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Analysis of Road Damage Factors Based on Vehicle Load and Volume on K.H. Zaenal Arifin Road Segment Cikulak – Cibogo

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Road damage, Pavement Condition Index (PCI), traffic volume, vehicle load, overlay thickness

ABSTRACT

Road damage on K.H. Zaenal Arifin Cikulak–Cibogo, characterized by potholes, crocodile cracks, and flooding, disrupts traffic and safety and is exacerbated by heavy vehicle loads and poor maintenance. This study analyzes damage factors (vehicle load, traffic volume) and assesses pavement conditions to recommend repair methods. A quantitative approach with field surveys, visual documentation, and PCI analysis was employed, supported by traffic volume conversion to passenger car units (smp) and ESAL calculations. The PCI score of 42 ("fair") reflected significant damage, with ESAL values indicating excessive axle loads (407,188). The key contributors were peak traffic (1,971 vehicles/hour) and inadequate pavement thickness. The study advocates for immediate repairs (e.g., patching, 7 cm overlay) and policy interventions to regulate vehicle loads. Future research should integrate sustainable materials and dynamic load modeling.

INTRODUCTION

Lately, we often see a lot of vehicles passing by on the highway (Mannering & Washburn, 2020). The large number of these vehicles sometimes makes the road more congested from day to day; it is not uncommon for many road drivers to be reckless when driving. Road density that is not balanced with driving knowledge can cause accidents. But accidents on the highway are not only caused by a lack of drivers' knowledge in driving, but also caused by poor road conditions (Ashraf et al., 2019; Gyimah, 2020; Hammad et al., 2019). This road damage is in the form of cracking, distortion, and surface defects (disintegration).

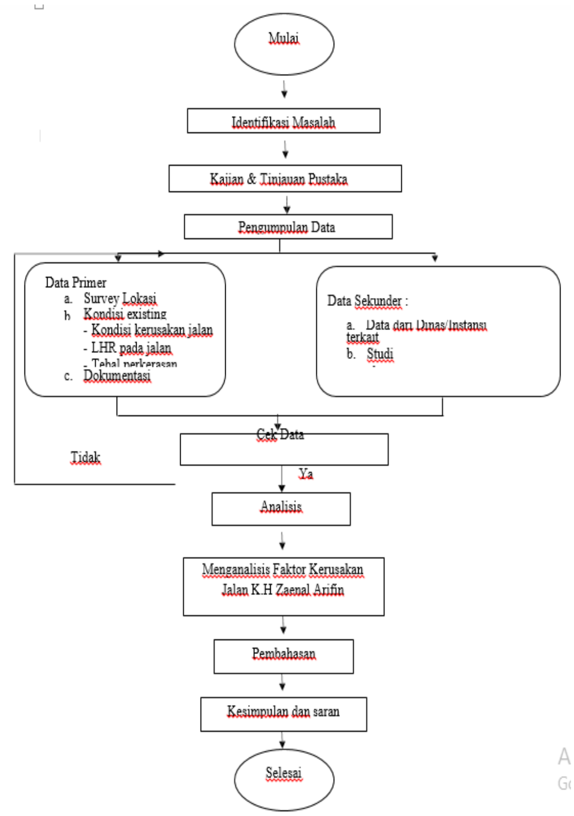
Road damage like this is usually caused by various factors, for example, rainwater, due to the load of heavy vehicles passing by (repeatedly), high groundwater level conditions, the result of mistakes in the implementation time, and can also be caused by planning errors. And it is not uncommon for this kind of damage to receive less attention from the government, as evidenced by the fact that this damage is left unattended for months. One of the problems of road damage occurred on the highway across K.H. Zaenal Arifin Cikulak - Cibogo.

The K.H. Zaenal Arifin line connects the villages of Cikulak and Cibogo. Road damage in this area, such as road damage in general, potholes, crocodile skin cracks, and even damage to this road if it rains, can flood the road. If it rains, water will pool in the holes so that the road is not visible, and this road also often experiences congestion (Adritama & Restuti, 2022; Taufikurrahman et al., 2022). This highway damage is influenced by several factors, including road damage due to overload and excessive volume of vehicles.

This study aims to analyze damage factors (vehicle load, traffic volume) and assess pavement conditions to recommend repair methods (Batioja-Alvarez et al., 2018; Bhandari et al., 2023; Zhao et al., 2022). Compared to prior studies (Prasetyo, 2024; Udiana I.M., 2023), this research uniquely integrates PCI analysis with ESAL-based load quantification to correlate pavement damage severity directly with traffic dynamics on K.H. Zaenal Arifin Road. It also proposes a specific overlay thickness (7 cm) tailored to calculated CESA values, advancing beyond generic repair recommendations in earlier works (Pratama, 2021; Yusra, 2021). The methodological combination of field surveys, empirical load calculations, and standardized PCI evaluation offers a replicable framework for similar contexts, filling gaps in localized damage assessment (Babi Almenar & Rugani, 2017; Dembski, 2020).

METHOD RESEARCH

This thesis employs a quantitative method based on actual conditions, supported by relevant data, including visual condition surveys, theoretical references, and field reviews. The research adopts a descriptive qualitative approach (Sugiyono, 2009; Ristekdikti, 2019) to analyze social phenomena by examining interrelated variables. Data collection involves observation techniques, such as direct visual surveys of road damage on Jalan Pangeran Sutajaya, using tools like survey forms, rulers, roll meters, digital cameras, markers (pilok), and walking distance meters to ensure accurate and valid findings.



The stages of research in the survey implementation include: (1) Preparation, ensuring equipment, supplies, and form completeness are checked; (2) Survey Implementation, involving filling out the survey form, observing and recording pavement damage locations, and photographing damaged road segments; and (3) Documentation Techniques, where photos related to the studied material are taken as part of data collection.

RESULT AND DISCUSSION

Results and Discussion

Pavement Surface Condition

The data on road damage was obtained from direct research in the field. The type of damage occurred almost the same as all the roads studied. The types of damage on the road section studied can be seen in the table below.

Table 1. Pavement damage on the KH Zaenal Arifin road section

Jenis Kerusakan	Keparahan Kerusakan	Luas Kerusakan (m²)
Pelapukan	Rusak Berat (High)	64,8593
Lubang	Rusak Berat (High)	52,9808
Retak Buaya	Rusak Berat (High)	209,105
Tambalan	Rusak Berat (High)	132,33
Total		459,275

Traffic Volume Conditions

The results of traffic volume data obtained from direct surveys in the field have vehicle units/hours, so they must be converted to junior high schools/hours by multiplying the traffic volume by the equivalence of passenger cars (emp). These differences occur due to different types or compositions of vehicles that cross the roads of the research area (Loganathan et al., 2013). Therefore, to equalize the unit of traffic volume to be used, it must be converted into passenger car units (smp) (Andika et al., 2022; Mubarak et al., 2024).

Table 1.3 shows the traffic volume results on Monday. Monday has the highest traffic flow of 1439 kend/hour, which, when converted to 73 SMP/hour, is 787 SMP/hour. The flow at peak hours occurs on Mondays from 16.00 to 17.00, which is 1971 kend/hour or 1039 SMP/hour. The following is a calculation of the traffic volume on the KH road section. Zaenal Arfinin Cikulak-Cibogo in the junior high school unit.

Table 2. Passenger car equivalence

Emp		
HV	LV	MC
1,3	1	0,4

Source: Directorate General of Highways 1997

Table 3. Calculation of KH Zaenal Arifin Road Traffic Volume in Junior High School Unit

No	Jenis Kendaraan	Senin	Kamis	Sabtu	Minggu	Total
1	HV	165,1	183, 3	176,8	175,5	700,7
2	LV	1921	1857	1765	1835	7378
3	MC	2634	2440,8	2438	2311,6	9824,4
Jumlah		4720,1	4481,1	4379,8	4322,1	17903,1
VLHR		787	747	730	720	2984

Vehicle Load

The load that is taken into account is the live load, which is the pressure load of the wheelbase of the vehicle passing on it, known as *the axle load*. Thus, the dead load (self-weight) of the construction is negligible.

The capacity of road pavement construction is in terms of the number of repetitions (trajectories) of the load of the axis of the traffic wheel in a standard axle load unit known as the ESAL (Equivalent Single Axle Load) unit. The standard unit of axle load is the axle load, which has a destructive power to the pavement construction of 1. And the axle load with a damage value 1 is a single axle load of 18,000 lbs or 18 kips or 8.16 tons.

This equivalent number is calculated from the equivalent of the PU Bina Marga. To calculate this equivalent number from 74 load sharing, it will be divided by the dividing factor of the load of a single-axle double-wheeled vehicle weighing 8.16 tons.

$$AE = \left(\frac{1000(\text{[illegible]})}{8160}\right) 1 + \left(\frac{1000(kg)}{8160}\right) 1 = 0,0005$$

Further calculations can be seen in **Table 4.**

Table 4. Normal Load Equivalent Figures

Gol. Kend	Beban Maksimal (ton)	Kelas Jalan AE KSAL (ton)	Konfigurasi Sumbu	Pembagian Beban	Angka Ekivalen
Gol 2	2	8,16	1-1	1-1	0,0005
Gol 3	2	8,16	1-1	1-1	0,0005
Gol 4	5	8,16	1-1	1,25-3,75	0,0452
Gol 5	9	8,16	1-1	3,06-5,94	0,3006
Gol 6	15	8,16	1-2	5,1-9,9	2,3192
Gol 7	34	8,16	1-2-2-2	6,12-9,52-9,18-9,18	4,3731

(sumber : Hasil perhitungan, 2017)

Source: Highway PU Equivalent

After getting the daily traffic volume, only the LV and HV are taken for the calculation of the ESAL LHR. Then, the LHR value is multiplied by the equivalent number. The ESAL results were obtained from the LHR multiplication obtained from the research area, which was 407,118, as shown in **Table 5**.

Table 5. ESAL Scores

Jenis kendaraan	LHR (kend/hari)	AE	ESAL (LHR x AE)
LV	1845	0,0005	0,922
HV	175	2,3192	406,266
Total			407,188

Source: Directorate General of Highways, 1997

1. Pavement Condition Index (PCI) Method Analysis

Based on road damage data obtained from surveys in the field, a condition assessment can be carried out to determine the PCI value in the section. The results of 75 studies on the KH road, Zaenal Arfin Cikulak-Cibogo, which has a length of 3 km and a width of 6 m, can be calculated. After examining the damage to the pavement that occurred in the field, the area of the damage can be calculated.

Table 6. KH Zaenal Arifin Road Damage Form

Formulir Rekapitulasi Kerusakan Pada Ruas Jalan Caracas-Pakembangan			Panjang Ruas Jalan 3 km Lebar Ruas Jalan 6 m	
Jenis Kerusakan	Keparahan Kerusakan	Luas Kerusakan (m^2)	Kerapatan (%)	Nilai Pengurang
Pelapukan	Rusak Berat (High)	64,8593	0,360	11
Lubang	Rusak Berat (High)	52,9808	0,294	30
Retak Buaya	Rusak Berat (High)	209,105	1,162	42
Tambalan	Rusak Berat (High)	132,33	0,735	17
Total		459,275	2,552	100

1. Density

So the density of pavement damage in the research area can be calculated as follows:

1. Weathering

   Density (Density) (%) = AdA� 100

   = 64,859318000 100

   = 0,360 %

2. Lubang

   Density (Density) (%) = AdA� 100

   = 52,98118000 x 100

   = 0,294 %

3. Crocodile crack

   Density (Density) (%) = AdA� 100

   = 209,10518000 x 100

   = 1,162 %

4. Tambalan

   Density (Density) (%) = AdA� 100

   = 132,3318000 x 100

   = 0,735 %

1. Deduct Value (DV)

After getting the density value for each damage, determine the *deduct value* of the step, namely, draw a vertical line according to the level of pavement damage (L, M, or H), pull the horizontal line to the left, then get a DV value on the pavement damage. For the values obtained for each segment, you can see Table **1.6** Road damage form.

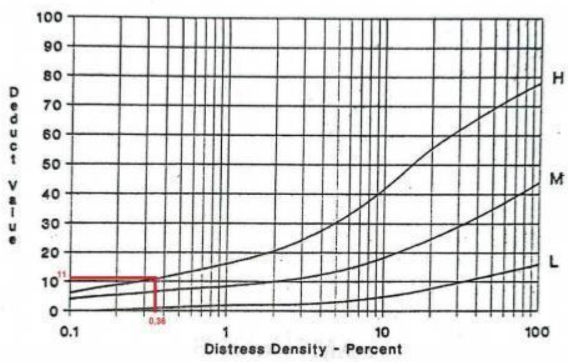


Figure 1. DV results of weathering pavement damage

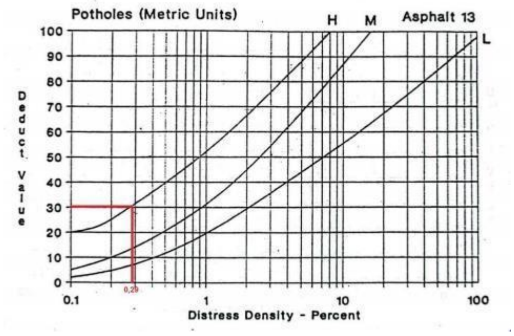


Figure 2. DV results of pit pavement damage

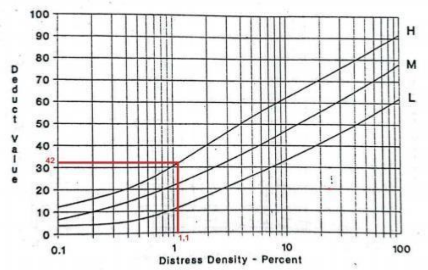


Figure 3. DV results of **crocodile cracked pavement** damage

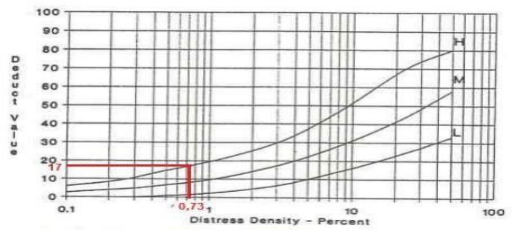


Figure 4. Results of DV damage to the pavement patch

1. **Total Deductible Value (TDV)**

To determine the total deduction value, draw a vertical draw according to q (the number of deduction values greater than 2 because the research area uses pavement with an asphalt surface), draw a horizontal line to the left, and the corrected deduction value of 58 can be seen in **Figure 5.**

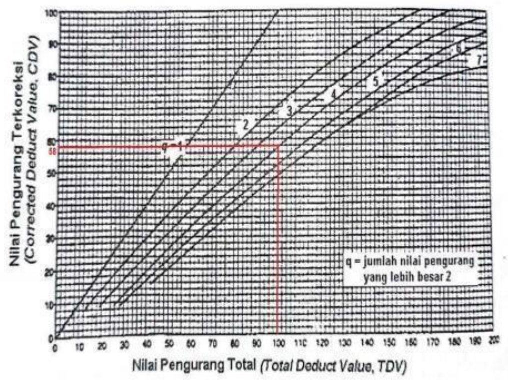


Figure 5. Graph of CDV calculation results

A. Nilai Pavement Condition Index (PCI)

Once the CDV is obtained, the PCI value for each segment unit can be calculated using the following:

PCI

= 100 – CDV
= 100 – 58
= 42

So, the PCI value is on the KH road. Zaenal Arifin Cikulak- Cibogo is 42 with a moderate (fair) condition value.

B. Analisis Perbaikan Jalan

To determine how to repair pavement damage on the KH road section. Zaenal Arifin Cikulak-Cibogo must determine the type and extent of the damage. The repair method used on flexible pavement is according to the practical instructions for routine road maintenance, UPR.02.1 of 1992, Director General of Highways. Damage handling for each damage is as follows:

In the case of alligator skin cracking, the treatment steps are:

1. Cleaning the part to be handled.
2. Marking the area to be treated squarely.
3. Spray 1.5 kg/m2 emulsion asphalt on the marked part until evenly distributed.
4. Spread coarse sand or fine, flattened aggregate.

When using fine aggregates, compacted with a light compactor. Furthermore, for handling hole damage and weathering is patching, patching can be done with the following steps, namely: 83

1. Make a square mark on the area to be treated with paint or chalk.
2. Dig the road layer in the area that has been marked with a square, until it reaches a solid layer.
3. Compacting the excavation base.
4. Fill the excavation pit with substitute materials (aggregate foundation coating material or cold asphalt mixture).
5. Compacting layer by layer.

Doing local asphalt pouring on top of the last layer.

Discussion

The road section of KH. Zaenal Arifin Cikulak-Cibogo is a route often passed by motor vehicles, cars, trucks, etc. From the number of vehicles that pass through the KH road (Li et al., 2022). Zaenal Arifin Cikulak-Cibogo, every day may not be in accordance with the volume and load of the permitted vehicle. Therefore, it causes damage to the road pavement on the section. From the above research results, the volume and weight of vehicles crossing the research road section and the value of road damage were analyzed. The results obtained from the analysis of the volume of 87 vehicles that crossed the research road section were calculated in units of junior high vehicles/day, namely MC 2456, LV 1845, and HV 175. Furthermore, the ESAL load calculation results from the LHR calculation multiplied by AE, namely LV of 0.922 and HV of 406.266, with a total ESAL in the research segment of 407.188. When viewed from the thickness of the current pavement with the vehicle's load that has been obtained, the thickness of the pavement cannot withstand the load it receives, so the pavement is damaged. After researching the pavement road section, the area of each type of road damage was obtained so that the PCI value on the KH road section could be determined. (Maullana & Indrastuti, 2023). Zaenal Arifin Cikulak-Cibogo is 42 with a fair condition. With the damage to the pavement that occurs on the section of Jalan Zaenal Arifin, it can be determined that the standard repair method that can be carried out according to the practical instructions for routine maintenance of the UPR.02.1 of 1992 of the Director General of Highways, namely Handling Method 2 (P2) Local Asphalt Planting (*Local Sealing*), Handling Method 5 (P5) Patching, Handling Method 6 (P6) *Leveling*. And for the thickness of the overlay with a CESA value of 2,920,973, the thickness of the overlay required is 7 cm (AC–WC = 4cm; AC – BC = 3 cm).

CONCLUSION

The study concludes that road damage on the K.H. Zaenal Arifin Cikulak–Cibogo segment is primarily caused by heavy vehicle loads, high traffic volume, and environmental factors, leading to cracks, potholes, and flooding. The Pavement Condition Index (PCI) analysis yielded a score of 42 ("fair"), indicating moderate deterioration requiring urgent repairs such as patching, local sealing, and overlay (7 cm thickness). Future research should explore advanced materials for pavement durability, incorporate real-time traffic monitoring to assess dynamic loads, and evaluate the socio-economic impact of road damage on local communities. Comparative studies on maintenance strategies across similar road segments could also optimize long-term solutions.

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