International Journal of Engineering and Science Applications

ISSN 2406-9833
Journal Homepage: http://pasca.unhas.ac.id/ijesca
Vol. 13, No. 1, May., 2026., pp 38 - 41

Evaluation of The Impact of Concrete Median on Surface Drainage and Flexible Pavement Performance on The Paguyaman–Tabulo Road Section (Shortcut III Lahumbo)

Eszra Sule Mangasik[1], Hendrie Juodi Palar[2*], Adriana Karundeng[3]

[1,2,3] Civil Engineering Department, Manado State Polytechnic, Manado, Indonesia

*Corresponding Author Email: hendripalar@yahoo.com

https://doi.org/10.18280/ijesca.123456

Received: 25 January 2026
Accepted: 18 April 2026

Keywords: *concrete median, surface drainage system, surface runoff, water ponding, flexible pavement performance*

ABSTRACT

This study aims to evaluate the impact of concrete medians on surface drainage and flexible pavement performance on the Paguyaman–Tabulo road section (Shortcut III Lahumbo). The analysis was conducted using the Kirpich method for time of concentration, the Mononobe method for rainfall intensity, the rational method for runoff discharge, and Manning's equation for drainage capacity. The results indicate that the runoff discharge exceeds the drainage capacity, potentially causing ponding, particularly around the concrete median, which is impermeable and obstructs flow distribution. However, the pavement performance evaluation using the Pavement Condition Index (PCI) method shows an excellent condition (PCI = 100) with no damage. Therefore, although there is a potential for ponding, it has not yet had a direct impact on pavement performance, but may reduce the service life in the future.

1. INTRODUCTION

The road surface is a critical component of the transportation system that supports mobility and ensures road user safety. The presence of a concrete median as a traffic separator plays a strategic role; however, its impermeable nature can alter runoff flow patterns and reduce the effectiveness of the surface drainage system. This condition may lead to water ponding and accelerate the deterioration of flexible pavement performance if not properly managed [1]. A common issue observed is the obstruction of water flow around the median, which increases surface runoff volume and the risk of pavement damage. Previous studies have shown that drainage is a key factor in maintaining road performance [2]. Therefore, this study aims to evaluate the effect of concrete medians on surface drainage and flexible pavement performance on the Paguyaman–Tabulo road section (Shortcut III Lahumbo) in order to provide optimal technical recommendations for median design on the studied roadway.

2. LITERATURE REVIEW

This theory explains how the characteristics of a surface influence both the volume and velocity of rainfall-induced runoff. The runoff coefficient is a key parameter that distinguishes the infiltration capacity of different surface types. Impervious surfaces such as concrete exhibit runoff coefficients approaching 1.0, indicating that nearly all precipitation is converted into surface runoff [3]. In the context of road infrastructure, a concrete median functions as a runoff-collecting surface that directs water toward the adjacent pavement. When the drainage system is unable to accommodate this additional runoff volume, surface ponding occurs, which becomes an entry point for structural deterioration in flexible pavements. Supporting studies reinforce this concept [4]. demonstrated that concrete surfaces possess high runoff coefficients, thereby increasing runoff volume and the risk of ponding in urban roads [5]. found that inadequate drainage channel capacity contributes to increased runoff and ponding, which directly correlates with a decline in

Pavement Condition Index (PCI) values. The presence of a concrete median has a significant effect on increasing surface runoff volume directed toward flexible pavement in the studied road segment. This theory states that water is the most destructive environmental factor affecting flexible pavements. When water infiltrates the base and subgrade layers, it significantly reduces the resilient modulus of the subgrade, increases tensile strain within the asphalt layer, and accelerates fatigue failure [6]. This degradation process is non-linear. Prolonged water saturation produces cumulative effects such as pumping, loss of structural support, and increased pore water pressure, ultimately shortening the service life of the pavement well below its initial design life [7]. demonstrated that inadequate drainage can reduce pavement service life by up to 50%.

Recent studies further support this theory [8]. confirmed that prolonged water ponding decreases pavement layer modulus and accelerates fatigue cracking [9]. identified a significant relationship between poor drainage conditions and increased cracking and surface deformation [10]. also found that premature failures in flexible pavements are strongly associated with high moisture levels and inadequate drainage systems.

There is a significant negative correlation between the performance of the drainage system around the concrete median and the condition of flexible pavement as measured by the Pavement Condition Index (PCI) - the poorer the drainage performance, the lower the PCI value. The following is the conceptual framework of this study as shown in Figure 1.

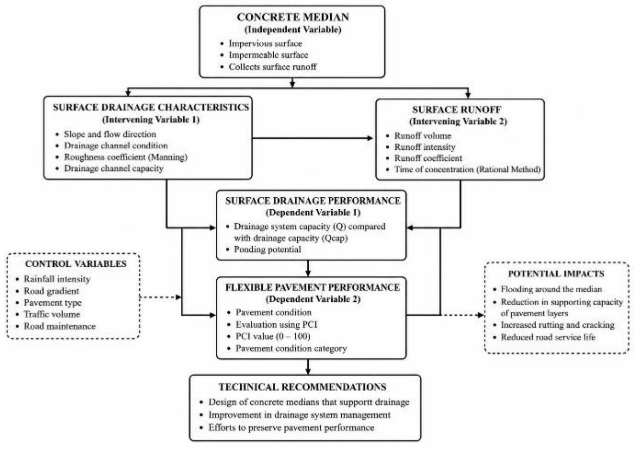


Figure 1. Conceptual framework

3. METHODOLOGY

This study employs a quantitative approach using a descriptive-analytical method to evaluate the impact of concrete medians on surface drainage and flexible pavement performance along the Paguyaman–Tabulo road section (Shortcut III Lahumbo). Data collection was conducted through field surveys (primary data), including measurements of drainage channel dimensions, median conditions, and pavement evaluation. Secondary data were obtained from rainfall records published in *Gorontalo Province in Figures* by the Central Bureau of Statistics (BPS) and from the Djalaluddin Meteorological Station (BMKG). Data analysis was performed by calculating the time of concentration using the Kirpich formula, rainfall intensity using the Mononobe method, runoff discharge using the Rational method, and channel capacity using Manning's equation. Pavement performance was evaluated using the Pavement Condition Index (PCI) method.

4. RESULT AND DISCUSSION

Table 1. Monthly Rainfall Data (mm) of Gorontalo Province, 2012–2021

Year	Total Rainfall (mm)	Monthly Average (mm)	Category
2012	1520.4	126.7	Normal
2013	1649.8	137.5	Normal
2014	1092.3	91.0	Moderately Dry
2015	844.9	70.4	Very Dry (El Niño)
2016	1721.0	174.0	Wet (La Niña)
2017	1803.0	150.3	Wet
2018	1625.0	135.4	Normal
2019	1102.0	91.8	Moderately Dry
2020	1485.0	123.8	Normal
2021	1713.9	142.8	Moderately Wet

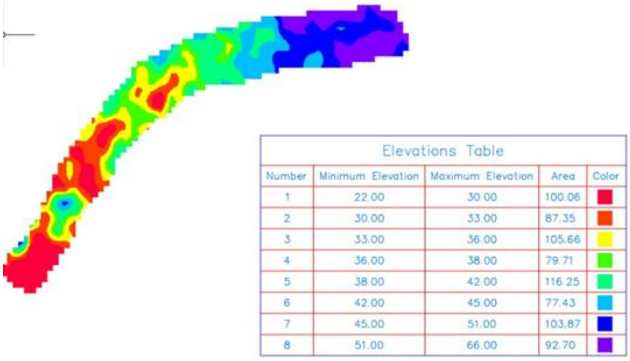
Based on Table 1, which presents rainfall data over the past ten years, the year 2016 was selected as the wettest year, having the highest rainfall, particularly with an average of 174 mm (very wet). This year was therefore used as the basis for calculating runoff discharge (Q).

4.1 Surface Drainage Analysis

This surface drainage analysis aims to evaluate the capacity of surface drainage along the road segment due to the presence of a concrete median, which is impermeable and increases rainfall runoff onto the pavement surface, thereby altering the surface drainage pattern.

4.2 Runoff Discharge Analysis

Table 2. Catchment area



Elevations Table				
Number	Minimum Elevation	Maximum Elevation	Area	Color
1	22.00	30.00	100.06	🟥
2	30.00	33.00	87.35	🟧
3	33.00	36.00	105.66	🟨
4	36.00	38.00	79.71	🟩
5	38.00	42.00	116.25	🟩
6	42.00	45.00	77.43	🟦
7	45.00	51.00	103.87	🟦
8	51.00	66.00	92.70	🟪

Based on the location map and the catchment area calculations obtained from Civil 3D, the total catchment area is determined to be 1.1625 km². The runoff discharge analysis is calculated using the Rational Method with the following formula:

(Equation 1)

Where:

Q = runoff discharge (m³/s)

C = runoff coefficient (0.10–0.30 for grass/park areas)

I = rainfall intensity (mm/hour)

A = catchment area (ha)

R(24) = maximum daily rainfall data (based on the 2016 rainfall data table, where the maximum rainfall reached 174 mm, representing a very wet month used for runoff discharge calculation)

t(c) = rainfall duration or time of concentration (hours)

The time of concentration is calculated using the Kirpich formula:

$$t_c = 0.0195 \cdot L^{0.77} \cdot S^{-0.385}$$

(Equation 2)

Given:

Flow length (L) = 9.5 m

Slope (S) = 0.02

$$t_c = 0.0195 \times (9.5)^{0.77} \times (0.02)^{-0.385}$$

$$t_c = 0.0195 \times 5.66 \times 4.51$$

$$t_c = 0.501 \text{ minutes}$$

Conversion to hours:

$$t_c = \frac{0.501}{60} = 0.0083 \text{ hours}$$

Rainfall intensity (I) can be calculated using the Mononobe formula:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{2/3} \text{ (mm/hour)}$$

(Equation 3)

$$I = \frac{174}{24}\left(\frac{24}{0.0083}\right)^{2/3}$$
$$I = 7.25 \times (2891)^{2/3}$$
$$I = 7.25 \times 203$$
$$I = 1472 \text{ mm/hour}$$

Catchment area (A) = 116.25 ha = 1.1625 km²
Thus:

$$Q = 0.00278 \cdot C \cdot I \cdot A$$
$$Q = 0.00278 \cdot 0.20 \cdot 1472 \cdot 1.1625$$
$$Q = 0.951 \text{ m}^3/\text{s}$$

4.3 Drainage Channel Capacity Evaluation

The channel capacity is analysed using Manning's equation:

$$Q = \frac{1}{n} \cdot A \cdot R^{\frac{2}{3}} \cdot S^{\frac{1}{2}} \text{ (Equation IV)}$$

With the following assumptions:

Manning's coefficient (n) = 0.015 (concrete channel, according to SNI 03-3424-1994)
Cross-sectional area (A) = 0.30 m²
Hydraulic radius (R) = 0.20 m
Channel slope (S) = 0.002

Thus:

$$Q = \frac{1}{0.015} \times 0.30 \times (0.20)^{2/3} \times (0.002)^{1/2}$$
$$Q = 0.28 \text{ m}^3/\text{s}$$

Discharge Comparison

1. Runoff discharge (Qrain) = 0.951 m³/s
2. Channel capacity (Qchannel) = 0.28 m³/s

Based on the calculation results above, it can be concluded that the runoff discharge (Qrain) > is greater than or equal to the channel capacity (Qchannel).

4.4 Effect of Concrete Median on Runoff

The implementation of a concrete median along the road segment significantly influences surface runoff behaviour within the drainage system. Due to its impermeable nature, the concrete median increases the volume of runoff directed onto the pavement surface. This condition leads to an increase in localized discharge that must be accommodated by the surface drainage system. Consequently, when the drainage capacity is insufficient, water ponding may occur along the median and on the road surface.

4.5 Field Ponding Evaluation

Figure 2. Surface ponding on flexible pavement

Based on direct field observations, the researcher identified the presence of water ponding at the median openings and along the edges of the concrete median, as shown in the figure above. This condition indicates inefficiency in the surface drainage system along the studied road segment. Rainwater that should normally flow into the side drainage channels is instead retained in areas adjacent to the concrete median and on the flexible pavement surface.

4.6 Flexible Pavement Performance Analysis

The analysis of flexible pavement performance along the Paguyaman–Tabulo road segment (Shortcut III Lahumbo) was conducted to determine the condition level of the pavement affected by water ponding and suboptimal drainage systems. This evaluation employs the Pavement Condition Index (PCI) method, which assesses surface conditions based on the type, severity, and extent of pavement distress.
The analysis was carried out separately to obtain a more representative assessment of pavement conditions, specifically for the left and right traffic lanes.

This situation may accelerate the deterioration of the flexible pavement in the future and reduce the level of safety for road users.

Table 3. PCI Table for the Left Lane and Right Lane

NO	SEGMENT (STA)	TYPE OF DISTRESS	DISTRESS AREA (%)	PCI VALUE	CATE GORY
1	0+000–0+100	NONE	0%	100	VERY GOOD
2	0+100–0+200	NONE	0%	100	
3	0+200–0+300	NONE	0%	100	
4	0+300–0+400	NONE	0%	100	
5	0+400–0+500	NONE	0%	100	
6	0+500–0+600	NONE	0%	100	
7	0+600–0+700	NONE	0%	100	
8	0+700–0+800	NONE	0%	100	
9	0+800–0+900	NONE	0%	100	
10	0+900–1+000	NONE	0%	100	
11	1+000–1+100	NONE	0%	100	
12	1+100–1+200	NONE	0%	100	
13	1+200–1+300	NONE	0%	100	
14	1+300–1+400	NONE	0%	100	
15	1+400–1+500	NONE	0%	100	
16	1+500–1+600	NONE	0%	100	
17	1+600–1+700	NONE	0%	100	
18	1+700–1+800	NONE	0%	100	
19	1+800–1+900	NONE	0%	100	
20	1+900–2+000	NONE	0%	100	
21	2+000–2+100	NONE	0%	100	
22	2+100–2+200	NONE	0%	100	
23	2+200–2+300	NONE	0%	100	
24	2+300–2+400	NONE	0%	100	
25	2+400–2+500	NONE	0%	100	
26	2+500–2+600	NONE	0%	100	
27	2+600–2+700	NONE	0%	100	

Table 4. PCI Value Classification

PCI Value	Condition
85 – 100	Excellent
70 – 85	Good
55 – 70	Fair
40 – 55	Poor
< 40	Very Poor

4.7 PCI Results Analysis

Based on the field survey results, the PCI analysis indicates that no pavement distress was identified on either lane, with both achieving a PCI value of 100 (Excellent condition). Although water ponding was observed at several locations, which has the potential to cause structural pavement damage, it has not yet affected the current pavement condition. Furthermore, the uniformity of PCI values across both lanes suggests that the distribution of traffic loads and the pavement construction conditions are relatively consistent.

4.8 Discussion

Based on the analysis results, it is indicated that the existing drainage capacity of 0.28 m³/s is insufficient to accommodate the runoff discharge of 0.951 m³/s, resulting in frequent water ponding on the flexible pavement surface. The presence of a concrete median further contributes to this condition by increasing the runoff coefficient and shortening the transverse flow path, which leads to the concentration of water around the pavement area.

Based on the PCI method calculations for the Paguyaman–Tabulo road segment (Shortcut III Lahumbo), the current PCI values range from 85 to 100%, indicating good to excellent pavement conditions, with no structural damage observed due to water infiltration despite the presence of ponding at several locations.

However, repeated ponding, if not properly addressed, may gradually reduce the performance of flexible pavement due to water infiltration. Prolonged water stagnation on the pavement surface increases the duration of contact with asphalt, which can weaken the asphalt–aggregate bond. This process may lead to a reduction in subgrade bearing capacity and trigger early-stage distresses such as hairline cracking, alligator cracking, rutting, and potholes.

This condition is consistent with the theory that the effectiveness of surface drainage is directly correlated with the service life of flexible pavement. Continuous ponding can potentially reduce the design service life (typically 10–20 years) and increase maintenance costs.

Based on the analysis results, it is indicated that the existing drainage capacity of 0.28 m³/s is insufficient to accommodate the runoff discharge of 0.951 m³/s, resulting in frequent water ponding on the flexible pavement surface. The presence of a concrete median further contributes to this condition by increasing the runoff coefficient and shortening the transverse flow path, which leads to the concentration of water around the pavement area.

Based on the PCI method calculations for the Paguyaman–Tabulo road segment (Shortcut III Lahumbo), the current PCI values range from 85 to 100%, indicating good to excellent pavement conditions, with no structural damage observed due to water infiltration despite the presence of ponding at several locations.

However, repeated ponding, if not properly addressed, may gradually reduce the performance of flexible pavement due to water infiltration. Prolonged water stagnation on the pavement surface increases the duration of contact with asphalt, which can weaken the asphalt–aggregate bond. This process may lead to a reduction in subgrade bearing capacity and trigger early-stage distresses such as hairline cracking, alligator cracking, rutting, and potholes.

This condition is consistent with the theory that the effectiveness of surface drainage is directly correlated with the service life of flexible pavement. Continuous ponding can potentially reduce the design service life (typically 10–20 years) and increase maintenance costs.

5. CONCLUSION

Based on the research findings, it is recommended to improve the effectiveness of the drainage system by adding openings to the concrete median and optimizing as well as widening the dimensions of the existing drainage channels to accommodate runoff discharge from both the median and the roadway.

In addition, routine maintenance of the drainage channels is necessary to prevent blockages. Preventive measures should also be implemented to maintain pavement performance, considering that recurring water ponding has the potential to reduce the long-term service life of the pavement.

REFERENCES

[1] Ring, G. W. (2023). Drainage of Concrete Pavement Structures. *Proceedings of the International Conference on Concrete Pavements*. https://doi.org/10.33593/iccp.v1i1.1191

[2] Kurniadi, A., Basalim, S., & Sumiyattinah, S. (2023). Analisis Pengaruh Kondisi Drainase Terhadap Kinerja Perkerasan Jalan. *JeLAST: Jurnal Teknik Kelautan, PWK, Sipil, Dan Tambang*, *10*(3). https://doi.org/10.26418/jelast.v10i3.69080

[3] Chow, V. Te, Maidment, D. R., & Mays, L. W. (1988). *Applied Hydrology*. McGraw-Hill.

[4] Ezquerro, L., Coimbra, R., Bauluz, B., Núñez-Lahuerta, C., Román-Berdiel, T., & Moreno-Azanza, M. (2024). Large dinosaur egg accumulations and their significance for understanding nesting behaviour. *Geoscience Frontiers*, *15*(5). https://doi.org/10.1016/j.gsf.2024.101872

[5] Latupono, M. R., Betaubun, R. J., & Istia, P. T. (2025). Analisis limpasan permukaan saluran drainase terhadap kerusakan perkerasan lentur pada ruas jalan Tanjakan 2000 Kota Ambon. *Jurnal Penelitian Multidisiplin Bangsa*, *1*(11). https://doi.org/10.59837/jpnmb.v1i11.394

[6] Huang, Y. H. (2004). *Pavement Analysis and Design* (2nd ed.). Pearson Prentice Hall.

[7] Cedergren, H. R. (1994). Drainage of Highway and Airfield Pavements. John Wiley \& Sons.

[8] Chen, X., & others. (2025). Enhancement of roadway pavement resilience to flooding: impact assessment and mitigation strategies. Transportation Research Part D. https://doi.org/10.1016/j.trd.2025.104946

[9] Fricilia, M., Hadiwardoyo, S. P., & Sumabrata, R. J. (2025). Correlation between drainage conditions and damage on the road surface with PCI method.

[10] Rajak, I. A., Altarans, I., & Faruk, F. (2025). Flexible pavement distress analysis using the Pavement Condition Index (PCI) method. Scientia: Journal of Multi Disciplinary Science.