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Analysis of Construction Requirements For Concrete and Asphalt Pavements on The Temuireng-Jetis Road Section, Mojokerto District

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ABSTRACT
This study analyzes the construction requirements for rigid (concrete) and flexible (asphalt) pavements on the Temuireng-Jetis road section in Mojokerto District, focusing on the cost-effectiveness and efficiency of both options. The research compares pavement thickness design, cost, and implementation time using the 2017 Pavement Design Manual (MDPJ) and Pd T-14-2003 standards. Data was collected through field surveys and reports from the Mojokerto District Public Works Office. The findings indicate that rigid pavement, with a 25 cm thickness, offers greater long-term economic advantages compared to flexible pavement due to its superior durability, reduced maintenance needs, and better performance under heavy traffic. Although rigid pavement has higher initial construction costs, it proves more cost-effective over time. Flexible pavement, while cheaper initially, incurs higher maintenance costs and is more prone to damage in high-traffic areas. The study recommends using rigid pavement for roads expected to support heavy vehicles and require extended service life. In conclusion, this research provides valuable insights into selecting the appropriate pavement type based on cost, durability, and long-term benefits, offering practical guidance for policymakers and engineers in Mojokerto and other regions facing similar infrastructure challenges.

Introduction

Good road infrastructure plays an important role in driving economic and social mobility around the world. Well-maintained and strategic roads reduce transportation costs, speed up the distribution of goods and improve accessibility for people. Reliable road infrastructure in developing countries can reduce poverty by opening up access to education, health and employment, improving people's well-being. In addition, sustainable road development also considers environmental impacts, such as erosion and ecosystem damage. The Asian Development Bank (ADB, 2021) emphasizes that road infrastructure development should be supported by careful planning and selection of environmentally friendly materials to minimize negative impacts. Roads built with the environment in mind not only improve soil stability, but also protect surrounding forest areas and water resources (Bokko, 2017).

Research conducted by UN-Habitat (2020) suggests that well-connected roads contribute to long-term economic stability. They create connectivity between cities and villages, support trade, and increase the region's competitiveness at the global level, especially in the agriculture and manufacturing sectors. Efficiently connected road infrastructure has far-reaching impacts on a country's economic development and social connectivity. According to OECD research (2020), investments in road infrastructure provide direct benefits to the transportation and logistics sectors, and reduce access inequalities between urban and rural areas. This development enables more efficient distribution of agricultural and industrial products, which supports regional competitiveness (Lendra et al., 2022).

Rigid pavement is a type of pavement that uses concrete as its main material, providing high structural durability and suitable for withstanding heavy traffic loads. Compared to flexible pavements, rigid pavements have a higher modulus of elasticity, allowing for more even load distribution to the subgrade. This makes it ideal for roads with heavy vehicle intensity, such as highways, intersections, and industrial areas (Bowles & Guo, 1996).

The main advantages of rigid pavement are high durability and a longer service life. Concrete's resistance to permanent deformation makes it an ideal choice in areas with heavy traffic and high vehicle loads. In addition, rigid pavements tend to require less frequent maintenance, although their initial construction costs are higher than those of flexible pavements (Das et al., 2016). However, rigid pavements have a disadvantage in terms of flexibility. Due to the rigid nature of concrete, these structures are more susceptible to cracking due to temperature changes, ground movement, or moisture changes. Cracks that appear often require joint repairs or localized repairs to prevent them from developing into larger damage. Therefore, joint maintenance in rigid pavements is an important factor to maintain road reliability (Garg, 2017).

Flexural pavement is a type of pavement that uses a layer of asphalt to spread the traffic load onto the base layer. Flexural pavements are flexible, which allows them to conform to minor movements and changes in the subgrade without causing permanent cracking. This makes it ideal for use in areas with less stable soils or with subgrade conditions that tend to change (Brown et al., 2015).

The main advantage of flexible pavement is its ability to adapt to soil deformation, especially on sites with non-uniform soil conditions. As such, flexible pavements provide good flexibility and driving comfort due to the smoother asphalt layer. In addition, flexible pavements tend to be cheaper in initial construction compared to rigid pavements (Mamlouk & Zaniewski, 2011). However, the disadvantage of flexible pavements is their shorter durability compared to rigid pavements, especially in the face of heavy traffic. They require more frequent maintenance, such as overlaying or repairing the surface layer to maintain road performance. On road sections with heavy traffic, especially heavy vehicles, flexible pavements are more prone to deformations such as grooves and cracks (Das et al., 2016).

The comparison between rigid (concrete) and flexible (asphalt) pavements aims to determine the best solution regarding service life and maintenance requirements. In this context, rigid pavements have the advantage of longer technical life and resistance to heavy loads, while flexible pavements are more economical in initial cost and flexible to soil changes (Prasetya & Marleno, 2020). The unique conditions of Mojokerto district, such as topographic variations and high traffic loads, make this study important as a reference for efficient road planning. The results of this study are expected to provide practical recommendations for the government and related parties to select appropriate pavement types, thus creating road infrastructure that supports sustainable development in Mojokerto at an optimal cost and time. The research questions in this study include. "What are the pavement specifications required for the construction of concrete pavement and asphalt pavement on the Temuireng - Jetis road section of Mojokerto Regency?"

Literature Review

Rigid Pavement

Cement concrete pavement or rigid pavement, consists of a cement concrete slab, with or without a sub-base layer, on top of a subgrade. In rigid pavement construction, the cement concrete slab is often also considered as the foundation layer, if there is an asphalt layer above it (Pd T-14-2003). The concrete slab, which is rigid and has a high modulus of elasticity, will distribute the traffic load to the subgrade covering a considerable area. Thus, the largest part of the capacity of the pavement structure is obtained from the concrete slab itself. This is different from flexible pavement where the pavement strength is obtained from the thickness of the sub-base layer, foundation layer and surface layer; where each layer contributes (Pd T-14-2003) (Witjaksana et al., 2019).

In the planning of cement concrete pavements, the strength of the concrete should be expressed in terms of the 28-day flexural strength, which is obtained from the results of beam testing with three-point loading (ASTM C-78) and is typically around 3-5 MPa (30-50 kg/cm2). The flexural tensile strength of concrete reinforced with fiber reinforcing materials such as steel fiber, aramidite or carbon fiber, should reach a flexural tensile strength of 5-5.5 MPa (50-55 kg/cm2). The plan strength shall be expressed as the characteristic flexural tensile strength rounded to the nearest 0.25 MPa (2.5 kg/cm2) (Massara et al., 2021).

Concrete can be reinforced with steel-fibre to increase its flexural tensile strength and control cracking in slabs especially for unusual shapes. Steel fibers can be used in concrete mixes, for toll plazas, roundabouts and bus stops. The length of steel fibers is between 15 mm and 50 mm with the ends widened as armature and/or reinforcing screws to improve bonding (Rahardjo et al., 2019). Typically fibers between 15 and 50 mm in length can be added to the concrete mix, at 75 and 45 kg/m^3, respectively. The cement to be used for concrete work should be selected and suitable for the environment in which the pavement is to be carried out (Pd T-14-2003).

Rigid pavement has a much higher stiffness (modulus of elasticity) than asphalt pavement (about 10 times). Any construction that receives a load from above, will channel or spread the load downward. In the case of pavement construction, one of its functions is to distribute and spread the traffic load received to the layer below to the subgrade (Walker, 2015). The load that is distributed to the layer below, produces a smaller pressure, due to the wider area that accommodates the load, so that it can be carried by the subgrade.

With the greater stiffness or modulus of elasticity of cement concrete, rigid pavement construction has a higher load spreading ability than flexible pavements. As a result, deflections are smaller and the stress acting on the subgrade is also low, therefore rigid pavements do not require strong foundation bearing capacity (Lock, 2020). The uniformity of the bearing capacity of the subgrade is very important, where there should be no noticeable change in the bearing capacity. This is contrary to the principle of flexible pavement planning where the base and subbase layers require high strength to distribute the stress from the wheel loads acting on the asphalt layer (Sahrianto et al., 2016).

Concrete pavement structural layers have different handling types. Each structural treatment consists of a concrete pavement layer on top, followed by a thin concrete foundation layer (LMC) and a class A aggregate drainage layer (Kerzner & Saladis, 2017). The first treatment is a subgrade that can be improved or a support layer added if required. In the second treatment, the subgrade is improved with compacted fill to the design CBR. While in the third treatment, subgrade improvement is done with a thickness of 850 mm and a CBR of more than 4%, if required. All these types of treatments represent adjustments to the subgrade to improve the bearing capacity of the road construction, depending on the conditions and technical requirements.

Flexural Pavement

The part of the highway that is paved with aggregate and asphalt or cement as a binder to create a certain structural layer with a certain stiffness, strength, thickness and stability, allowing traffic loads to be safely distributed to the roadbed. the road surface must be strong enough to withstand traffic loads (Lebang & Lewaherilla, 2021).

The design method for flexible pavements can be done with layered pavements. This technique relates the instructions in the form of wheel loads, pavement structure, and material mechanical properties, with the result being the pavement response to wheel loads such as stresses, strains, or deflections. This structural response is used to estimate the capacity of the pavement structure to resist permanent deformation and fatigue cracking.

Since the predictions are based on material performance in the laboratory and observations in the field, this approach is often referred to as the empirical mechanistic method. The main advantage of the mechanistic design method is its ability to analyze the impact of design input modifications, such as changes in equipment and traffic loads, quickly and rationally. Some of the advantages of this method compared to the purely empirical method include:

1. Can be used analytically to evaluate changes or variations in vehicle load on pavement performance.
2. The performance of pavements with new materials can be evaluated based on the mechanical properties of the materials.
3. It can be used to analyze the effect of changes in material properties due to environment and climate on pavement performance.
4. Evaluate pavement response in relation to specific pavement damage modes.
5. In general, the pavement structure model used in this manual is a multi-layer structure that is linear elastic, isotropic (for bounded materials) and anisotropic for unbounded materials, the CTB layer is considered to have experienced cracking (post cracking condition).

Previous studies have highlighted the comparison between rigid and flexible pavements. For instance, Prasetya & Marleno (2020) analyzed the investment costs of both pavement types and concluded that rigid pavements offer better long-term durability despite higher initial costs. Similarly, Sahrianto et al. (2016) examined the construction methods and costs of flexible and rigid pavements, indicating that rigid pavements are more suitable for high-traffic roads due to their higher strength and longer lifespan. These studies emphasize the importance of considering both initial investment and long-term maintenance when selecting pavement types for infrastructure projects.

The urgency of this research is underscored by the rapid development of road infrastructure in Indonesia, particularly in regions like Mojokerto District, where traffic volumes are increasing and road maintenance is becoming a significant challenge. The Temuireng-Jetis road section plays a crucial role in regional connectivity, and choosing the appropriate pavement type is essential to ensure long-term cost-efficiency and minimal disruption. With ongoing urbanization and the rise in heavy traffic, it is vital to assess which pavement solution will provide the best value in terms of durability, maintenance, and overall lifecycle costs.

While several studies have compared rigid and flexible pavements in terms of cost and performance, few have focused on the specific conditions of Mojokerto District, where varying topography and traffic patterns influence pavement performance. Additionally, there is limited research examining the combined impact of initial construction costs, long-term maintenance, and environmental factors in determining the most cost-effective pavement solution. This research aims to fill this gap by providing a comprehensive analysis of both pavement types under the unique conditions of the Temuireng-Jetis road section.

This study offers a novel contribution by providing a localized comparison of rigid and flexible pavements for a specific road section in Mojokerto District. Unlike previous studies, which have largely focused on generic comparisons, this research integrates local data, such as traffic volume and subgrade conditions, to recommend the most suitable pavement type. Moreover, the study introduces a detailed analysis of lifecycle costs, incorporating both initial construction costs and long-term maintenance, offering a more holistic view of pavement selection.

The objective of this research is to evaluate the construction requirements and cost-effectiveness of rigid and flexible pavements on the Temuireng-Jetis road section in Mojokerto District. By comparing pavement thickness, cost, and performance, the study aims to recommend the most efficient and sustainable solution for road infrastructure in the region. The findings will benefit policymakers, engineers, and contractors by providing data-driven insights into pavement selection, helping to optimize costs, improve road quality, and ensure long-term durability. This research also contributes to the broader field of infrastructure planning by offering practical guidance on how to balance construction costs, maintenance, and overall sustainability.

Research Methods

Literature Study

At the literature study stage, the author looks for relevant references by studying previous research conducted by Ibrahim MNarendra A. (2023) entitled Comparison of Rigid Pavement and Flexural Pavement Based on Cost and Plan Life (Case Study Lot-3 Kretek Bridge 2 Bantul).

Location Determination

Determination of location as an important aspect in order to obtain the required data is something that needs to be considered. The location is on the Temuireng - Jetis road in Mojokerto Regency.

Study Location Map of Temuireng - Jetis Road Section.

Data

This research uses two types of data, namely primary data and secondary data. Primary data in this study was collected directly by researchers from the project site for research purposes to obtain visual and more specific data. Primary data obtained in this study includes Average Daily Traffic which serves to calculate the number / volume of passing vehicles and photo documentation which serves to determine the state of the environment directly / visually. Then, secondary data is collected through third-party agencies in the form of related agencies in order to obtain planning reports. The secondary data includes *Dynamic Cone Penetrometer* Per 100m and topographic data & road map sections sourced from the PUPR Office of Mojokerto Regency.

Violence Planning

At this stage, researchers began to analyze the pavement. This analysis aims to understand the technical requirements of the pavement. The process involved designing the overall pavement design. In addition, researchers also determine the thickness of the pavement according to the required specifications. This is done to ensure that the road is able to withstand traffic loads and adapt to environmental conditions during its planned life.

Data

The data in this study includes primary and secondary data. Primary data itself consists of interviews and observations at South Surabaya Hospital. The secondary data used in this study are project investment value, detailed health service data, and hospital operational and maintenance cost data.

Revenue Analysis Technique

For revenue analysis, identification and analysis of data that has been obtained related to revenue is carried out, which includes:

1. The Health Service Tariff refers to the existing service tariffs of Surabaya City Government Hospitals, as stipulated in Surabaya City Regional Regulation Number 7 of 2023 concerning Regional Taxes and Levies;

Subsidies sourced from the Surabaya City Regional Revenue and Expenditure Budget (APBD) are carried out by calculating the total hospital revenue minus the hospital management costs. From the results of these calculations will be obtained the amount of hospital management cost subsidies provided by the Surabaya City Government for the management of South Surabaya Hospital.

Results and Discussions

Rigid Pavement Calculation

a. Bottom Foundation Calculation

In the planning of the Bendung - Bantengan road section of Mojokerto Regency, CBR test data conducted by the Public Works Office of the Mojokerto Regency Bina Marga Division, the CBR used is as follows:

Table 1. CBR Data

STA	CBR Value (%)
0+025	21,80
0+325	37,40
0+475	13,60
0+655	41,00

The CBR data was sorted and analyzed using the Percentile Method with a 90% confidence level:

Table 2. Percentile Method CBR Data

No.	STA	CBR Value (%)
1	0+475	13,60
2	0+025	21,80
3	0+325	37,40
4	0+655	41,00

Percentile Calculation:
Percentile = Total Data x (80% - Confidence Value (%))
= 4 x (80% - 90%)
= 4 x 10%
= 0.4 (Rounded to 1, then data number 1 CBR 13.60% is used)

After knowing the soil CBR value, then determine the axis repetition value to determine the minimum bottom foundation thickness. Through calculations, after plotting into a line diagram, the bottom foundation is obtained using Binder Material (BP) = 100 mm and Effective Subgrade CBR of 37%.

b. **Calculation of Concrete Plate Thickness**

Pavement Type = Jointed concrete pavement without reinforcement (BBTT)
Shoulder type = Sirtu
Plan life = 40 years
Concrete compressive strength (fc) = 350 kg/cm2
Concrete compressive strength (fc') = 0.83 x 35 = 29.05 Mpa
Flexural tensile strength (fcf) = $0{,}75\sqrt{29{,}05}$
= 4.04 Mpa
Load safety factor = 1.00 (Table 2.7)
JSKN = 76.794.337,10
Subgrade CBR = 13,60 %
Effective soil CBR = 33,00 %
Interpretive thickness of concrete slab = 25 cm

Calculation of the concrete slab thickness to be used by selecting a specific slab thickness and analyzing it from the erosion factor.

An example of interpolation to find the Equivalent Stress value with CBR 37% STRT = 0.68; CBR 50% STRT = 0.65, obtained by CBR 37% as follows:

STRT = 25 +((33-25)/(35-25)) x (0,68 - 0,70) = 0,68

Table 3. Effective CBR Interpolation Calculation

CBR	Equivalent Stress		Erosion Factor of Wear Spokes	
	STRT	STRG	STRT	STRG
25	0,70	1,16	1,92	2,52
33	**0,68**	**1,12**	**1,91**	**2,51**
35	0,68	1,11	1,91	2,51

(Source: Calculation Result)

Next calculate the Stress Ratio Factor (FRT) and Erosion Factor, the calculation results are as follows:

Table 4 Calculation of FRT and Erosion Factor

FRT		Erosion Factor	
STRT	STRG	STRT	STRG
0,17	**0,28**	**1,91**	**2,51**

(Source: Calculation Result)

An example of FRT calculation to find the STRT value, the value of 0.17 is obtained from the following calculation:

$$\text{FRT STRT} = \frac{Tegangan\ Ekivalen}{\text{Kuat tarik lentur (fcf)}} \frac{Tegangan\ Ekivalen}{\text{Kuat tarik lentur (fcf)}} = \frac{0,68}{4,04} \frac{0,68}{4,04} = 0,17$$

c. **Reinforcement Calculation**

Calculation of the use of dowels as a connector or binder in concrete plate joints can be seen from the following table:

Table 5. Dowel Size against Plate Thickness

Thickness of Plate Jobs		Dowel					
		Diameter		Long		Distance	
Inches	Mm	Inches	Mm	Inches	Mm	Inches	Mm
6	150	0,75	19	18	450	12	300
7	175	1	25	18	450	12	300
8	200	1	25	18	450	12	300
9	225	1,75	32	18	450	12	300
10	250	1,75	32	18	450	12	300
11	275	1,75	32	18	450	12	300
12	300	1,5	38	18	450	12	300
13	325	1,5	38	18	450	12	300
14	350	1,5	38	18	450	12	300

(Source: Cement Concrete Pavement Planning Pd T-14-2003)

From the table above, a spoke/dowel with a maximum diameter of 32 mm can be used. Shrinkage joints are installed every 4.00 m according to the lane width, spokes are used with a length of 45 cm. The spacing between the spokes is 30 cm, in accordance with the regulations in the table for jointed concrete pavements without reinforcement.

- Distance between joints (b) = 4 m (provision)
- Thickness of plate (h) = 250 mm = 0.25 m
- Plate width = 2 x 4.00 = 8.00 m
- Steel grade = BJTP-280 & BJTS-420
- Fy = 280 Mpa (Plain)
  = 420 Mpa (Thread)
- Concrete content weight = 2400 kg/m^3

➢ Tie bar:

As Needed = 204 x b h
= 204 x 4 x 0.25
= 204 mm^2/m'

Tested with D16 - 500 mm threaded steel reinforcement bars

As = ¼ x π x d^2 x Amount
= ¼ x 3.14 x $16^{2\ x}$ 2
= 401.92 mm^2 > 204 mm^2 **(Tiebar Ok)**

The distance between the tie bars used is 500 mm, so the length of the tie bar is as follows:

L = (38.3 x ϕ) + 50
= (38,3 x 16) + 50
= 662.8 mm = 600 mm = 60 cm

So it can be concluded as follows:

1. 25cm thick concrete slab
   - Dowel diameter = 32 mm
   - Dowel length = 450 mm
   - Dowel distance = 300 mm
   - Tie bar diameter = D16 mm
   - Length of tie bar = 600 mm
   - Tie bar spacing = 500 mm
2. Foundation Layer
   - CTB = 100 mm

Flexural Pavement Planning

Shoulder type = Sirtu
Plan life = 20 years
20th Plan Life (R) = 54,93
40th Plan Life (R) = 109,30
Subgrade CBR = 13,60 %
Effective soil CBR = 33,00 %
Directional distribution factor (DD) = 0,50
Lane distribution factor (DL) = 80%

Furthermore, the 40-year plan traffic load (CESA5) is calculated to determine the thickness of the foundation layer, the 20-year plan traffic load (CESA4) to determine the type of flexible pavement and the 20-year plan traffic load (CESA5) to determine the thickness of the flexible pavement.

Based on the data obtained that the CBR value is 13.60% and CESA5 40th 77,267,668, the foundation design used is determined using Design Chart - 2, namely with a subgrade value of CBR 13.60% and CESA5 40th 77,267,668, it does not require subgrade improvement. Based on the results of the calculation of the 20th CESA5 traffic load of 38,831,775, plotting is carried out and the results of the design of flexible pavement and foundation layers are obtained as follows:

AC - WC	= 40 mm	= 4 cm
AC - BC	= 160 mm	= 16 cm (AC Base replaced AC - BC)
CTB	= 150 mm	= 15 cm
LPA Kls A	= 150 mm	= 15 cm

Discussion

The findings of this study provide significant insights into the comparative advantages of rigid and flexible pavement for road infrastructure, specifically in the Mojokerto Regency. The analysis demonstrates that rigid pavement, despite its higher initial construction cost, offers greater economic efficiency over the long term. This is attributed to its longer service life and reduced maintenance requirements, making it particularly suitable for road sections with heavy traffic loads and extended design life expectations, such as the Jetis-Temuireng road.

Rigid pavement's higher modulus of elasticity allows for superior load distribution to the subgrade, thereby reducing stress and minimizing structural damage over time. This characteristic makes it an optimal choice for roads with consistent heavy traffic or industrial usage. Conversely, flexible pavement, while less expensive initially and more adaptable to subgrade movement, has limitations in durability. Its shorter lifespan and frequent maintenance requirements significantly increase lifecycle costs, especially in areas subjected to high vehicle loads.

These findings underline the importance of integrating traffic patterns and expected road usage into the decision-making process when selecting pavement types. Furthermore, the environmental impact of both pavement types warrants further attention. Rigid pavement construction involves higher energy consumption and potential challenges in material disposal, whereas flexible pavement allows for easier repair and recycling, making it potentially more environmentally sustainable under certain conditions.

This study highlights the need for a comprehensive approach in road planning and construction, where economic, operational, and environmental factors are equally prioritized. Future research should focus on evaluating innovative materials and maintenance models to further enhance the sustainability and cost-effectiveness of road infrastructure projects in regions like Mojokerto Regency.

Conclusion

Based on the analysis conducted, this study concludes that rigid pavement offers significant advantages in terms of durability and economic efficiency for long-term infrastructure projects. Using the Pd T-14-2003 method, a rigid pavement design with a road width of 8 meters, concrete pavement thickness of 25 cm, and a cement-treated base (CTB) layer of 10 cm was developed. In comparison, the flexible pavement design, calculated using the MDPJ 2017 method, comprises a Class A aggregate foundation layer with a thickness of 15 cm, an upper foundation layer of CTB with a thickness of 15 cm, an asphalt concrete binder course (AC-BC) of 16 cm, and a wearing layer (AC-WC) of 4 cm. These specifications highlight the structural and material differences between the two pavement types. Rigid pavement demonstrates higher initial costs but lower maintenance requirements and longer service life, making it suitable for high-traffic road sections. Conversely, flexible pavement involves lower initial costs but higher maintenance needs, particularly in heavy traffic conditions. This study provides critical insights into pavement selection, balancing construction costs, operational efficiency, and long-term sustainability.

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