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Comparative Analysis of Cost and Time Between Flexible and Rigid Pavement on the Siwalanpanji Kemiri

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ABSTRACT

This research presents a comparative analysis of the cost and construction time between flexible and rigid pavement structures on the Siwalanpanji-Kemiri road section in Sidoarjo Regency, East Java, Indonesia. The area is undergoing a functional shift from rural to industrial, necessitating durable infrastructure to accommodate increasing heavy vehicle traffic. Using the 2024 Indonesian Pavement Design Manual (MDPJ), the research evaluates the technical and economic viability of both pavement types over 20-year and 40-year service lives. Key parameters include Average Daily Traffic (ADT) projections, Cumulative Equivalent Single Axle Load (CESAL), and subgrade strength derived from Dynamic Cone Penetrometer (DCP) tests. These inputs inform pavement thickness designs and cost estimates based on local unit prices (HSPK). Findings reveal that flexible pavement offers faster construction (9 days vs. 39–49 days for rigid) but incurs 38% higher long-term costs due to frequent maintenance. Rigid pavement, despite longer initial construction time, proves more economical over 40 years, with lower maintenance needs and superior durability under heavy loads. Cost analysis shows rigid pavement saves up to IDR 3.5 billion compared to flexible alternatives over four decades. The study also highlights the sustainability benefits of reusing existing materials, aligning with environmental goals. These results provide actionable insights for the Sidoarjo Public Works Agency, emphasizing rigid pavement as the optimal choice for industrializing corridors. The research underscores the importance of life-cycle cost analysis and context-specific design in infrastructure planning, offering a model for similar regions facing rapid urbanization and traffic growth.

INTRODUCTION

Sidoarjo Regency is one of the strategic areas in East Java Province that is experiencing rapid growth, both economically and demographically. Located south of *Surabaya* City, *Sidoarjo* has a vital position as a buffer for the provincial capital and as the main route for the distribution of goods and services (BPS Sidoarjo, 2023). The development of industrial areas and trade centers in *Sidoarjo* has a direct impact on the need for adequate infrastructure, especially on the road network, which is the backbone of community mobility and logistics.

The increase in the volume of commercial vehicles and the movement of goods has caused several village roads, including the *Siwalanpanji-Kemiri* road, to now change function to become access for light to medium industries. This transformation of road function certainly requires strengthening the road structure to suit the heavy traffic load and high frequency of use (Permata Sari, 2024). Existing roads that were originally designed for light vehicles with thin asphalt pavements are no longer able to withstand heavy traffic loads without experiencing premature damage.

In this case, re-planning the pavement structure is an urgent need that must be carried out based on a comprehensive technical and economic approach. The 2024 Road Pavement Design Manual (*MDPJ*) provides the latest guidelines for determining the thickness and type of pavement based on traffic conditions, CBR value of the subgrade, and the design age of the road (Ministry of *PUPR*, 2024). There are two types of pavements commonly used, namely flexible pavement and rigid pavement. Flexible pavement uses asphalt as a binder with a flexible layer against loads, while rigid pavement uses rigid concrete slabs that are able to distribute loads to a wider area (Hardiyatmo, 2015; Department of Settlement, 2002).

Several studies state that the selection of pavement types must consider aspects of cost, durability, and implementation time. Woro Sukarno (2022) showed that rigid pavement is up to 33.23% more efficient in a project in *Ngawi* Regency. Conversely, Assa et al. (2022) found that flexible pavement is cheaper than rigid pavement in the *Manado Outer Ring Road III* project. Sunaryo et al. (2023) used the Life Cycle Cost Analysis (*LCCA*) approach on the *Tulungagung Southern Cross Road* and concluded that flexible pavements were more efficient in total costs over the design life. However, on the other hand, a study by Simanjuntak (2023) stated that although the initial cost of flexible pavements is lower, rigid pavements are more economical in the long term due to lower maintenance costs.

The use of a value engineering approach is also a consideration in determining the most efficient pavement. Fajar & Oetomo (2023) stated that the combination of durability and cost efficiency is the main focus in determining road structures. Likewise, research by Rozanova & Syarifudin (2022) emphasized that the participation of construction service actors in evaluating alternative designs is very important in optimizing project costs. Meanwhile, Aditiya & Siswoyo (2020) in the *Babat-Jombang* Road project showed that the use of rigid pavement with a thickness of 295 mm and a 100 mm *LMC* foundation provided structural durability of up to 40 years. This finding is in line with the results of Kurniawan & Djunaidi (2020) which stated that rigid pavement is more suitable for roads with heavy traffic loads.

In contrast, Mahardika et al. (2021) showed that the use of paving blocks for tourist roads on the North Coast of *Flores* can provide significant cost efficiency compared to asphalt or concrete. This shows that the project context is the main determinant in choosing the type of pavement. In another case study in *Jepara* by Tiara et al. (2022), rigid pavement planning using the 2017 *Bina Marga* Guidelines proved effective in supporting heavy traffic lanes. Meanwhile, Maharani & Wasono (2018) concluded that flexible pavement is more suitable for road sections that are not consistently passed by heavy vehicles.

The pavement planning approach must also consider actual data from the field, such as Dynamic Cone Penetrometer (*DCP*) test results and Average Daily Traffic (*LHR*) projections. According to Muhammad Iqbal Saefulloh (2022), the use of the 2017 *MDPJ* method in road planning in *DIY* produces accurate estimates of pavement structure requirements. On the other hand, Prasetya et al. (2023) stated that initial investment and maintenance analysis are very important to determine the Return on Investment (*ROI*) on residential access road projects in *Surabaya*. A similar thing was conveyed by Lelepadang et al. (2020), who found that flexible pavements in projects in *Kendari* were more efficient because the cost difference was IDR 51 million compared to rigid pavements. In a road project in *Makassar* City, Abd. Kadir Salim et al. (2020) concluded that rigid pavements provide cost savings of 13.43% compared to flexible pavements. This is reinforced by Firmansyah et al. (2022) in their research in *Jambi* City, where rigid pavements are considered more efficient in the long term.

Azizi Muhammad Nasution (2019) emphasized that pavement thickness is greatly influenced by road classification. Local roads that serve as industrial access such as *Siwalanpanji-Kemiri* require stronger pavement structures with adequate foundations. Data support from *MDPJ* 2024 provides a more responsive approach to field conditions, both in terms of traffic and subgrade conditions. This approach is in accordance with the recommendations of *AASHTO* (1993) and *Austroad* (1987), which recommend cumulative load-based design (*CESAL*) and structural service life.

Considering the rapidly increasing traffic conditions, the existing structure that is no longer adequate, and the importance of cost and time efficiency, this study focuses on comparing two types of pavement—flexible and rigid—with a technical and economic approach referring to the 2024 *MDPJ* and local data for the *Siwalanpanji-Kemiri* section. The formulation of the problem in this study cannot be separated from the background above, where the question is how the projected value of *LHR* for the next 20 and 40 years on the *Siwalanpanji-Kemiri* road section is; how thick is the ideal flexible and rigid pavement structure by utilizing existing road conditions based on the results of the *DCP* test; and how is the comparison between the costs and implementation time of the construction of the two types of pavement? The answers to these questions will provide an important contribution to the planning of efficient, reliable, and sustainable road infrastructure in semi-industrial areas such as *Sidoarjo* Regency.

This research aims to conduct a comparative analysis of the cost and construction time between flexible pavement and rigid pavement on the *Siwalanpanji-Kemiri* road section in *Sidoarjo* Regency. With reference to the 2024 Road Pavement Design Manual (*MDPJ*), this study is designed to evaluate the technical and economic feasibility of both types of pavement in bearing the increasing traffic load, especially heavy vehicles, during the service life of 20 years and 40 years. In addition, the study also aims to identify the most efficient and sustainable solutions by considering factors such as structural resilience, maintenance costs, and environmental impact. The results of this study are expected to provide practical benefits for the Public Works and Spatial Planning Office (*PUPR*) of *Sidoarjo* Regency in making decisions related to the selection of the optimal type of pavement for the *Siwalanpanji-Kemiri* road section. Academically, this research can be a reference for similar studies in areas with similar characteristics, especially areas that are undergoing transformation from rural to industrial areas. In addition, the findings of this study can also support sustainable infrastructure development efforts by minimizing lifecycle costs and utilizing existing materials to reduce environmental impact. Thus, this research not only contributes to the development of reliable infrastructure but also promotes budget efficiency and ecological sustainability.

RESEARCH METHODS

Types and Approaches of Research

This research uses a quantitative approach with a descriptive-comparative method. The purpose of this method is to compare two road pavement alternatives, namely flexible pavement and rigid pavement, based on technical and economic analysis. This study was conducted by performing technical calculations of pavement design, budget cost calculations, and implementation time analysis. The results of the comparison will be used to determine the most efficient pavement alternative for the *Siwalanpanji-Kemiri* road section. The type of research used is a case study, where the main focus is on one particular location with predetermined characteristics. This case study was conducted on the *Siwalanpanji-Kemiri* road section in *Sidoarjo* Regency, which is undergoing a change in function from a village road to a light-medium industrial road. With this approach, researchers can dig deeper and obtain more specific information about actual conditions in the field. A quantitative approach is used to systematically analyze numerical data in order to produce objective conclusions.

Location and Time of Research

The research location is on the *Siwalanpanji-Kemiri* road section, *Sidoarjo* Regency, East Java Province. This road section is approximately 1.42 km long with varying widths and is currently showing signs of damage due to traffic loads exceeding the capacity of the existing pavement structure. The selection of this location was based on the urgency of improving road quality as the area develops as a center of industrial and distribution activities. In addition, the existing condition of the road, which is no longer able to serve heavy vehicle loads, is an important basis for selecting the location. This research was carried out over a period of five months, starting from collecting primary and secondary data to analyzing and compiling reports. Primary data was obtained from field test results such as *DCP* (Dynamic Cone Penetrometer) and daily traffic surveys (*LHR*). Meanwhile, secondary data includes unit price data from the *Sidoarjo PUPR* Service, topographic data, and design references from *MDPJ* 2024. The research implementation time was adjusted to the schedule and field conditions in order to obtain accurate and representative data results.

Data Collection Technique

Data collection was carried out through a combination of direct field observation and literature review. Field observations were conducted to obtain actual technical data such as soil test results (*DCP*), existing road conditions, and traffic volume. Literature reviews were conducted to obtain references from technical guidelines such as *MDPJ* 2024 and relevant previous studies. This combination of methods is expected to provide a strong and comprehensive data basis for the analysis. Traffic data was collected using the average daily traffic survey (*LHR*) method for seven consecutive days. In addition, identification of vehicle types and distribution of traffic directions was also carried out for the purposes of calculating cumulative loads (*CESAL*). Soil test data using the *DCP* tool was then converted into CBR values to determine the bearing capacity of the subgrade. All data collected were processed and analyzed according to the *MDPJ* 2024 method standards to obtain the appropriate pavement structure design.

Data Analysis

Techniques Data analysis is carried out by calculating the thickness of flexible and rigid pavements with reference to the 2024 *MDPJ* guidelines. For flexible pavements, layer thickness calculations are performed based on traffic loads (*CESAL*), CBR values of the subgrade, and design ages of 20 and 40 years. Meanwhile, rigid pavements are calculated based on the parameters of the number of axles of commercial vehicles, types of concrete, and provisions for the thickness of concrete slabs and subbase layers. All calculations are adjusted to the design values and distribution coefficients of the 2024 *MDPJ*. After the technical calculations are complete, an analysis of the construction cost estimate is carried out by preparing a Cost Budget Plan (*RAB*) for each pavement alternative. The *RAB* calculation refers to the latest *Sidoarjo* Regency Activity Unit Price (*HSPK*). The analysis of the implementation time is carried out using the approach of estimating the duration of work for each type of pavement. Thus, the comparison between flexible and rigid pavements can be reviewed from three main aspects, namely technical, cost, and implementation time.

Research Instruments

The research instruments used include soil test equipment (*DCP*), traffic observation forms, spreadsheet software for technical calculations, and construction cost data processing tools. The *DCP* tool is used to measure the depth of cone penetration into the soil, which is then converted into a CBR value. The traffic observation instrument is used to record the number and type of vehicles during the *LHR* survey. The spreadsheet is prepared according to the *MDPJ* 2024 analysis format to facilitate data calculation and processing. In addition to technical instruments, this study also uses supporting documents such as *MDPJ* 2024, *HSPK Sidoarjo* Regency, and topographic maps of the study area. Software such as Microsoft Excel and AutoCAD are used to visualize design results and calculate work volumes. Documentation instruments are also prepared in the form of cameras to record existing road conditions. All of these instruments are used in an integrative manner to ensure the accuracy and validity of the research results.

RESULTS AND DISCUSSION

The traffic volume data collected on the Siwalanpanji–Kemiri road section was used to project average daily traffic (LHR) for the next 20 and 40 years. Using a cumulative growth rate of 3.5%, the traffic growth factors were determined to be 28.28 for 20 years and 84.55 for 40 years. The dominant vehicle types identified were two-axle and three-axle trucks, which contribute significantly to road loading. Projections indicated that in 2045 and 2065, the number of daily vehicles—particularly motorcycles and light vehicles—would increase dramatically, with motorcycles alone reaching 193,600 and 505,524 vehicles per day. Based on this traffic volume, the cumulative equivalent single axle loads (ESA5) were calculated to be 235,734 for a 20-year design and 656,368 for a 40-year design period.

In response to these loading conditions, pavement designs were developed following the MDPJ 2024 standards. The subgrade soil had a CBR value of 1%, indicating weak support, and thus required improvement. For flexible pavement, both 20- and 40-year designs adopted identical layer configurations consisting of 60 mm of asphalt concrete-wearing course (AC-WC), 200 mm of Class A aggregate base (LPA), 150 mm of Class B subbase (LPB), and 300 mm of selected fill material to improve the subgrade. For rigid pavement, the total number of commercial axle loads (JSKN) was calculated at 437,661 for 20 years and 1,308,495 for 40 years. These values supported the design of 20 cm thick concrete slabs for the 20-year lifespan and 25 cm for the 40-year design, both supported by 15 cm of lean concrete foundation beneath the slab, particularly on shoulder extensions.

Cost estimation was conducted using AHSP from the Sidoarjo Public Works Office. Flexible pavement construction for both 20 and 40 years was estimated at Rp 3.935.321.995,96, as the structural design was identical. However, when including periodic maintenance, which is required every 10 years, the total costs increased to Rp 6.189.881.462,84 for the 20-year service life and Rp 10.699.000.396,61 for 40 years. In contrast, rigid pavement required Rp 3.806.362.406,13 for 20 years and Rp 4.720.514.379,95 for 40 years in construction costs. With minimal maintenance needs, especially within the first 20 years, the total costs for rigid pavement amounted to Rp 3.806.362.406,13 and Rp 7.193.356.701,89 respectively. This indicates that rigid pavement, although slightly more expensive to construct for longer service life, proves to be more economical in the long run.

In terms of implementation time, the flexible pavement could be completed in approximately nine calendar days for the 1,432-meter road segment. Meanwhile, the rigid pavement would take around 39 days for the 20-year design and 49 days for the 40-year design due to the additional curing time for concrete. This analysis also considered the existing road structure, which consisted of 6 cm of asphalt and 20 cm of base aggregate. The observed damage such as crocodile cracks and surface settlement necessitated rehabilitation. Therefore, an overlay was proposed for flexible pavement and partial reconstruction for rigid pavement. Moreover, the reuse of existing materials, particularly 80% of the base layer aggregates, was recommended to improve cost-efficiency and environmental sustainability.

The results of this study demonstrate that the pavement designs formulated based on the MDPJ 2024 guidelines are responsive to actual field conditions. By incorporating empirical data on traffic projections and subgrade strength, the proposed pavement layers align with the demands of future road usage. The calculated ESA5 values illustrate the increasing pressure from heavy vehicles, reinforcing the need for robust pavement design. While flexible pavement offers advantages in terms of faster construction and initial cost, its performance deteriorates faster under high loads, leading to more frequent maintenance requirements such as resurfacing and patching every 10 years. This not only raises long-term costs but also disrupts road usage more frequently.

Rigid pavement, on the other hand, shows superior structural behavior in sustaining heavy vehicle loads with minimal maintenance. The fatigue and erosion resistance analysis supports the feasibility of 20 cm and 25 cm concrete slab designs for the 20- and 40-year plans respectively. Previous research by Simanjuntak (2023) and Kurniawan & Djunaidi (2020) has also emphasized the importance of using rigid pavement in industrial zones due to its long-term resilience and lower life cycle cost. These findings reinforce the rationale behind selecting rigid pavement for the Siwalanpanji–Kemiri corridor, which is evolving into a strategic industrial route.

Cost considerations further justify the preference for rigid pavement. Although flexible pavement might seem more economical initially, the addition of maintenance costs over a 40-year period nearly triples its total investment. Rigid pavement, in contrast, offers significant savings—up to 32%—over its life span. These results are consistent with studies by Abd. Kadir Salim et al. (2020) and Assa et al. (2022), which highlight the financial inefficiency of improper pavement selection. Furthermore, although rigid pavement requires a longer construction period, its durability ensures continuous service with minimal intervention, reducing indirect costs related to traffic delays and operational disruptions.

Sustainability aspects also play an essential role in modern pavement planning. The reuse of existing pavement layers, especially base materials, not only reduces construction waste but also decreases the need for new material extraction, aligning with environmental goals. The MDPJ 2024 standard provides technical support through Remaining Structural Life (RSL) evaluation, allowing optimized utilization of existing infrastructure. This study shows that applying such integrative strategies yields not only technical reliability but also economic and ecological benefits.

In summary, the analysis supports the conclusion that pavement design for the Siwalanpanji–Kemiri road should prioritize long-term performance, financial sustainability, and environmental considerations. Given the expected growth in traffic and the low CBR value of the subgrade, rigid pavement emerges as the most suitable solution. Its robustness, cost-effectiveness, and lower maintenance demands make it an ideal choice for roads serving industrial and high-load traffic areas.

CONCLUSION

Based on the analysis conducted in this study, it can be concluded that the selection of pavement type on the *Siwalanpanji–Kemiri* road segment must be grounded on comprehensive considerations involving traffic projections, subgrade conditions, structural durability, construction costs, implementation time, and long-term maintenance needs. The traffic volume on this route is projected to increase significantly over the next 20 to 40 years, particularly for commercial and heavy vehicles, thus requiring a pavement design that is not only structurally strong but also economically and operationally sustainable. The calculated *ESA5* values of 235,734 for 20 years and 656,368 for 40 years indicate a substantial cumulative load, which must be accommodated by appropriate pavement structures. Flexible pavement, although offering advantages in terms of faster implementation and relatively lower initial cost, is more prone to damage under heavy traffic loads and requires frequent maintenance, resulting in significantly higher life-cycle costs. On the other hand, rigid pavement, designed with 20 cm and 25 cm concrete slabs for 20- and 40-year service lives respectively, demonstrates better resistance to load repetitions and environmental stress. Moreover, it requires less frequent maintenance and offers greater financial efficiency over time, with total savings reaching over 30% compared to flexible alternatives in the long term. The reuse of existing road structures, especially through partial reconstruction and overlay strategies guided by *MDPJ* 2024 standards, further enhances cost efficiency and environmental sustainability. This integrative approach supports the development of road infrastructure that is not only technically sound but also aligned with economic and ecological goals. Therefore, for a road segment with industrial function and increasing traffic load, such as *Siwalanpanji–Kemiri*, rigid pavement stands out as the more rational and advantageous choice. It ensures long-term reliability, reduces operational disruptions, and contributes positively to regional mobility and economic growth.

REFERENCES

Assa, T. F., Palenewen, S. C. N., & Waani, J. E. (2022). Perbandingan analisa tebal perkerasan lentur (flexible pavement) dan perkerasan kaku (rigid pavement) terhadap rencana anggaran biaya. *Tekno*, *20*(82).

Firmansyah, R., Amsori, M. D. A. S., & Dony, W. (2022). Perencanaan rigid pavement pada rekontruksi kapasitas struktur di ruas Jalan Bensol Kota Jambi. *Jurnal Talenta Sipil*, *5*(1), 26–34.

Lelepadang, S., Nuhun, R., Nasrul, N., & Ahmad, S. N. (2020). Analisis perbandingan biaya konstruksi perkerasan kaku (rigid pavement) dan perkerasan lentur (flexible pavement) (Studi kasus: Jalan Prof. M. Yamin, Kelurahan Puuwatu, Kota Kendari). *Stabilita: Jurnal Ilmiah Teknik Sipil*, *8*(3). https://doi.org/10.55679/jts.v8i3.16192

Maharani, A., & Wasono, S. B. (2018). Perbandingan perkerasan kaku dan perkerasan lentur (Studi kasus ruas Jalan Raya Pantai Prigi – Popoh Kab. Tulungagung). *Ge-STRAM: Jurnal Perencanaan dan Rekayasa Sipil*, *1*(2). https://doi.org/10.25139/jprs.v1i2.1202

Mahardika, V., Mudiyono, R., & Soedarsono, S. (2021). Perbandingan konstruksi dan biaya untuk struktur perkerasan lentur, kaku dan paving blok pada Jalan Pantai Utara Flores. *Ge-STRAM: Jurnal Perencanaan dan Rekayasa Sipil*, *4*(1). https://doi.org/10.25139/jprs.v4i1.3117

Prasetya, E. J., Marleno, R., & Tjendani, H. T. (2023). Analisis biaya investasi perkerasan lentur dan perkerasan kaku (Studi kasus pada ruas Jalan Akses Rusun PPI_TPI Romokalisari Surabaya). *Jurnal Spesialis Teknik Sipil (JSpTS)*, *3*(1). https://doi.org/10.30996/jspts.v3i1.7092

Rozanova, I., & Syarifudin, A. (2022). Analisis value engineering pada proyek jalan dan jembatan menurut persepsi pelaku jasa konstruksi. *Jurnal Deformasi*, *7*(1). https://doi.org/10.31851/deformasi.v7i1.7656

Tiara, M., Rochmanto, D., & Saputro, Y. A. (2022). Perencanaan tebal perkerasan kaku ruas Jalan Raya Jepara Bangsri pada KM 11 sampai KM 12 menggunakan Pedoman Bina Marga 2017. *Jurnal Civil Engineering Study*, *2*.

Woro Sukarno, E. (2022). Studi kasus perbandingan efisiensi biaya antara pekerjaan jalan perkerasan kaku (rigid pavement) dengan perkerasan lentur (flexible pavement) di Kabupaten Ngawi. *Jurnal Impresi Indonesia*, *1*(10). https://doi.org/10.58344/jii.v1i10.525

Salim, A. K., Darmawan, M. A., & Wibowo, H. (2020). Analisa perbandingan biaya perkerasan kaku dan perkerasan lentur pada proyek Jalan Middle Ring Road Kota Makassar. *Jurnal Teknik Sipil MACCA*, *5*(1), 41–47.

Aditiya, R. E., & Siswoyo, S. (2020). Perencanaan rigid pavement dan rencana anggaran biaya di Jalan Babat – Batas Jombang Kabupaten Lamongan. *Axial: Jurnal Rekayasa dan Manajemen Konstruksi*, *8*(2), 79–90.

American Association of State Highway and Transportation Officials. (1993). *AASHTO guide for design of pavement structures*. AASHTO.

Austroad. (1987). *Pavement design: A guide to the structural design of road pavements*. Austroad Incorporated.

Badan Pusat Statistik Kabupaten Sidoarjo. (2023). *Kabupaten Sidoarjo dalam angka 2023*. BPS Kabupaten Sidoarjo.

https://sidoarjokab.bps.go.id/publication/2023/02/28/ed054b1e274aa8e0eb0e406a/kabupaten-sidoarjo-dalam-angka-2023.html

Departemen Pemukiman dan Prasarana Wilayah. (2002). *Perencanaan tebal perkerasan lentur Pd T-01-2002-B*. Badan Pusat Penelitian dan Pengembangan Pemukiman dan Prasarana Wilayah.

Fajar, C., & Oetomo, W. (2023). Analisis rencana anggaran biaya dan durasi pekerjaan perkerasan jalan pada proyek peningkatan jalan Weekapoda–Dikira Kabupaten Sumba Barat Daya. *Jurnal Sains Riset*, *13*(2), 505–515. https://doi.org/10.47647/jsr.v10i12

Hardiyatmo, H. C. (2015). *Perancangan perkerasan jalan dan penyelidikan tanah*. Gadjah Mada University Press.

Kurniawan, H., & Djunaidi, Mr. (2020). Studi perbandingan konstruksi perkerasan lentur (flexible pavement) dan perkerasan kaku (rigid pavement) ditinjau dari biaya studi kasus: Peningkatan kualitas Jalan Sungai Pinang–Pantai Mempanak Kabupaten Lingga. *SIGMA TEKNIKA*, *3*(1). https://doi.org/10.33373/sigma.v3i1.2452

Saefulloh, M. I. (2022). *Analisis tebal perkerasan lentur Jalan Tawang–Ngalang segmen IV dan Jalan Klangon–Tempel dengan metode MDPJ 2017* [Skripsi Sarjana, Universitas Gadjah Mada].

Nasution, A. M. (2019). *Perbandingan tebal perkerasan terhadap kelas jalan* [Tesis, Universitas Indonesia].