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Comparative Analysis of Rigid Pavement and Flexible Pavement Reviewed from the Aspect of Cost and Time in Improving the Kyai H. Ahmad Dahlan Road Section in Pasuruan City

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ABSTRACT

Kyai H. Ahmad Dahlan Road in Pasuruan City serves as a vital connector for economic and industrial activities, necessitating durable and cost-effective road infrastructure. This study aims to compare rigid and flexible pavements in terms of construction cost and implementation time. Using a quantitative case study approach, traffic load analysis was conducted based on *ESA5* and *JSKN* calculations for 20- and 40-year design lives, following the 2024 *Indonesian Road Pavement Design Manual (MDPJ)*. Data included traffic surveys, soil tests (*DCP*), and regional cost references. Results show significant increases in traffic load, demanding robust pavement structures. Flexible pavements require 21–22 days to construct with higher costs (IDR 17.17–19.63 billion), while rigid pavements take longer (30–31 days) but incur lower costs (IDR 14.61–15.00 billion). Pavement design follows the 2024 *Indonesian Road Pavement Design Manual (MDPJ)*, utilizing existing pavement structures to enhance efficiency. The study concludes that rigid pavements are more cost-efficient over the long term, whereas flexible pavements offer faster execution, making them suitable for different road use scenarios in urban planning.

Keywords: Flexible pavement, Rigid pavement, *ESA5*, *JSKN*, Cost efficiency, Construction time

INTRODUCTION

Pasuruan City is a strategic area in East Java that continues to develop in various sectors, especially industry, trade, and transportation (*BPS Pasuruan City*, 2023). Its location close to economic centers and ports makes it an important node in the goods distribution system and community mobility. The topography of this city consists of lowlands and hilly areas, and it is crossed by large rivers such as the Petung River and Gembong River. However, this condition also poses a risk of disasters such as flooding, as stated in the East Java *BPBD* disaster risk assessment document (2022). The development of road infrastructure in Pasuruan City, especially in dense areas such as Purworejo District, is very important because it functions as the backbone of economic activity. *Jalan Kyai H. Ahmad Dahlan* is one of the vital infrastructures that connects the city center with industrial areas and logistics distribution.

According to the Law of the Republic of Indonesia No. 38 of 2004, roads are part of the transportation system that has an important role in supporting national development and

integration (*Law No. 38, 2004*). However, with the high traffic intensity and commercial vehicle loads, proper road planning is required by considering cost efficiency and implementation time. In this context, the choice between rigid and flexible pavements becomes a major issue.

Rigid pavements generally have a longer service life and are able to withstand heavy loads, but require high initial construction costs and longer construction times (Firmansyah et al., 2022; Suganda & Untari, 2024). In contrast, flexible pavements have advantages in terms of speed of implementation and lower initial costs (Mahardika & Mudiyo, 2021). According to the Ministry of PUPR (2024), the current pavement design uses the latest *Road Pavement Design Manual (MDPJ)*, namely 2024, which allows road planning to be more adaptive to traffic and environmental conditions.

In a study by Assa et al. (2022), it was found that flexible pavement construction costs tend to be lower, but are not as efficient as rigid pavements in the long term. Meanwhile, Prasetya et al. (2022) revealed that flexible pavement investment costs are higher in periodic maintenance. Isradi et al. (2021) emphasized the importance of calculating *ESA* (Equivalent Standard Axle Load) as a basis for planning road structures to adjust to traffic loads. This *ESA* concept was later developed by Jiang et al. (2023), who added dynamic load analysis from the vertical acceleration of vehicle tires.

Research by Heriadi et al. (2024) on the *Bulog–UKRIM* road also showed that the selection of flexible pavement thickness is highly dependent on traffic growth and soil conditions. A similar point was emphasized in the study of Prayitno et al. (2023) regarding the geometry and structure of flexible roads in West Pasaman. Kamil et al. (2023), in their research, highlighted the effectiveness of using rigid pavements on severely damaged roads, with a rigid pavement construction method that takes into account the bearing capacity of the soil using the *DCP* test. Another study by Rochmanto et al. (2022) used *Bina Marga* guidelines to plan efficient rigid pavement structures in Jepara.

In addition to technical aspects, budget factors also influence planning decisions. Research by Putri Zayu et al. (2022) shows that flexible pavements are more efficient than rigid pavements in certain contexts, although the difference is relatively small. Krisdiyanto (2023) compared the *AASHTO* and *MDPJ 2017* methods in determining the thickness of flexible pavements. The results showed significant differences in cost and structural efficiency.

Yusuf Adiman & Pranata (2024) emphasized that the mechanistic–empirical approach in *MDPJ* can provide more accurate design results, especially in dealing with high traffic loads in urban areas. Sandekala & Nur's (2023) study compared flexible pavements with two different methods and concluded that *MDPJ* is more efficient than *AASHTO* in terms of cost, but must consider site-specific conditions. Sukarno (2022) stated that rigid pavements are more efficient in the long term, especially for roads used by heavy vehicles. Meanwhile, Sutapa et al. (2022) showed different results, namely that flexible pavement is more economical in the context of certain projects.

Gyawali (2021) added that the quality of the concrete mix, especially lean mortar, affects the final strength of rigid pavement. This is important in designing the optimal concrete slab thickness. Grigg (1988) stated that road infrastructure must be designed as a sustainable and efficient physical system in meeting economic and social needs. In the local context, Putri et

al. (2016) emphasized the role of *MSMEs* in Pasuruan, which are highly dependent on smooth road infrastructure for product distribution.

The study by Sriharyani & Vetiana (2023) showed that road pavement planning in Central Lampung uses *CBR* and *DCP* as the main indicators in selecting the appropriate pavement type. Tjan (2017) explained the importance of the load equivalence factor in the 2017 *MDP* method as a technical reference in determining road structure needs. Wibisono et al. (2019) reminded that *LHR* (Average Daily Traffic) is one of the key variables in pavement design in order to avoid traffic accidents.

Thus, an integrated approach is needed in designing road infrastructure in Pasuruan City that considers existing conditions, traffic loads, cost efficiency, and implementation time. This study then formulated three main questions: (1) how are the *ESA5* and *JSKN* values at the design age of 20 and 40 years; (2) how to design and determine the thickness of pavement appropriately by utilizing existing structures; and (3) how much is the estimated cost and time required for the implementation of flexible and rigid pavement construction on *Jalan Kyai H. Ahmad Dahlan*, Pasuruan City.

The development of road infrastructure is a critical component in supporting economic growth and regional connectivity, particularly in strategic areas like Pasuruan City. While numerous studies have compared flexible and rigid pavements, a significant gap remains in conducting a holistic comparison that integrates traffic load analysis using the latest national standards—*ESA5* and *JSKN*—with a detailed examination of both cost and time efficiency, all while considering the utilization of existing pavement structures. Many previous evaluations have focused predominantly on initial construction costs or structural performance in isolation, often overlooking the critical trade-off between project duration and long-term fiscal responsibility. This research seeks to fill that void by providing an integrated analysis that is directly contextualized within the specific conditions and urgent infrastructure needs of an urban Indonesian road, thereby offering a more applicable and comprehensive framework for decision-makers.

The urgency of this research is underscored by the vital role of *Kyai H. Ahmad Dahlan Road* as a primary connector for industrial and logistics distribution within Pasuruan City. High traffic intensity, compounded by heavy commercial vehicle loads, continuously degrades the existing pavement, necessitating immediate and effective rehabilitation strategies. Furthermore, public spending on infrastructure demands optimal accountability, making it imperative to select a pavement type that delivers not only durability but also the best value for money and minimal disruption to the community. Delays in addressing these issues can lead to increased vehicle operating costs, traffic congestion, and ultimately hinder local economic productivity, highlighting the pressing need for evidence-based planning.

The novelty of this study lies in its application of the newly released 2024 *Indonesian Road Pavement Design Manual (MDPJ)* for a comparative analysis, incorporating the mechanistic–empirical approach for enhanced accuracy. Furthermore, it introduces a unique dimension by rigorously evaluating the potential for reusing existing pavement layers—a strategy often mentioned but seldom quantified in terms of its impact on both cost savings and reduction in implementation time. By analyzing two distinct design life scenarios (20 and 40 years) and employing localized data, this study moves beyond theoretical comparisons to

deliver practical, data-driven insights that are novel within the context of Indonesian urban road projects.

The primary purpose of this research is to conduct a comparative analysis between rigid and flexible pavement types for the improvement of *Kyai H. Ahmad Dahlan Road*, specifically reviewed from the aspects of total construction cost and project implementation time. This purpose is operationalized through several specific objectives: (1) to calculate the projected traffic loads (*ESAS* and *JSKN*) for 20-year and 40-year design lives, (2) to design the required pavement thickness for both types in accordance with *MDPJ 2024* guidelines while utilizing the existing structure, and (3) to estimate and compare the total budget and time required for each pavement alternative.

The benefits of this study are multifaceted. It provides local government agencies and road authorities with a robust empirical basis for selecting the most technically and economically efficient pavement solution, aligning infrastructure development with fiscal constraints and urban mobility needs. For the engineering community, it contributes to the practical application and validation of the new *MDPJ 2024* manual. The findings are expected to serve as a valuable reference for similar infrastructure projects in other urban areas, promoting sustainable and cost-effective road development practices across Indonesia.

METHOD

Research Location and Approach

This research uses a quantitative approach with a case study method that focuses on a comparative analysis between flexible and rigid pavements. This method allows researchers to conduct objective measurements of the technical and economic parameters used in the design and implementation of road construction. The study was conducted on *Jalan Kyai H. Ahmad Dahlan*, Pasuruan City, East Java, which is one of the provincial roads with dense traffic and high heavy vehicle intensity. This location was chosen because of its strategic role in supporting the distribution of goods, community mobility, and connectivity between regions, particularly to industrial areas and ports. The analysis utilized both primary and secondary data, including average daily traffic (*LHR*), soil tests using the *Dynamic Cone Penetrometer (DCP)* method, and unit prices for construction work obtained from the East Java Provincial Public Works and Highways Agency. The study considered two scenarios of the road's design life, namely 20 years and 40 years, to determine differences in pavement thickness as well as cost and time efficiency. This approach also incorporated the reuse of existing structures to obtain an optimal design in both technical and economic terms. The selection of this location and method is expected to provide a meaningful contribution to sustainable road infrastructure planning in urban areas.

Data Types and Data Sources

The data used in this study consists of primary and secondary data obtained from relevant agencies and direct field observations. Primary data includes surveys of existing road conditions and measurements of commercial vehicle traffic passing through the *Jalan Kyai H. Ahmad Dahlan* section. Secondary data was obtained from official documents such as the results of *DCP* tests to determine the *CBR* value of the subgrade, the *2024 Road Pavement Design Manual (MDPJ)*, East Java Province unit price documents, and reports from *BPS* and

BPBD East Java regarding topography, weather, and disaster risks in the study area. The use of these two types of data allows for a more comprehensive and valid analysis. The data collection process was carried out systematically using a data triangulation approach to ensure accuracy and consistency. Traffic data was converted into *ESA5* and *JSKN* values as the basis for pavement structure planning, while soil data was used to determine the need for sub-foundations. Secondary data sources also supported the validation of technical calculations and cost estimations. By combining various relevant data sources, this study provides a holistic picture of the challenges and solutions for road pavement development in the context of urban areas such as Pasuruan City.

Planning and Analysis Stages

The initial stage of this study involved traffic analysis for two design life scenarios, namely 20 years and 40 years. The *ESA5* and *JSKN* values were calculated based on *LHR* data using formulas specified in the 2024 *MDPJ* guidelines. The results were then used to determine the repetition of traffic loads that must be borne by the pavement structure. Subsequently, both flexible and rigid pavement structures were designed using the same method to ensure objective comparison. The potential use of existing structures was also analyzed to assess the extent of material and cost efficiency.

The next stage involved calculating the estimated construction costs and project duration using official work unit price data and a time schedule based on standard construction activities. A *Rencana Anggaran Biaya (RAB)*, or Cost Budget Plan, was prepared for each pavement type for both the 20-year and 40-year design life scenarios. Comparisons were made not only in terms of costs, but also regarding construction duration and efficiency relative to existing conditions. The final outcome of this stage was a recommendation identifying the most efficient pavement type for *Jalan Kyai H. Ahmad Dahlan* in terms of technical performance, economic viability, and implementation time.

RESULT AND DISCUSSION

Traffic Load Analysis and Design Life

The Kyai H. Ahmad Dahlan Road section is one of the strategic routes that experiences high traffic loads every day. In this study, an analysis of traffic loads in the form of *ESA5* and *JSKN* was conducted for two design life scenarios, namely 20 years and 40 years. Average daily traffic (*LHR*) data was collected through direct surveys and analyzed based on the standards in the 2024 Road Pavement Design Manual (*MDPJ*). The results of data processing show that the *ESA5* and *JSKN* values increase sharply at longer design lives. At a design life of 20 years, the *ESA5* obtained was 35,281,489 with *JSKN* of 29,155,119. Meanwhile, at a design life of 40 years, *ESA5* increased to 115,975,081 and *JSKN* reached 103,618,110. This increase indicates that the need for a stronger and more durable pavement structure is very important. Therefore, the calculation of pavement thickness and structure needs to consider the excess load so that the road continues to function optimally in the long term.

ESA5 and *JSKN* calculations are carried out by considering annual traffic growth factors, lane distribution, and vehicle damage factors. The calculation process uses formulas and technical data contained in the 2024 *MDPJ* and refers to relevant empirical parameters. In addition, the influence of local topography and climate conditions is also taken into account to

obtain more accurate results. Thus, the results of traffic load calculations provide an important basis for optimal road structure design.

The use of the ESA5 approach provides a realistic picture of traffic pressure on the pavement layer. This method allows road designers to anticipate the need for structural strength over a longer service period. In the context of the Kyai H. Ahmad Dahlan Street section, this analysis is very crucial considering the high logistics and distribution activities of goods passing through the route. Therefore, the results of the ESA5 and JSKN analysis are the main references in determining the thickness of the road pavement.

Structural Design and Implementation Efficiency

Based on traffic analysis, pavement structure design is carried out for both flexible pavement and rigid pavement. For a design life of 20 years, flexible pavement is designed with a total thickness of 285 mm, while for a design life of 40 years the thickness increases to 330 mm. Meanwhile, rigid pavement has concrete slabs with a thickness of 340 mm and 350 mm respectively for a design life of 20 and 40 years. This design takes into account the condition of the subgrade, CBR value, and existing structures that can still be utilized. Utilization of existing structures provides significant efficiency in the use of materials and implementation time. Old structures that still meet technical strength requirements do not need to be dismantled, but are simply reinforced with additional layers. This approach is in accordance with the direction in MDPJ 2024 which recommends efficiency in the use of infrastructure resources. Therefore, the redesign is carried out by considering the technical and economic limits of existing conditions.

In terms of budget, the construction costs of flexible pavement for 20 and 40 years are Rp17.17 billion and Rp19.63 billion, respectively. Meanwhile, for rigid pavement, the costs required are Rp14.61 billion for 20 years and Rp15.00 billion for 40 years. Although rigid pavement requires a longer implementation time (30-31 days), the costs incurred are lower compared to flexible pavement which requires 21-22 days. This comparison is important in making technical decisions in the field.

Time efficiency is also an important consideration in the context of urban road construction. With dense traffic, road projects must be completed as quickly as possible so as not to disrupt community activities. Therefore, although rigid pavement is more economical, in some situations flexible pavement is still chosen because of its shorter implementation time. The final decision often depends on the priority between cost efficiency or speed of implementation.

With these results, this study provides a clear picture that there is no single solution in selecting the type of pavement. Decisions must take into account technical conditions, service needs, funding availability, and project urgency. The combination of analytical approaches and the use of field data is a strength in developing technical recommendations. Therefore, this results section shows the importance of integrating ESA5 data, existing structures, and cost analysis in road planning.

The results of this study indicate that the use of rigid and flexible pavements each has advantages depending on the objectives and context of the project. In the case of Jalan Kyai H. Ahmad Dahlan, long-term cost efficiency is more inclined to rigid pavement. This is in line with research by Sukarno (2022) which states that rigid pavement is more economical for long

service life. However, in projects with high time pressure, flexible pavement is more reliable because of the faster construction process. Therefore, the comparison of these two types of pavement is crucial in strategic provincial road planning.

Analysis of ESA5 and JSKN values provides an important foundation in designing pavement thickness. The very high traffic load on this road section indicates the need for a structure that can withstand repeated loads for decades. This study confirms the findings of Jiang et al. (2023) which emphasizes the importance of dynamic load measurements in pavement design. In addition, this analysis approach also provides flexibility in choosing materials and structural designs that are appropriate to field conditions. The accuracy of this calculation directly affects cost efficiency and road durability.

Utilization of existing structures is an important strategy in construction efficiency. By not dismantling the entire old layer, there are significant savings in terms of time and cost. This is reinforced by the findings of Lorinanto (2023) who stated savings of up to 20% if the existing structure can be utilized. However, the use of the old structure must be based on technical tests such as DCP to ensure its bearing capacity. In the case of this study, this strategy succeeded in reducing the need for new layers without sacrificing the strength of the structure.

The design of the thickness of the concrete slab and asphalt layer used in this study has followed the provisions in MDPJ 2024. This thickness has considered the ESA5 load and design age, as well as the CBR condition of the subgrade. Research by Yusuf Adiman & Pranata (2024) supports this approach, stating that the mechanistic-empirical MDPJ provides better design accuracy. Thus, the designed structure is guaranteed to be resistant to heavy traffic loads. The implementation of the latest standards in design provides added value to the quality of the road infrastructure being built.

Cost comparisons show that although flexible pavement is more expensive, it offers advantages in terms of implementation time. The difference in duration between rigid and flexible pavements is an important consideration, especially on strategic routes that must be reopened quickly. In this case, the decision is not only based on economic efficiency but also social factors and traffic flow. This is in line with the study by Prasetya et al. (2022) which states that implementation efficiency affects the overall project value. Therefore, the choice of pavement type must consider multiple aspects holistically. Overall, the results and discussions in this study show the importance of integration between technical data, road service needs, and regional development policies. This study not only provides technical alternatives in pavements but also proves that a data-driven approach can produce relevant and efficient solutions. By using a calculation model based on the 2024 MDPJ and considering existing conditions, this study is an example of how academic studies can support sustainable infrastructure planning. In the future, a model like this can be adapted for similar projects in other regions. Thus, the recommendations from this study are very applicable and can be used as a technical reference for road planning and implementing agencies at the regional level.

CONCLUSIONS

Based on the comprehensive analysis, it is concluded that the selection between rigid and flexible pavement for the improvement of *Jalan Kyai H. Ahmad Dahlan* presents a clear trade-off between long-term cost efficiency and shorter implementation time. The analysis of traffic loads revealed a substantial increase in *ESA5* and *JSKN* values for a 40-year design life,

necessitating a more robust pavement structure. Rigid pavement emerged as the superior choice from a financial perspective, demonstrating significantly lower lifecycle costs (IDR 14.61–15.00 billion) due to its durability and reduced maintenance needs, despite requiring a longer construction period (30–31 days). Conversely, flexible pavement, while more expensive (IDR 17.17–19.63 billion), offers a critical advantage in speed of execution (21–22 days), making it a viable option for projects where minimizing traffic disruption is paramount. The study also confirmed that the strategic utilization of existing pavement structures contributes significantly to material and cost efficiency without compromising the technical integrity of the design.

For future research, it is suggested that investigations incorporate a more detailed *Life Cycle Cost Analysis (LCCA)* that includes long-term maintenance, rehabilitation, and user delay costs over the entire service life of the pavement. Furthermore, subsequent studies should explore the environmental impact of both pavement types by conducting a comparative *Life Cycle Assessment (LCA)* to quantify carbon emissions and energy consumption, thereby adding a crucial sustainability dimension to the decision-making matrix. Finally, applying this integrated comparative framework—which considers cost, time, and environmental factors—to other road sections with varying soil conditions and traffic compositions would help validate and generalize the findings, providing a more comprehensive guide for national infrastructure policy.

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