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Flexible Pavement Thickness Design on Pahlawan Road Using the Bina Marga 2017 Method

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ABSTRACT

This study aims to design the flexible pavement thickness for the Pahlawan Road section in Gambut District, Banjar Regency, using the Bina Marga 2017 method. Increased traffic volume due to infrastructure development in the area has caused significant damage to the road body. To address this issue, a pavement structure capable of withstanding higher traffic loads is required. Primary data collected included a 3-day Average Daily Traffic (LHR) survey and on-site Dynamic Cone Penetrometer (DCP) testing, which yielded a subgrade CBR value of 5%. The analysis and calculations revealed that the optimal pavement layer thicknesses for a 20-year design life are: a 4 cm Asphalt Concrete-Wearing Course (AC-WC), a 6 cm Asphalt Concrete-Binder Course (AC-BC), an 8 cm Asphalt Concrete-Base (AC-Base), a 30 cm Class A Aggregat Foundation Layer (LFA), and a 20 cm Selected Fill. These calculations were based on a total Cumulative Equivalent Single Axle (CESA) value of 4,091,676.6, underscoring the need for a robust pavement structure. The study concludes that using appropriate design standards is crucial to ensuring the road's quality, safety, and durability against future traffic loads

INTRODUCTION

Road infrastructure is one of the most crucial elements that underpin social welfare and economic development by enabling efficient mobility of people, goods, and services. The performance and serviceability of a road network depend heavily on its pavement design, particularly the accuracy of thickness determination to ensure structural integrity and longevity (Mallick & El-Korchi, 2022). Proper pavement design allows roads to withstand repeated axle loads and environmental factors while minimizing deformation and cracking that can compromise safety and riding comfort (Pei et al., 2025; Zhang et al., 2025). Recent studies have highlighted that the interaction between traffic loading, material properties, and climate strongly influences pavement deterioration, necessitating context-specific design methodologies (Bhandari et al., 2023; Vakili et al., 2021).

In Indonesia, rapid urban growth and increasing mobility demands have significantly altered the performance requirements of existing road infrastructures. The expansion of regional airports and industrial zones has generated new traffic patterns, leading to higher traffic volumes on access routes that were not originally designed for such loading conditions (Alsulami et al., 2024; Raharjo & Wibowo, 2024). These conditions often result in premature pavement distress, including rutting, cracking, and surface wear, which disrupt local economic activity and increase maintenance costs (Yola et al., 2024; Gertler et al., 2024). Accordingly, accurate and locally adapted pavement design is essential to sustain road serviceability and ensure long-term investment efficiency (Mahfuda et al., 2025).

The 2017 Bina Marga Pavement Design Manual remains the principal guideline for flexible pavement design in Indonesia (Bina Marga, 2017). This method incorporates the concept of Equivalent Standard Axle (ESA) and the Vehicle Damage Factor (VDF) to translate heterogeneous traffic into equivalent load repetitions, providing the basis for determining layer thicknesses under specific reliability and environmental conditions (Bina Marga, 2020). Multiple recent studies in Indonesia have applied the Bina Marga 2017 method to regional and urban contexts, reporting effective pavement configurations consisting of asphalt concrete wearing course (AC-WC), asphalt concrete binder course (AC-BC), asphalt concrete base (AC-Base), Class A aggregate base, and selected fill (Fariyadin et al., 2025; Pratama et al., 2025; Yulianti et al., 2023). These applications confirm that the method remains robust for different subgrade conditions across the Indonesian archipelago.

Subgrade characterization plays a vital role in the success of pavement design because the thickness of upper layers depends on the bearing capacity of the subgrade. The Dynamic Cone Penetrometer (DCP) test has gained wide acceptance as a rapid, cost-effective, and reliable method for estimating the California Bearing Ratio (CBR) in the field (Vakili et al., 2021; Moffat et al., 2025). Recent research efforts have sought to refine the empirical relationship between DCP penetration index and CBR values, accounting for local soil classifications and moisture contents (Keskin & Özgan, 2025; Wibowo et al., 2024; Hayadi et al., 2021). Indonesian studies particularly emphasize the need for local calibration of DCP–CBR correlations due to varying soil compositions across regions (Wibowo et al., 2024). Such localized approaches enhance the reliability of pavement design and are well aligned with the practical context of tropical soil conditions (Chokkerd et al., 2024).

Preventive maintenance strategies, such as early crack sealing and periodic overlaying, have been proven to significantly extend the lifespan of flexible pavements, especially under conditions of increased post-development traffic (Min et al., 2025). Integrating maintenance planning into the design stage—by considering surface course durability, drainage performance, and structural reliability—provides long-term economic and environmental benefits (Bhandari et al., 2023; Gertler et al., 2024). Moreover, recent advances in sustainable pavement materials and recycling practices also support the goal of enhancing road resilience in developing regions (Zhang et al., 2025).

In this study, Jalan Pahlawan, located in Gambut Subdistrict, Banjar Regency, serves as the research site. This road functions as a primary access route for local residents and as an alternative corridor linking Banjarmasin City with Tanah Laut Regency. After the construction of a new airport in 2020, this section experienced a notable increase in traffic volume, leading to visible structural distress and a decline in service performance. Therefore, it is essential to rehabilitate and strengthen this corridor through a flexible pavement design using the Bina Marga 2017 method. Primary data were collected through Average Daily Traffic (ADT) surveys and DCP testing to evaluate subgrade bearing capacity via CBR estimation. The calculated results suggest the need for a multi-layer pavement system comprising AC-WC, AC-BC, AC-Base, Class A aggregate foundation, and selected fill, designed according to actual field conditions. The findings are expected to contribute to improved pavement design practices for similar road conditions in South Kalimantan and to provide a reference for local planners in integrating data-driven and cost-effective pavement rehabilitation strategies.

METHODS

Research Design

This study adopted a quantitative case study design, focusing on the Pahlawan Road section in Gambut District, Banjar Regency, South Kalimantan, Indonesia. The quantitative approach was selected to allow measurable, data-driven analysis of traffic loads, soil characteristics, and structural performance parameters that influence pavement design (Alavi et al., 2021). The case study design facilitates in-depth investigation of local conditions that represent typical problems in regional roads exposed to increasing traffic demands and weak subgrade soils (Kusuma et al., 2023).

The primary objective was to determine the optimal flexible pavement thickness that meets design requirements based on the Bina Marga 2017 Manual of Pavement Design (MDP). This guideline integrates empirical and mechanistic-empirical principles, aligning national standards with international best practices in pavement engineering (Ministry of Public Works and Housing, 2017).

Data Collection Framework

1. Primary Data Collection

a. Average Daily Traffic (ADT) Survey

The ADT survey was conducted over three consecutive days, covering both weekdays and weekends to capture variations in traffic flow. Observations were made manually at strategic cross-sections using the manual tally count method, in compliance with the Bina Marga 2017 and AASHTO (2018) standards. The data were classified into vehicle categories—light vehicles, medium trucks, heavy trucks, and motorcycles—and later converted to Equivalent Single Axle Load (ESAL) using conversion factors based on axle configurations and load repetitions (Rahman et al., 2022).

To ensure accuracy, peak-hour adjustment factors (PHF) and growth rate projections were also applied. The projected design traffic was computed using the formula:

$$N = 365 \times ADT \times (1 + r)^n \times F$$

where r is the annual traffic growth rate and n is the design period (years).

b. Dynamic Cone Penetrometer (DCP) Testing

The DCP test was carried out at multiple sampling points along the road alignment at 100–200 m intervals to obtain representative soil strength data. Each test recorded the number of blows required for specific penetration depths, typically up to 800 mm, as per ASTM D6951/D6951M-18 standards.

The DCP index (mm/blow) was then correlated to the California Bearing Ratio (CBR) using updated empirical correlations from regional studies suited for tropical soils (Tahar et al., 2021; Zhang & Chen, 2023). This test is efficient and reliable for evaluating subgrade strength, particularly in field conditions with high moisture variability such as those in Banjarmasin’s swampy areas (Irawan et al., 2024).

2. Secondary Data Collection

Secondary data were obtained from government agencies and meteorological institutions to complement field data, including:

Rainfall data from the Meteorology, Climatology, and Geophysics Agency (BMKG) for the last 10 years to evaluate hydrological influences.

Soil classification maps from the Banjar Regency Public Works Office.

Land-use data to assess potential environmental impacts and runoff patterns affecting subgrade moisture (Adnan et al., 2022).

This combination of datasets enabled a holistic understanding of the geotechnical and environmental context, which is essential for reliable pavement design in humid tropical climates (Santoso et al., 2023).

Data Processing and Analysis

The analysis was conducted through a three-stage process:

Stage 1: Traffic Load Analysis (ADT ⟶ ESAL Conversion)

Traffic data from the ADT survey were converted into Equivalent Single Axle Loads (ESAL) using the standard Bina Marga equivalency factors. Each vehicle type was multiplied by its load equivalency factor to obtain cumulative ESAL values for the design life. The traffic growth rate and design period (typically 10–20 years) were applied to project total traffic loading (Faisal et al., 2020; Liu et al., 2022).

Stage 2: Subgrade Strength Analysis (DCP ⟶ CBR Conversion)

Penetration data obtained from the DCP test were plotted against depth, and the DCP penetration index (mm/blow) was calculated for each layer. The CBR value was then estimated using correlations such as:

$$CBR = 292 / (DPI)^{1.12}$$

where DPI = DCP Penetration Index.

Representative CBR values were derived by averaging multiple test results and eliminating outliers beyond one standard deviation (Rauf et al., 2024; Nugraha et al., 2023).

Stage 3: Pavement Thickness Design

The flexible pavement layer thickness was determined using Design Chart 3B from the MDP Bina Marga (2017) based on input parameters—CBR, ESAL, and reliability factor (R). The design output included:

- Surface course (Asphalt Concrete Wearing Course)
- Base course (Crushed Aggregate)
- Subbase course (Granular Material)

Each layer's thickness was iteratively checked against performance criteria for rutting, fatigue, and deflection, ensuring that the pavement structure met durability and serviceability requirements (Mahmood et al., 2021; Santoso et al., 2023). The recommended design balances cost efficiency with long-term performance under local climatic and traffic conditions.

Quality Control and Validation

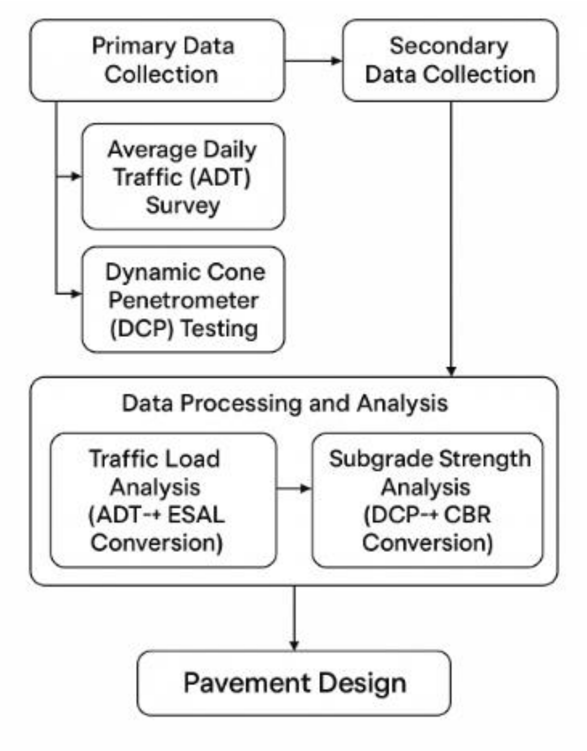
To ensure data reliability:

- Field measurements were repeated at randomly selected points.
- Data validation was performed through cross-checking CBR results with laboratory compaction tests.
- Sensitivity analysis assessed the influence of variations in CBR and traffic growth rate on layer thickness outcomes.

These steps enhanced the credibility and reproducibility of results (Al-Zubaidi et al., 2022).

Tabel 1. Summary of Methodological Flow

Stage	**Process**	**Output**
1	ADT survey and ESAL computation	Total design traffic (ESAL)
2	DCP testing and CBR correlation	Representative subgrade strength
3	Pavement design using MDP 2017	Optimal layer thickness (surface, base, subbase)



Picture 1. Research Methodological Flow

RESULTS AND DISCUSSION

This study began with the collection of primary and secondary data, which served as the basis for calculating the road pavement thickness. The data obtained from the field and the results of the analysis are presented in detail as follows:

a. Subgrade Soil Data The bearing capacity data of the subgrade soil was obtained through *Dynamic Cone Penetrometer* (DCP) testing at three different points on the road. The test results showed a variation in CBR values, reflecting the soil conditions along the road section. The average CBR value used as the design parameter was **5.59%**, with a maximum value of 5.79% and a minimum of 5.19%. This value indicates that the subgrade has a moderate bearing capacity, requiring structural reinforcement above it to support heavy traffic loads.

b. Traffic Data The Average Daily Traffic (ADT) data was collected over a 3-day period on the Pahlawan Road section. The survey results showed a significant volume of commercial vehicles, as follows:

Table 2. Traffic Data

Vehicle Type	Number of Vehicles (Per day)
Small Bus	10
Large Bus	4
Light Truck (2 Axles)	52
Medium Truck (2 Axles)	92
Truck (3 Axles)	4
Total	**162**

This ADT data formed the basis for calculating the cumulative standard axle load. The calculation process started by determining the **ESA** (Equivalent Standard Axle) value for each type of commercial vehicle. For example, for a Small Bus:

ESA=(ADTSmallBus×VDF4)×DL
ESA=(10×0.3) ×1=3

The total **CESA5** (Cumulative Equivalent Single Axle) value obtained from all commercial vehicles over a design life of **20 years** was **4,091,676.6**. This value indicates a very high traffic load, exceeding the light-to-medium traffic range, and is the main reference for selecting the pavement design chart.

Based on the data analysis, the CESA5 value of 4,091,676.6 million indicates that the Pahlawan Road section falls into the heavy traffic category. Therefore, in accordance with the **Manual of Pavement Design No. 04/SE/Db/2017**, the pavement design must refer to **Design Chart 3B**. This chart is specifically intended for flexible pavements that use granular foundation layers and are designed to withstand high cumulative axle load repetitions.

The designed pavement thickness obtained from Design Chart 3B provides a comprehensive structural solution to the road's problems. Each layer has a specific function that is essential for supporting traffic loads:

a. **Selected Fill (20 cm):** This layer serves to raise the road's elevation and improve the bearing capacity of the subgrade soil with a CBR value of 5.59%. A well-compacted fill layer ensures a stable foundation and prevents road body subsidence, which is crucial given the location's history of flooding.
b. **Class A Aggregate Foundation Layer (LFA) (30 cm):** This layer is the main component of the granular foundation, serving to distribute the load from the layers above it over a wider area, so that the pressure on the subgrade does not exceed its allowable limits. The Class A LFA has a high quality and is able to effectively withstand wheel shear forces.
c. **Asphalt Foundation Layer (AC-Base) (8 cm):** This layer serves as the main load-bearing layer beneath the surface course. AC-Base plays a crucial role in distributing the load to the LFA below.
d. **Binder Course (AC-BC) (6 cm):** This layer functions as a binding layer between the AC-Base and the AC-WC, ensuring a strong bond and distributing the load evenly.
e. **Wearing Course (AC-WC) (4 cm):** This is the top layer that directly receives friction from vehicle wheels. AC-WC is designed to be waterproof, preventing water from penetrating the pavement structure, and to provide a smooth, non-slip surface for driver comfort and safety.

Overall, this pavement thickness design is an appropriate solution because it is based on actual traffic data and local soil bearing capacity. The recommended layer composition will collectively enhance the road's structural bearing capacity, prevent premature damage, and ensure the road can function optimally throughout its **20-year** design life.

CONCLUSION

Based on a detailed analysis of the structural conditions and requirements of Jalan Pahlawan, Gambut, Banjar Regency, this study concludes that the pavement damage was caused by a significant increase in traffic volume and vehicle loads following the new airport's construction. This increase resulted in a cumulative Equivalent Single Axle Load (ESAL) value that exceeded the pavement's initial design capacity, leading to fatigue cracking and rutting (Huang, 2004).

By using the Bina Marga 2017 method, supported by accurate primary data from an Average Daily Traffic (ADT) survey and on-site Dynamic Cone Penetrometer (DCP) testing, this research successfully formulated an appropriate technical solution. The subgrade's California Bearing Ratio (CBR) value, obtained from the DCP testing, proved to be a vital parameter in determining the soil's bearing capacity for designing the optimal pavement thickness (Hankare et al., 2018).

As a final result, this study recommends a flexible pavement structure consisting of specifically designed layers: an asphalt mixture (Asphalt Concrete) for the surface course (AC-WC, AC-BC, AC-Base) and a foundation layer (Class A Aggregate Foundation) over a Selected Fill. This configuration is engineered to effectively distribute traffic loads to the subgrade, thereby withstanding repeated loads and ensuring the road's service life is as planned (AASHTO, 1993; Direktorat Jenderal Bina Marga, 2017). The implementation of this design is expected to restore the road's function, enhance user safety, and support economic mobility in the region.

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