parts designated for public traffic, including complementary buildings and facilities, whether on, above, below ground, or water surfaces, excluding rail and cable roads [4]. Road pavement refers to the construction built upon the subgrade, designed to receive and distribute traffic loads without causing significant damage to the road structure itself, thereby ensuring comfort during its service life [5].

Over time, road pavement layers experience service level deterioration due to traffic loads, subgrade bearing capacity, weather conditions, environmental factors, and poor drainage [6]. This observation is corroborated by Latjemma (2023) [7], who identifies weather, traffic, construction implementation, pavement design, and maintenance as critical factors affecting pavement condition.

Road pavement construction consists of multiple layers placed on compacted subgrade. These layers are designed to distribute traffic loads downward. Typically, road pavement includes the subbase course, base course, and surface course layers. Enhancing the utilization of Asbuton as a binder material in road pavements instead of oil asphalt is essential, given the ample availability of Asbuton to meet Indonesia's road construction needs [8]. The subgrade refers to the natural ground surface, excavation surface, or compacted fill surface, serving as the foundation for pavement layers [9]. According to Yasin (2023) [10], the Pt T-01-2002-B method in flexible pavement planning is considered more conservative compared to the Bina Marga 2017 method.

Overloading by vehicles significantly reduces road service life, necessitating increased pavement thickness. Flexible pavement surfaces are more sensitive to service life [11], a view supported by Rahmawati research (2022) [12], which attributes 57.2% of road damage to excessive heavy vehicle loads. A planning lane is defined as a traffic lane within a road section that accommodates the highest traffic volume. In the absence of lane markings, the number of lanes is determined by the width of the pavement. The vehicle distribution coefficients (C) for light and heavy vehicles on planning lanes are specified in Table 1.

Table 1. Vehicle distribution coefficient (C)

The number of lanes	**Light vehicles *)**		**Heavy vehicles **)**	
Lanes	**One Way**	**Two Way**	**One Way**	**Two Way**
1 lane	1,00	1,00	1,00	1,00
2 lanes	0,60	0,50	0,70	0,50
3 lanes	0,40	0,40	0,50	0,475
4 lanes	-	0,30	-	0,45
5 lanes	-	0,25	-	0,42
6 lanes	-	0,20	-	0,40

Source: Departemen Pekerjaan Umum, 2018

The average daily equivalent traffic for each vehicle type is determined at the beginning of the design life. This is calculated for two-way traffic on roads without medians or for each direction on roads with medians. The average daily equivalent of a single axle on the planned lane at the start of the period can be calculated using the following equation:

$$LEP = \Sigma LHR \text{ x } C \text{ x } E \quad (1)$$

where: *LEP* is the initial equivalent traffic (Initial Equivalent Cross), *LHR* is the average daily traffic, *C* is the vehicle coefficient (vehicle distribution coefficient), and *E* is the equivalent axle load factor.

The final equivalent cross (LEA) is calculated using the equation:

$$LEA = \Sigma LHR \text{ x } (1+i)UR \text{ x } C \text{ x } E \quad (2)$$

where: *LEA* is the final equivalent cross (Final Equivalent Cross), *LHRJ* is the average daily traffic, *i* is the traffic growth rate, *UR* is the design life, *C* is the vehicle distribution coefficient, and *E* is the equivalent axle load factor.

Meanwhile, the middle equivalent cross (LET) is calculated using the equation:

$$LET = 0{,}5 \text{ x } (LEP + LEA) \quad (3)$$

Determination of pavement thickness index is based on the value of the planned equivalent cross. The planned equivalent cross (LER) is calculated using the equation:

$$LER = LET \text{ x } FP \quad (4)$$

where: FP is the adjustment factor.

Table 2. Surface index at the beginning of the design life (IPt)

LER (Cross equivalent plan)	Road Classification			
	Local	Collector	Arterial	Toll
< 10	1,0 – 1,5	1,5	1,5 – 2,0	-
10 – 100	1,5	1,5 – 2,0	2,0	-
100 – 1000	1,5 – 2,0	2,0	2,0 – 2,5	-
> 1000	-	2,0 – 2,5	2,5	2,5

Source: Departemen Pekerjaan Umum, 2018

Several previous studies in similar areas include research by Wulansari (2018) [13], who investigated the thickness of flexible pavement using component analysis and the AASHTO method on the Nagrak Road section in Bogor Regency. Sudarno at all (2018) [14], analyzed pavement thickness on the Magelang-Purworejo Highway from KM 8 to KM 9 using the Bina Marga 1987 method. Anisari, Adriyati & Ihsani (2023) [15], studied pavement thickness on the Banjang-Pulau Nyiur to Batu Mandi Road in Hulu Sungai Utara, applying the Bina Marga 2017 method with a design life of 20 years and a traffic growth rate of 3.5%.

Additionally, Handayani & Wicaksono (2021) [16], conducted a study on pavement thickness along the Purwodadi-Nongkojajar Road using the MDPJ 2017 method. Similarly, Isradi at all (2021) [17] analyzed pavement thickness on the Trans Sumatera Toll Road from Pekanbaru to Dumai using the MDPJ 2017 method.

Studies focusing on road damage include research by Prapsetyo at all (2020) [18], who assessed pavement damage in military housing areas using the pavement condition index (PCI) method. Maullana & Indrastuti (2023) [19], also utilized the PCI method to analyze damage levels on the Laswi Road in Majalengka. Additionally, Selvianti at all (2022) [20] employed the Surface Distress Index (SDI) method to identify road conditions in East Kolaka Regency.

a. Research Location

The research was conducted on the Palingi - Lansilowo road section in Konawe Kepulauan Regency, Southeast Sulawesi Province. The focus of the study was a 2 km stretch divided into two observation segments: Sta. 0+000 to 1+000 and 1+000 to 2+000. The division of segments per kilometer was made to identify road damage following the Surface Distress Index calculation procedure [21].

Fig. 1. Research location

b. Technique of Data Collection

Traffic surveys were conducted in accordance with the Traffic Survey Guidelines Pd.T-19-2004-B [22]. The surveys were carried out over two days, specifically on Tuesdays and Sundays, from 6:00 AM to 6:00 PM. Traffic was classified into three categories: light vehicles (Classes 2, 3, 4), bus 8 (Class 5.a), and two-axle trucks weighing 10 tons (Class 7.a). The survey aimed to determine the average daily traffic on the Palingi-Lansilowo road in 2023.

Road damage identification involved measuring the total area of road cracks, ruts, surface raveling, and the number of potholes in each segment (per kilometer). The collected data were then analyzed using mathematical equations. Pavement thickness calculations were conducted using the Component Analysis method, while pavement condition analysis employed the Surface Distress Index method. The Surface Distress Index (SDI) method is used to assess road damage levels and serves as the basis for determining road repair priority scales [23]. Road pavement condition assessment standards are provided in Table 3.

Table 3. Standard of road pavement condition assessment (SDI)

Classification of Road Damage	SDI Value
good	< 50
moderate	50 – 100
lightly damaged	100 – 150
heavily damaged	> 150

Source: Direktorat Jenderal Bina Marga, 2011

3. Results and discussion

a. Road Damage

The condition of the road pavement was assessed based on the SDI (Surface Distress Index) criteria. he identified types of road damage include functional damages such as cracking, potholes, rutting, and raveling. The degree of damage (Kd) indicates the percentage of the damaged road area relative to the total area of the observation segment.

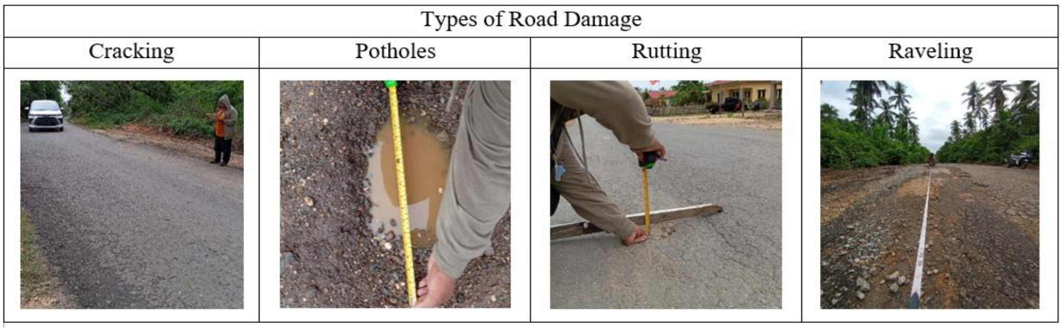

Fig. 2. Types of road damage on Palingi-Lansilowo
Source: own work.

Table 4. Results of road damage identification

Segment	Station	Type of Damage		
		Cracking (m^2)	Potholes (pcs)	Rutting (cm)
I	0+000 - 1+000	71,94	28	4,75
II	1+000 - 2+000	16,17	17	1,67

Source: own work.

Table 5. Results of road damage analysis using the SDI (*Surface Distress Index*) Method

Station	Total Area Of Cracks		Average Crack Widts		Total Number Of Potholes		Average Depth Of Wheel Rutting			SDI	Condition
0+000 - 1+000	< 10%	5	Fine < 1 mm		< 10/km	15	< 1 cm	0,5	5	**185**	Heavily Damaged
	10 - 30%	20	Med 1-3 mm	2	10 - 50/km	75	1-3 cm	2	5		
Segment I	> 30%	40	Wide > 3 mm		>50/km	225	> 3 cm	5	20		
Assessment	5		10		75	85	5	20	185		
1+000 - 2+000	< 10%	5	Fine < 1 mm		< 10/km	15	< 1 cm	0,5	5	**95**	Medium
	10 - 30%	20	Med 1-3 mm	2	10 - 50/km	75	1-3 cm	2	5		
Segment II	> 30%	40	Wide > 3 mm		>50/km	225	> 3 cm	5	20		
Assessment	5		10		75	85	2	5	95		

Source: own work.

According to Table 5, the SDI value for segment I (Sta. 0+000 to 1+000) is 185, categorizing the road pavement condition as Heavily Damaged. In contrast, segment II (Sta. 1+000 to 2+000) has an SDI value of 95, indicating a Moderate condition for the road pavement.

b. Road Pavement Thickness

The initial traffic data was collected through direct surveys conducted over two days, specifically on Tuesday and Sunday, with observations spanning 12 hours each day. Based on the analysis results, the traffic volume for the planning year 2023 is categorized as follows:

- Light vehicles weighing 2 tons = 470 vehicles (Classes 2,3, 4)
- 8-ton buses = 40 vehicles (Class 5a)
- 10-ton 2-axle trucks = 31 vehicles (Class 7a)

Motorcycle volumes were excluded from pavement thickness planning due to their negligible impact on road pavement damage. California Bearing Ratio (CBR) data was obtained from field testing using the Dynamic Cone Penetration (DCP) device. The analysis results of the CBR data are presented in Table 6.

Table 6. Field CBR values for Palingi-Lansilowo road

Segment	Station	CBR (%)
I	0 + 100	7,0
	0 + 300	7,0
	0 + 500	7,0
	0 + 700	6,5
	0 + 900	8,5
II	1 + 100	6,4
	1 + 300	9,0
	1 + 500	7,9
	1 + 700	7,3
	1 + 900	6,0

Source: own work.

$CBR_{segment}$ I = 7,2 - (8,5 - 6,5) / 2,48 = 6,4%
$CBR_{segment}$ II = 7,3 - (9,0 - 6,0) / 2,48 = 6,1%

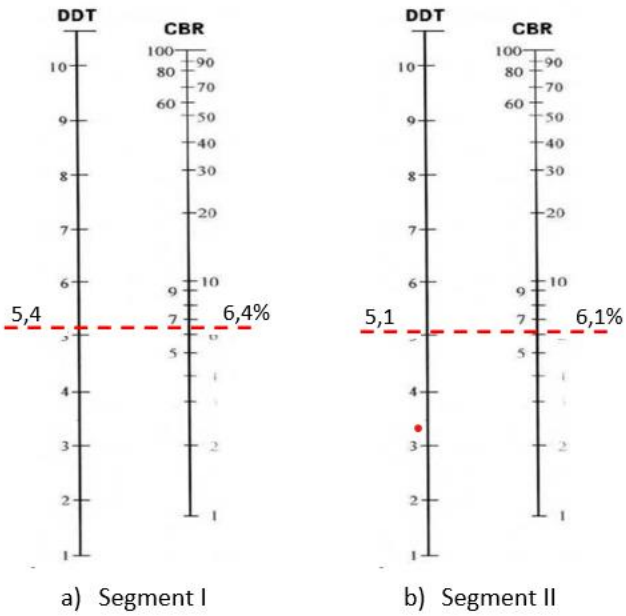

Fig. 3. Correlation of CBR values and soil bearing capacity (DDT), Segment I & II
Source: own work.

Soil bearing capacity was determined by correlating the subgrade's CBR value with the Soil Bearing Capacity (DDT). According to Figure 3, in segment I (Sta. 0+000 to 1+000), a CBR value of 6.4% corresponds to a DDT value of 5.4. Similarly, in segment II (Sta. 1+000 to 2+000), a CBR value of 6.1% corresponds to a DDT value of 5.1.

Table 7. Equivalent cross value

Description	Equivalent Cross Value
Initial equivalent cross (LEP)	9,5582
Final equivalent cross (LEA)	20,5654
Middle equivalent cross (LET)	15,0618
Plan equivalent cross (LER)	15,0618

Source: own work.

It is noted that traffic growth rate (i) is projected at 5% (implementation period) and increase to 8% (design life). The average road gradient ranges between 6% and 10%, with maximum annual rainfall recorded at 264.9 mm/year. Heavy vehicles constitute 13% of traffic, resulting in the regional factor (FR) being 1.0. The planned surface layer utilizes Asphalt Concrete with a roughness > 1000 mm/km, resulting in an initial Surface Index at the beginning of the design life (IPo) ranging from 3.9 to 3.5. For the Palingi-Lansilowo main road, classified as a collector road with a LER value of 15.0618 (Table 8), the Surface Index at the end of the design life (IPt) is calculated to be 1.5. Based on IPo = 3.9-3.5 and IPt = 1.5, the Pavement Thickness Index (ITP) is determined using Nomogram 5.

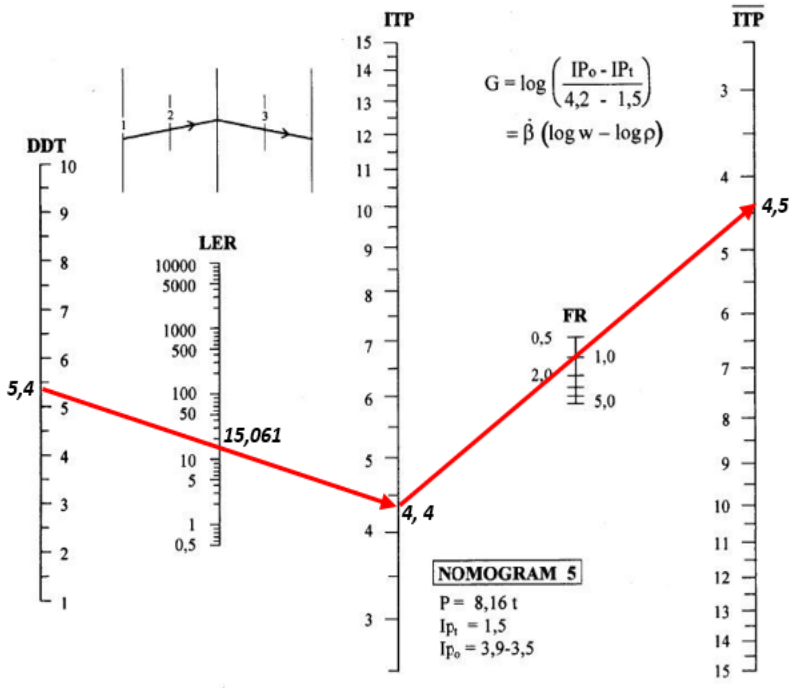

Fig. 4. Nomogram 5 for pavement thickness index (ITP), based on IPo values of = 3,9 - 3,5 and IPt = 1,5
Source: own work.

Referring to Figure 4, with a DDT value of 5.4 and LER value of 15.0618, the Pavement Thickness Index (ITP) is calculated to be 4.4 and 4.5. Using the relative strength coefficients of materials and considering the minimum thickness limit of the foundation layer, the road pavement structure is determined as follows:

- Surface course (Asphalt Concrete MS 340 kg)
  $a_1 = 0,30$; $D_1 = 5$ cm
- Base course (Crushed Stone)
  $a_2 = 0,14$; $D_2 = 15$ cm
- Subbase course (Sand and Gravel)
  $a_3 = 0,11$

To find the value of D_3:

$ITP = a_1 . D_1 + a_2 . D_2 + a_3 . D_3$
$4,5 = 0,30 \times 5 + 0,14 \times 15 + 0,11 \times D_3$
$4,5 = 3,60 + 0,11 \times D_3$
$D_3 = (4,5 - 3,60) / 0,11$
$= 8,18 \text{ cm} \sim 15 \text{ cm}$

Therefore, the pavement thickness is:
$h = D_1 + D_2 + D_3 = 35$ cm

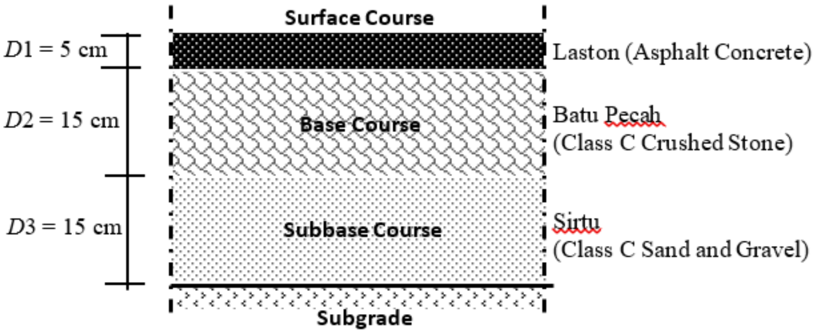

Fig. 5. Pavement structure of Palingi-Lansilowo Road using the Component Analysis Method
Source: own work.

4. Conclusion

The current road pavement structure has been in operation since 2017 but is currently severely deteriorated, with approximately 50% damage. In terms of pavement thickness, the analysis yields similar results using the Component Analysis method; subbase course of 15 cm, base course of 15 cm, and surface course of 5 cm. However, there is a distinction in the materials used; Class C Sand and Gravel for the subbase course, Class C Crushed Stone for the base course, and Asphalt Concrete for the surface course.

In contrast, the current road surface employs CPHMA (Cold Paving Hot Mix Asbuton).
The use of the Component Analysis method in pavement planning proves highly suitable for district roads due to its cost-effectiveness. To maintain the road structure throughout its design life, it is crucial to consider vehicle loading factors and the bearing capacity of the subgrade. Regular road maintenance is essential to preserve road quality until it reaches its design life.

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