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Cost, Time and Pavement Alternatives Analysis of Technical and Costs

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ABSTRACT

The research on the Teuku Umar Road - Rajawali Road Preservation project aims to find out the technical calculations, costs and time so that a more efficient alternative can be chosen. The calculation analysis on Rigid Pavement and Flexible Pavement uses the Road Pavement Design Manual Method No. 02 / M / BM / 2017 with a 20-year plan life. In the calculation of the AHSP cost analysis of the Highways Sector in accordance with Permen PUPR No. 8 of 2023. Periodic maintenance costs for rigid pavement are 6% and routine maintenance costs on flexible pavement are 2% while periodic maintenance costs are 8% of the initial budget. The results of this research analysis show the cost of rigid pavement is Rp. 11,349,200,000 and the implementation time is 120 calendar days. While the cost of flexible pavement is Rp. 8,414,500,000 and the implementation time is 95 calendar days. The results of the calculation of choosing a more efficient alternative based on the calculation of Capitalized Cost show that rigid pavement in terms of cost is smaller than flexible pavement, so rigid pavement alternatives are chosen.

Keywords: Rigid Pavement, Flexible Pavement, Capitalized Cost

1. Introduction

Government Regulation No. 34/2006 on Roads explains that the conceptual and comprehensive implementation of roads needs to see roads as a unified road network system that binds and connects activity centers. In this connection, the primary road network system and the secondary road network system are known (Abizar & Widodo, 2021). In each road network system, roads are grouped according to function, status, and road class. The grouping of roads based on status gives the Government the authority to organize roads that have national services and local governments to organize roads in their areas in accordance with the principles of regional autonomy (Pradıpta, 2021).

Data from the Ministry of PUPR (2023 Semester II) road stability in good condition in Indonesia amounted to 94.18% of the total length of the National Road 47,603.49 Km. The achievement of this percentage is certainly supported by many factors, including infrastructure development factors in regions throughout Indonesia (Prahastyo et al., 2019). The stability of provincial roads in East Java based on data from the East Java Provincial Bina Marga Public Works Office in 2023 amounted to 89.09% of the total length of 1421 km. Sampang Regency is one of four regencies located on Madura Island, East Java (Bangkalan, Pamekasan and Sumenep).

The regional boundary to the north is bordered by the Java Sea, to the south is bordered by the Madura Strait, to the east is bordered by Pamekasan Regency, while to the west is bordered by Bangkalan Regency. The length of roads in 2024 based on road data from the Sampang Regency Public Works and Spatial Planning Office contained in the Regency Road Decree Number: 188.45/457.1/KEP/434.013/2023 is 754.12 Km with

details of steady conditions of 44.65% and unsteady conditions of 55.35%. Infrastructure development is important in today's society (Prasetya & Marleno, 2020)). This can be seen from the rampant development of infrastructure development in various sectors, ranging from roads, telecommunications, clean water networks to energy supply systems (Putra, 2022).

The development of road infrastructure in the current era, especially road development on district roads, is carried out based on the Vision and Mission of the 2019-2024 RPJMD leadership of the Sampang Regent and Deputy Regent of Sampang H. Slamet Junaidi - H. Abdullah Hidayat which is contained in Mission point 3 Infrastructure "Improving Quality and Sustainable Infrastructure Development". The condition of Sampang Regency roads is based on road condition data from the Sampang Regency Public Works and Spatial Planning Office in 2023, road stability is 46.54% of the total length of 754.12 Km district roads and the type of flexible pavement is more dominant at 464.25 Km. It is necessary to conduct several reviews to overcome the level of road damage decreasing (Muhammad, 2021).

As an implementer of public policy, the Sampang Regency Public Works and Spatial Planning Office is a technical implementing element of Regional Government affairs which has the task of carrying out Government affairs in the field of public works which includes planning, implementing and controlling services in accordance with Regional Head policies. Related to this, many public works activities have been carried out. However, not all public works activities, especially infrastructure development, can support quality and sustainable infrastructure development in Sampang Regency. Thus, to see the level of success and achievement of the objectives of the implementation program, it is necessary to carry out activities on the benefits/impacts of development implementation programs that have been carried out (Sidabutar et al., 2021)

The feasibility of the type of construction carried out on a project at this time needs to be done in order to obtain effective construction life and cost effectiveness without leaving the existing quality (Sugeng et al., 2017). In this case focuses on the cost and time implemented on rigid pavement and flexible pavement. The increasingly tight budget allocation from the Sampang Regency Regional Government to the Regional Apparatus Organization (OPD) through the Sampang Regency Public Works and Spatial Planning Office that handles projects on district roads makes it necessary to implement long-lived pavement construction so as to minimize maintenance costs in order to obtain increasingly stable road conditions.

Sampang City is a medium-sized city whose population is increasing from year to year. The more population that requires the use of land transportation, the more the level of congestion and road damage, especially on Jalan Teuku Umar - Jl. Rajawali. The area is the central area of traffic movement activities such as Srimangunan Main Market and Trunojoyo Terminal located on Teuku Umar Street while Muhammad Zyn Hospital is located on Rajawali Street. The Sampang Regency Government through the Sampang Regency Public Works and Spatial Planning Office is currently in the process of planning the improvement of Teuku Umar Road - Rajawali Road along approximately 1370 meters with the consideration of facilitating traffic flow in the area.

Pavement planning is something that must be planned as well as possible so that road construction can facilitate traffic flow in accordance with the planned life (Supriyatno, 2023). If during the implementation and use period no damage occurs, it means that road users can use and smooth the road comfortably and safely. So far, there have been many road plans that are not in accordance with the planning so that the road pavement does not last according to the planned life (Tandelilin, 2010). In order to avoid this, it is necessary to design the right type of pavement planning for the Teuku Umar Road - Rejawali Road (Sampang) Preservation project.

In general, there are 2 (two) types of pavement construction that are often implemented, namely Rigid Pavement construction and Flexible Pavement construction. Flexible pavement costs tend to be cheaper in terms of initial implementation of the work. High maintenance costs on flexible pavement but short service life and maintenance that often occurs during the service period make the costs required for flexible pavement greater. Whereas on rigid pavement, the service life is higher but the maintenance cost is relatively low. Of the two types of construction, it can be analyzed to determine the most appropriate and efficient type of pavement. For the Preservation project of Jalan Teuku Umar - Jalan Rejawali Sampang Regency by considering the components of construction costs, maintenance / maintenance and calculation of alternative selection using the Capitalized Cost method.

Analysis of alternative selection can be done after planning calculations of both Rigid Pavement and Flexible Pavement construction types with secondary data obtained by research. Of the two pavements will then be compared in terms of construction costs and implementation time so as to obtain a pavement that is economically more profitable and efficient. With this calculation, it can be used as a policy for the Local Government.

An analysis is needed to determine the right type of pavement for the Teuku Umar Road - Rejawali Road Preservation project. Based on this background, this research aims to calculate construction costs and economic analysis of each pavement construction using the Capitalized Cost method so that a comparison of the two types of pavement layer construction can be made, then the most efficient and profitable alternative type of pavement construction is selected according to the predetermined plan life.

2. Methodology

The object of this research is to determine the technical calculation, cost and time of Rigid Pavement and Flexible Pavement. The research location on the Teuku Umar Road - Rajawali Road Preservation project in Sampang Regency, East Java Province is geographically located at the coordinates -7.195082 °S 113.245538 °E. Below is a location map sourced from Google Maps. The instrument in this research is the Standard regulations for the calculation of technical structures on Rigid Pavement and Flexible Pavement with the regulations of the Road Pavement Design Manual No. 02 / M / BM / 2017.

The data collection procedure carried out in this study is secondary data in the form of LHR (Average Daily Traffic) Data, CBR (California Bearing Ratio) Data. The data analysis that will be carried out is a technical analysis of the comparison of Rigid Pavement and Flexible Pavement in terms of implementation costs by comparing the amount of costs incurred with the economic benefits obtained over the next 20 (forty) years. The calculation method for rigid pavement planning and flexible pavement uses the Road Pavement Design Manual No. 02/M/BM/2017.

3. Results and Discussion

3.1. Calculation of Rigid Pavement Cost Budget Plan

Calculation of the Cost Budget Plan on Rigid Pavement based on the analysis of the Regulation of the Minister of PUPR Number 8 of 2023 and the resulting budget for work implementation as follows:

Table 1. Recapitulation of Rigid Pavement Cost Budget Plan

Register	Description	Total Price of Work (IDR)
Register 1	General	240.129.770,00
Register 2	SMKK	424.617.414,14
Register 3	Main Occupation	9.546.364.679,87
Register 4	Daily Work	13.420.964,33
(A) Total price of work		10.224.532.828,35
(B) Value Added Tax (VAT)		1.124.698.611,12
(C) Total price of work = (A) + (B)		**11.349.231.439,46**
(D) Rounded		**11.349.200.000,00**
Amount: Eleven Billion Three Hundred Forty-Nine Million Two Hundred Thousand Rupiahs		

Source: Researcher Processed Data, 2024

3.2. Calculation of Flexural Pavement Cost Budget Plan

The analysis of the calculation of the Cost Budget Plan on Flexible Pavement is based on the analysis of the Regulation of the Minister of PUPR Number 8 of 2023 and the resulting budget for work implementation as follows:

Table 2. Recapitulation of Flexural Pavement Cost Budget Plan

Register	Description	Total Price of Work (IDR)
Register 1	General	240.129.770,00
Register 2	SMKK	424.617.414,14
Register 3	Main Occupation	9.546.364.679,87
Register 4	Daily Work	13.420.964,33
(A) Total price of work		7.580.685.929,79
(B) Value Added Tax (VAT) 11% x (A)		883,875,452,28
(C) Total price of work = (A) + (B)		**8.414.561.328,07**
(D) Rounded		**8.414.500.000,00**
Amount: Eight Billion Four Hundred Fourteen Million Five Hundred Thousand Rupiahs		

Source: Researcher Processed Data, 2024

From the results of the analysis of the implementation costs carried out between Rigid Pavement and Flexible Pavement on the Preservation of Teuku Umar Road - Rajawali Road, the following results were obtained:

a. Rigid Pavement Construction Cost = Rp. 11,349,200,000
b. Flexible Pavement Construction Cost = Rp. 8,414,500,000
c. Budget Difference = Rp. 2,934,700,000
d. Difference (%) = 25.86%

3.3. Calculation of Rigid Pavement Work Duration

Minimum duration is the longest productive time for labor to complete a unit of work. The minimum duration is obtained from the definition of the coefficient index of labor or tools with the assumption that the main labor group (Pokja) used is at least equal to 1 person each. Then derive the formula for the person-day coefficient index using a mathematical logic approach. The derivation of the formula is as follows:

a. Road Body Preparation Work

a) Firing and leveling the surface of damaged existing roads using Motor Greder equipment

Hp E13 Tool Specifications:

Greder length (Lh) = 50 m
Width of compaction area (w) = 3.50 m
Effective blade width (b) = 2.60 m
Overlap width (bo) = 0.15 m
Tool efficiency factor (Fa) = 0.83
Average speed (v) = 4 km/hour
Number of passes (n) = 4 passes
Number of passing lanes (N) = w/(b-b0) = 3,50/(2,60-0,15) = 1,43 lane

Cycle time

1 pass leveling (T1) = Lh : (v x 1000) x 60 = 50 : (4000 x 60) = 0,75 minutes
Other (T2) = 1,00 minutes
Ts1 = T1 + T2 = 1,75 minutes
Production capacity (Q1) $= \frac{Lh\ x\ (Nx\ (b-b0)+b0)x\ Fa\ x\ 60}{N\ x\ n\ x\ Ts1}$ = 909 m²/hours
Duration $= \frac{V}{Q\ x\ tk}$ $= \frac{V}{Q\ x\ tk}$ = 2,15 day ≈ 3 day

b) Compaction of road body surface with Tandem/Vibro Roller

Tool specifications 5-8 Ton Hp E19

Average speed (v) = 4 km/hour
Work area width (w) = 10.00 m
Tool wheel width (b) = 1.68 m

Overlap width (b0) = 0.15 m
Number of passes (n) = 8 passes
Tool efficiency factor (Fa) = 0.83
Material conversion factor (Fk) = 0.91
Passing lanes (N) = w/(b-b0) = 10,00/(1,68-0,15) = 6,54 times
Production capacity (Q2) = $\frac{Lh\ x\ (Nx\ (b-b0)+b0)x\ Fa\ x\ Fk}{N\ x\ n}$ = 586,5 m²/hour
Duration = $\frac{V}{Q\ x\ tk}$ = = 3,33 day ≈ 4 day

c) Watering the road body with Water Tanker

Tool specifications 3000-4000 L

Water tank volume (V) = 4000 liters
Tool efficiency factor (Fa) = 0.83
Water demand (Wc) = 0.07 (assumption)
Water pump capacity (Pa) = 100 liters/minute
Surface soil (t,gr) = 0.2 m
Production capacity (Q3) = (Pax Fa x 60)/(1000 x Wc x t.gr) = 355,7 m²/hour
Duration = V/(Q x tk) = 13.700/(355,7 x 7) = 5,50 day ≈ 6 day

Duration for road body preparation work = 3 + 4 + 6 (days) = 13 days

b. Class A Foundation Layer Work

a) Delivery of Aggregate Material from base camp to site by Dump truck

Dump truck Tronton 10 Ton tool specifications:

Distance from base camp to site (L) = 10.83 Km
Body capacity (V) = 10 tons
Aggregate content weight (D1) = 1.81 tons/m³
Tool efficiency factor (Fa) = 0.83
Wheel loader capacity (Q1) = 101.50 m³/hour
Average loading speed (v1) = 25 km/hour
Empty average speed (v2) = 35 km/hour

Cycle time,

Load time (T1) = V x 60/Q1 x D1 = 10 x 60 / 101.5 x 1.81 = 3.26 minutes
Travel time (T2) = (L/v1) x 60 minutes = (10.83/25) x 60 minutes = 26.00 minutes
Empty travel time (T3) = (L/v2) x 60 minutes = (10.83/35) x 60 minutes = 18.57 minutes
Exact time (ready to return) T4 = 1.45 minutes
Total time (Ts2) = T1+T2+T3+T4 = 3,26+26+18,57+1,45 = 49,27 minutes
Production capacity (Q1) = $\frac{V\ x\ Fa\ x\ 60}{Ts2+D1}$ = 5,58 m²/hour

Assumption of 3 dump trucks from basecamp to site per day

Duration = $\frac{V}{Q\ x\ 3\ x\ tk}$ = $\frac{2055}{5{,}58\ x\ 3\ x\ 7}$ = 17,53 day ≈ 18 day

b) Firing and leveling of class A aggregate beds using a Motor Greder.

Motor Greder tool specifications

Overlay length (Lh) = 50 m
Pavement width (L2) = 10 m
Effective blade width (b) = 2.40 m
Overlap width (b0) = 0.15 m
Average speed (v) = 4 km/hour
Efficiency factor (Fa) = 0.83
Number of passes (N) = L2/(b-b0) = 10/(2,40-0,15) = 4,76

Cycle time,

Equipment 1 pass (T1)	= Lh : (v x 1000) x 60 = 50 : (4 x 1000) x 60 = 0,75 minutes
Other (T2)	= 1,00 minutes
Ts3	= 1,75 minutes
Production capacity (Q2)	$= \frac{Lh\ x\ (Nx\ (b-b0)+b0)x\ t\ x\ Fa\ x\ 60}{N\ x\ n\ x\ Ts1}$ = 153,9 m²/hour
Duratio	$= \frac{V}{Q\ x\ tk} = \frac{2.055}{153,9\ x\ 7}$ = 1,91 day ≈ 2 day

c) Compaction of road body surface with Tandem/Vibro Roller

Tool specifications 5-8 Ton Hp E19

Average speed (v)	= 2.5 km/hour
Width of work area (L2)	= 3.50 m
Effective compaction width (b)	= 1.20 m
Overlap width (b0)	= 0.3 m
Number of passes (n)	= 6 passes
Tool efficiency factor (Fa)	= 0.83
Lane passes (N) = L2/(b-b0)	= 3.50/(1.2-0.3) = 3.89 times
Production capacity (Q3)	$= \frac{(v\ x\ 1000)\ x\ (Nx\ (b-b0)+b0)x\ Fa\ x\ t}{N\ x\ n}$ = 56,91 m²/hour
Duration	$= \frac{V}{Q\ x\ tk} = \frac{2.055}{56,91\ x\ 7}$ = 5,16 day ≈ 6 day

d) Watering the road body with Water Tengker

Tool specifications 3000-4000 L

Water tank volume (V)	= 4000 liters
Tool efficiency factor (Fa)	= 0.83
Water demand (Wc)	= 0.07 (assumption)
Water pump capacity (Pa)	= 100 liters/minute
Production capacity (Q4)	$= \frac{Pax\ Fa\ x\ 60}{1000\ x\ Wc}$ = 71,14 m²/hour
Duration	$= \frac{V}{Q\ x\ tk} = \frac{2.055}{71,14\ x\ 7}$ = 4,13 day ≈ 5 day

Duration for Class A Foundation Layer works 21 days

c. Concrete Work fc' 15 MPa (Lean Concrete)

a) Concrete production in batching plant

Specifications of batching plant

Tool capacity (V)	= 25 m³/hour
Factor efisiensi (Fa)	= 0,83
Production capacity (Q1)	= V x Fa = 25 x 0,83 = 20,75 m³/hour

b) Concrete casting

Specification of 5 m3 alligator truck mixer

Drum capacity (V)	= 5.00 m³
Efficiency factor (Fa)	= 0.83
Effective working hours (tk)	= 7.00 hours
Average fill speed (v1)	= 20 km/hour
Average of empty speed (v2)	= 30 km/hour

Cycle time,

Filling (T1)	= (V/Q1) x 60 = (5/20.75) x 60 = 14.46 minutes
Transporting (T2)	= (tk/v1) x 60 = (7/20) x 60 = 21.00 minutes
Return (T3)	= (tk/v2) x 60 = (7/30) x 60 = 14.00 minutes

(Ts1) = T1 + T2 + T3 = 14.46+21+14 = 49.46 minutes

Production capacity (Q2) = $\frac{V\ x\ Fa\ x\ 60}{Ts1}$/(Ts1) 5,03 m³/hour

Assumption of 3 truck mixers from basecamp to site per day

Duration = $\frac{V}{Q\ x\ tk} = \frac{1370}{5{,}03\ x\ 7\ x\ 3}$ = 12,97 day ≈ 13 day

d. Cement Concrete Works fs' 3.8 MPa (using Concrete Paver)

a) Concrete production in batching plant

Specifications of batching plant

Tool capacity (V) = 25 m³/hour
Efficiency factor (Fa) = 0.83
Production capacity (Q1) = V x Fa = 25 x 0,83 = 20,75 m³/hour

b) Concrete casting using concrete paver

Tool specifications

Rigid volume (V) = 2,740 m³
Effective working hours (tk) = 7.00 hours
Pavement layer thickness (t) = 0.20 m
Width of 1 lane overlay (Lbr) = 5.00 m
Tool Efficiency Factor (Fa) = 0.83 (Permen PUPR No. 8/2023)
Overlay speed (v) = 3.00 m/minute
Production capacity (Q) = v x 60 x Lbr x t x Fa = 3,00 x 60 x 5,00 x 0,20 x 0,83= 149,40 m³
Duration = $\frac{V}{Q\ x\ tk} = \frac{2740}{149{,}40\ x\ 7}$ = 58,48 hari ≈ 59 day

e. Thermoplastic Marking Work

Marking paint applicator

Painting capacity (C) = 40 kg/hour
Amount of paint per m² (Rate) = 3.225 kg/m²
Tool Efficiency Factor (Fa) = 0.83
Production capacity (Q1) = $\frac{C\ x\ Fa}{Rate} = \frac{40\ x\ 0{,}83}{3{,}225}$ = 10,30 m²/hour
Duration = $\frac{V}{Q\ x\ tk} = \frac{427{,}44}{10{,}30\ x\ 7}$ = 5,93 day ≈ 6 day

Table 3. Recapitulation of Rigid Pavement Time

No.	Main Occupation	Duration (day)
1.	Road Body Preparation	13
2.	Class A Aggregate Foundation Layer	21
3.	Concrete, fc'15 Mpa	13
4.	Cement Concrete Pavement fs' 3.8 MPa	59
5.	Thermoplastic Road Markings	6

Source: Researcher Calculation Results, 2024

From the results of the analysis of the table above and processed into a time scheduling schedule with a beam diagram, the total time of rigid pavement construction work is 120 calendar days.

3.4. Calculation of Flexural Pavement Work Duration

The duration of flexible pavement work is the amount of time required to complete the entire work. The time taken to obtain work efficiency can also be referred to as the length of time or duration against risk factors.

a. Road Body Preparation Work

a) a) Fireplace and leveling of damaged existing road surfaces using Motor Greder equipment

Hp E13 Tool Specifications:

Greder length (Lh)	= 50 m
Width of compaction area (w)	= 3.50 m
Effective blade width (b)	= 2.60 m
Overlap width (bo)	= 0.15 m
Tool efficiency factor (Fa)	= 0.83
Average speed (v)	= 4 km/hour
Number of passes (n)	= 4 passes
Number of passing lanes (N)	= w/(b-b0) = 3,50/(2,60-0,15) = 1,43 lane

Cycle time

Leveling 1 pass (T1)	= Lh : (v x 1000) x 60 = 50 : (4000 x 60) = 0,75 minutes
Other (T2)	= 1,00 minutes
Ts1	= T1 + T2 = 1,75 minutes
Production capacity (Q1)	$= \frac{Lh\ x\ (Nx\ (b-b0)+b0)x\ Fa\ x\ 60}{N\ x\ n\ x\ Ts1}$ = 909 m²/hour
Duration	$= \frac{V}{Q\ x\ tk} = \frac{13.700}{909\ x\ 7}$ = 2,15 day ≈ 3 day

b) Compaction of road body surface with Tandem/Vibro Roller

Tool specifications 5-8 Ton Hp E19

Average speed (v)	= 4 km/hour
Work area width (w)	= 10.00 m
Tool wheel width (b)	= 1.68 m
Overlap width (b0)	= 0.15 m
Number of passes (n)	= 8 passes
Tool efficiency factor (Fa)	= 0.83
Material conversion factor (Fk)	= 0.91
Traverse lane (N)	= w/(b-b0) = 10,00/(1,68-0,15) = 6,54 times
Production capacity (Q2)	$= \frac{Lh\ x\ (Nx\ (b-b0)+b0)x\ Fa\ x\ Fk}{N\ x\ n}$ = 586,5 m²/hour
Duration	$= \frac{V}{Q\ x\ tk} = \frac{V}{Q\ x\ tk}$ = 3,33 day ≈ 4 day

c) Watering the road body with Water Tengker

Equipment specifications 3000-4000 L

Water tank volume (V)	= 4000 liters
Tool efficiency factor (Fa)	= 0.83
Water demand (Wc)	= 0.07 (assumption)
Water pump capacity (Pa)	= 100 liters/minute
Surface soil (t,gr)	= 0.2 m
Production Capacity (Q3)	$= \frac{Pax\ Fa\ x\ 60}{1000\ x\ Wc\ x\ t.gr}$ = 355,7 m²/hour
Duration	$= \frac{V}{Q\ x\ tk} = \frac{13.700}{355,7\ x\ 7}$ = 5,50 day ≈ 6 day

Duration for road body preparation work = 3 + 4 + 6 (days) = 13 days

b. Class A Foundation Layer Work

a) Delivery of Aggregate Materials from base camp to site by Dump Truck

Dump truck Tronton 10 Ton tool specifications:

Distance from base camp to site (L) = 10.83 Km

Body capacity (V)	= 10 tons
Aggregate content weight (D1)	= 1.81 tons/m³
Tool efficiency factor (Fa)	= 0.83
Wheel loader capacity (Q1)	= 101.50 m³/hour

Average loading speed (v1) = 25 km/hour
Empty average speed (v2) = 35 km/day

Cycle time,

Load time (T1) = V x 60/Q1 x D1 = 10 x 60 / 101.5 x 1.81 = 3.26 minutes
Travel time (T2) = (L/v1) x 60 minutes = (10.83/25) x 60 minutes = 26.00 minutes
Empty travel time (T3) = (L/v2) x 60 minutes = (10.83/35) x 60 minutes = 18.57 minutes
Exact time (ready to return) T4 = 1.45 minutes
Total time (Ts2) = T1+T2+T3+T4 = 3.26+26+18.57+1.45 = 49.27 minutes
Production Capacity (Q1) $= \frac{V\ x\ Fa\ x\ 60}{Ts2+D1}$ = 5,58 m²/hour

Assumption of 4 dump trucks from basecamp to site per day

Duration $= \frac{V}{Q\ x\ 3\ x\ tk} = \frac{5480}{5{,}58\ x\ 4\ x\ 7}$ = 35 day

b) Firing and leveling of class A aggregate beds using a Motor Greder.

Motor Greder tool specifications

Overlay length (Lh) = 50 m
Pavement width (L2) = 10 m
Effective blade width (b) = 2.40 m
Overlap width (b0) = 0.15 m
Average speed (v) = 4 km/hour
Efficiency factor (Fa) = 0.83
Number of passes (N) = L2/(b-b0) = 10/(2,40-0,15) = 4,76

Cycle time,

Equipment 1 pass (T1) = Lh : (v x 1000) x 60 = 50 : (4 x 1000) x 60 = 0.75 minutes
Miscellaneous (T2) = 1.00 minute
Ts3 = 1.75 minutes
Production capacity (Q2) $= \frac{Lh\ x\ (Nx\ (b-b0)+b0)x\ t\ x\ Fa\ x\ 60}{N\ x\ n\ x\ Ts1}$ = 153,9 m²/hour
Duration $= \frac{V}{Q\ x\ tk} = \frac{5480}{153{,}9\ x\ 7}$ = 5,09 day ≈ 5 day

c) Compaction of road body surface with Tandem/Vibro Roller

Tool specifications 5-8 Ton Hp E19

Average speed (v) = 2.5 km/hour
Width of work area (L2) = 3.50 m
Effective compaction width (b) = 1.20 m
Overlap width (b0) = 0.3 m
Number of passes (n) = 6 passes
Tool efficiency factor (Fa) = 0.83
Lane passes (N) = L2/(b-b0) = 3.50/(1.2-0.3) = 3.89 times
Production capacity (Q3) $= \frac{(v\ x\ 1000)\ x\ (Nx\ (b-b0)+b0)x\ Fa\ x\ t}{N\ x\ n}$ = 56,91 m²/hour
Duration $= \frac{V}{Q\ x\ tk} = \frac{5480}{56{,}91\ x\ 7}$ = 13,75 day ≈ 14 day

d) Watering the road body with Water Tanker

Equipment specifications 3000-4000 L

Water tank volume (V) = 4000 liters
Tool efficiency factor (Fa) = 0.83
Water demand (Wc) = 0.07 (assumption)
Water pump capacity (Pa) = 100 liters/minute

Production Capacity (Q4) $= \frac{Pax\ Fa\ x\ 60}{1000\ x\ Wc}$ = 71,14 m²/hour

Duration $= \frac{V}{Q\ x\ tk} = \frac{5.480}{71,14\ x\ 7}$ = 11 day

Duration for Class A Foundation Layer works 40 days

c. AC-BC Intermediate Layer Laston Work

a) Asphalt mixing plant production

60T/h AMP tool specifications

Production capacity (V) = 60 tons
Tool efficiency factor (Fa) = 0.83
Production Capacity (Q4) = V x Fa = 60 x 0,83 = 49,80 tons

b) Transportation of Asphalt to site by Dump truck

Body capacity (V) = 7 tons
Basecamp to site distance (L) = 10.83 Km
Tool efficiency factor (Fa) = 0.83
Average loading speed (v1) = 25 km/hour
Average empty speed (v2) = 30 km/hour
AMP capacity /batch (Q2b) = 1.00 tons
Time to prepare 1 batch (Tb) = 1.00 minute

Cycle time,

Filling the tub (T1) = (V/Q2t) x Tb = (7/1)x 1 = 7 minutes
Hauling (T2) = (L/v1) x 60 = (10.83/25) x 60 = 26.00 minutes
Spillage time (T3) = 1.45 minutes
Returning (T4) = (L/v2) x 60 = (10.83/30) x 60 = 18.57 minutes
Ts = 53.02 minutes
Production capacity (Q3) $= \frac{V\ x\ Fa\ x\ 60}{Ts}$ = 6,58 tons/hour

Assumption of 14 DT (10 tons) per day

Duration $= \frac{V}{Q\ x\ tk} = \frac{1.874,16}{6,58\ x\ 7\ x\ 3}$ = 13,56 day ≈ 14 day

c) Sanding and firing with Asphalt Finisher

Sanding speed (V) = 5 m/minute
Tool efficiency factor (Fa) = 0.83
Hanparan width (b) = 5.00 m
Production capacity (Q4) = V x 60 x t x b x Fa = 5x60x0,04x5x0,83 = 49,80 tons

d) Initial compaction with Tandem Roller 6-8T

Average speed (v) = 4 km/hour
Effective width of compactor (b) = 1.68 m
Overlap width (b0) = 0.15 m
Number of passes (n) = 6 passes
Number of passing lanes (N) = W/(b-b0) = 5 / (1.68-0.15) = 3.27
Production capacity (Q5) $= \frac{(vx1000)x(Nx(b-b0)+b0)xFaxtxD1}{n\ x\ N}$ = 79,88 tons/hour
Duration $= \frac{V}{Q\ x\ tk} = \frac{1.874,16}{79,88\ x\ 7}$ = 3,36 day ≈ 4 day

e) Final compaction with 8-10T Tire Roller

Average speed (v) = 6 km/hour
Effective width of compactor (b) = 2.29 m
Overlap width (b0) = 0.15 m

Number of lanes (n) = 6 lanes
Number of passing lanes (N) = W/(b-b0) = 5 / (2.29-0.15)
= 1,64
Production capacity (Q5) = $\frac{(vx1000)x(Nx(b-b0)+b0)xFaxtxD1}{n\ x\ N}$ = 254,51 tons/hour
Duration = $\frac{V}{Q\ x\ tk}$ = $\frac{1.874,16}{254,51\ x\ 7}$ = 1,05 day ≈ 2 day

The duration of the Laston Between AC-BC work is 16 days

d. AC-WC Wear Layer Laston Work

a) Asphalt mixing plant production

60T/h AMP tool specifications

Production capacity (V) = 60 tons
Tool efficiency factor (Fa) = 0.83
Production Capacity (Q4) = V x Fa = 60 x 0,83 = 49,80 tons

b) Transportation of Asphalt to site by Dump truck

Body capacity (V) = 7 tons
Basecamp to site distance (L) = 10.83 Km
Tool efficiency factor (Fa) = 0.83
Average loading speed (v1) = 25 km/hour
Average empty speed (v2) = 30 km/hour
AMP capacity /batch (Q2b) = 1.00 tons
Time to prepare 1 batch (Tb) = 1.00 minute

Cycle time,

Filling the tub (T1) = (V/Q2t) x Tb = (7/1)x 1 = 7 minutes
Hauling (T2) = (L/v1) x 60 = (10.83/25) x 60 = 26.00 minutes
Spillage time (T3) = 1.45 minutes
Returning (T4) = (L/v2) x 60 = (10.83/30) x 60 = 18.57 minutes
Ts = 53.02 minutes
Production capacity (Q3) = $\frac{V\ x\ Fa\ x\ 60}{Ts}$ = 6,58 tons/hour

Assumption of 14 DT (10 tons) per day

Duration = $\frac{V}{Q\ x\ tk}$ = $\frac{1.249,44}{6,58\ x\ 7\ x\ 3}$ = 9,04 day ≈ 10 day

c) Sanding and firing with Asphalt Finisher

Sanding speed (V) = 5 m/minute
Tool efficiency factor (Fa) = 0.83
Hanparan width (b) = 5.00 m
Production capacity (Q4) = V x 60 x t x b x Fa = 5x60x0,04x5x0,83 = 49,80 tons

d) Initial compaction with Tandem Roller 6-8T

Average speed (v) = 4 km/hour
Effective width of compactor (b) = 1.68 m
Overlap width (b0) = 0.15 m
Number of passes (n) = 6 passes
Number of passing lanes (N) = W/(b-b0) = 5 / (1.68-0.15) = 3.27
Production capacity (Q5) = $\frac{(vx1000)x(Nx(b-b0)+b0)xFaxtxD1}{n\ x\ N}$ = 79,88 tons/hour
Duration = $\frac{V}{Q\ x\ tk}$ = $\frac{1.249,44}{79,88\ x\ 7}$ = 2,23 day ≈ 3 day

e) Final compaction with 8-10T Tire Roller

Average speed (v) = 6 km/hour
Effective width of compactor (b) = 2.29 m
Overlap width (b0) = 0.15 m
Number of lanes (n) = 6 lanes
Number of passing lanes (N) = W/(b-b0) = 5 / (2.29-0.15) = 1.64
Production capacity (Q5) $= \frac{(vx1000)x(Nx(b-b0)+b0)xFaxtxD1}{n\ x\ N}$ = 254,51 tons/hour
Duration $= \frac{V}{Q\ x\ tk} = \frac{1.249,44}{254,51\ x\ 7}$ = 0,70 day ≈ 1 day

e. Thermoplastic Marking Work

Marking paint applicator

Painting capacity (C) = 40 kg/hour
Amount of paint per m² (Rate) = 3.225 kg/m²
Tool Efficiency Factor (Fa) = 0.83
Production Capacity (Q1) $= \frac{C\ x\ Fa}{Rate} = \frac{40\ x\ 0,83}{3,225}$ = 10,30 m²/hour
Duration $= \frac{V}{Q\ x\ tk} = \frac{427,44}{10,30\ x\ 7}$ = 5,93 day ≈ 6 day

Table 4. Recapitulation of Flexural Pavement Time

No.	Main Occupation	Duration (day)
1.	Road Body Preparation	13
2.	Class A Aggregate Foundation Layer	40
3.	Intermediate Layer Laston (AC-BC)	16
4.	Wear Layer Laston (AC-WC)	12
5.	Thermoplastic Road Markings	6

Source: Researcher Calculation Results, 2024

From the results of the analysis of the table above and processed into time scheduling scheduling with beam diagrams, the total time of flexible pavement construction work is 95 calendar days.

3.5. Analysis of Alternative Selection Over the Life of the Plan

a. Periodic Maintenance of Rigid Pavement

Rigid pavement requires periodic maintenance every 5 years to maintain the quality and life of the pavement plan. The periodic maintenance costs incurred every 5 years are 6% of the initial budget (Permen PU No. 13/PRT/M/2011).

Table 5. Periodic Maintenance of Rigid Pavement

Initial Construction Cost (Rp.)	Periodic Maintenance (%)	Periodic Maintenance Costs (Rp.)
Rp. 11.349.200.000	6 %	Rp. 680.952.000

Source: Researcher Calculation Results, 2024

b. Routine Maintenance of Flexural Pavement

On flexible pavement, routine maintenance is required every 1 year to maintain the quality and life of the pavement plan. The routine maintenance costs incurred every 1 year are 2% of the initial budget (Permen PU No. 13/PRT/M/2011).

Table 6. Routine Maintenance of Flexural Pavement

Initial Construction Cost (Rp.)	Periodic Maintenance (%)	Periodic Maintenance Costs (Rp.)
Rp. 8.414.500.000	2 %	Rp. 168.290.000

Source: Researcher Calculation Results, 2024

c. Periodic Maintenance of Flexural Pavement

For flexible pavement, periodic maintenance is required every 4 years to maintain the quality and life of the pavement plan. The periodic maintenance costs incurred every 4 years is 8% of the initial budget (Permen PU No. 13/PRT/M/2011).

Table 7. Periodic Maintenance of Flexural Pavement

Initial Construction Cost (Rp.)	Periodic Maintenance (%)	Periodic Maintenance Costs (Rp.)
Rp. 8.414.500.000	8 %	Rp. 673.160.000

Source: Researcher Calculation Results, 2024

3.6. Engineering Economic Value Calculation and Alternative Selection

From the results of the calculation of economic value according to the 20-year plan life of the evaluation results and engineering calculations for Rigid Pavement and Flexible Pavement construction with the following scenarios. Rigid Pavement has a large initial cost, no routine maintenance costs, only periodic costs carried out every 5 years at a cost of Rp. 680,952,000. While Flexible Pavement has a lower initial cost and routine maintenance costs every 1 year amounting to Rp. 168,290,000 and periodic maintenance every 4 years at a cost of Rp. 673,160,000.

Table 8. Maintenance Scheme of Rigid Pavement and Flexural Pavement

No.	Description	Value (Rp.)	Decription
A	**Rigid Pavement**		
1.	Routine Maintenance	No	Every Year
2.	Periodic Maintenance	Rp. 680.952.000	Every 5 Years
B	**Flexible Pavement**		
1.	Routine Maintenance	Rp. 168.290.000	Every year
2.	Periodic Maintenance	Rp. 673.160.000	Every 4 Years

Source: Researcher Calculation Results, 2024

a. Rigid Pavement

P = Initial Construction Cost Rp. 11,349,200,000
i = Bank Interest Rate 6% (Bank Indonesia December 2023)
A1 = Routine Maintenance Cost Rp. 0
A2 = Periodic Maintenance Cost Rp. 680,952,000 / 5 Years
= Rp. 680.952.000 x (A/F,i,n)
= Rp. 680.952.000 x (A/F,6%,5)
= Rp. 680.952.000 x 1,1774
= Rp. 801.752.884
Cc = (A1+A2) / i
= (Rp. 0 + 801.752.884) / 6%
= Rp. 13.362.548.066
Cc Tot. = P + Cc
= Rp. 11.349.200.000 + Rp. 13.362.548.066
= Rp. 24.711.748.066

b. Flexural Pavement

P = Initial Construction Cost Rp. 8,414,500,000
i = Bank Interest Rate 6% (Bank Indonesia December 2023)
A1 = Routine Maintenance Cost Rp. 168,290,000 / Year
A2 = Periodic Maintenance Cost Rp. 673,160,000 / 4 Years
= Rp. 673.160.000 x (A/F,i,n)
= Rp. 673.160.000 x (A/F,6%,4)

= Rp. 673.160.000 x 1,2286
= Rp. 827.044.376

Cc = (A1+A2) / i
= (Rp. 168.290.000 + Rp. 827.044.376) / 6%
= Rp. 16.588.906.266

Cc Tot. = P + Cc
= Rp. 8.414.500.000 + Rp. 16.588.906.266
= Rp. 25.003.406.266

From the results of economic calculations of costs on the Teuku Umar Road - Rajawali Road Preservation project, which is a type of Collector road clarification, it shows that the selection of alternative construction types based on the calculation of Capitalized Cost with scenarios on routine and periodic maintenance costs with updated bank interest rates i = 6% shows the following results:

Rigid Pavement = Rp. 24.711.748.066
Flexible Pavement = Rp. 25.003.406.266
Difference = Rp. 291.658.200
Difference (%) = 1,18 %

From the results of the above calculations, it shows that Rigid Pavement in terms of cost is smaller than Flexible Pavement, so the Rigid Pavement alternative is chosen.

4. Conclusion

The results of the analysis of the calculation of the Cost Budget Plan on Rigid Pavement amounted to Rp. 11,349,200,000 and required 120 calendar days of work while the results of the analysis of the calculation of the Cost Budget Plan on Flexible Pavement amounted to Rp. 8,414,500,000 and required 95 calendar days of work. The results of the calculation of the selection of a more efficient alternative based on the calculation of Capitalized Cost with a scenario of routine and periodic maintenance costs with the latest bank interest rate of 6% and a 20-year plan life show the following results: Rigid Pavement of Rp. 24,711,748,066, Flexible Pavement of Rp. 25,003,406,266, with a difference of 1.18%.

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