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Cost and Time Comparison Research Between Rigid Pavement And Flexible Pavement on the Temuireng-Jetis Road Section, Mojokerto District

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ABSTRACT

Road infrastructure plays a critical role in supporting economic and social development, particularly in developing regions such as Mojokerto Regency. The development of roads not only enhances community mobility but also facilitates the efficient flow of goods and services. This research aims to compare the cost and construction time of rigid and flexible pavement on the Temuireng-Jetis road section in Mojokerto District. The research uses a comparative analysis approach, examining construction specifications, budget plans, and project timelines. The results indicate that rigid pavement, with an estimated cost of IDR 3,202,246,813, is more cost-efficient compared to flexible pavement, which costs IDR 4,667,881,104. Additionally, rigid pavement construction takes 119 days with 25 workers per day, while flexible pavement has a shorter timeline but higher long-term maintenance costs. This research highlights the importance of selecting the appropriate pavement type based on both initial costs and long-term efficiency. The findings provide valuable insights for policymakers and planners in Mojokerto Regency, emphasizing the need for careful consideration of material selection, maintenance, and cost efficiency in road infrastructure development. Future research should explore environmental impacts and the integration of modern computational tools to further optimize pavement design and decision-making.

Keywords: Cost Budget Plan, Jeti-Temuireng, Rigid Pavement, Soft Pavement.

INTRODUCTION

Road development plays a vital role in driving economic growth, especially in developing regions. The existence of proper roads not only improves community mobility, but also accelerates the flow of distribution of goods and services, which has a direct impact on economic and social activities. Research shows that good quality road infrastructure can improve the welfare and productivity of a region (Kusumastuti et al., 2021). Mojokerto Regency, with its varied topography and geography, needs road infrastructure to connect various areas, so that social and economic activities can take place without obstacles. Adequate roads also provide people with easy access to facilities such as schools, health services, and other public services, which in turn support the improvement of residents' quality of life (Rahardjo et al., 2019).

Cost management is an integral process in ensuring project success by effectively controlling and managing costs. It starts from the early stages of the project, where budgets are planned and set based on well-thought-out estimates. At this stage, various cost components such as labor, materials, and equipment are analyzed to ensure a realistic budget. Good cost management enables the project to achieve the expected results without exceeding the set budget. The cost management process involves several important steps, including budget planning, cost estimation, and allocating budgets to individual project elements. Cost estimation is a crucial aspect of project management, as accurate estimates help prevent potential overspending. The estimation methods used may vary, such as rough estimates in the early stages and more detailed estimates in the final planning stages. The results of these estimates are then used as the basis for creating an accurate project budget (Maharani & Wasono, 2018).

Monitoring and controlling costs is a core part of cost management. During the course of a project, the project manager must continuously monitor actual expenditures and compare them with the established budget. One of the commonly used tools in this monitoring is Earned Value Management (EVM) analysis, which helps in evaluating project performance based on cost and schedule (Forth & Lock, 2020). Good cost management plays an important role in maintaining project viability without exceeding budget limits, and at the same time ensuring quality is not compromised. By applying structured cost management techniques, project teams can optimize the use of resources and achieve project goals with high efficiency (Walker, 2015).

Time management is the process of planning, organizing, and controlling time to ensure that the project runs according to a predetermined schedule. The main stages in time management include schedule planning, determining activity durations, and allocating resources to each task. By managing time effectively, projects can be completed on target without significant delays (PMI, 2021). The schedule planning process begins with the identification and sequencing of project activities. In this stage, tools such as network diagrams or Gantt charts are often used to sort activities based on their dependencies. The use of the Critical Path method also helps determine which activities require higher priority to keep the project on schedule (Kerzner & Saladis, 2017).

Allocating resources in time management is important to ensure that each task has an adequate amount of time to be completed with the desired quality (Wahjono, 2022). This resource management includes scheduling labor, materials, and equipment, so that there is no buildup or lack of resources that can cause delays. Schedule monitoring and control is carried out continuously to ensure that the project remains on track. Any deviations that occur are immediately identified and corrective action can be taken so that the project does not exceed the predetermined time. One of the tools used for monitoring is Earned Value Management (EVM), which helps measure progress based on the time and budget that has been used (Kamil et al., 2023).

The relationship between cost and time in project management is very close, as both directly affect the success of the project. When the project runs on schedule, costs can be kept within budget. However, if there are delays, project costs tend to increase due to the addition of resources, such as additional labor and materials, to complete the work on time. Good control between the two helps maintain project effectiveness and efficiency (Forth & Lock, 2020). Determining this relationship is important for establishing trade-offs between accelerating completion or squeezing the budget. For example, if the project takes less time, the project manager may have to allocate additional resources, which increases costs. Methods such as Crash Analysis help identify the additional costs of accelerating critical activities in the project without sacrificing quality (Forth & Lock, 2020).

Cost and time play an important role in determining the most efficient pavement type for a given project, particularly in the context of rigid (concrete) and flexible (asphalt) pavements. Rigid pavement is a type of pavement that uses concrete as its main material, provides high structural durability and is suitable for withstanding heavy traffic loads. Compared to flexible pavements, rigid pavements have a higher modulus of elasticity, allowing for a more even load distribution to the subgrade. This makes it ideal for roads with heavy vehicle intensity, such as highways, intersections, and industrial areas. Meanwhile, Flexural pavement is a type of pavement that uses a layer of asphalt to spread the traffic load to the subgrade. Flexural pavement is flexible, which allows it to conform to small 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 (Sutapa et al., 2022).

Cost and time management is very important because rigid pavements (concrete) and flexible pavements (asphalt) have different structures and characteristics. Rigid pavements have high initial construction costs and take longer to install and cure, but generally have a longer service life and lower maintenance costs. Meanwhile, flexible pavements have lower initial costs and shorter construction times, making them more suitable for projects with limited budgets and quick turnaround needs (Mamlouk & Zaniewski, 2014); (Das et al., 2016).

The difference in construction time between these two types of pavements affects both short-term and long-term costs. Rigid pavements, although more expensive upfront, can reduce total project costs in the long run because they require less frequent maintenance. In contrast, more flexible pavements require periodic repairs and overlays to maintain road quality, which increases maintenance costs (Qiao, 2015). From a time perspective, projects that require quick completion may be better suited to flexible pavements, especially if the budget does not cover the cost of rigid pavements. However, flexible pavements can deform faster on roads with heavy traffic, requiring attention to the timing of maintenance to maintain traffic efficiency.

Road infrastructure development is one of the vital elements in promoting economic growth and quality of life (Awainah et al., 2024). Good roads are essential to improve the smooth flow of transportation, facilitate the distribution of goods and services, and increase population accessibility. Mojokerto Regency, as one of the growing regions, requires road planning that not only meets technical standards but is also economical. Some city and district governments often use asphalt pavement, which has a limited service life and requires intensive maintenance. The cost of maintaining asphalt roads can be very high, especially in areas with extreme weather conditions or heavy traffic loads. The use of concrete pavements can be an alternative and has several advantages of a longer planned life, lower maintenance costs, and construction that is more resistant to heavy loads. However, concrete roads are often perceived as more expensive than asphalt roads at the initial construction stage. Therefore, careful planning is required to ensure that the construction of concrete roads can be done economically without compromising on quality and durability. This involves various aspects, including material selection, structural design, and efficient construction methods.

Based on the above background, the purpose of this research is to analyze the comparison between the use of rigid (concrete) and flexible (asphalt) pavements in the construction of road infrastructure in Mojokerto Regency, taking into account the factors of construction cost and time as well as the impact on road maintenance efficiency. The benefit of this research is that it provides insights for planners and policy makers in Mojokerto Regency on how to plan and choose the right type of pavement according to road construction and maintenance needs. This research is expected to help reduce long-term road maintenance costs and increase time efficiency in the construction process, which in turn supports local economic growth by providing better and sustainable transportation infrastructure.

RESEARCH METHOD

Research Location

Location is one of the important aspects that must be considered to get the data that is needed. The selection of the right location greatly influences the success of the research. Therefore, determining the location needs to be done by considering various relevant factors. In this research, the location chosen was on the Temuireng - Jetis road section. The road section is considered suitable to support data collection. This area is included in the administrative area of Mojokerto Regency.

Figure 1. Research Location of Temuireng - Jetis Road Section

Data

The data in this research includes two data, namely primary and secondary data. The following is an explanation of the two data in this research.

a. Primary Data

Primary data is information collected directly by researchers from the project site with the aim of obtaining specific and visual data. In this research, primary data collection was carried out directly by the author on the Temuireng - Jetis road section. Because the data is obtained directly from the first source, it is expected that the results are more accurate, relevant, and in accordance with the problems studied in the research. Primary data obtained include:

1) Data type : LHR (Average Daily Traffic)
2) Analysis Function : Knowing the number / volume of passing vehicles
3) Data type : Photo Documentation.
4) Analysis Function : Knowing the state of the environment directly / visually

b. Secondary Data

Secondary data is information obtained indirectly, usually through related agencies, to obtain data in the form of planning reports. This data is useful in assisting research planning, simplifying the problem formulation process, and supporting analysis. The following secondary data was collected:

1) Data type : DCP (Dynamic Cone Penetrometer) Per 100 m
Analysis Function : Knowing the Existing Soil Parameters
Source : Mojokerto District PUPR Office
2) Data type : Topographic Data & Road Section Map
Analysis Function : Knowing the environmental conditions and slope of the soil at the site in order to plan pavement leveling.
Source : Mojokerto District PUPR Office

Comparison of Cost and Implementation Time

The researcher compared the pavement thickness in terms of ease/speed of implementation through type and pavement analysis on the Temuireng - Jetis road section, Mojokerto Regency. Then at the final stage, the two types of pavement that have passed the analysis, began to calculate the cost budget, so that they can be compared to determine the type of pavement that can be implemented and economical.

RESULT AND DISCUSSION

Rigid Pavement Budget Plan

Based on the calculations and analysis that has been done, for the use of Rigid Pavement with a length of 655 m amounting to Rp 3,202,246,813 (Three billion two hundred two million two hundred sixty-six thousand eight hundred thirteen rupiah), as for the details of the budget plan for the use of rigid pavement can be seen in Table 1.

Table 1. Rigid Pavement Cost Budget Details

No	Type of Work	Analysis Code	Volume	SAT	Unit Price (Rp.)	Unit Price + Tax (Rp.)	Total
I	**PRELIMINARY WORK**						
1	PJU Pole Removal	-	1.00	Mast	1,250,000.00	1,387,500.00	1,387,500.00
2	PLN SUTR Pole Removal	-	4.00	Mast	3,500,000.00	3,885,000.00	15,540,000.00
3	Mobilization and Demobilization	-	3.00	Unit	3,500,000.00	3,885,000.00	11,655,000.00
4	Site Clearance	-	1.00	ls	131,000.00	145,410.00	145,410.00
5	Implementation of Construction Safety Management System (Budget 2)	-	1.00	pek	9,813,884.97	10,893,412.31	10,893,412.31
							39,621,322.31
II	**EARTHWORKS**						
1	Ordinary Excavation Including Disposal of Excavation Waste	El-311a	7.00	m3	369,282.63	41,050.72	287,355.01
2	Ordinary Backfill (Berm) + Compaction	El-321a	170.00	m3	150,380.71	166,922.59	28,376,840.79
							28,664,195.80
III	**CONCRETE PAVEMENT**						

No	Type of Work	Analysis Code	Volume	SAT	Unit Price (Rp.)	Unit Price + Tax (Rp.)	Total
1	Cement Treated Base (CTB)	El-551	502.00	m3	754,921.33	837,962.67	420,657,261.69
2	Polythene Plastic Installation	El-361	5306.00	m2	2,933.33	3,256.00	17,276,336.00
3	Reinforcing Iron Dowel Support	B.17.a1.2	3298.00	Kg	2,691,490.00	29,875.54	98,529,527.62
4	Dowel Iron	B.17.a1.1	15648.00	Kg	22,220.00	24,664.20	385,945,401.60
5	Iron Painting	A.4.7.1.16a	249.00	m2	40,875.00	45,371.25	11,297,441.25
6	Iron Tie Bar	B.17.a2.1	1240.00	kg	21,350.00	23,698.50	29,386,140.00
7	Concrete Fs = 40Kg/CM2	7.1(1)b	1312.00	m3	1,447,715.95	1,606,964.70	2,108,337,689.90
8	Groving work	A.4.1.2.22	5306.00	m2	833.33	925.00	4,098,050.00
9	Concrete Cutting Work	A.4.1.2.22	1951.00	m	6,069.30	6,736.92	13,143,726.46
10	Joint Sealant	A.4.1.2.22	487.00	Liters	82,283.00	82,283.00	44,479,721.31
							3,133,151,295.83
Numbered Four Billion Three Hundred Seventy Eight Million Eight Hundred Thousand Nine Hundred Forty Three Rupiahs				Physical Quantity			3,202,246,813.94
				Total			3,202,246,813.94
				Rounded			3,202,246,813.00

Rigid Pavement Implementation Time

The implementation time in this research only discusses the construction time of the implementation of work Comparison of Rigid Pavement and Flexible Pavement in Terms of Cost and Time of work from the Department of Public Works and Spatial Planning of Mojokerto Regency, East Java Province. Rigid pavement work time can be seen in table 2.

Table 2. Rigid Pavement Work Time

No	Type of Work	Analysis Code	Volume	SAT	Koefting	Worker Requirement (Person/Day)	Number of Workers (Person)	Total Time (Days)	Total Time (Weeks)
I	**PRELIMINARY WORK**								
1	PJU Pole Removal	-	1.00	Mast				1.00	0.17
2	PLN SUTR Pole Removal	-	4.00	Mast				1.00	0.17
3	Mobilization and Demobilization	-	3.00	Unit				3.00	0.50
4	Site Clearance	-	1.00	Is				2.00	0.33
5	Implementation of Construction Safety Management System (Budget 2)	-	1.00	pek				1.00	0.17
II	**EARTHWORKS**								

No	Type of Work	Analysis Code	Volume	SAT	Koefting	Worker Requirement (Person/Day)	Number of Workers (Person)	Total Time (Days)	Total Time (Weeks)
1	Ordinary Excavation Including Disposal of Excavation Waste	El-311a	7.00	m3	0	-	25	-	-
2	Ordinary Backfill (Berm) + Compaction	El-321a	170.00	m3	0.04	6	25	0.24	0.04
III	**CONCRETE PAVEMENT**								
1	Cement Treated Base (CTB)	El-551	502.00	m3	1.13	569	25	22.75	3.79
2	Polythene Plastic Installation	El-361	5306.00	m2	0.01	35	25	1.41	0.24
3	Reinforcing Iron Dowel Support	B.17.a1.2	3298.00	Kg	0.02	51	25	2.03	0.23
4	Dowel Iron	B.17.a1.1	15648.00	Kg	0.02	241	25	9.64	1.61
5	Iron Painting	A.4.7.1.16a	249.00	m2	0.24	60	25	2.42	0.40
6	Iron Tie Bar	B.17.a2.1	1240.00	kg	0.02	19	25	0.76	0.13
7	Concrete Fs = 40Kg/CM2	7.1(1)b	1312.00	m3	1.13	1,486	25	59.45	9.91
8	Groving work	A.4.1.2.22	5306.00	m2	0.01	35	25	1.41	0.24
9	Concrete Cutting Work	A.4.1.2.22	1951.00	m	0.01	29	25	1.17	0.19
10	Joint Sealant	A.4.1.2.22	487.00	Liters	0.48	233	25	9.31	1.55
							AMOUNT	119.00	20

Rigid Pavement Work

Based on the calculations and analysis that has been done, for the use of Rigid Pavement with a length of 655 m amounting to Rp 3,202,246,813 (Three billion two hundred two million two hundred and sixty-six thousand eight hundred and thirteen rupiah), if carried out with workers 25 workers / day can be implemented with a time of 119 days or 20 weeks.

Flexural Pavement Budget Plan

Based on the calculations and analysis that has been done, for the use of Flexural Pavement with a length of 655 m amounting to Rp 4,667,881,104 (Four billion six hundred sixty seven million eight hundred eighty-one thousand one hundred and four rupiah), while the details of the concrete pavement construction cost budget plan can be seen in Table 3.

Table 3. Flexural Pavement Cost Budget Details

No	Type of Work	Analysis Code	Volume	SAT	Unit Price (Rp.)	Unit Price + Tax (Rp.)	Total
I	**PRELIMINARY WORK**						
1	PJU Pole Removal	-	1.00	Mast	1,250,000.00	1,387,500.00	1,387,500.00

No	Type of Work	Analysis Code	Volume	SAT	Unit Price (Rp.)	Unit Price + Tax (Rp.)	Total
2	PLN SUTR Pole Removal	-	4.00	Mast	3,500,000.00	3,885,000.00	15,540,000.00
3	Mobilization and Demobilization	-	3.00	Unit	3,500,000.00	3,885,000.00	11,655,000.00
4	Site Clearance	-	1.00	ls	131,000.00	145,410.00	145,410.00
5	Implementation of Construction Safety Management System (Budget 2)	-	1.00	pek	9,813,884.97	10,893,412.31	10,893,412.31
							39,621,322.31
II	**EARTHWORKS**						
1	Ordinary Excavation Including Disposal of Excavation Waste	El-311a	1310.00	m3	36,982.63	41,050.72	53,776,436.96
2	Ordinary Backfill (Berm) + Compaction	El-321a	130.00	m3	150,380.71	166,922.59	21,699,937.07
							75,476,374.03
III	**ASPHALT PAVEMENT**						
1	Class A Aggregate Foundation Layer	El-551	766.00	m3	352,359.92	931,119.51	299,597,545.08
2	Cement Treated Base (CTB)	El-551	766.00	m2	754,921.33	837,962.67	641,879,407.28
3	Resorbent Coating - Liquid Asphalt	El-611	4454.00	liter	14,710.91	16,329.11	72,729,842.63
4	Adhesive Layer - Liquid Asphalt	El-612	2096.00	liter	15,535.93	17,244.88	36,145,270.92
5	Leveling Wear Layer Laston (AC-WC)	EL-635b	440.00	tons	1,357,323.07	1,506,628.61	662,916,589.54
6	Laston Layer Between Levelers (AC-BC) Leveling	El-636b	1844.00	tons	1,387,267.57	1,539,867.00	2,839,514,752.98
							4,552,783,408.43
Amount: Four Billion Three Hundred Seventy Eight Million Eight Hundred Thousand Nine Hundred Forty Three Rupiahs				Physical Quantity			4,667,881,104.77
				Total			4,667,881,104.77
				Rounded			4,667,881,104.00

Flexural Pavement Implementation Time

The time of implementation in this research only discusses the construction time of the implementation of work Comparison of Concrete Pavement and Asphalt Pavement in Terms of

Cost and Time of work from the Public Works and Spatial Planning Office of Mojokerto Regency, East Java Province.

Table 4. Flexural Pavement Work Time

No	Type of Work	Analysis Code	Volume	SAT	Koefting	Worker Requirement (Person/Day)	Number of Workers (Person)	Total Time (Days)	Total Time (Weeks)
I	**PRELIMINARY WORK**								
1	PJU Pole Removal	-	1.00	Mast				1.00	0.17
2	PLN SUTR Pole Removal	-	4.00	Mast				1.00	0.17
3	Mobilization and Demobilization	-	3.00	Unit				3.00	0.50
4	Site Clearance	-	1.00	ls				2.00	0.33
5	Implementation of Construction Safety Management System (Budget 2)	-	1.00	pek				1.00	0.17
II	**EARTHWORKS**								
1	Ordinary Excavation Including Disposal of Excavation Waste	El-311a	7.00	m3	0.00	5	5	0.97	0.16
2	Ordinary Backfill (Berm) + Compaction	El-321a	170.00	m3	0.04	5	5	0.93	0.15
III	**CONCRETE PAVEMENT**								
1	Class A Aggregate Foundation Layer	El-551	766.00	m3	0.01	8	5	1.51	0.25
2	Cement Treated Base (CTB)	El-551	766.00	m2	0.22	165	5	31.95	5.49
3	Resorbent Coating - Liquid Asphalt	El-611	4454.00	liter	0.00	2	5	0.32	0.05
4	Adhesive Layer - Liquid Asphalt	El-612	2096.00	liter	0.00	1		0.15	0.02
5	Leveling Wear Layer Laston (AC-WC)	EL-635b	440.00	tons	0.03	14	5	2.78	0.46

No	Type of Work	Analysis Code	Volume	SAT	Koefting	Worker Requirement (Person/Day)	Number of Workers (Person)	Total Time (Days)	Total Time (Weeks)
6	Laston Layer Between Levelers (AC-BC) Leveling	El-636b	1844.00	tons	0.06	115	5	22.97	3.83
							AMOUNT	70.57	11.76

Rigid Pavement Work

Based on the calculations and analysis that has been done, for the use of Rigid Pavement with a length of 655 m amounting to Rp 4,667,881,104 (Four billion six hundred sixty seven million eight hundred eighty-one thousand one hundred and four rupiah), if carried out with workers 5 workers / day can be implemented with a time of 71 days or 12 weeks.

Discussion

This research provides a comparative analysis of rigid and flexible pavement designs for the Jetis-Temuireng road section in Mojokerto Regency, focusing on construction specifications, costs, and implementation timelines. The findings reveal significant differences between the two pavement types, offering valuable insights into their respective advantages and limitations. Regarding the first research question, the specifications for rigid pavement include a concrete pavement thickness of 25 cm and a Cement Treated Base (CTB) layer with a thickness of 10 cm, both designed to withstand heavy traffic loads over an extended lifespan. In contrast, the flexible pavement design includes a Class A aggregate foundation layer with a thickness of 15 cm, an upper foundation layer of CTB measuring 15 cm, an Asphalt Concrete Binder Course (AC-BC) of 16 cm, and a Laston Wear Layer (AC-WC) of 4 cm. These specifications highlight the structural differences between the two designs, with rigid pavement offering higher durability and load distribution capabilities, while flexible pavement provides adaptability to subgrade variations.

In addressing the second research question, the cost analysis indicates that the construction cost for rigid pavement is Rp3,202,246,813, significantly lower than the flexible pavement cost of Rp4,667,881,104. This aligns with previous studies that have indicated that rigid pavements, although more expensive in initial construction, typically offer lower maintenance costs over their lifecycle (Syarif et al., 2024). Additionally, rigid pavement requires 119 days for implementation, with a workforce of 25 people per day, reflecting its longer construction timeline compared to flexible pavement, which is completed in a shorter period. This aspect has been observed in several studies, including those by (Qiao, 2015), which noted that while flexible pavements may have a faster construction timeline, their long-term costs due to frequent maintenance are higher.

These findings suggest that rigid pavement is more suitable for high-traffic areas requiring long-term efficiency and minimal maintenance, as it offers better value over its lifetime despite the higher initial investment. However, flexible pavement may be advantageous in projects with limited budgets or where rapid construction is essential, particularly in less trafficked or temporary routes (Fawcett et al., 2015). Future studies should explore not only the environmental impacts of these pavements but also lifecycle costs, including the potential for using sustainable materials such as recycled asphalt or alternative cementitious materials, to provide a more comprehensive understanding of the long-term economic and environmental implications of each pavement type.

CONCLUSION

The conclusion of this research shows that the construction cost of rigid pavement on the Jetis-Temuireng road section (655 m) in Mojokerto Regency is IDR 3,202,246,813, while the cost of flexible pavement reaches IDR 4,667,881,104, which shows that rigid pavement is more economical. The construction duration for rigid pavement with 25 workers per day is estimated to take 119 days. This research highlights the cost efficiency of rigid pavement, but does not consider other important factors such as user comfort, environmental impact, and long-term maintenance. Further research is expected to explore these aspects and integrate modern computational tools, such as AI-based simulations, to improve the accuracy of pavement design and decision-making processes in the future.

REFERENCES

Awainah, N., Sulfiana, S., Nurhaedah, N., Jamaluddin, J., & Aminullah, A. (2024). Peran Infrastruktur Dalam Mendorong Pertumbuhan Ekonomi Dan Peningkatan Kualitas Hidup Masyarakat. *Jurnal Review Pendidikan Dan Pengajaran (JRPP)*, *7*(3), 6847–6854. https://doi.org/10.31004/jrpp.v7i3.29285

Das, S., Forer, L., Schönherr, S., Sidore, C., Locke, A. E., Kwong, A., Vrieze, S. I., Chew, E. Y., Levy, S., & McGue, M. (2016). Next-generation genotype imputation service and methods. *Nature Genetics*, *48*(10), 1284–1287. https://doi.org/10.1038/ng.3656

Fawcett, W., Urquijo, I. R., Krieg, H., Hughes, M., Mikalsen, L., & Gutiérrez, Ó. R. R. (2015). Cost and environmental evaluation of flexible strategies for a highway construction project under traffic growth uncertainty. *Journal of Infrastructure Systems*, *21*(3), 5014006. https://doi.org/10.1061/(ASCE)IS.1943-555X.000023

Forth, S., & Lock, D. (2020). *The Practitioner Handbook of Project Controls*. Taylor & Francis.

Kamil, F., Setiawan, A., & Purnomo, J. (2023). Perencanaan Perkerasan Kaku (Rigid Pavement) pada Kerusakan Jalan Wolter Monginsidi. *Dinamika Teknik Sipil: Majalah Ilmiah Teknik Sipil*, *16*(1), 28–36. DOI: 10.23917/dts.v16i1.21404

Kerzner, H., & Saladis, F. P. (2017). *Project management workbook and PMP/CAPM exam research guide*. John Wiley & Sons.

Kusumastuti, K., Miladan, N., Istanabi, T., Suminar, L., Yudana, G., Aliyah, I., Soedwiwahjono, S., Pamardhi-Utomo, R., Werdiningtyas, R., & Putra, R. P. (2021). Peran Kelompok Swadaya Masyarakat Dalam Mewujudkan Penataan Kampung Yang Berkelanjutan (Studi Kasus: Kampung Ngemplak, Jebres, Kota Surakarta). *Desa-Kota: Jurnal Perencanaan Wilayah,* *Kota, Dan Permukiman*, *3*(2), 171–178.

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), 89–94.

Mamlouk, M. S., & Zaniewski, J. P. (2014). *Materials for civil and construction engineers*. Pearson London, UK:

Qiao, Y. (2015). *Flexible pavements and climate change: impact of climate change on the performance, maintenance, and life-cycle costs of flexible pavements*. University of Nottingham.

Rahardjo, H., Kim, Y., & Satyanaga, A. (2019). Role of unsaturated soil mechanics in geotechnical engineering. *International Journal of Geo-Engineering*, *10*, 1–23.

Sutapa, I. K., Wirahaji, I. B., & Ariadi, I. M. G. (2022). Analisis Perbandingan Perkerasan Kaku dan Perkerasan Lentur Pada Proyek Peningkatan Jalan Celukan Bawang-Pelabuhan. *Reinforcement Review in Civil Engineering Studies and Management*, *1*(1), 36–49. https://doi.org/10.38043/reinforcement.v1i1.4099

Syarif, M., Ahmad, S. N., Utomo, P. K., Purnama, H., Sari, D. P., Bachtiar, E., Isdyanto, A., Londongsalu, J., Aryadi, A., & Herlambang, A. R. (2024). *Material Konstruksi*. TOHAR MEDIA.

Wahjono, S. I. (2022). *Manajemen dan peran manajer*. Bahan Ajar Manajemen. Penerbit: ResearchGate. https://www. researchgate. net

Walker, A. (2015). *Project management in construction*. John Wiley & Sons.