



Comparison of Concrete and Asphalt Pavement Planning in Terms of Cost and Time on the Tulangan-Kludan Road Segment, Sidoarjo Regency

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Abstract

This study compares the planning of concrete and asphalt pavement on the Tulangan–Kludan road segment in Sidoarjo Regency, focusing on cost and implementation time. The research analyzes projections of average daily traffic (ADT), optimal pavement design for 20-year and 40-year service lives, construction cost estimates, and implementation duration. The methodology refers to the 2024 Road Pavement Design Manual (MDPJ) guidelines and field-testing data using the Dynamic Cone Penetrometer (DCP). The results show that concrete pavement has a longer service life with minimal maintenance requirements, making it suitable for industrial roads with heavy traffic loads. On the other hand, asphalt pavement offers advantages in terms of lower initial construction costs and shorter implementation time. This study reveals that although concrete pavement requires a higher initial investment, it is more cost-effective in the long term due to its lower maintenance needs over a 40-year service period. Meanwhile, asphalt pavement is more economical for a 20-year service life, especially under medium traffic conditions. The unique contribution of this research lies in its integration of local ADT projections with the latest MDPJ 2024 standards, producing context-specific insights that can guide infrastructure planning. This comparative analysis provides practical recommendations for infrastructure development planning in Sidoarjo Regency, particularly in supporting industrial area growth in Tulangan District.

Keywords: Road pavement, concrete pavement, asphalt pavement, cost analysis, MDPJ 2024, Sidoarjo

INTRODUCTION

Sidoarjo Regency plays an important role in supporting the economy of East Java. Strategically located between Surabaya and Pasuruan, this region serves as a key distribution route for goods and services (Handayati, 2018; Wagistina et al., 2022). The Tulangan District, in particular, has developed into a center of furniture and woodcraft industries that are renowned internationally. This industrial growth has directly contributed to increased transportation activity, especially from heavy vehicles transporting raw materials and finished products.

The existing condition of the Tulangan-Kludan road segment currently uses asphalt pavement, which has shown significant structural damage. Field observations have identified various types of deterioration, such as alligator cracking, rutting, and plastic deformation along the segment. These damages not only affect the comfort of road users but also reduce the logistical efficiency of the industries in the area (Bina Marga Sidoarjo, 2023).

The soil characteristics in Tulangan District are predominantly silty clay with medium plasticity. This type of soil has relatively low bearing capacity and is highly sensitive to changes in moisture content (Liu, Huang, Feng, & Xie, 2023; Paprocki, Stark, & Wadman, 2023; Pham & Sutman, 2023). This condition is worsened by the tropical wet climate, which allows water to easily seep into the pavement structure, accelerating deterioration—especially in flexible pavements. Thus, a design approach that adapts to local conditions is necessary to ensure a longer service life (PUPR, 2022).

The Sidoarjo Regency Government, through the Department of Public Works for Highways and Water Resources, has initiated a comparative study between the use of flexible and rigid pavement for road improvement projects. This study is relevant not only due to technical and existing conditions but also because it aligns with the latest 2024 Road Pavement Design Manual (MDPJ), which offers a more detailed approach to vehicle load calculations, soil characteristics, and planned road lifespan (MDPJ, 2024).

The 2024 MDPJ introduces significant updates to pavement planning, especially in determining structural pavement design based on traffic variables, soil conditions, and design life. One major update is the classification of pavement based on service life: 20 years for asphalt and granular layers, and 40 years for road foundation layers and concrete structures. For industrial roads that do not allow overlays due to operational factors, a 40-year design life is recommended, making rigid pavement more relevant due to its minimal maintenance needs despite its higher initial cost (MDPJ, 2024).

Previous studies have shown that cost-efficiency between rigid and flexible pavement largely depends on technical context, design life, and traffic conditions. Prasojo and Narendra (2023) found that flexible pavement was more economical with a total cost of IDR 23.16 billion compared to IDR 31.66 billion for rigid pavement on the KIT Batang road project. Conversely, Prasetya et al. (2023) reported different findings, where rigid pavement saved up to IDR 9.92 billion for a 20-year design life in the access road study for Rusun PPI-TPI Romokalisari.

Fajarianto et al. (2023) recorded savings of IDR 3.02 billion on rigid pavement using the Bina Marga method compared to the Austroads method. Simanjuntak (2023) highlighted that despite the higher initial cost of rigid pavement, its long-term efficiency remains an advantage due to minimal maintenance needs. Meanwhile, other studies such as Assa et al. (2022) and Sutapa et al. (2022) found that flexible pavement is more economical for medium-scale projects (Abd. Kadir Salim et al., 2020; Adhita Maharani, 2018; Aditiya & Siswoyo, 2020).

These differing research results emphasize the importance of contextual analysis when selecting the type of pavement (Goswami, Mitchell, & Bhagavatula, 2018; Marcelino, de Lurdes Antunes, Fortunato, & Gomes, 2021). For major roads frequently used by heavy vehicles with high traffic volumes, rigid pavement may be more efficient due to its higher durability and longer service life. However, for roads with less traffic, flexible pavement may be a more practical and economical choice (Asres, Ghebrab, & Ekwaro-Osire, 2021; Little, Allen, & Bhasin, 2018; Qiao, Dawson, Parry, Flintsch, & Wang, 2020).

The *comparison* between concrete and asphalt pavement is important because both types have different characteristics, advantages, and disadvantages, particularly regarding cost-efficiency and implementation time. Choosing the right type of pavement directly affects the road's service life, maintenance requirements, and the efficiency of logistics distribution and public mobility in the area (Ministry of PUPR, 2022).

The current condition of the Tulangan-Kludan road segment shows serious damage to the existing flexible pavement structure. Widespread alligator cracking, longitudinal and transverse cracks, and surface deformation indicate material fatigue and reduced load-bearing capacity. This condition is worsened by a suboptimal drainage system, allowing rainwater to easily infiltrate and accelerate damage to the lower pavement layers.

This problem is inseparable from the industrial development of Tulangan, which has experienced increased activity in the past decade. This area has become a growth center for small and medium industries, particularly in the furniture and craft sectors. The increased industrial mobility has directly impacted daily traffic volume, especially heavy vehicles such as trucks and pickups that frequently pass through the road segment. This results in axle loads exceeding the original design capacity of the asphalt pavement, which was only intended for light to medium traffic.

This study has scientific urgency due to the need to formulate road infrastructure development strategies that are not only technically efficient but also offer optimal service life and minimize long-term maintenance costs. In MDPJ 2024, rigid pavement is recommended for industrial roads with heavy traffic and no potential for overlay. However, in practice, many local road projects have not consistently applied this standard due to technical data limitations and a lack of comprehensive evaluation in design choices.

Compared to previous research that mostly focused on structural analysis or laboratory studies of pavement materials, this study employs a multidimensional approach covering technical design, budget efficiency, and construction speed. Some earlier studies also tended to compare only one design life or consider only initial construction costs, without accounting for life-cycle costs and the actual impact of industrial traffic.

This research offers a new contribution through a comparative simulation of the two pavement types for 20- and 40-year design lives, using local parameters such as ADT, subgrade CBR, and construction cost analysis based on Sidoarjo Regency's standard cost list (HSPK). To date, no study has specifically examined the Tulangan-Kludan road segment by incorporating ADT projections, DCP testing, budget estimation, implementation duration, and pavement life projection based on MDPJ 2024 and Sidoarjo's HSPK.

RESEARCH METHOD

To address the question of how to project the average daily traffic (ADT) and determine the most appropriate pavement design between rigid (concrete) and flexible (asphalt) types on the Tulangan–Kludan road segment, this study adopts a technical and quantitative approach. The research is designed to yield robust technical designs, with traffic projections made for two service life scenarios: 20 years and 40 years. This location was selected due to the current decline in pavement quality and the continually increasing traffic volume each year.

The Tulangan–Kludan road segment is located in Sidoarjo Regency, East Java. Based on initial observations, the road has experienced various forms of damage, indicating that the current pavement structure has exceeded its ideal service life. Cracks, potholes, and minor to moderate deformations are commonly found on the road surface. Therefore, a technical assessment was conducted on projected traffic loads and alternative pavement structure designs, both concrete-based and asphalt-based.

To accurately project traffic volume, two types of data were collected: primary and secondary data. For primary data, a direct traffic survey was conducted in the field during peak hours on working days to obtain actual vehicle volume data for the segment. This data includes vehicle types, vehicle counts per hour, traffic directions, and peak periods. For secondary data, the researcher used information from the Sidoarjo Regency Transportation and Public Works Department, such as annual traffic growth rates, commercial vehicle classifications, and vehicle distribution by time and direction. In addition, road topographic maps were used to assess elevation and gradient, which may influence pavement structure planning.

Traffic Projection (ADT)

After the data was collected, projections of ADT were calculated for 20- and 40-year periods. The base-year ADT was derived from the traffic survey. The following formula was used to calculate annual traffic growth:

$$LHR_t = LHR_0 \times (1 + r)^t$$

Where:

LHR_t = LHR in year t

LHR₀ = LHR in the base year (survey result)

r = traffic growth rate (in percent per year)

t = year of projection (20 or 40)

The annual traffic growth rate was determined based on historical data, generally ranging from 5–7% per year depending on regional characteristics. The projection results were then used to calculate cumulative traffic loads for the design life.

Traffic Load: CESA and JSKN

To design pavement thickness, two important parameters were calculated from the projected ADT:

- 1) CESA (Cumulative Equivalent Standard Axle Load): Used for flexible (asphalt) pavement design, calculated in terms of cumulative traffic load in 8.16-ton equivalent standard axle units.
- 2) JSKN (Jumlah Sumbu Kendaraan Niaga or Number of Commercial Vehicle Axles): Used for rigid (concrete) pavement design, calculated as the total number of commercial vehicle axles that will pass through the road during its service life.

These values were calculated using formulas from the 2024 Road Pavement Design Manual (MDPJ 2024), which includes conversion factors for light and heavy vehicles, as well as standard 50:50 directional traffic distribution for two-way roads.

Pavement Structure Design

Once the CESA and JSKN values were determined, pavement structure designs were prepared using two different approaches:

a. Flexible Pavement (Asphalt) Design

Using CESA from the ADT projections, the flexible pavement structure was designed by considering subgrade strength (from CBR values obtained via DCP testing), safety factors, and the planned service life. It generally includes a subbase, base course, and surface layer. The thickness of each layer was calculated to withstand traffic loads over 20 and 40 years without structural failure.

b. Rigid Pavement (Concrete) Design

Using JSKN parameters, the rigid pavement design was based on either reinforced or unreinforced concrete slabs, depending on projected load and cost considerations. Slab thickness was determined to withstand vehicle load stresses and environmental temperature changes. Joint and drainage designs were also included to optimize service life.

Material and Work Volume Estimation

Each design alternative resulted in a breakdown of material requirements such as aggregate volume, asphalt, cement, reinforcing steel, and other materials. This calculation is crucial for preparing the Bill of Quantity (BoQ) and assessing the efficiency of each pavement type. Material prices referred to the Standard Unit Price List (HSPK) of Sidoarjo Regency to ensure alignment with field conditions.

Design Validation and Evaluation

After completing the designs and determining structural thickness, an evaluation was conducted to ensure the designs met load resistance criteria for the projected service life. Additionally, comparisons were made between the two design scenarios to observe how thickness requirements change when extending the service life from 20 to 40 years. These findings formed the basis for determining whether concrete or asphalt is more efficient, depending on projected ADT levels over the long term.

RESULTS AND DISCUSSION

This study aimed to project the traffic volume (LHR) and determine the optimal pavement design for the Tulangan–Kludan road segment in Sidoarjo Regency, considering two service life scenarios: 20 years and 40 years. Based on the field survey, the vehicle composition consisted of passenger cars (LV), small buses (5A), two-axle light trucks (6A), two-axle medium trucks (6B), and three-axle trucks (7A2). Using cumulative traffic growth factors (R) of 28.28 for a 20-year period and 84.55 for a 40-year period, traffic projections showed that medium two-axle trucks (6B) would reach 38,404 vehicles per day by the 20th year and increase to 114,819 vehicles per day by the 40th year.

To determine the pavement load, the Equivalent Standard Axle (ESA5) method was used, factoring in daily traffic volumes, growth rates, lane distribution, and vehicle damage factors. The ESA values were found to be 14,297,371 for the 20-year design and 39,471,328 for the 40-year design, indicating a significant rise in traffic load over time.

The flexible pavement design integrated the existing structure—which consisted of a 6 cm asphalt layer and a 40 cm aggregate base—and adjusted the overlay thickness accordingly. For the 20-year design, the pavement structure included a 40 mm AC-WC (wearing course), 75 mm AC-BC (binder course), and 100 mm AC-Base, totaling 21 cm of new layers. For the 40-year design, the AC-WC remained at 40 mm, while the AC-BC was increased to 60 mm and the AC-Base to 185 mm, resulting in a 28 cm overlay. These adjustments were based on locally available materials and the condition of the existing road.

For the rigid pavement (concrete), the JSKN (total number of axle repetitions) was calculated at 28,324,116 for 20 years and 84,681,898 for 40 years. The resulting design for the 20-year service life required a concrete slab of 25 cm thickness, while the 40-year design required 30 cm. Both used 32 mm diameter dowels with 450 mm length and 300 mm spacing, and D16 deformed tie bars with 600 mm length and 500 mm spacing. A 100 mm lean concrete base was applied only on widened road sections.

In terms of cost, asphalt pavement construction without maintenance was estimated at IDR 9,951,479,157 for 20 years and IDR 13,001,241,891 for 40 years. Including maintenance, the total costs were IDR 11,811,680,444 and IDR 23,947,021,455, respectively. For concrete pavement, the total cost including maintenance was significantly lower: IDR 5,908,783,672 for 20 years and IDR 7,472,273,017 for 40 years.

As for construction duration, asphalt pavement required 18 days for the 20-year design and 23 days for the 40-year design, while concrete pavement took 107 days and 128 days, respectively. These durations were calculated under the assumption of 10 workers per day.

Discussion

The results of the traffic growth and ESA analysis highlight the importance of designing pavement structures that can withstand significant increases in vehicle load over time. The ESA value nearly tripled from the 20th to the 40th year, justifying the need for thicker pavement layers to ensure long-term serviceability and structural integrity.

Flexible pavement showed advantages in terms of construction speed and adaptability. The use of existing pavement layers allowed for a cost-effective solution, while the layered structure (AC-WC, AC-BC, and AC-Base) provided flexibility and performance under high traffic volumes. The selection of layer thicknesses based on local materials further optimized resource use and minimized construction disruptions. However, asphalt pavement requires regular maintenance, with overlay intervals every 10 years for non-structural needs and every 20 years for structural ones. This introduces long-term costs and scheduling considerations that must be anticipated.

Rigid pavement, although requiring a longer construction period, demonstrated superior long-term performance. The increased slab thickness and reinforcement

specifications—such as dowels and tie bars—ensure resistance to fatigue and erosion, even under heavy truck traffic. Notably, for the 20-year design, concrete pavement does not require maintenance within its service life. For the 40-year design, maintenance was only needed in the form of a 13 cm overlay, confirming the durability and structural reliability of concrete pavement.

Economically, concrete pavement offered a substantial cost advantage in the long term. The total cost difference between the 40-year asphalt and concrete designs was nearly IDR 16 billion, demonstrating that despite higher initial costs, concrete provides better value for long-term infrastructure investment. Nevertheless, asphalt remains a logical choice when quick project completion is required, such as in urban environments with high daily traffic volumes or economic dependency on fast road access.

Furthermore, both pavement types benefitted from the integration of existing road structures. Reusing these elements helped reduce material use, excavation volume, and construction time, while supporting environmental sustainability. This reflects a practical and efficient planning approach that balances structural needs with real-world constraints.

In conclusion, the choice between flexible and rigid pavement must be based on a comprehensive assessment of traffic projections, material availability, construction timeline, environmental impact, and lifecycle cost. While asphalt pavement may be preferable for rapid execution, concrete pavement stands out as a more durable and cost-efficient solution for long-term infrastructure needs.

CONCLUSION

This study concludes that selecting flexible (asphalt) or rigid (concrete) pavement for the Tulangan–Kludan road segment should consider projected traffic loads, service life, construction time, and financial efficiency. With ESA values rising from 28.59 million at year 20 to 78.94 million at year 40, pavement thickness and strength must be adjusted accordingly. Flexible pavement allows faster construction and use of local materials but requires periodic maintenance every 10–20 years, increasing long-term costs. Rigid pavement, although requiring longer construction, offers higher durability and minimal maintenance, proving more cost-effective over a 40-year lifespan by saving nearly IDR 18 billion compared to asphalt. Both types benefit from integrating existing road structures, enhancing cost and time efficiency. Asphalt suits short-term or rapid deployment needs, while concrete is more sustainable and economical for long-term infrastructure. Future research should explore lifecycle environmental impacts and the feasibility of hybrid pavement designs under evolving traffic conditions to further optimize cost, durability, and ecological sustainability.

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