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Assessment of Pavement Performance Using the Pavement Condition Index (PCI): A Case Study of the Bengrah II Project in Palembang, Indonesia

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ABSTRACT: Road pavement condition is essential for ensuring the smooth mobilization of materials, heavy equipment, and personnel in large-scale construction projects. Excessive loading from project vehicles often accelerates pavement deterioration, as observed along Mayor Memet Sastra Wirya Street, the main access road for the multi-year Bengrah II Project in Palembang. This study evaluated pavement distress types types and severity levels using the Pavement Condition Index (PCI) method based on field observations, photographic documentation, and dimensional measurements of visible defects. The analysis produced PCI values ranging from 62 to 70, with an average PCI of 67, classifying the pavement as Good. The dominant types of distress were alligator cracking and surface deformation (bumps and sags), primarily caused by repetitive heavy vehicle loading and inadequate drainage conditions. Despite the overall good classification, localized structural deterioration indicates early functional decline of the pavement. These results highlight that continuous heavy traffic associated with construction activities significantly affects pavement performance. Therefore, preventive maintenance actions such as surface overlays, shallow patching, and stricter vehicle load control, are recommended to sustain road functionality and extend service life. The findings contribute to pavement management strategies and policy formulation for maintaining construction access roads under intensive loading conditions.

KEYWORDS: Pavement distress types; Pavement Condition Index (PCI); flexible pavement; heavy vehicle loading; Palembang

1. Introduction

Road infrastructure was one of the most critical components in supporting national development and ensuring the mobility of people and goods [1–4]. Roads served as the primary means of transportation, connecting different regions and facilitating the efficient distribution of resources, services, and socio-economic activities [5–7]. Along with rapid population growth, urban expansion, and intensified construction activities, the demand for durable and high-performing road infrastructure became increasingly essential [8–10]. However, in many regions of Indonesia, road pavement conditions often deteriorated prematurely due to excessive traffic loads, inadequate maintenance, and environmental factors such as rainfall and flooding [11–14]. These challenges continued to pose significant problems for local and regional transportation networks [15–18].

In the case of Palembang City, road deterioration was particularly evident along routes that served as access corridors for large-scale infrastructure projects. One notable example was the Bengrah II building and infrastructure development project, a multi-year construction activity involving intensive use of heavy vehicles and material transport. The repeated movement of overloaded construction trucks along Mayor Memet Sastra Wirya Street caused various types of pavement distress, including alligator cracking, bumps, rutting, and potholes [19–22]. Such conditions disrupted traffic flow, compromised user safety, and accelerated the structural degradation of the pavement [23–26]. The combination of heavy traffic loading and insufficient drainage further amplified this deterioration, highlighting the urgent need for a systematic evaluation of the pavement's existing performance.

Despite the extensive use of the PCI method in road evaluations, limited research had applied it to construction access roads exposed to repetitive heavy vehicle loading within active multi-year project environments. Most existing studies focused on public urban roads or national highways, while the unique operational conditions of project access roads characterized by unbalanced traffic flow, concentrated loading, and temporary structural interventions, remained underexplored. This represented a critical research gap in regional pavement performance studies, particularly in the context of Palembang and other rapidly developing urban areas.

The novelty of this study lay in its application of the PCI method to quantitatively evaluate pavement deterioration on a construction access road subjected to repetitive heavy loads during the Bengrah II multi-year project. The research provided new insights into how sustained project-related traffic affected pavement functionality, offering evidence-based recommendations for preventive maintenance and infrastructure management. This case-specific analysis contributed to the limited body of literature on project-based pavement performance assessment in Indonesia and served as a potential model for evaluating similar access roads in other cities experiencing intensive development.

Based on this background, the study aimed to identify and classify the types of pavement distress observed along the selected road section, assess the extent of pavement deterioration using the PCI method, and develop suitable maintenance recommendations to maintain pavement serviceability under continuous construction-related loading conditions. The findings were expected to assist road authorities and project managers in developing more targeted maintenance strategies and improving the long-term sustainability of access roads supporting large-scale construction projects.

2. Materials and Methods

2.1. Study area.

The study was conducted on Mayor Memet Sastra Wirya Street, located in the Ilir Timur II District of Palembang City, Indonesia. This road section was selected because it served as a key corridor connecting the Public Works and Spatial Planning Office of Palembang with the Port Hospital of Palembang, accommodating high traffic volumes, particularly from heavy vehicles associated with ongoing construction activities [1, 3, 6]. The investigated road segment had an approximate length of 400 meters and formed part of the primary urban collector network. Based on records obtained from the Palembang City Public Works and Spatial Planning Office, the pavement structure consisted of flexible pavement (asphalt concrete) with a surface age of approximately seven to eight years since the last major overlay. The subgrade comprised silty clay soil, while the base and sub-base layers consisted of crushed aggregate materials. According to maintenance history data, the most recent routine maintenance and partial resurfacing were carried out in 2017, primarily involving minor patching and surface rejuvenation. No major structural rehabilitation had been recorded since that period. This background highlighted the importance of assessing the current pavement condition under repetitive heavy traffic loads from the Bengrah II construction project, which could accelerate surface deterioration.

2.2. Materials and equipment.

The materials and equipment used in this study were relatively simple but adequate to support accurate field data collection [5, 8, 12]. A roll meter was employed to measure road width and the dimensions of each pavement distress type, while survey forms and writing instruments were used for systematic documentation of field observations. A clipboard facilitated data recording during fieldwork, and a smartphone camera was utilized to capture photographic evidence of the observed distresses. These tools enabled both quantitative and qualitative data to be collected in a consistent and reliable manner.

2.3. Data Collection.

Data collection consisted of both primary and secondary sources. Primary data were obtained directly from field surveys conducted in May 2024 during the dry season. The survey involved observing road conditions, measuring the geometric characteristics of the pavement, and identifying the type, severity, and extent of visible pavement distresses (jenis kerusakan perkerasan) [9, 13, 16]. Each defect was carefully measured and recorded according to its dimensions and classified by distress category. Secondary data were collected from government institutions, technical documents, and scientific publications related to pavement performance assessment [18, 22, 28].

2.4. Research procedure.

To ensure consistency and accuracy in the assessment, the 400-meter road section was divided into 50-meter segments. Each segment was examined in detail to identify the prevailing types of pavement distress, including alligator cracking, bumps, rutting, and potholes [10, 20, 24]. Observed distresses were recorded on survey forms, while their physical conditions were documented through photographs. This systematic segmentation allowed for detailed analysis and accurate classification of pavement condition throughout the study area [26, 29, 32].

2.5. Data analysis.

The collected data were analyzed using the PCI method as described in ASTM D6433-20 [6, 21, 30]. This analytical framework provided a standardized approach for evaluating pavement surface conditions based on the type, extent, and severity of observed distresses.

Before PCI computation, each identified jenis kerusakan perkerasan (pavement distress type) was measured according to its length, width, and affected area, depending on the distress category. Linear distresses such as alligator cracking, longitudinal cracking, and transverse cracking were recorded by their length (m) and width (mm), while areal distresses such as patches, raveling, and potholes were quantified by area (m^2). The severity level for each distress, categorized as low, medium, or high, was determined following the specific criteria outlined in ASTM D6433-20, which considered the extent of cracking, depth of deformation, and degree of disintegration.

After the field data were compiled, the analytical process was carried out sequentially. First, the distress density was calculated to represent the proportion of each distress type within the inspected sample unit. Next, the deduct value (DV) for each distress was determined based on its density and severity level. The allowable maximum deduct value (m) was then identified to account for overlapping effects among multiple distresses. Subsequently, the total deduct value (TDV) was computed as the sum of all individual DVs within each unit. Finally, the corrected deduct value (CDV) was derived using the ASTM correction curves to eliminate double-counting effects and ensure the accuracy of the pavement condition evaluation..

The final PCI rating for each test unit and segment was calculated using Equation (1):

$$PCI = 100 - CDV (1)$$

The PCI values obtained for each test unit were then averaged across the seven 60-meter segments, representing the entire 420-meter study section. According to the PCI classification scale, pavement conditions were categorized into standard rating levels ranging from “Failed” (0–10) to “Excellent” (85–100) [37–40].

2.6. Ethical considerations.

This research was limited to observational field surveys and the use of secondary data. It did not involve human participants, animals, or sensitive personal information; therefore, ethical clearance was not required for the implementation of this study.

3. Results and Discussion

3.1. Road condition at the study site.

Mayor Memet Sastra Wirya Street, located in the Ilir Timur II District of Palembang City, served as a vital access route connecting the Public Works and Spatial Planning Office of Palembang with the Port Hospital of Palembang. This road segment played an essential role in supporting daily mobility and logistics, with traffic characterized by high intensity and dominated by heavy construction vehicles. Such conditions made pavement quality a critical factor for ensuring traffic safety, structural integrity, and riding comfort. According to data from the Palembang City Department of Transportation (Dinas Perhubungan), the road section accommodated an estimated daily traffic volume of 3,200 to 3,500 vehicles, approximately 25 to 30 percent of which were heavy vehicles such as dump trucks, cement mixers, and project transporters. The average equivalent single axle load (ESAL) for these vehicles ranged between 7.5 and 8.2 tons, imposing substantial and repetitive loading stress on the flexible pavement structure.

The physical condition of the pavement is shown in Figure 1 (view from the Public Works Office direction) and Figure 2 (view from the Port Hospital direction). These visual observations indicated that the pavement had been affected by repetitive axle loading, surface deformation, and particularly inadequate roadside drainage, which accelerated localized deterioration. Field inspections revealed that the drainage along the road shoulders was mostly shallow, partially clogged, and unevenly graded, preventing effective runoff during rainfall events. As a result, water stagnation frequently occurred at several low-lying points along the carriageway, especially near manholes and utility crossings. The prolonged presence of standing water softened the subgrade layer and weakened the bond between the asphalt surface and underlying layers, leading to raveling, stripping, and premature fatigue cracking. These drainage deficiencies were identified as one of the primary contributors to the accelerated deterioration of the pavement structure.

Figure 1. Pavement distress types observed from the direction of the Public Works and Spatial Planning Office of Palembang.

Figure 2. Pavement distress types observed from the direction of the Port Hospital of Palembang.

In addition, the previous installation of the Wastewater Treatment Plant (IPAL) pipeline involved deep trench excavation and temporary backfilling along one side of the carriageway. Although the trenches were refilled and patched, the backfill materials were not adequately compacted, creating differential settlements and weak zones within the pavement layers. Over time, these weak spots developed into potholes, longitudinal cracks, and surface depressions, particularly under repeated heavy truck traffic. During the rainy season, these areas exhibited severe water ponding and erosion, which further expanded the damaged zones.

Repeated heavy loads from construction vehicles associated with the Bengrah II project further aggravated these conditions, especially in the midsection and near the project access points, where construction trucks frequently turned or idled. To mitigate further deterioration, the Department of Transportation installed roadside concrete barriers to prevent heavy trucks from stopping or parking on the main carriageway. However, without improvements to the roadside drainage system and rehabilitation of the IPAL excavation areas, the pavement was expected to continue deteriorating at an accelerated rate.

3.2. Pavement distress types analysis.

Field surveys identified two dominant jenis kerusakan perkerasan, namely alligator cracking and surface deformation in the form of bumps and sags. To ensure a systematic and representative assessment, the study area covered a total pavement length of 420 m, which was divided into seven segments, each 60 m long. This segmentation approach allowed detailed evaluation of distress patterns along both the left and right sides of the carriageway, enabling more accurate classification of the pavement condition for each section. The results of this segmentation and the observed jenis kerusakan perkerasan are summarized in Table 1, and further illustrated with photographic documentation in Table 2. The survey findings showed that alligator cracking was concentrated in segments STA 0+000–0+060, 0+060–0+120, 0+240–0+300, 0+300–0+360, and 0+360–0+420. Meanwhile, bumps and sags were primarily found in STA 0+120–0+180 and STA 0+180–0+240. Alligator cracking reflects surface fatigue due to repetitive vehicle loading, whereas bumps and sags suggest structural deformation potentially linked to weak subgrade conditions or excessive axle loads.

Table 1. Pavement distress types by road segment.

No	STA (m)	Segment	Position	Type of Distress	Condition
1	0+000 – 0+060	1	Left	Alligator cracking	Minor
2	0+060 – 0+120	2	Left	Alligator cracking	Minor
3	0+120 – 0+180	3	Left	Bumps and sags	Moderate
4	0+180 – 0+240	4	Right	Bumps and sags	Moderate
5	0+240 – 0+300	5	Right	Alligator cracking	Minor
6	0+300 – 0+360	6	Right	Alligator cracking	Minor
7	0+360 – 0+420	7	Right	Alligator cracking	Minor

Table 2. Field survey documentation of pavement distress types by segment (PCI method).

No	STA (m)	Position	Type of Distress	Photo Documentation
1	0+000 – 0+060	Left	Alligator cracking	
2	0+060 – 0+120	Left	Alligator cracking	

No	STA (m)	Position	Type of Distress	Photo Documentation
1	0+000 – 0+060	Left	Alligator cracking	
3	0+120 – 0+180	Left	Bumps and sags	
4	0+180 – 0+240	Right	Bumps and sags	
5	0+240 – 0+300	Right	Alligator cracking	
6	0+300 – 0+360	Right	Alligator cracking	
7	0+360 – 0+420	Right	Alligator cracking	

3.3. PCI evaluation.

The severity of pavement distresses was quantified using the Pavement Condition Index (PCI) method, following the procedures outlined in ASTM D6433-20. The analysis included the calculation of distress density, deduct values (DV), corrected deduct values (CDV), and the derivation of the final PCI score for each segment. The summary of PCI values across the seven evaluated segments is presented in Table 3. The analysis revealed that PCI values ranged from 62 to 70, with an overall average PCI of 67. Based on the standard classification, this condition corresponded to the "Good" category, indicating that the pavement remained structurally sound and serviceable under existing load conditions. However, the presence of surface cracking and deformation, particularly alligator cracking and bumps or sags, indicated the early stages of functional and structural deterioration that required preventive maintenance to sustain performance.

Table 3. Recapitulation of PCI calculation results

No	Sample Unit	Position	STA (m)	PCI Value	Condition
1	1	Left	0+000 – 0+060	70	Good
2	2	Left	0+060 – 0+120	69	Good
3	3	Left	0+120 – 0+180	62	Good
4	4	Right	0+180 – 0+240	67	Good
5	5	Right	0+240 – 0+300	68	Good
6	6	Right	0+300 – 0+360	66	Good
7	7	Right	0+360 – 0+420	70	Good
	Average			67	Good

When compared with findings from other regional studies, the PCI results in Palembang were relatively consistent with those reported for urban access and secondary roads exposed to repetitive heavy vehicle loading. In Lampung, Zaid et al. (2021) reported PCI values between 60 and 68 for urban collector roads subjected to heavy truck traffic, classifying them as being in good to satisfactory condition [41]. In Bandung, Jannah et al. (2022) found PCI values ranging from 65 to 72, with surface cracking as the dominant distress type, also categorized as good [42]. In Wamena, Papua, Rahman et al. recorded lower PCI values between 55 and 63, attributed to poor drainage and higher rainfall intensity, which led to fair pavement conditions [43]. Meanwhile, in Surabaya, Yunus et al. reported PCI scores between 68 and 75, reflecting good to very good performance on roads with improved maintenance and better subdrainage systems [44]. These comparisons demonstrated that the average PCI value of 67 in Palembang aligned with the regional trend for urban roads under mixed heavy traffic conditions. The slightly lower range compared with Surabaya could be attributed to drainage inadequacy and the impact of repeated heavy construction loads from the Bengrah II project. Overall, the pavement on Mayor Memet Sastra Wirya Street remained in serviceable condition, but proactive preventive maintenance, including overlays, shallow patching, and improved drainage, was essential to prevent further deterioration toward the fair category.

3.4. Recommended maintenance actions.

Based on the PCI classification and the types of observed distresses, technical maintenance recommendations were formulated as outlined in Table 4. For segments exhibiting alligator cracking with moderate severity, the recommended treatment is surface overlay, while for segments affected by bumps and sags, shallow patching either partial or full-depth is suggested depending on the extent of deformation.

Table 4. Recommended pavement maintenance based on distress condition

STA (m)	Position	Type of Distress	Severity Class	Recommended Action
0+000 – 0+060	Left	Alligator cracking	M (Moderate)	Overlay (surface treatment)
0+060 – 0+120	Left	Alligator cracking	M (Moderate)	Overlay (surface treatment)
0+120 – 0+180	Left	Bumps and sags	M (Moderate)	Shallow patching (partial or full-depth)
0+180 – 0+240	Right	Bumps and sags	M (Moderate)	Shallow patching (partial or full-depth)
0+240 – 0+300	Right	Alligator cracking	M (Moderate)	Overlay (surface treatment)
0+300 – 0+360	Right	Alligator cracking	M (Moderate)	Overlay (surface treatment)
0+360 – 0+420	Right	Alligator cracking	M (Moderate)	Overlay (surface treatment)

The overlay treatment was recommended for areas exhibiting fatigue or alligator cracking, as it provided a cost-effective approach to restore structural capacity and surface smoothness without requiring complete reconstruction. The application of a new asphalt layer improved load distribution, sealed surface cracks, and reduced water infiltration into the base and subgrade layers. Compared with full-depth rehabilitation, overlays typically extended pavement service life by approximately five to ten years at about 40 to 60 percent lower cost, making them an efficient preventive measure for moderately deteriorated pavements.

For bumps and sags, shallow patching was recommended to correct localized deformations and restore surface evenness. Partial-depth patching was suitable when the distress was confined to the upper surface layers, whereas full-depth patching was necessary when deformation extended into the base layer. This approach ensured that the repaired areas regained sufficient structural support and surface integrity, thereby preventing the initiation of additional cracking or rutting.

Overall, although the pavement was classified as being in good condition, preventive maintenance remained essential to preserve functionality and safety. Without timely interventions, the existing defects could develop into severe structural failures, requiring more costly rehabilitation. The implementation of a scheduled overlay and selective patching program, combined with effective control of heavy vehicle operations and improved roadside drainage, would sustain pavement performance and extend its service life.

4. Conclusions

Based on the analysis conducted using the PCI method, the pavement condition of Mayor Memet Sastra Wirya Street in Palembang was classified as *Good*, with PCI values ranging from 62 to 70 and an average PCI of 67. The dominant types of pavement distress identified were alligator cracking and surface deformation (bumps and sags), generally exhibiting low to moderate severity. These results indicated that the pavement remained serviceable under current loading conditions but required preventive maintenance to sustain its performance and prevent early structural deterioration. To ensure long-term functionality, safety, and cost efficiency, several preventive maintenance measures were recommended. These included the application of overlays to sections affected by alligator cracking and shallow patching on segments displaying surface deformation. Timely implementation of these treatments would reduce further deterioration, extend pavement service life, and maintain riding comfort and operational safety for road users. From an economic perspective, adopting preventive maintenance strategies such as overlays and patching provided substantial cost savings compared with delayed rehabilitation or full-depth reconstruction. Preventive interventions could reduce total maintenance expenditure by approximately 50 to 60 percent over the pavement's life cycle, while maintaining road functionality and safety under urban traffic conditions. Furthermore, sustaining a smooth and structurally sound pavement surface contributed to improved fuel efficiency, reduced vehicle operating costs, and lower accident risks, thereby supporting broader objectives of urban road safety and sustainability. The findings emphasized the importance of integrating preventive pavement management into the maintenance policy for urban roads in Palembang and other developing cities. A proactive approach combining periodic monitoring, timely surface treatment, and strict regulation of heavy vehicle operations would ensure that urban pavements remain durable, cost-effective, and safe under increasing transportation demands.

Competing Interest

All authors should disclose any financial, personal, or professional relationships that might influence or appear to influence their research.

Author Contribution

This study was conducted by Aldi Armahedi and Ely Mulyati. Ely Mulyati handled conceptualization, supervision, and project administration, while Aldi Armahedi conducted fieldwork, data collection, and analysis. Both developed the methodology. Aldi prepared the draft, and Ely reviewed and edited it. Both approved the final manuscript for publication.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. All raw field measurement data, photographic documentation, and PCI calculation sheets were collected and processed by the research team during the May 2024 survey period and can be provided for verification or further analysis.

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