Field Performance of Asphalt with LDPE Additive as an Overlay Pavement Material: The Case of Taft Avenue, Manila City

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Abstract: The Philippines adopted and implements innovations in sustainable road construction, such as the incorporation of low-density polyethylene (LDPE) plastic waste for asphalt as an additive. This study reveals the functional performance of asphalt with an LDPE additive as an overlay material, using the pavement condition index (PCI) based on ASTM D6433. It aims (1) to observe and identify the types of road surface defects along road sections overlaid with conventional asphalt material and asphalt with LDPE additive material, and (2) to calculate and compare the PCI of road sections overlaid with conventional asphalt and asphalt with LDPE additive materials. Distresses such as alligator cracking, joint reflection cracking, potholes, and patching were identified and classified in accordance with guidelines. Results showed that the pavement condition indices and ratings of road sections overlaid with asphalt with LDPE additive pavement are relatively lower than those of road sections overlaid with conventional asphalt. The findings indicate that the surveyed overlaid road sections need preventive maintenance and rehabilitation to prevent further pavement deterioration. Furthermore, the regular monitoring of pavement conditions should be given importance. Integration of other significant data such as traffic volume, flood data, and other factors that might affect the performance of overlay materials can be helpful to improve further assessment. Overall, this study highlights the necessity for further study on the performance of asphalt with LDPE additive materials as a sustainable overlay material for in-situ pavement.

Keywords: Pavement Condition Index (PCI), LDPE, Asphalt Pavement, Overlay Material, Sustainable Pavement Material

1. INTRODUCTION

The use of recycled and alternative materials in road construction has gained increasing attention as part of sustainable infrastructure initiatives. Among these materials is low-density polyethylene (LDPE) plastic waste, which has been explored as an additive or modifier in hot mix asphalt (HMA). Previous laboratory-based studies reported that plastic-modified asphalt

mixtures may improve stability, rutting resistance, and moisture resistance under controlled conditions (Ma *et al*., 2021; Awwad & Shbeeb, 2007).

In the Philippines, the Department of Public Works and Highways (DPWH), through its research arm and materials testing hub, the Bureau of Research and Standards (BRS), implemented pilot projects involving LDPE plastic bag waste as an additive in asphalt material for pavement. The first small-scale pilot trial site was located along Taft Avenue, Ermita, Manila, where adjacent sections of concrete pavements were overlaid with conventional asphalt material and asphalt with LDPE additive material. The project reported that the modified asphalt mixture complied with laboratory requirements of Item 310 - Bituminous Concrete Surface Course under DPWH Standard Specifications for Highways, Bridges and Airports, 2013 Edition. Table 1 shows the project details of the pilot trial at Taft Avenue, as per DPWH's Final Evaluation Report of the project.

Table 1. Project details of first small-scale pilot trial
Source: DPWH's Final Evaluation Report on LDPE (Campit *et al.*, n.d)

Contract Effectivity Date	October 28, 2019
Date of Completion	February 01, 2020
Location	Taft Avenue, K002+(-272) to K002+015.3, Southbound, Ermita, Manila
Total Length	293 linear meters Conventional HMA: 144 meters HMA with LDPE waste: 149 meters
Total Width	11.10 meters
Number of Lanes	Four (4) lanes
ACP Thickness	50mm
Job Mix Formula	AC: 5.33% by weight of mix LDPE Content: 7.39% by weight of binder (3.8kg per metric ton)
DPWH Implementing Office	DPWH, South Manila District Engineering Office



Actual photo of First Small-Scale Pilot Trial

Although laboratory evaluations reported promising results for asphalt with LDPE additive mixtures, pavement performance under actual roadway conditions may still differ due to different factors that were not considered in a controlled environment, such as long-term exposure to traffic loading, environmental conditions, pavement aging, and maintenance activities. Because of these factors, field-based pavement condition assessment remains important in evaluating the actual in-service performance of overlay materials several years after implementation.

One of the most commonly used methods in evaluating in-situ pavement is quantifying the Pavement Condition Index (PCI). This method evaluates pavement condition based on observed pavement surface distresses and provides a standardized numerical representation of the pavement condition. The American Society for Testing and Materials (ASTM) developed guidelines on calculating PCI, which can be found in ASTM D6433 (ASTM International, 2020).

Despite numerous laboratory research on LDPE as a pavement material and the implementation of the DPWH LDPE pilot project, only few studies have evaluated the field performance of asphalt with LDPE additive pavements using PCI-based assessment under actual roadway conditions. To address this research gap, the present study aims:

1. To observe and identify the types of road surface defects along road sections overlaid with conventional asphalt material and asphalt with LDPE additive material, and

2. To calculate and compare the PCI of road sections overlaid with conventional asphalt material and asphalt with LDPE additive material.

The study is limited to selected sample units within the asphalt with LDPE additive and conventional asphalt sections along Taft Avenue and focuses on pavement surface condition assessed using ASTM D6433. The methodological limitations of the study are further discussed in Section 3.9.

2. REVIEW OF RELATED LITERATURE

2.1 Plastic-Modified Asphalt as Sustainable Pavement Material

The increasing demand for sustainable infrastructure has encouraged the use of recycled and alternative materials in pavement engineering, including the incorporation of waste plastics into asphalt pavements. Waste plastics have been investigated as asphalt modifiers because of their availability, reuse potential, and possible engineering benefits when incorporated into asphalt mixtures (Ma *et al*., 2021).

Among the commonly used plastic modifiers are high-density polyethylene (HDPE) and low-density polyethylene (LDPE). Previous laboratory studies reported that polyethylene-modified asphalt mixtures may improve Marshall stability, rutting resistance, stiffness characteristics, and moisture resistance under controlled conditions (Ma *et al*., 2021; Awwad & Shbeeb, 2007). Polyethylene-modified mixtures were likewise observed to exhibit improved resistance to permanent deformation compared to conventional asphalt mixtures (Awwad & Shbeeb, 2007).

Several studies also noted that the performance of plastic-modified asphalt mixtures may vary depending on asphalt binder properties, aggregate characteristics, production processes, and traffic exposure (Ma *et al*., 2021). Consequently, the long-term field performance of asphalt with LDPE additive pavements remains an important area for further evaluation.

2.2 Long-Term Field Performance of Asphalt Pavements

Long-term pavement performance is influenced by several structural, operational, and environmental conditions throughout the pavement service life. Repeated traffic loading contributes to the development of pavement distresses such as rutting, fatigue cracking, and roughness, while pavement structural characteristics such as layer thickness, base condition, and subgrade support also influence pavement durability and performance (Bhandari *et al*., 2023).

Environmental exposure likewise affects pavement deterioration over time. Temperature fluctuations, precipitation, oxidation, moisture infiltration, and asphalt aging gradually reduce pavement condition and pavement durability (Bhandari *et al*., 2023; Sirin *et al*., 2018). Studies on asphalt aging further noted that oxidation and long-term environmental exposure may alter asphalt binder properties and contribute to pavement deterioration under field conditions (Sirin *et al*., 2018).

In urban roads, operational conditions such as braking movements, stopping activities, drainage conditions, maintenance interventions, and utility cuts may further influence pavement deterioration. Previous studies emphasized that pavement distresses observed in the field result

from the combined effects of material properties, traffic exposure, pavement structure, and environmental conditions over time (Bhandari *et al*., 2023).

Because of this, field pavement condition evaluation remains important in assessing the actual in-service condition of asphalt pavements under real roadway conditions.

2.3 Pavement Evaluation Methods and the Use of PCI

Pavement evaluation is conducted to assess pavement condition and performance using different functional and structural indicators. Common pavement evaluation approaches include serviceability, structural capacity, safety, and surface distress. Among these approaches, visual pavement condition assessment remains widely used because it provides a practical and systematic method for identifying observable pavement distresses and estimating pavement condition (ASTM International, 2020).

One of the most widely used visual pavement evaluation systems is the Pavement Condition Index (PCI), standardized under ASTM D6433, "Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys" (ASTM International, 2020). The PCI method provides a numerical representation of pavement condition based on the type, severity, and extent of observable pavement distresses. ASTM D6433 identifies several distress types for asphalt pavements, including alligator cracking, rutting, potholes, edge cracking, longitudinal and transverse cracking, weathering, and raveling.

The standard likewise provides procedures for distress identification, severity classification, quantity measurement, and deduct value computation, thereby establishing a systematic framework for visual pavement condition evaluation (ASTM International, 2020). Previous studies also noted that PCI-based assessment is useful in pavement management and pavement monitoring because it provides a standardized and repeatable approach for evaluating pavement condition (ASTM International, 2020; Shahin, 2005).

Several studies further explored the relationship between PCI and other pavement performance indicators such as ride quality and roughness indices, highlighting the continued use of PCI as a practical tool for assessing pavement condition in pavement management applications (Arhin *et al*., 2015; Park *et al*., 2007).

In the Philippines, the Department of Public Works and Highways (DPWH) uses the Visual Condition Index (VCI) under the Road Condition (ROCOND) assessment framework for pavement condition evaluation (DPWH, 2019). Similar to PCI, the VCI method relies on visual pavement inspection. However, PCI under ASTM D6433 provides more detailed distress classification and standardized deduct value procedures for asphalt pavement assessment.

2.4 DPWH Research and Development of Asphalt Mix with LDPE additive

The DPWH Bureau of Research and Standards (BRS) conducted laboratory evaluation and field performance monitoring to assess the feasibility of using low-density polyethylene (LDPE) plastic waste as an additive in hot mix asphalt (HMA). Laboratory testing was performed to determine the optimum mix design and evaluate its compliance with the requirements for heavy traffic under DPWH Standard Specifications for Highways, Bridges and Airports, Volume II.

The conventional HMA was initially designed using the Marshall method. Asphalt binder contents ranging from 4.5% to 6.5% by weight of mix, at 0.5% increments, were evaluated, resulting in an optimum binder content of 5.33% by weight of mix. Using the optimized conventional HMA as the basis, LDPE polymer waste contents of 5%, 10%, 15%, and 20% by weight of binder were subsequently evaluated. Based on curve fitting of the

resulting mix properties against the applicable Marshall mix design criteria, the optimum LDPE content was determined to be 7.39% by weight of binder (Campit *et al*., n.d).

The LDPE additive consisted of plastic bag waste from Laguna dumpsite. The plastic bag wastes were shredded into varying sizes: from 6.35 mm. to 12.7 mm. For the pilot application, the LDPE was incorporated into the asphalt mixture through a dry process, wherein the shredded plastic waste was heated and coated with cement before being introduced into the heated aggregates, followed by the addition of asphalt binder. The job mix formula subsequently adopted for the Taft Avenue pilot used 5.2% asphalt cement by weight of mix and 7.30% LDPE polymer waste by weight of binder established during the laboratory evaluation. Table 2 shows the adopted mix composition for the asphalt with LDPE additive (Campit *et al*., n.d).

Table 2. Job mix formula for conventional HMA and HMA with plastic bag waste (LDPE)
Source: DPWH's Final Evaluation Report on LDPE (Campit *et al.*, n.d)

Component	Percentage of component		Weight of components in kgs	
	Conventional	HMA	Conventional	HMA
¾" Aggregate	4.00%	4.00%	40.00 kgs	40.00 kgs
⅜" Aggregate	39.00%	39.00%	390.00 kgs	390.00 kgs
S-1 Aggregate	52.00%	52.00%	520.00 kgs	520.00 kgs
Reclaimed Filler	4.00%	4.00%	40.00 kgs	40.00 kgs
Hydrated Lime	1.00%	1.00%	10.00 kgs	10.00 kgs
Bitumen: Asphalt Cement (PG 60-70)	5.20%	5.20% (by weight of mix)	52.00 kgs	52.00 kgs
Additive: LDPE Polymer Waste (Shredded 6.35mm to 12.70mm)	-	7.30% (by weight of bitumen)	-	3.80 kgs

Table 3 summarizes the laboratory test results for both conventional and asphalt with LDPE additive mixes. The laboratory evaluation showed that both conventional and asphalt with LDPE additive mixtures satisfied the required specifications. While both mixtures exhibited comparable bulk specific gravity and air void content, the asphalt with LDPE additive achieved higher Marshall stability and lower rut depths under repeated loading, indicating improved resistance to permanent deformation under laboratory conditions.

Table 3. Laboratory test results of conventional and asphalt with LDPE additive
Source: DPWH's Final Evaluation Report on LDPE (Campit *et. al*, n.d)

Laboratory Test	Standard Reference	Requirement for Heavy Traffic	Conventional Hot Mix Asphalt	Asphalt with LDPE additive Hot Mix
Bulk Specific Gravity	ASTM D2726	-	2.423	2.421
Percent Air Voids	ASTM D3203	3 – 5	4.50	4.50
Marshall Stability, lbs.	ASTM D6927	1,800 minimum	2,582.88	2,846.51
Flow, 0.25 mm	ASTM D6927	8 minimum	12.75	13.80
Rutting Resistance Test	AASHTO T324	No. of passes = 3,000	Rut depth = 4.52	Rut depth = 2.48
		No. of passes = 6,000	Rut depth = 11.25	Rut depth = 6.32
		No. of passes = 9,000	Rut depth = 18.12	Rut depth = 9.90

Following the laboratory evaluation, the DPWH conducted a pilot test in using both conventional and asphalt with LDPE additive as an overlay material along Taft Avenue, Manila. These sections were monitored within a year, monthly for the first six months and quarterly for the next six months. During the monitoring period, crack mapping, skid resistance tests, sand

patch tests, and rutting tests were conducted. Table 4 shows the summary of the tests conducted and their corresponding results.

Table 4. Field performance monitoring of the conventional and asphalt with LDPE additive
Source: DPWH's Final Evaluation Report on LDPE (Campit *et. al*, n.d)

Performance Monitoring	Conventional HMA	Asphalt with LDPE additive HMA	Remarks
Crack Mapping	The first surface defect was observed after 16 months (June 2021) of project completion. After 1 year and 10 months, no new surface defect was observed. Only 1 surface defect was observed.	The first two surface defects were observed after 10 months (November 2020) of project completion. More surface defects (a total of 16) were observed after 22 months (December 2021) of project completion.	Surface defects appeared earlier and more frequently in asphalt with LDPE additive as compared to conventional asphalt.
Skid Resistance Test (ASTM E303)*	Average Skid Resistance Value = 63.4	Average Skid Resistance Value = 55.6	Both sections pass the United Kingdom's Department for International Development Overseas Road minimum SRV of 50.
Sand Patch Test (ASTM E965)*	Average textural depth = 0.68	Average textural depth = 0.78	Both sections conformed with UK Specifications' acceptable textural depth of 0.50mm.
Rutting Test (ASTM E1703)*	2mm deep rutting was observed on Lane 4 outer wheel path after 13 months (February 2021) of project completion. 3mm deep rutting started on Lane 3 inner wheel path on November 2021.	4mm deep rutting started on Lane 3 inner wheel path in November 2021. 3mm deep rutting started on Lane 4 outer wheel path on December 2021.	Rutting appeared earlier on conventional asphalt, but a deeper rut depth was observed at asphalt with LDPE additive section.

* Evaluation was conducted 22 months (December 2021) after project completion.

Contrary to the results from the laboratory evaluation, the field performance results of conventional asphalt and asphalt with LDPE additive as an overlay material provide mixed insights. Based on Table 4, both overlaid sections provide enough frictional resistance, and surface roughness was achieved, as they passed the skid resistance and sand patch tests, respectively, during the monitoring period. However, the crack mapping indicates early manifestations of distresses on the surface along the sections overlaid with the asphalt with LDPE additive. Rutting was observed within the monitoring period for both sections. The presence of multiple cracks along the sections overlaid with asphalt with LDPE additive materials, indicate that field performance may have been influenced by factors beyond the asphalt mixture properties alone.

2.5 Traffic Loading and Pavement Deterioration

Traffic loading is one of the primary factors influencing pavement deterioration. Repeated vehicle loading contributes to the development of distresses such as rutting and fatigue cracking, while cumulative traffic volume, vehicle composition, and axle loads affect the long-

term performance of asphalt pavements (Bhandari *et al*., 2023). Consequently, traffic characteristics should be considered when interpreting the pavement condition of adjacent roadway sections, particularly when evaluating the long-term field performance of different pavement materials.

2.6 Research Gap

Previous studies on asphalt with LDPE additive mainly focused on laboratory evaluation of binder mixtures. These studies reported potential engineering benefits associated with LDPE modification of asphalt; however, fewer studies have evaluated the long-term field pavement performance of asphalt with LDPE additive under actual roadway traffic and environmental exposure. Limited studies within the Philippine context have likewise applied PCI-based visual pavement assessment to compare asphalt with LDPE additive and conventional asphalt pavements under actual roadway conditions.

3. METHODOLOGY

This study quantifies the functional performance of the pavement overlaid with asphalt with LDPE additive material along Taft Avenue, using PCI. The assessment was conducted in accordance with the ASTM D6433, six years after the project completion. The methodology was selected to quantify the surface distresses on overlaid pavement with conventional and asphalt with LDPE additive and compare their performance 6 years after the implementation.

3.1 Research design

This study is divided into three phases: preparation, field work, and analysis. Figure 1 shows the procedure for executing the study. The preliminary work include the selection of the study site, sample size computation, and survey material preparation. Fieldwork was done on May 03, 2026 along the selected road sections. After gathering the data from the fieldwork, the desk work commenced. The process includes all the calculations and assessments done for the study.

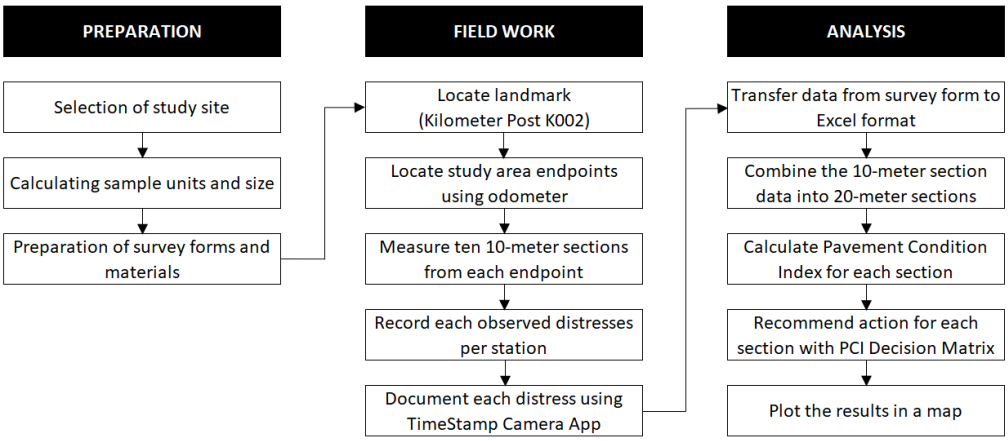


Figure 1. Research Procedure Flowchart

3.2 Study site

The DPWH conducted the first small-scale pilot trial of asphalt with LDPE additive as an overlay material along Taft Avenue Southbound, Manila City (see Figure 2). As per DPWH, the total length of the conventional hot mix asphalt is 144 meters, while the hot-mix asphalt with LDPE waste is 149 meters. From kilometer post K-002+000, 15.3 meters was measured southbound, and 272 meters was measured northbound, adding up to a total of 287.3 meters of study site. For the entirety of the span, the total width of the road is 11.10 meters, covering the four (4) southbound lanes of the road. The project was implemented by DPWH, South Manila District Engineering Office. Six years after the completion of the project, an assessment of the pavement condition is essential to check and compare the performance of the asphalt with LDPE additive and conventional HMA; thus, this study site was selected.

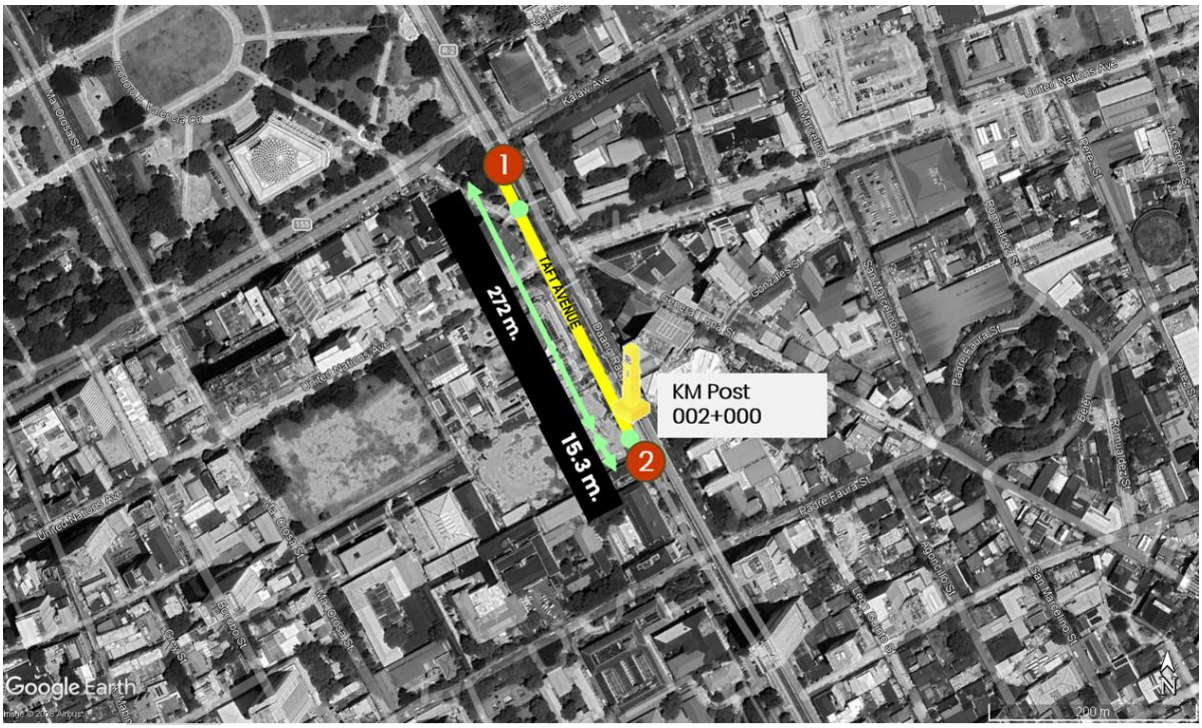
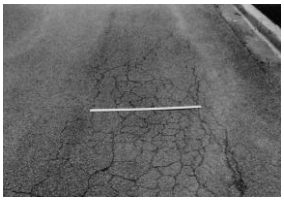


Figure 2. Study Site at Taft Avenue, Manila City

3.3 Pavement Condition Survey (ASTM D6433)

ASTM D6433, the “Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys", is a visual type of survey that quantifies the pavement condition of roads. In the Philippines, there is a localized version of the PCI named the Visual Condition Index (VCI) which was localized and was adopted by the Department of Public Works and Highways (DPWH). However, the PCI includes a wider range of pavement distress classifications, which justifies its use in this study.

As per ASTM D6433, there are 19 distresses that need to be assessed for asphalt and concrete pavements (ASTM International, 2020). Figure 3 shows the surface distresses included in the pavement condition index survey for asphalt pavements.



a. Alligator Cracking



b. Bleeding



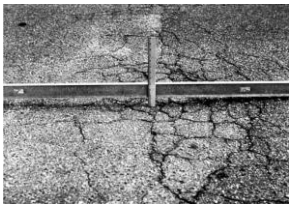
c. Block Cracking



d. Bumps and Sags*



e. Corrugation*



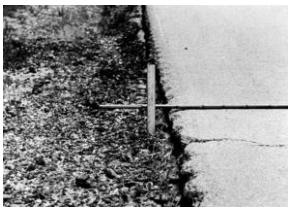
f. Depression



g. Edge Cracking



h. Joint Reflection Cracks



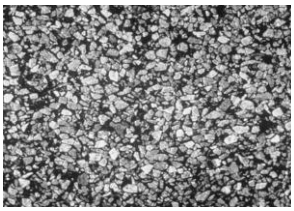
i. Lane/Shoulder Drop off



j. Longitudinal/ Transverse Cracks



k. Patching & Utility Cut Patching



l. Polished Aggregate



m. Potholes



n. Railroad Crossing*



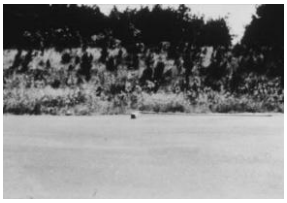
o. Rutting



p. Shoving*



q. Slippage Cracking*



r. Swell*



s. Weathering/ Ravelling

*Distresses measured using Ride Quality

Figure 3. Types of Surface Distresses for Asphalt Pavement as per ASTM D6433, (ASTM International, 2020)

The result of a PCI survey is a numerical indicator that provides a rating of the surface condition of the pavement. However, ASTM D6433 stated that the PCI cannot measure the structural capacity or provide direct measurement of skid resistance. Amongst the different types of pavement condition surveys, PCI is considered to be one of the most practical, easy, and cost-effective methods of surveying since it relies only on visual assessment of a given road segment.

Of the 19 distresses, 5 of them fall under a subcategory of Ride Quality, which can be measured by riding in a car and evaluating the comfort level altered by the said distresses. Although ride quality-related surface distresses can be subjectively measured visually like the other distresses, it is important to note that the accuracy varies from actually riding a test car.

The pavement condition survey was conducted jointly by two researchers. For each sample unit, the surveyors identified and agreed on the type and severity of observed pavement distresses based on the definitions and classification guidelines prescribed in ASTM D6433, after which the corresponding distress quantities were measured and recorded. The same procedure and criteria were applied to both the asphalt with LDPE additive and conventional asphalt sections. No formal inter-rater reliability test was conducted; however, joint assessment using the same ASTM D6433 criteria was employed to promote consistency in distress identification and measurement.

3.4 Sampling Procedure

In accordance with ASTM D6433, asphalt pavement sample units should have an area of 225 ± 90 m². Given the 11.10 meter width of the four-lane study pavement, the corresponding acceptable sample-unit length was calculated using Equation 1. Table 5 shows that the acceptable sample length ranges from 12.16 m. to 28.38 m. For simplicity and ease of field measurement, a 20 meter sample-unit length was adopted, corresponding to an area of 222 m² per sample unit.

$$\frac{225 \pm 90\ m^2}{x\ (width\ in\ m)} = Acceptable\ Sample\ Length \tag{1}$$

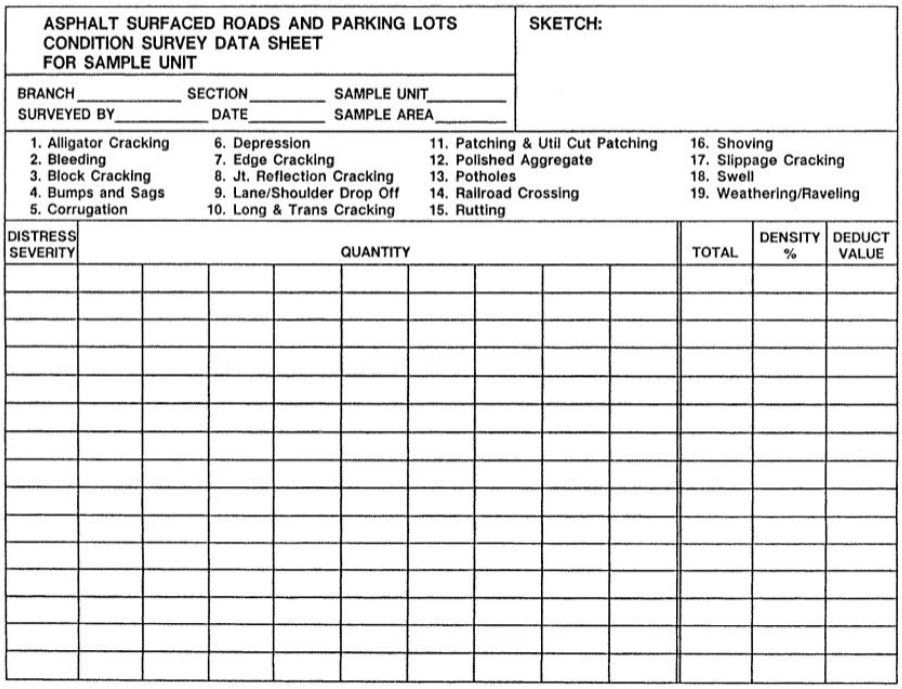
Table 5. Calculation of sample-unit length

Minimum Sample-Unit Length	Maximum Sample-Unit Length
$225\ m^2 - 90\ m^2 = 135\ m^2$	$225\ m^2 + 90\ m^2 = 315\ m^2$
$\frac{135\ m^2}{11.10\ m\ width} = \mathbf{12.16\ m}$	$\frac{315\ m^2}{11.10\ m\ width} = \mathbf{28.38\ m}$

Five 20 meter sample units were surveyed for each pavement type, resulting in a surveyed length of 100 m. for the asphalt with LDPE additive section and 100 m. for the conventional section, or 200 m. in total. Note that the total project length is 293 linear meters. Comparable midblock sections were selected for both pavement types. The sections within the United Nations Avenue–Taft Avenue intersection were excluded due to field safety considerations and to maintain comparability between the sampled sections.

3.5 Survey Form

Figure 4 shows the original survey form from ASTM D6433 for asphalt pavements. In this survey form, surveyors are tasked to manually identify the corresponding number of each distress, paired with its severity, and the quantity per distress severity type.



ASPHALT SURFACED ROADS AND PARKING LOTS
CONDITION SURVEY DATA SHEET
FOR SAMPLE UNIT

SKETCH:

BRANCH_____ SECTION_____ SAMPLE UNIT_____
SURVEYED BY_____ DATE_____ SAMPLE AREA_____

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Sags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/Shoulder Drop Off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Raveling

DISTRESS SEVERITY	QUANTITY										TOTAL	DENSITY %	DEDUCT VALUE

Figure 4. PCI survey sheet for asphalt pavement as per ASTM D6433, (ASTM International, 2020)

For the PCI survey of this study, a revised format of the survey form was created and is shown in Figure 5. The revised PCI survey form was used for easier and clearer separation of each distress type. The researchers minimized several difficulties by creating a revised survey form for the PCI survey, which are 1) backtracking of types of distress (during field survey, it might be difficult to manually check the list one by one and indicate their severity), and 2) possibility of double input. Due to the list being blank, double-input of the same distress and severity is highly likely.

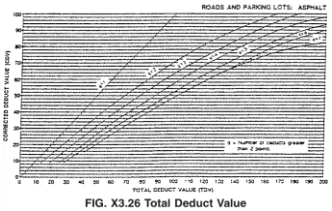
ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT																	Sketch
Branch				Date													
Section				Sample Unit													
Surveyor				Sample Area													
Distress		Sev	Description	Quantity										Total	Density	D-Value	
1	Alligator Cracking (in m2)	H	Well-defined pieces on network														
		M	Network of light cracks														
		L	Parallel hairline, unconnected cracks														
2	Bleeding (in m2)	H	Considerable asphalt sticks to shoes														
		M	Asphalt sticks to shoes														
		L	Asphalt does not stick to shoes														
3	Block Cracking (in m2)	H	High-severity cracks														
		M	Medium-severity cracks														
		L	Low-severity cracks														
4	Bumps and Sags (in linear m)	H	High-severity ride quality														
		M	Medium-severity ride quality														
		L	Low-severity ride quality														
5	Corrugation (in m2)	H	High-severity ride quality														
		M	Medium-severity ride quality														
		L	Low-severity ride quality														
6	Depression (in m2)	H	Max depth more than 50mm (2")														
		M	Max depth 25-50mm (1"-2")														
		L	Max depth 13-25mm (1/2"-1")														
7	Edge Cracking (in linear m)	H	Considerable breakup along edge														
		M	Medium cracks with some breakup														
		L	Low cracking w/ no breakup														
8/10	Jt. Reflection Cracking (Aphalt over PCC) / Longitudinal and Transverse Cracking (Asphalt only) (in linear m)	H	Any of the following exists: - Any crack surrounded by M-H severity secondary cracks - Nonfilled cracks >3" - Crack of any width where 4" of pavement are severely broken														
		M	Any of the following exists: - Nonfilled crack width > 10mm (3/8") and <75mm (3") - Nonfilled cracks<75mm (3") surrounded by light secondary cracking - Filled crack surrounded by light secondary cracking														
		L	Any of the followng exists: - Nonfilled crack width <10mm (3/8") - Filled crack of any width														
9	Lane/ Shoulder Drop Off (in linear m)	H	Elev. Difference >100mm														
		M	Elev. Difference >50mm & <100mm														
		L	Elev. Difference >25mm & <50mm														
11	Patching & Util Cut Patching (in m2)	H	Patch is badly deteriorated														
		M	Patch is moderately deteriorated														
		L	Patch is in good condition														
12	Polished Aggregate (in m2)	NA	Smooth asphalt surface, no rough or angular particles to provide good skid resistance														
13	Potholes (in # of holes)	H	Refer to Table X1.1														
		M															
		L															
14	Railroad Crossing (in m2)	H	High-severity ride quality														
		M	Medium-severity ride quality														
		L	Low-severity ride quality														
15	Rutting (in m2)	H	Rut depth >25mm (1")														
		M	Rut depth = 13-25mm (1/2"-1")														
		L	Rut depth = 16-13mm (1/4"-1/2")														
16	Shoving (in m2)	H	High-severity ride quality														
		M	Medium-severity ride quality														
		L	Low-severity ride quality														
17	Slippage Cracking (in m2)	H	Any of the following exists: - Average crack width > 40mm - Crack broken to easily removed pcs														
		M	Any of the following exists: - Average crack width >10 and <40mm - Crack moderately spalled														
		L	Average crack width <10mm														
18	Swell (in m2)	H	High-severity ride quality														
		M	Medium-severity ride quality														
		L	Low-severity ride quality														
19	Weathering/ Ravelling (in m2)	H	Aggregates worn away considerably														
		M	Aggregates has worn away														
		L	Aggregates started to wear away														

Figure 5. Revised PCI survey sheet format for this study

3.6 Calculation procedure

Table 6 shows the step-by-step calculation of pavement condition index of asphalt pavement.

Table 6. Method of computation for pavement condition index of asphalt pavement

Step	Description	Formula/s needed
Step 1: Calculating the total quantity of distresses	For each distress type per severity level, the total quantity of distresses are calculated using summation.	$Total\ qty = \sum Individual\ Distresses$
Step 2: Calculating the density of each distress	Density is calculated by dividing the total quantity by the total area of the section studied. For this case, since each section is 11.10 meters wide and 20 meters long, the denominator would be 222.0 m².	$Density = \frac{Total\ quantity}{Area\ of\ Section}$
Step 3: Approximating deduct value per type of distress	Using ASTM D6433's Annex X3. Deduct Values Curves for Asphalt, the deduct values are approximated with each distress density in percentage.	Refer to Annex X3 of ASTM D6433.
Step 4: Listing all deduct values per section	With the deduct values per section, a list is created arranging the values from highest to lowest.	N/A
Step 5: Calculating the quantity of maximum deduct value, m	Using the highest deduct value, the maximum deduct value is calculated using Equation 4.	$m = 1 + \left(\frac{9}{98}\right) * (100 - \max DV)$
Step 6: Adjusting quantity of deduct values	The number of deduct values is adjusted by obtaining the top m values from the original deduct values list. If the calculated maximum number of deduct values are higher than the actual number of deduct values, all deduct values must be considered in further calculations. The decimals from the maximum deduct value (m) must be multiplied to the next deduct value to be excluded as percentage.	N/A
Step 7. Compute the corrected deduct values using Total Deduct Value Curve.	The sum of the adjusted quantity of deduct values is then calculated. The number of values greater than 2 is counted, labelled as q. The corrected deduct value is approximated using the total deduct value and q, from Figure X3.26 Total Deduct Value of ASTM D6433.	 FIG. X3.26 Total Deduct Value *Source: ASTM D6433*
Step 8: Calculate the corrected deduct values iteratively.	The deduct values is inspected, and the smallest value greater than 2 is converted to 2, then step 7 is repeated. This is iteratively done until only one deduct value is greater than 2. From the list of corrected deduct values, the highest values is then selected. This will be the maximum corrected deduct value (maximum CDV).	N/A
Step 9: Determining the pavement condition index and rating from the maximum corrected deduct value	The maximum CDV is subtracted from 100 to obtain the pavement condition index of the section. The PCI is compared with Figure 6 to determine the PCI rating.	Refer to Figure 6 for the PCI Rating.

3.7 Data Analysis

ASTM has a standard rating scale for the pavement condition index of a road, and it is shown in Figure 6. The standard rating scale has seven (7) levels of ratings, namely: Good, Satisfactory, Fair, Poor, Very Poor, Serious, and Failed. Typically, a value greater than 55, or "fair," is considered acceptable, while those below must be considered for further inspection and may be subject to repair.

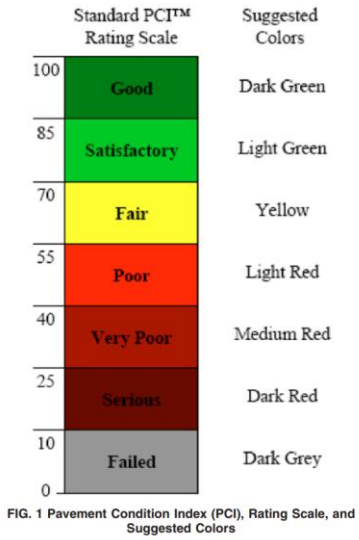


Figure 6. Pavement Condition Index Rating Scale,
(ASTM International, 2020)

3.8 Traffic Count and Delay Survey

A preliminary traffic count and delay survey was conducted at the midblock sections of both asphalt with LDPE additive and conventional asphalt pavements to provide additional context on the traffic characteristics of the two study sections. Since the locations of the asphalt with LDPE additive and conventional asphalt sections are separated by an intersection, traffic volume and vehicle composition may differ between the two sections.

The survey was conducted for 20 minutes and was intended only to provide a preliminary snapshot of traffic volume, vehicle composition, and delay characteristics at the time of observation. It was not intended to represent daily or long-term traffic loading. The short observation period does not account for temporal variations in traffic throughout the day and does not provide information on cumulative axle loading.

The surveyors conducted a 20-minute traffic count and delay survey at the study site on June 22, 2026. Each surveyor was stationed at elevated platforms and used video recording to capture the traffic volume, and desk work followed to manually count the vehicles per type for the duration of the survey. The following classifications were used for the traffic count survey.

1) Passenger Cars/ Taxi/ SUVs/ AUVs/ Pick-ups/ Owner-type jeeps
2) Van/ UV Express
3) Jeepneys (PUJ)
4) Buses
5) Mini-bus/ Modern Jeepney
6) Medium Trucks/ Delivery trucks/ L300 (2-axle)

7) Large Trucks (3+ axle)
8) Tricycles (subtypes: traditional tricycles, e-trike)
9) Motorcycles
10) Bicycles (subtypes: traditional bicycles, e-bike, e-scooter, pedicab

A preliminary delay survey was also done and recorded through the video recording to check the frequency and duration of vehicles being stationary near traffic signals. For the conventional asphalt section, there is a signalized U-turn intersection, while for the asphalt with LDPE additive section, there is a 4-legged signalized intersection. The assessment of the delays may help in explaining the severity and frequency of surface defects due to stationary vehicle loading on the pavements.

3.9 Study Limitations

The study has several methodological limitations that should be considered in interpreting the findings. First, the PCI assessment covered five 20-meter sample units for each pavement type, representing a total surveyed length of 200 meters rather than the entire 293 meter pilot project. Sections within the United Nations Avenue–Taft Avenue intersection were excluded due to field safety considerations and to maintain comparability between the sampled sections.

Second, the pavement condition assessment was based on visual identification and measurement of surface distresses following ASTM D6433. Although the survey was jointly conducted by two researchers using the same ASTM D6433 criteria, no formal inter-rater reliability test was performed. In addition, ride quality-related distresses requiring vehicle-based assessment were excluded.

Third, the traffic count and delay survey was limited to a 20-minute observation period and therefore represents only the traffic conditions observed during the survey period. It does not capture daily or long-term variations in traffic volume and vehicle composition or cumulative axle loading. Consequently, the traffic survey results are used only as preliminary contextual information and not as a comprehensive measure of long-term traffic loading.

Finally, other factors that may influence pavement deterioration, including drainage and flooding conditions, maintenance history, and construction quality, were not comprehensively evaluated in this study. Therefore, differences in PCI between the two pavement sections should not be attributed solely to the pavement material.

4. RESULTS AND DISCUSSION

4.1 PCI of Conventional Asphalt and Asphalt with LDPE additive

4.1.1 Actual Site Photos

Figure 7 shows photographs from the study site for both Station 1 and Station 2. There is a very noticeable visual difference between the asphalt pavement from both Station 1 and Station 2 in terms of number and severity of distress.



a. Alligator cracking at Station 1



g. Joint reflection racking at Station 2



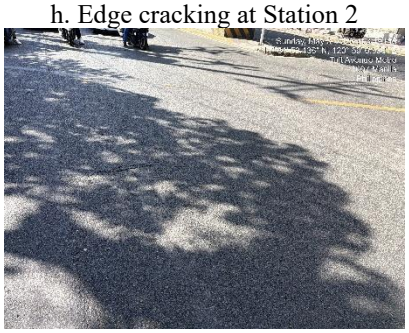
b. Patching at Station 1



h. Edge cracking at Station 2



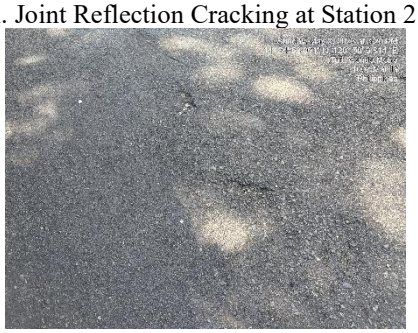
c. Weathering/ Ravelling at Station 1



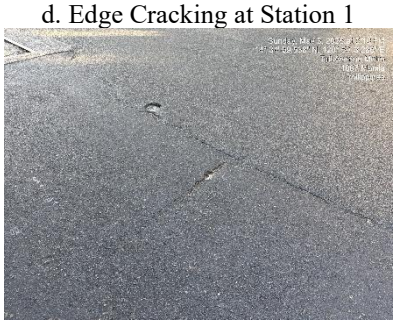
i. Joint Reflection Cracking at Station 2



d. Edge Cracking at Station 1



j. Weathering/ Ravelling at Station 2



f. Joint Reflection Cracking at Station 1



k. Block Cracking at Station 2

Figure 7. Surface defects observed during visual condition survey along Taft Avenue

4.1.2 Calculation of Pavement Condition Index

The following results are obtained from the PCI Survey. Please take note that for all steps, only the computation for station 1 section 1 will be shown. The same computation was applied to other sections of both asphalt with LDPE additive and conventional asphalt pavement. The full step-by-step computation of Pavement Condition Indices for all sections is found in Appendix A.

Step 1: Calculating the quantity of distresses.

From the individual quantities in Figure 8, the total quantity per row shall be calculated. For example, for the joint reflection cracking at medium severity, the total of all eight quantities is at 71.30 meters.

Step 2: Calculating the density of each distress.

Density for the joint reflection cracking at medium severity can be calculated by dividing the total quantity by the total area of the section, as shown below.

$$Density = \frac{71.30\ m}{222\ m2} * 100 = 32.12\%$$

Distress		Sev	Description	Station 1. 0000 - 0020												
				Quantity										Total	Density	D-Value
1	**Alligator Cracking** (in m2)	H	Well-defined pieces on network	0.70										0.70	0.32	21.00
		M	Network of light cracks	0.65										0.65	0.29	13.00
		L	Parallel hairline, unconnected cracks		3.90									3.90	1.76	15.00
2	**Bleeding** (in m2)	H	Considerable asphalt sticks to shoes											-	-	
		M	Asphalt sticks to shoes											-	-	
		L	Asphalt does not stick to shoes											-	-	
3	**Block Cracking** (in m2)	H	High-severity cracks											-	-	
		M	Medium-severity cracks	1.90										1.90	0.86	2.00
		L	Low-severity cracks	5.80										5.80	2.61	2.00
4	**Bumps and Sags** (in linear m)	H	High-severity ride quality											-	-	
		M	Medium-severity ride quality											-	-	
		L	Low-severity ride quality											-	-	
5	**Corrugation** (in m2)	H	High-severity ride quality											-	-	
		M	Medium-severity ride quality											-	-	
		L	Low-severity ride quality											-	-	
6	**Depression** (in m2)	H	Max depth more than 50mm (2")											-	-	
		M	Max depth 25-50mm (1"-2")	3.30										3.30	1.49	10.00
		L	Max depth 13-25mm (1/2"-1")											-	-	
7	**Edge Cracking** (in linear m)	H	Considerable breakup along edge											-	-	
		M	Medium cracks with some breakup											-	-	
		L	Low cracking w/ no breakup											-	-	
8/10	**Jt. Reflection Cracking** (Aphalt over PCC) / **Longitudinal and Transverse Cracking** (Asphalt only) (in linear m)	H	Any of the following exists: - Any crack surrounded by M-H severity secondary cracks - Nonfilled cracks >3" - Crack of any width where 4" of pavement are severely broken											-	-	
		M	Any of the following exists: - Nonfilled crack width > 10mm (3/8") and <75mm (3") - Nonfilled cracks<75mm (3") surrounded by light secondary cracking - Filled crack surrounded by light secondary cracking	10.00	10.00	10.00	1.30	10.00	10.00	10.00	10.00			71.30	32.12	32.00
		L	Any of the followng exists: - Nonfilled crack width <10mm (3/8") - Filled crack of any width											-	-	
9	**Lane/ Shoulder Drop Off** (in linear m)	H	Elev. Difference >100mm											-	-	
		M	Elev. Difference >50mm & <100mm											-	-	
		L	Elev. Difference >25mm & <50mm											-	-	
11	**Patching & Util Cut Patching** (in m2)	H	Patch is badly deteriorated											-	-	
		M	Patch is moderately deteriorated	3.78	2.89	9.02								15.69	7.07	26.00
		L	Patch is in good condition											-	-	

Figure 8. Filled-out survey sheet for LDPE Section 1

Step 3: Approximating the deduct value for each type of distress.

The deduct value is approximated by aligning the density with the severity using the deduct value curve for joint reflection cracking in asphalt pavement. In this example, at density = 32.12%, the deduct value is approximately 32, as shown in Figure 9.

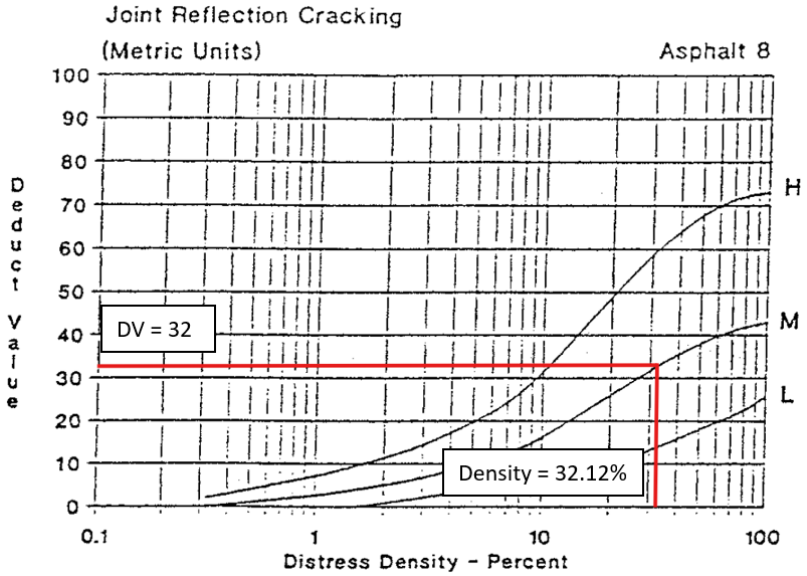


Figure 9. Approximation of deduct value from distress density

Step 4: Listing all deduct values per section

After approximating all deduct values from the deduct value curves, they shall be arranged in decreasing order, as shown in Table 7.

Table 7. Original deduct values for LDPE Section 1, arranged in descending order

Original Deduct Values											
LDPE Section 1	D-value	32.0	26.0	21.0	18.0	15.0	13.0	10.0	4.0	2.0	2.0

Step 5: Calculating the quantity of maximum deduct value, m

Since there is a limit to the number of deduct values for PCI computation, the maximum deduct value is calculated as shown below.

$$Maximum\ deduct\ value, m = 1 + \frac{9}{98}(100 - 32) = 7.24$$

Step 6: Adjusting quantity of deduct values

With the original ten deduct values, the maximum calculated deduct value is only 7.24. This means that the top 7 deduct values will be considered, along with 24% of the eighth deduct value, as shown in Table 8.

Table 8. Adjusted number of deduct values from Station 1 Section 1

Adjusted number of deduct values								
LDPE Section 1	32.00	26.00	21.00	18.00	15.00	13.00	10.00	0.98

Step 7: Compute the corrected deduct values using the Total Deduct Value Curve

The sum of the remaining deduct values is then calculated, as shown in the "Total" column of Table 9. The value of q = 7 is determined by counting the number of deduct values that are greater than 2. Using the total deduct value = 135.98 and q = 7, the corrected deduct value (CDV) is then approximated, as shown in Figure 10. The approximated CDV is then listed as 65.

Step 8. Calculate the corrected deduct values iteratively.

After calculating the corrected deduct value for iteration 1, the smallest deduct value greater than 2 is then converted to 2. Step 7 is then repeated until there is only 1 remaining deduct value greater than 2, as shown in Table 9.

Table 9. Tabulation of iterative calculations of corrected deduct values

LDPE Section 1											
#	Deduct Values								Total	q	CDV
1	32.00	26.00	21.00	18.00	15.00	13.00	10.00	0.98	135.98	7.00	65.00
2	32.00	26.00	21.00	18.00	15.00	13.00	2.00	0.98	127.98	6.00	62.00
3	32.00	26.00	21.00	18.00	15.00	2.00	2.00	0.98	116.98	5.00	61.00
4	32.00	26.00	21.00	18.00	2.00	2.00	2.00	0.98	103.98	4.00	60.00
5	32.00	26.00	21.00	2.00	2.00	2.00	2.00	0.98	87.98	3.00	56.00
6	32.00	26.00	2.00	2.00	2.00	2.00	2.00	0.98	68.98	2.00	50.00
7	32.00	2.00	2.00	2.00	2.00	2.00	2.00	0.98	44.98	1.00	45.00
8								0.98	0.98	0.00	0.00

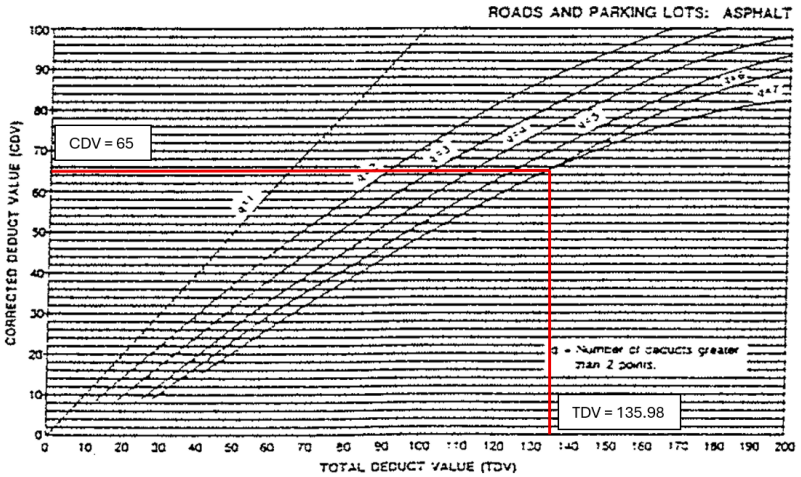


Figure 10. Sample approximation of CDV at iteration 1 of Station 1 Section 1.

Step 9: Determining the pavement condition index and rating from the maximum corrected deduct value.

The maximum CDV is then determined by checking the highest CDV from Table 9. The maximum CDV is subtracted from 100 to finally calculate for the pavement condition index. For Station 1 Section 1, the pavement condition index is therefore computed to be 35.

Using the pavement condition index rating scale from Figure 6, the PCI rating for station 1 section 1 is determined to be "Very Poor", as shown in Table 10.

Table 10. Computation of the pavement condition index for Station 1 Section 1

LDPE Section 1	
Max CDV	65.00
PCI	35.00
Rating	Very Poor

4.1.3 Pavement Condition Index Values

For LDPE-added asphalt station, Table 11 shows the PCI values calculated. The PCI values range from 22 to 45, with an average of 32.00. The section with the lowest PCI value is section 3, which has a value of 22.00. Sections 5 have the highest PCI value at station 1, with a value of 45.00. Table 11 also shows the PCI values calculated for conventional asphalt stations. The PCI values range from 32 to 73, with an average of 53.40. Section 3 has the lowest PCI value at 32.00, while section 1 has the highest, with 73.00.

Table 11. PCI Values of asphalt with LDPE additive and conventional asphalt pavements

Location	Pavement Condition Index	
	LDPE	Conventional
Section 1	35.00	73.00
Section 2	34.00	49.00
Section 3	22.00	32.00
Section 4	24.00	48.00
Section 5	45.00	65.00
AVERAGE	**32.00**	**53.40**

4.1.4 Pavement Condition Index Ratings

Table 12 shows the PCI rating for each section from the asphalt with LDPE additive and conventional stations. Sections 3 and 4 of the asphalt with LDPE additive station experience the worst PCI rating of "Serious," while the remaining sections are either “Very Poor” or "Poor." On average, the asphalt with LDPE additive station has a “Very Poor” rating. Similarly, section 3 of the conventional station experiences the worst PCI rating of “Very Poor," while 2 sections experience a “Poor” rating. The other two sections are “Satisfactory” and "Fair." On average, Station 2 has a “Poor” rating.

Table 12. PCI Ratings of asphalt with LDPE additive and conventional asphalt pavements

Location	Pavement Condition Index	
	LDPE	Conventional
Section 1	Very Poor	Satisfactory
Section 2	Very Poor	Poor
Section 3	Serious	Very Poor
Section 4	Serious	Poor
Section 5	Poor	Fair
AVERAGE	**Very Poor**	**Poor**

4.2 Comparison of Asphalt with LDPE additive and Conventional Asphalt Pavement

Using the calculated PCI values and their corresponding PCI ratings, there is an evident difference between the pavement condition of asphalt with LDPE additive pavement as compared to conventional asphalt pavement. From the survey results, it is noticeable that the pavement condition indices of sections from station 1 are less than those from station 2. On average, the PCI of Station 1 is at 32.00, and the PCI of Station 2 is at 53.40, with a difference of 21.40.

The PCI ratings serve a more practical way of labelling the pavement condition indices, with station 1 having ratings from “Poor” to “Serious”, while station 2 has “Satisfactory” to “Very Poor”, as shown in Figure 11. There is also a noticeable difference in the PCI ratings between the two stations if the sections are examined individually. However, on average, the difference in their PCI rating is only one scale up, from “Very Poor” of station 1 to “Poor” of station 2.

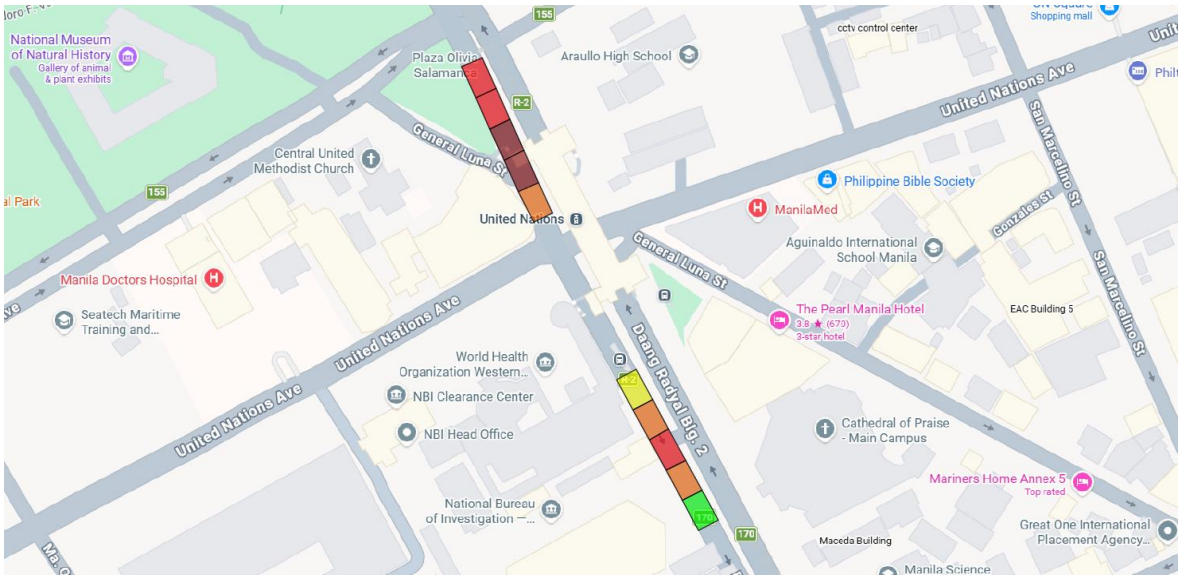


Figure 11. Site Plan with Pavement Condition Index Ratings
Base Map: Google Maps *(not to scale)*

Comparing the performance of the two stations, it can be clearly seen that Station 2 has a better overall pavement condition index. Although the Pavement Condition Index Rating is not a singular guide for assessing pavement performance, this study has shown that there is a visible difference in the performance of conventional asphalt pavement and asphalt pavement with LDPE plastic waste additive. However, the observed difference in PCI should not be attributed solely to the pavement material, as other site-specific factors such as traffic loading, drainage and flooding conditions, maintenance history, and construction quality may also have influenced pavement deterioration.

4.3 Preliminary Traffic Characteristics of Study Sections

As mentioned in Section 3.8, preliminary traffic count and delay surveys were conducted to provide additional context for interpreting the observed differences in PCI.

Based on the 20-minute observation period, both sections experienced comparable traffic volumes, as shown in Table 13. However, these findings should be interpreted as preliminary and do not necessarily represent long-term traffic loading conditions. In addition, the difference

in traffic volume of some vehicle types such as medium trucks, mini-bus/ modern jeepney, and buses suggest the need for a 16-hour traffic count to account for the actual total volume for a whole day. A 16-hour count will provide a more comprehensive insight into the daily traffic volume experienced by both sections.

Table 13. 20-minute traffic count data at study section

Type of Vehicle	Conventional HMA	Asphalt with LDPE additive HMA
Passenger Cars	253	230
Vans/ UV Express	33	28
Jeepneys	77	80
Buses	29	5
Mini-bus/ Modern Jeepney	5	31
Medium Trucks (2-axle)	14	4
Large Trucks (3+ axle)	2	2
Tricycles	5	5
E-Trike	76	64
Motorcycles	465	457
Bicycles	10	16
E-bike	0	0
E-scooter	0	1
Pedicab	0	0
TOTAL	969	923

The 20-minute delay survey shows the difference in traffic behavior in between the two study sections. For the asphalt with LDPE additive section, there tends to be a lesser frequency of delays observed compared to conventional asphalt, as shown in Table 14. Conversely, the average delay time experienced at asphalt with LDPE additive HMA is approximately double the average delay of conventional HMA. This suggests that although the asphalt with LDPE additive HMA section experiences less delays, the comparably longer duration that vehicles are stationary in this section may contribute to worsening pavement distress over time.

Table 14. 20-minute Delay Survey at study section

Delay Data	Conventional HMA		Asphalt with LDPE additive HMA
	Through	U-Turn	
Number of delays observed	8	8	4
Average delay time, s	46.25 seconds	58.13 seconds	107.09 seconds
Total delay, s	370.00 seconds	465.00 seconds	428.37 seconds

4.4 Synthesis of Findings

The Pavement Condition Index (PCI) assessment of asphalt with LDPE additive and conventional asphalt pavements in Taft Avenue, Manila City conducted 6 years after the project completion aligns with the performance monitoring of the DPWH. The crack mapping from DPWH indicated that surface defects were observed earlier in the asphalt with LDPE additive section, and that the frequency of defects are higher in the same section as compared to the conventional asphalt section. Similarly, the PCI assessment has shown that the pavement performance of the asphalt with LDPE additive section is lower than the conventional section.

Conversely, the results from the PCI survey and the crack mapping are opposite that of the laboratory evaluations. For the bulk specific gravity, percent air voids, marshall stability, and flow, the laboratory evaluation rates both conventional and asphalt with LDPE additive samples as passed. However, tests relating to rutting display different results: the laboratory rutting resistance test shows that the rut depth of asphalt is also half of the rut depth of

conventional samples, while in the performance monitoring rutting test, the rutting for both sections are almost similar.

Although the traffic count survey suggests that there is generally the same volume of traffic in both sections, the delay survey otherwise indicates that the difference in behavior of vehicles near signalizations may cause the decline of pavement quality over time in the LDPE section. However, since both surveys were conducted over a 20-minute observation period, the results should be interpreted as indicative rather than comprehensive representation of the long-term traffic conditions in the study site. Therefore, while the PCI assessment indicates poorer pavement condition in the asphalt with LDPE additive section, the observed difference cannot be attributed solely to the LDPE additive as an overlay material. Other factors not comprehensively evaluated in this study, including long-term traffic loading, drainage and flooding conditions, maintenance history, and construction quality, may have contributed to the observed pavement deterioration.

5. CONCLUSION

This study evaluated the pavement condition of asphalt with LDPE additive and conventional asphalt road sections in Taft Avenue, Manila City using the Pavement Condition Index (PCI) method from ASTM D6433.

The pavement condition assessment showed that the asphalt with LDPE additive section displayed several surface distresses, such as longitudinal cracking, rutting, raveling, block cracking, and alligator cracking. Most observed distresses were of medium and high severity, indicating that the asphalt with LDPE additive pavement considerably deteriorated 6 years after construction.

In alignment with ASTM D6433, it can be clearly stated that the pavement condition index of the conventional asphalt performs better (average PCI = 53.40) than the asphalt with LDPE additive (average PCI = 32.00). The results show that the computed PCI ratings indicate that the sections considered in the study require preventive and rehabilitation measures. Furthermore, it was found that the sections overlaid with conventional asphalt material have a higher PCI rating than those overlaid asphalt sections with LDPE additive material. However, further evaluation is recommended since specific site factors were not comprehensively included in the study, such as drainage and flooding conditions, materials, maintenance, and rehabilitation history of the underlying pavement, and construction quality.

Comparing the PCI survey data with laboratory evaluations and performance monitoring from the DPWH, there is an apparent similarity between the crack mapping data and PCI ratings. However, laboratory assessments in a controlled environment show a positive response on the performance of asphalt with LDPE additive pavement.

Overall, the study highlights the importance of regular pavement condition assessments to ensure road safety, serviceability, and long-term pavement performance.

6. RECOMMENDATIONS

Based on the findings of the study, the following recommendations are presented:

First, it is highly recommended that for future assessments of sustainable road construction practices, a multi-faceted, multi-disciplinary study must be done. For the case of this study, only the pavement condition index of Taft Avenue, Manila City was studied. Further examinations on structural capacity, laboratory results, flooding hazards, traffic volume and

distribution, and public health must also be checked to have a better understanding of the results produced by the PCI. For instance, the stationary time of vehicles near signalizations may indicate a contribution of traffic loading on the pavement deterioration. Projects such as DPWH's historical AADT surveys and Project NOAH's flood data may also be of utmost importance and will help greatly in explaining the whole picture for the changes in performance of asphalt pavements with LDPE additive.

Second, the second small-scale pilot trial at Quirino Avenue, Manila City must also be thoroughly examined not only with PCI but with the other tests as stated above. This will further diversify the data, giving insights into the differences in flood situation and traffic volumes in Quirino.

Third, there is a need for a localized version of the PCI decision matrix. To further contextualize the meaning behind the PCI ratings, a decision matrix plotting the PCI rating with the type of road must be created to have a quick insight into the action needed to be done for the roads surveyed.

Fourth, more advanced methods for determining the pavement condition index must be employed for systematic road surveys. Although the PCI survey method outlined by ASTM D6433 is low-cost and practical, the speed of survey is undermined and the whole process is tedious for the surveyors. Also, the use of AI will substantially erase the subjective nature of PCI surveys, making the assessments more objective and aligned with only one standard. In calculations, machine learning or regression models may be devised in order to eliminate the tedious desk work which depends more on graph approximations.

Lastly, policy talks shall be initiated in terms of the regular monitoring not only of projects with sustainable innovations such as the use of LDPE additives but also for all roads in general. An annual monitoring of roads will serve as a metric required for approvals of reconstruction or rehabilitation of roads. The data from the monitoring will also greatly help in comparing the actual performance of roads against the forecasted service life at the beginning of the project.

APPENDIX. Full step-by-step computation of Pavement Condition Indices for all sections

1. Original Deduct Values for All Sections

LDPE Sec. 1	D-value	32.0	26.0	21.0	18.0	15.0	13.0	10.0	4.0	2.0	2.0	
LDPE Sec. 2	D-value	36.0	35.0	23.0	16.0	9.0	8.0	6.0	1.0			
LDPE Sec. 3	D-value	60.0	36.0	22.0	20.0	18.0	0.3					
LDPE Sec. 4	D-value	45.0	38.0	25.0	25.0	14.0	9.0	7.0	3.0	0.5		
LDPE Sec. 5	D-value	36.0	27.0	18.0	9.0	5.0	2.5					
CONV Sec. 1	D-value	17.0	11.0	8.0	5.0	5.0	4.0					
CONV Sec. 2	D-value	25.0	23.0	12.0	11.0	11.0	10.0	10.0	8.0	5.0	5.0	2.0
CONV Sec. 3	D-value	27.0	25.0	25.0	17.0	17.0	14.0	13.0	10.0	9.0	8.0	
CONV Sec. 4	D-value	26.0	18.0	15.0	11.0	10.0	10.0	10.0	9.0	8.0	6.0	4.0
CONV Sec. 5	D-value	15.0	13.0	11.0	10.0	9.0	8.0	7.0	1.0			

2. Adjusted Number of Deduct Values for All Sections

LDPE Section 1	32.00	26.00	21.00	18.00	15.00	13.00	10.00	0.98
LDPE Section 2	36	35	23	16	9	8	5.27	
LDPE Section 3	60	36	22	20	12.12			
LDPE Section 4	45	38	25	25	14	9	0.36	
LDPE Section 5	36	27	18	9	5	2.50		
CONV Section 1	17	11	8	5	5	4		
CONV Section 2	25	23	12	11	11	10	10	7.10
CONV Section 3	27	25	25	17	17	14	13	7.04
CONV Section 4	26	18	15	11	10	10	10	7.16
CONV Section 5	15	13	11	10	9	8	7	1

3. Computations for Corrected Deduct Values

LDPE Section 1

#	Deduct Values								Total	q	CDV
1	32.00	26.00	21.00	18.00	15.00	13.00	10.00	0.98	135.98	7.00	65.00
2	32.00	26.00	21.00	18.00	15.00	13.00	2.00	0.98	127.98	6.00	62.00
3	32.00	26.00	21.00	18.00	15.00	2.00	2.00	0.98	116.98	5.00	61.00
4	32.00	26.00	21.00	18.00	2.00	2.00	2.00	0.98	103.98	4.00	60.00
5	32.00	26.00	21.00	2.00	2.00	2.00	2.00	0.98	87.98	3.00	56.00
6	32.00	26.00	2.00	2.00	2.00	2.00	2.00	0.98	68.98	2.00	50.00
7	32.00	2.00	2.00	2.00	2.00	2.00	2.00	0.98	44.98	1.00	45.00

LDPE Section 2

#	Deduct Values								Total	q	CDV
1	36.00	35.00	23.00	16.00	9.00	8.00	5.27		132.27	7.00	62.00
2	36.00	35.00	23.00	16.00	9.00	8.00	2.00		129.00	6.00	63.00
3	36.00	35.00	23.00	16.00	9.00	2.00	2.00		123.00	5.00	64.00
4	36.00	35.00	23.00	16.00	2.00	2.00	2.00		116.00	4.00	66.00
5	36.00	35.00	23.00	2.00	2.00	2.00	2.00		102.00	3.00	64.00
6	36.00	35.00	2.00	2.00	2.00	2.00	2.00		81.00	2.00	58.00
7	36.00	2.00	2.00	2.00	2.00	2.00	2.00		48.00	1.00	48.00

LDPE Section 3

#	Deduct Values								Total	q	CDV
1	60.00	36.00	22.00	20.00	12.12				150.12	5.00	77.50
2	60.00	36.00	22.00	20.00	2.00				140.00	4.00	78.00
3	60.00	36.00	22.00	2.00	2.00				122.00	3.00	74.50
4	60.00	36.00	2.00	2.00	2.00				102.00	2.00	72.00
5	60.00	2.00	2.00	2.00	2.00				68.00	1.00	68.00

LDPE Section 4

#	Deduct Values								Total	q	CDV
1	45.00	38.00	25.00	25.00	14.00	9.00	0.36		156.36	6.00	76.00
2	45.00	38.00	25.00	25.00	14.00	2.00	0.36		149.36	5.00	76.00
3	45.00	38.00	25.00	25.00	2.00	2.00	0.36		137.36	4.00	76.00
4	45.00	38.00	25.00	2.00	2.00	2.00	0.36		114.36	3.00	71.00
5	45.00	38.00	2.00	2.00	2.00	2.00	0.36		91.36	2.00	64.00
6	45.00	2.00	2.00	2.00	2.00	2.00	0.36		55.36	1.00	55.00

LDPE Section 5

#	Deduct Values								Total	q	CDV
1	36.00	27.00	18.00	9.00	5.00	2.50			97.50	6.00	48.00
2	36.00	27.00	18.00	9.00	5.00	2.00			97.00	5.00	50.00
3	36.00	27.00	18.00	9.00	2.00	2.00			94.00	4.00	54.00
4	36.00	27.00	18.00	2.00	2.00	2.00			87.00	3.00	55.00
5	36.00	27.00	2.00	2.00	2.00	2.00			71.00	2.00	52.00
6	36.00	2.00	2.00	2.00	2.00	2.00			46.00	1.00	46.00

Conventional Section 1

#	Deduct Values								Total	q	CDV
1	17.00	11.00	8.00	5.00	5.00	4.00			50.00	6.00	20.00
2	17.00	11.00	8.00	5.00	5.00	2.00			48.00	5.00	21.00
3	17.00	11.00	8.00	5.00	2.00	2.00			45.00	4.00	23.00
4	17.00	11.00	8.00	2.00	2.00	2.00			42.00	3.00	26.00
5	17.00	11.00	2.00	2.00	2.00	2.00			36.00	2.00	27.00
6	17.00	2.00	2.00	2.00	2.00	2.00			27.00	1.00	27.00

Conventional Section 2

#	Deduct Values								Total	q	CDV
1	25.00	23.00	12.00	11.00	11.00	10.00	10.00	7.10	109.10	8.00	48.00
2	25.00	23.00	12.00	11.00	11.00	10.00	10.00	2.00	104.00	7.00	51.00
3	25.00	23.00	12.00	11.00	11.00	10.00	2.00	2.00	96.00	6.00	46.00
4	25.00	23.00	12.00	11.00	11.00	2.00	2.00	2.00	88.00	5.00	44.00
5	25.00	23.00	12.00	11.00	2.00	2.00	2.00	2.00	79.00	4.00	44.00
6	25.00	23.00	12.00	2.00	2.00	2.00	2.00	2.00	70.00	3.00	44.00
7	25.00	23.00	2.00	2.00	2.00	2.00	2.00	2.00	60.00	2.00	44.00
8	25.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	39.00	1.00	39.00

Conventional Section 3

#	Deduct Values								Total	q	CDV
1	27.00	25.00	25.00	17.00	17.00	14.00	13.00	7.04	145.04	8.00	66.00
2	27.00	25.00	25.00	17.00	17.00	14.00	13.00	2.00	140.00	7.00	68.00
3	27.00	25.00	25.00	17.00	17.00	14.00	2.00	2.00	129.00	6.00	63.50
4	27.00	25.00	25.00	17.00	17.00	2.00	2.00	2.00	117.00	5.00	62.00
5	27.00	25.00	25.00	17.00	2.00	2.00	2.00	2.00	102.00	4.00	58.00
6	27.00	25.00	25.00	2.00	2.00	2.00	2.00	2.00	87.00	3.00	56.50
7	27.00	25.00	2.00	2.00	2.00	2.00	2.00	2.00	64.00	2.00	47.00
8	27.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	41.00	1.00	41.00

Conventional Section 4

#	Deduct Values								Total	q	CDV
1	26.00	18.00	15.00	11.00	10.00	10.00	10.00	7.16	107.16	8.00	52.00
2	26.00	18.00	15.00	11.00	10.00	10.00	10.00	2.00	102.00	7.00	49.00
3	26.00	18.00	15.00	11.00	10.00	10.00	2.00	2.00	94.00	6.00	45.00
4	26.00	18.00	15.00	11.00	10.00	2.00	2.00	2.00	86.00	5.00	44.00
5	26.00	18.00	15.00	11.00	2.00	2.00	2.00	2.00	78.00	4.00	44.00
6	26.00	18.00	15.00	2.00	2.00	2.00	2.00	2.00	69.00	3.00	44.00
7	26.00	18.00	2.00	2.00	2.00	2.00	2.00	2.00	56.00	2.00	41.00
8	26.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	40.00	1.00	40.00

Conventional Section 5

#	Deduct Values								Total	q	CDV
1	15.00	13.00	11.00	10.00	9.00	8.00	7.00	1.00	74.00	7.00	35.00
2	15.00	13.00	11.00	10.00	9.00	8.00	2.00	1.00	69.00	6.00	30.00
3	15.00	13.00	11.00	10.00	9.00	2.00	2.00	1.00	63.00	5.00	31.50
4	15.00	13.00	11.00	10.00	2.00	2.00	2.00	1.00	56.00	4.00	30.00
5	15.00	13.00	11.00	2.00	2.00	2.00	2.00	1.00	48.00	3.00	30.00
6	15.00	13.00	2.00	2.00	2.00	2.00	2.00	1.00	39.00	2.00	29.00
7	15.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	28.00	1.00	28.00

4. Computation of Pavement Condition Indices from Max Corrected Deduct Values

Station	Max CDV	PCI	Rating
LDPE Section 1	65	35	Very Poor
LDPE Section 2	66	34	Very Poor
LDPE Section 3	78	22	Serious
LDPE Section 4	76	24	Serious
LDPE Section 5	55	45	Poor
Conventional Section 1	27	73	Satisfactory
Conventional Section 2	51	49	Poor
Conventional Section 3	68	32	Very Poor
Conventional Section 4	52	48	Poor
Conventional Section 5	35	65	Fair

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