Comparative Analysis of Rigid and Flexible Pavement Planning in Terms of Cost and Time on the Kedamean–Sidoraharjo–Randegan Road, Gresik Regency

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ABSTRACT

The development of transportation infrastructure plays a pivotal role in supporting regional economic growth, particularly in areas undergoing rapid industrial and residential expansion. This study aims to conduct a comparative analysis between rigid pavement (concrete) and flexible pavement (asphalt) in terms of cost efficiency and implementation time on the Kedamean Sidoraharjo Randegan road section in Gresik Regency, East Java. The region's strategic position, reinforced by the operation of the Krian Legundi Bunder Manyar (KLBM) toll road, has significantly increased traffic flow, thereby creating an urgent need for durable and sustainable road infrastructure. This research employs a quantitative descriptive approach by integrating traffic projections (Average Daily Traffic or LHR) for the 20th and 40th year horizons, CESAL calculations (Cumulative Equivalent Standard Axle Load), and pavement structure design using the MDPJ 2017 method for flexible pavement and Pd T-14-2003 for rigid pavement. Additionally, cost estimations are based on regional unit prices issued by the Gresik Regency Public Works Department. Findings indicate that although flexible pavement offers shorter construction time and lower initial costs, rigid pavement proves more cost-effective in the long run due to its durability and lower maintenance needs. The study also highlights that utilizing existing pavement layers can reduce construction costs by up to 10%, aligning with sustainable infrastructure practices. The results are expected to serve as a practical guideline for civil engineering practitioners and local governments in making strategic decisions regarding pavement type selection based on traffic intensity, budget availability, and long-term development goals.

Introduction

Gresik Regency, as the main buffer area for Surabaya City, has experienced rapid development in various sectors, especially transportation infrastructure (Susanti et al., 2024). This area has a strategic geographical position and rich natural potential that can be optimized to support regional economic growth (BPS Gresik Regency, 2023). One effort to improve connectivity and logistics efficiency is through the development of reliable and efficient road infrastructure.

Significant development in South Gresik began with the operation of the *Krian-Legundi-Bunder-Manyar* (*KLBM*) Toll Road, which opens fast access to ports and major industrial areas (DPUTR Gresik Regency, 2023). With this toll road, the mobility of people and goods has increased drastically, so an adequate supporting road system is needed. The *Kedamean - Sidoraharjo - Randegan* Road is one of the important sections in South Gresik which currently requires repair and improvement of the road structure. The availability of sturdy and durable road infrastructure is very much needed to support the movement of logistics and the development of industrial and residential areas (Ahmad Rois Abid, 2025).

In the context of road planning, the two main types of pavements that are considered are rigid pavements and flexible pavements. The selection of this type of pavement is highly dependent on aspects of cost, implementation time, and technical conditions in the field (Ministry of PUPR, 2017). Rigid pavements, which are made from cement concrete, offer a long service life and the ability to withstand heavy loads optimally (Ministry of PUPR, 2003). This is very suitable for roads with high traffic intensity, such as industrial access and goods distribution (*Sewaalatberat.co.id*, 2020).

However, the initial cost of building rigid pavements tends to be higher, and the repair process takes longer (Ridwan & Romadhon, 2019). On the other hand, flexible pavements have the advantage of flexibility and ease of maintenance, with lower initial costs (*Pengadaan.web.id*, 2020). According to AASHTO (1993), the selection of pavement type must consider *Average Daily Traffic* (*ADR*), the design life of the road, and the characteristics of the subgrade. *MDPJ 2017* also emphasizes the importance of a mechanistic-empirical approach in pavement design (Ministry of PUPR, 2017).

Previous studies have shown varying results. Assa et al. (2022) stated that although the initial cost of flexible pavement is cheaper, its service life is shorter compared to rigid pavement. Meanwhile, Lelepadang et al. (2020) showed that flexible pavement is more economical in the case of low-traffic neighborhood roads. A comparison of cost efficiency between the two types of pavement is also discussed by Mahardika et al. (2021) who found that paving blocks can be a more cost-effective alternative. However, for main distribution roads such as in *Kedamean - Sidoraharjo - Randegan*, concrete or asphalt pavement remains the main priority.

Kamil et al. (2023) in a study on *Jalan Wolter Monginsidi* found that concrete road structures are better able to withstand deformation and cracks compared to asphalt, especially under heavy traffic loads. On the other hand, Krisdiyanto (2023) and Arrasis & Doni (2023) highlighted that flexible pavements are more easily adjusted to subgrade conditions and weather changes, so they are more appropriate for certain conditions. Dewi (2023) also emphasized the importance of a stable subgrade or base soil in determining the efficiency and durability of pavements, both flexible and rigid. Therefore, DCP and CBR testing are important bases in determining road structure design.

Ahmad Irwan Hanafi et al. (2023) stated that utilizing existing structures can be a sustainable solution in road construction, because it can reduce costs and implementation time. Adhita Maharani (2018) showed that efficiency-based road planning not only considers layer thickness, but also logistical accessibility and its impact on community economic activities. Kurniawan & Djunaidi (2020) proved that the selection of pavement types greatly affects the cost-effectiveness of road construction and operation in the long term.

According to Carlos Alexandro Putra Atmaja & Hanie Teki Tjendani (2024), road projects that are not carefully designed can experience delays and cost overruns, therefore comparative studies are very important. Tiara et al. (2022) and Aditiya & Siswoyo (2020) added that planning methods that refer to national standards such as *Pd T-14-2003* and *MDPJ 2017* provide more accurate results in planning the thickness of road layers. Firmansyah et al. (2022) emphasized that the efficiency of road construction is not only determined by the material, but also the project management approach and construction quality control.

Azizi Muhammad Nasution (2019) added that the road class must be adjusted to the traffic volume, so that the pavement structure can work optimally and not waste costs. The Gresik Regency Government through DPUTR (2023) has prepared a strategic plan for road infrastructure development that prioritizes inter-regional connectivity and financing efficiency. In responding to the need for road development in South Gresik, especially on the *Kedamean - Sidoraharjo - Randegan* section, careful planning is needed that considers the comparison of pavement types technically and economically.

The objective of this study is to design an efficient road pavement by considering the *Average Daily Traffic* (*ADT*) values for the 20th and 40th years, determining the pavement thickness design for both concrete and asphalt by utilizing the existing structure, and calculating the estimated costs and construction time for the road section. This approach aims to produce a pavement design that is not only effective in the short term but also has optimal durability in the long term, thereby minimizing maintenance requirements and additional expenses in the future (Rois, 2025; MDPI, 2021; McKinsey & Company, 2020).

The benefits of this research are expected to provide valuable contributions to decision-making in road construction projects, particularly in selecting the most suitable pavement types and construction strategies based on traffic conditions and budget constraints. Furthermore, the findings of this study can serve as a reference for local governments, contractors, and planning consultants in designing road infrastructure projects that are more sustainable, efficient, and cost-effective. Ultimately, road development will enhance accessibility, boost the local economy, and ensure greater comfort and safety for road users (Bappenas, 2023; AASHTO, 2020; World Bank, 2022).

Research Method

Types and Approaches of Research

This study uses a descriptive quantitative approach with a case study method on the *Kedamean - Sidoraharjo - Randegan* road section in Gresik Regency. The main objective of this approach is to compare the efficiency between flexible pavement and rigid pavement in terms of cost and implementation time. With a quantitative approach, the analysis is carried out through technical and economic calculations based on primary and secondary data obtained from the research location. The case study approach was chosen to examine in depth the local context and actual conditions of the existing road structure. This method allows researchers to understand the specific characteristics of road projects and provide relevant, applicable recommendations. In addition, the quantitative approach provides an objective basis for determining the most efficient pavement design. Case studies are also useful in evaluating the impact of utilizing existing structures on cost efficiency and the duration of construction work. The final results of this study are expected to be used as a reference by local governments and civil engineering practitioners in road construction planning.

Location and Time of Research

This research was conducted on the *Kedamean - Sidoraharjo - Randegan* road section located in *Kedamean District*, Gresik Regency. This area was chosen because it is experiencing rapid infrastructure development due to direct connectivity to the *KLBM* Toll Road and logistics distribution centers. The existing road conditions indicate the need to improve the quality of the pavement to support optimal mobility of goods and services. This location also has representative topographic and traffic characteristics for comparative analysis of two types of pavement. The research was carried out from February to May 2025. This time span includes the stages of field data collection, laboratory analysis, and both technical and economic calculations. Implementation was conducted in stages, starting from traffic surveys and soil testing, to the preparation of pavement designs using the *MDPJ 2017* and *Pd T-14-2003* methods. The sufficiently long research period allowed researchers to identify in detail the variables that influence the effectiveness and efficiency of road planning.

Data Collection Technique

The data used in this study consist of primary and secondary data. Primary data were obtained through an *Average Daily Traffic* (*LHR*) survey, *DCP* (*Dynamic Cone Penetrometer*) test, and observations of existing road pavement conditions. Meanwhile, secondary data include location maps, historical traffic data, unit prices of work from the Gresik Regency *DPUTR*, and supporting literature such as design manuals and previous research journals. The combination of these two types of data provides a strong basis for conducting a comparative analysis between rigid and flexible pavements. The traffic survey was conducted to project the *LHR* value for the 20th and 40th years of the design period. The *DCP* test was used to determine the bearing capacity of the subgrade, which is the basis for determining the thickness of the pavement layer. In addition, visual documentation and field notes were used to understand the actual condition of the road structure to be analyzed. With systematic data collection, the accuracy of design and cost estimation can be significantly improved.

Results and Discussion

Average Daily Traffic Projection (*ADR*)

Traffic analysis was conducted by collecting *LHR* data on the *Kedamean - Sidoraharjo - Randegan* road section for the base year. The projection was carried out using the annual growth method, assuming traffic growth of 5% per year. The calculation results show that the *LHR* in the 20th year reached 49,840 vehicles per day, and in the 40th year reached 143,018 vehicles per day. The number of vehicles in the 20th year consisted of 31,532 passenger cars and 49,840 total vehicles, while in the 40th year the number of passenger cars reached 94,273 vehicles from a total of 143,018 vehicles. This value shows a significant increase that requires higher and more durable road pavement quality. The *LHR* growth is used as a basis for determining the thickness of the pavement layer, both rigid and flexible. The high *LHR* value during the planning period highlights the importance of designing a road pavement structure able to withstand heavy traffic loads and high frequency. Therefore, the design of the pavement structure must consider the repeated loads of large vehicles crossing the road every day. This projection also reinforces the importance of efficient and sustainable long-term planning.

To support the validity of the data, a traffic survey was conducted at three strategic points along the road section. The survey results showed that the composition of vehicles was dominated by heavy vehicles and goods vehicles. This data strengthens the *LHR* projection, which shows an increasing trend due to the growth of logistics and distribution activities in southern Gresik. In addition, the existence of the *KLBM* Toll Road also accelerates the increase in traffic intensity on the road section.

By considering the growth data and distribution of vehicle types, the calculation of the total traffic load is converted to *CESAL* (*Cumulative Equivalent Standard Axle Load*) units. The total *CESAL* value for a 20-year design life is 9,597,730, and for a 40-year design life is 27,174,808. This value indicates that the pavement structure must be designed to withstand very high loads throughout its service life. (Table: Recapitulation of *LHR* and *CESAL* Projections for Years 20 and 40.) The conclusion of this analysis is that the *Kedamean - Sidoraharjo - Randegan* road section has experienced a significant increase in terms of vehicle volume and type. Therefore, the choice of pavement type is highly dependent on the ability to withstand long-term traffic loads. Both rigid and flexible pavements must be analyzed based on future traffic loads, not just existing conditions. This forms a strong basis for determining the next technical planning steps.

Structural Design and Cost Estimation

Pavement design was carried out using two approaches, namely the *Road Pavement Design Manual (MDPJ 2017)* for flexible pavement and *Pd T-14-2003* for rigid pavement. The analysis was performed by considering *DCP* data for the bearing capacity of the subgrade, as well as *CESAL* data to determine the design traffic load. The design results show that the total thickness of the flexible pavement layer consists of 4 cm *AC-WC*, 6 cm *AC-BC*, 20 cm *AC-Base*, and 30 cm *LPA*. For rigid pavement, it consists of a 28 cm cement concrete slab, 10 cm lean concrete, and 15 cm class A aggregate. The *Cost Budget Plan (RAB)* shows that the construction cost for flexible pavement is Rp34,223,586,885 for a design life of 20 years and Rp41,555,772,054 for a design life of 40 years. Meanwhile, the construction cost for rigid pavement is Rp31,613,806,800 for a 20-year design life and Rp35,773,553,803 for a 40-year design life. The construction cost of flexible pavement is higher in the long term, although technically the implementation is faster. This shows that the selection of pavement types needs to consider the balance between initial investment and long-term efficiency.

In addition to costs, the implementation time is also analyzed based on the productivity of the equipment and construction work methods. The construction of flexible pavement is estimated to take 20 days for both design lives. Meanwhile, the construction of rigid pavement takes 490 days for a 20-year design life and 581 days for a 40-year design life, due to the concrete curing process and the gradual implementation method. This large time difference is an important consideration for projects with time constraints or high traffic impacts. A shorter implementation duration can provide additional benefits in terms of reducing traffic disruption and accelerating road functions.

The use of existing structures as lower foundation layers is also analyzed as an efficiency effort. By maintaining some of the existing layers, costs can be reduced by 8–10%, depending on the actual road conditions. This approach also supports the principle of sustainable development by reducing construction waste and the use of new materials. This efficiency is a relevant added value in environmentally-based technical planning. The final results of the design analysis show that both types of pavement have their own advantages, depending on the context of their use. Flexible pavements excel in terms of implementation time and repair flexibility, while rigid pavements excel in durability, technical life, and long-term cost efficiency. Therefore, the decision to select the type of pavement must consider the entire project life cycle and actual traffic loads. This analysis provides a strong basis for developing a comprehensive road infrastructure planning strategy.

Based on the results of the *LHR* projection and *CESAL* calculations, it can be concluded that the traffic load on the *Kedamean - Sidoraharjo - Randegan* road section is very high and tends to increase sharply. This requires that the road pavement structure be designed to withstand heavy vehicle loads repeatedly in the long term. In this context, rigid pavement is a superior solution in terms of structural resistance. However, high initial costs remain a major challenge for project implementers, especially with limited regional budgets. Comparison of pavement thickness and implementation costs shows a clear trade-off between time and cost efficiency with strength and service life. Flexible pavement has advantages in construction speed and ease of maintenance, though its long-term durability is lower. On the other hand, rigid pavement requires a longer construction process but provides long-term economic benefits through reduced maintenance costs. Therefore, the selection of pavement types must be based on an analysis of the specific needs of the project.

In this study, the influence of the existing structure is one of the important variables considered in road redesign. The use of existing layers as a sub-base has a significant impact on cost and time efficiency. In addition, this strategy also supports the concept of sustainable development by minimizing the use of new resources. Thus, the combination of technical approaches and sustainability principles is vital in road planning. The results of the analysis also show that the use of the *MDPJ 2017* and *Pd T-14-2003* design methods can produce precise and measurable technical recommendations. Both methods consider long-term traffic loads, soil conditions, and characteristics of the materials used. The accuracy of the design results is highly dependent on the quality of field data such as *DCP* test results and *LHR* surveys. Therefore, it is important for road planners to always update data and adjust methods based on current conditions.

In terms of development policy, the results of this study provide important input for local governments in setting priorities for road infrastructure development. The use of regional funds should be focused on the construction of rigid pavements on roads with heavy and intensive traffic. Meanwhile, flexible pavements can be applied to secondary roads or areas with lower traffic. This approach will result in efficient budget allocation and improve the overall quality of road services. The conclusion of this analysis is that there is no single type of pavement that is superior for all situations. Each type has advantages and disadvantages that must be considered comprehensively. Therefore, the planning approach must be carried out contextually, based on actual data and projections of future needs. The results of this study are expected to serve as a reference in formulating efficient, sustainable, and appropriate road development policies.

Conclusion

Based on the results of traffic analysis, pavement structure design, and cost and implementation time estimates, it can be concluded that the *Kedamean - Sidoraharjo - Randegan* road section will experience a significant increase in traffic over the next 20 to 40 years. *Average Daily Traffic* (*ADR*) projections show high growth, thereby requiring a robust road structure design that can withstand heavy traffic loads on a continuous basis. The design results indicate that rigid pavements are superior in terms of load resistance and long-term cost efficiency, while flexible pavements are more economical in terms of initial costs and implementation time. Therefore, the selection of pavement types needs to be adjusted to traffic conditions, budget availability, and road service life requirements in order to achieve efficiency and sustainability in infrastructure development. Based on these conclusions, it is recommended that the planning for road structures on the *Kedamean - Sidoraharjo - Randegan* section consider the use of rigid pavements on segments with high traffic intensity and continuous heavy loads. For segments with moderate to low traffic, flexible pavements can serve as a more economical and faster alternative for implementation. In addition, the utilization of existing pavement structures should be optimized to reduce costs and support the principles of sustainable development. It is hoped that the results of this study can be used as a reference by the local government and related parties in formulating road development strategies that are effective, efficient, and in accordance with the technical conditions and long-term needs of the Gresik area.

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