

Permanent Deformation Characterization of Permeable Interlocking Concrete Pavement Materials under Heavy Traffic Loading

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Abstract :

Permeable pavements are becoming a common component of storm-water management system all over the world. However, the research work conducted on the mechanistic design and structural performance of permeable pavements carrying higher traffic volumes and heavier loads, as well as the behavior of permeable interlocking concrete pavement (PICP) as surface and structure supporting more heavy trucks are very limited in the previous studies. In this paper, the structure performance of PICP under heavy traffic loading with a Heavy Vehicle Simulator (HVS) was investigated for PICP which is based on mechanistic analysis and partially validated with accelerated pavement testing (APT) results. The results include the rutting performance of PICP sections with three different thicknesses of subbase layer (reservoir layer) under dry, wet and drained conditions and with different load levels. It was found that the permanent deformation appeared in subbase contribute more to rutting depth than that in subgrade. The increment in subbase thickness did benefit to prevent rutting development. Besides that, wet condition accelerated rutting development of PICP structure.

Key Words : stormwater management; permeable interlocking concrete pavements; rutting; accelerated pavement testing; mechanistic-empirical design

1. Introduction

Although permeable pavements are becoming increasingly common for stormwater management, they are mostly used in parking lots, basic access streets, recreation areas, and landscaped areas, all of which carry very light, slow moving traffic [1-5]. Previous work has focused primarily on permeable pavements with open-graded (porous) asphalt or (pervious) portland cement concrete surfacing [1-6]. Very little research has been undertaken on the structural behavior of permeable interlocking concrete pavement surfacing and structure for heavy trucks. To understand how permeable interlocking concrete pavements (PICP) perform under heavy traffic loading, a research project was conducted by the University of California Pavement Research Center (UCPRC) and coordinated through the Interlocking Concrete Pavement Institute (ICPI) and the Concrete Masonry Association of California and Nevada with additional support from the California Nevada Cement Association[1-3]. The objective of this whole project was to produce thickness design tables for permeable interlocking concrete pavement (PICP) based on mechanistic analysis and partially

validated with accelerated pavement testing [3]. This paper summarizes themain results from APT testing and reveals the structural performance of PICP under heavy traffic loading, to explore the specific effects of load level, subbase thickness, and moisture condition.

2. Method

The test track design was developed using the results from the mechanistic analysis described in references [2, 3]. Based on the results of the mechanistic analysis, the theoretical structure was designed (Figure 1). The test section numbers were as follows (HC refers to the specific HVS equipment used for testing): section 678HC for dry test, section 679HC for wet test, section 680HC for drained test.During the dry test, no change in subgrade moisture condition occurred. In the wet test, water was soaked through the pavers next to the test section and allowed to fill the pavement structure until it overflowed. In the drained test, no water was added and testing was started once the water level receded to the top of the subgrade. A schematic in Figure 1 shows an HVS test section along with the stationing and coordinate system.

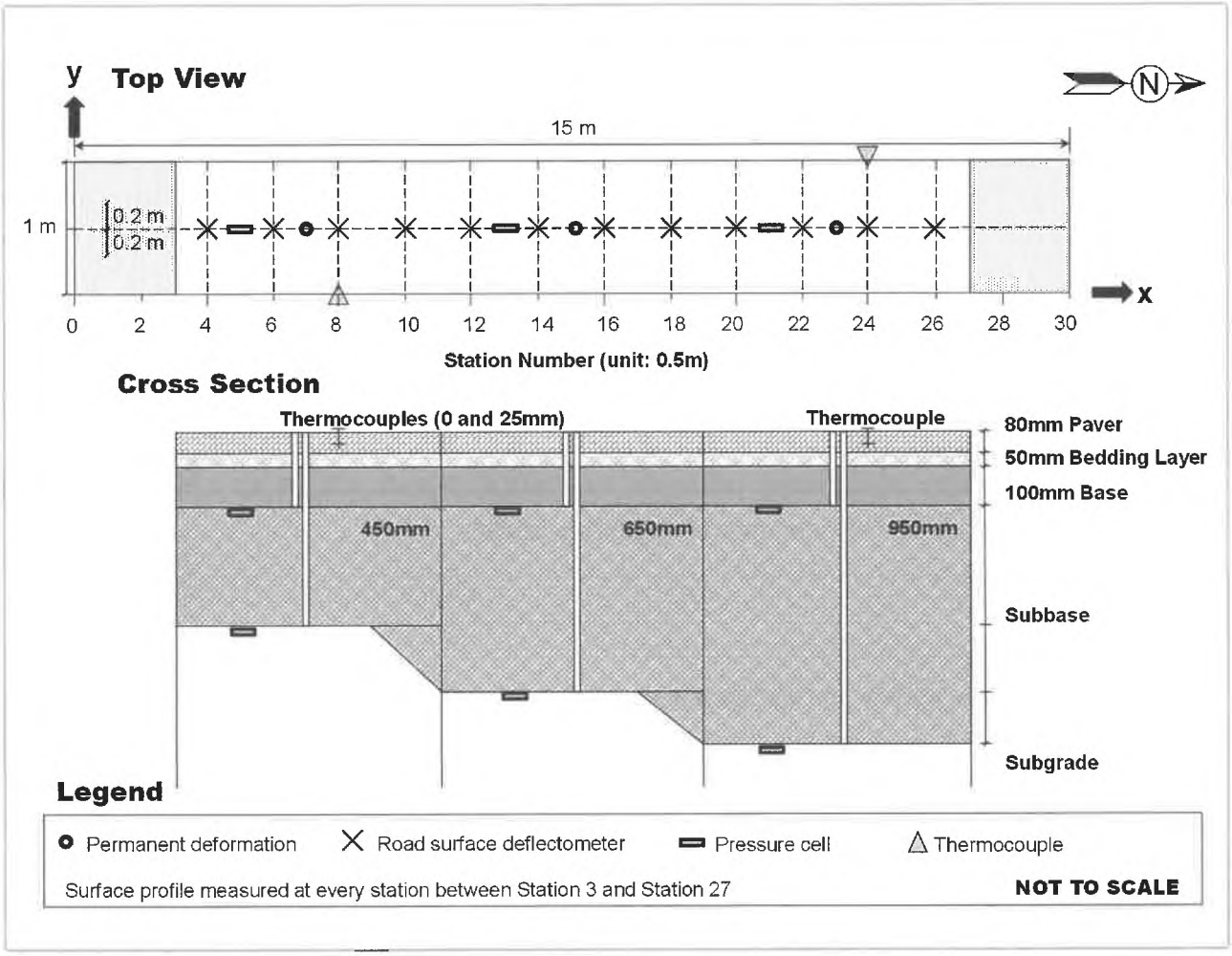


Figure 1. Proposed pavement structure for PICP test track and schematic of an extended HVS test section.

The HVS loading program for each test is summarized in Table 1. Equivalent Standard Axle Loads (ESALs) were determined using the following conversion (Equation 1): ESALs = (axle load/18,000)$^{4.0}$

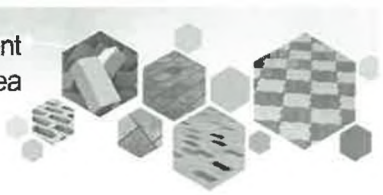


Table 1. Summary of HVS Loading Program

Section #	Test Moisture Condition (Date)	Half-Axle Wheel Load (kN)	Repetitions	ESALs
678HC	Dry	25 40 60	100,000 100,000 140,000	15,259 100,000 708,750
679HC	Wet	25 40 60 80	100,000 100,000 140,000 40,000	15,259 100,000 708,750 640,000
680HC	Drained	25 40	100,000 25,000	15,259 25,000
Project Total			845,000	2,328,277

3. Results

3.1 Dry Test (Section 678HC)

Figure 2(a) shows the development of surface permanent deformation (average maximum total rut) with load repetitions for the three subsections.After completion of trafficking, the average maximum rut depth (average of the total rut recorded at each station) for the 450 mm, 650 mm, and 950 mm subbase subsections was 24.5 mm, 21.4 mm, and 17.7 mm, respectively. The test was stopped when the average maximum rut on the 450 mm subbase subsection reached 25 mm.

Permanent deformation in the underlying layers is shown in Figure 2. During the 25 kN wheel loading, most of the rutting occurred in the 450 mm subbase layer. After the load change to 40 kN, the rate of increase in permanent deformation in the subbase remained relatively constant, but increased in the subgrade. Throughout the test, most of the permanent deformation was 13.2 mm in the 650 mm subbase layer at the end of the test. This implies that the thicker subbase limited deformation in the subgrade. At the end of the test, the permanent deformation in the subbase was 12.5 mm, with just 0.7 mm recorded in the subgrade. Permanent deformation in the 650 mm and 950 mm subbase was therefore similar under dry conditions, but the thicker subbase essentially prevented any deformation in the subgrade.

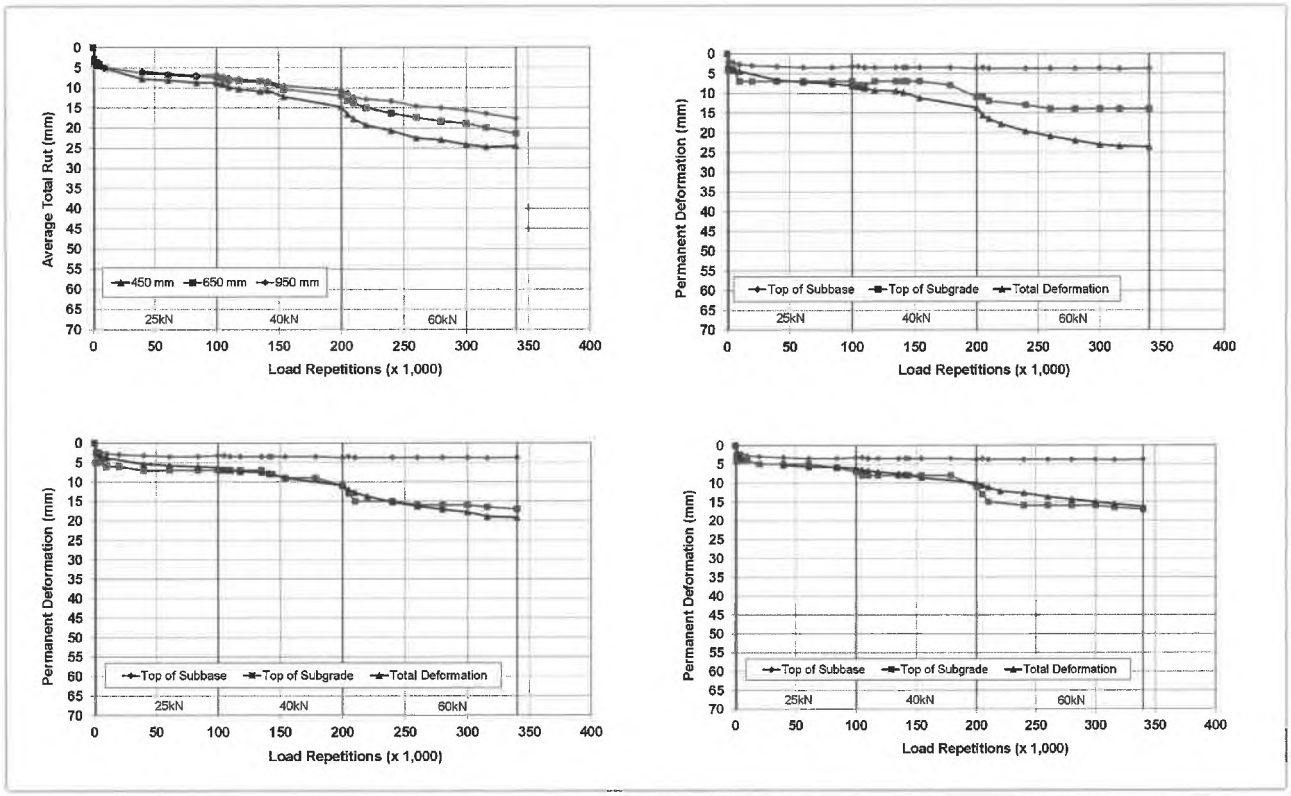


Figure 2. 678HC dry test: (a) Average maximum total rut depth; (b) Permanent deformation of 450 mm subbase; (c) Permanent deformation of 650 mm subbase; (d) Permanent deformation of 950 mm subbase

3.2 Wet Test (Section 679HC)

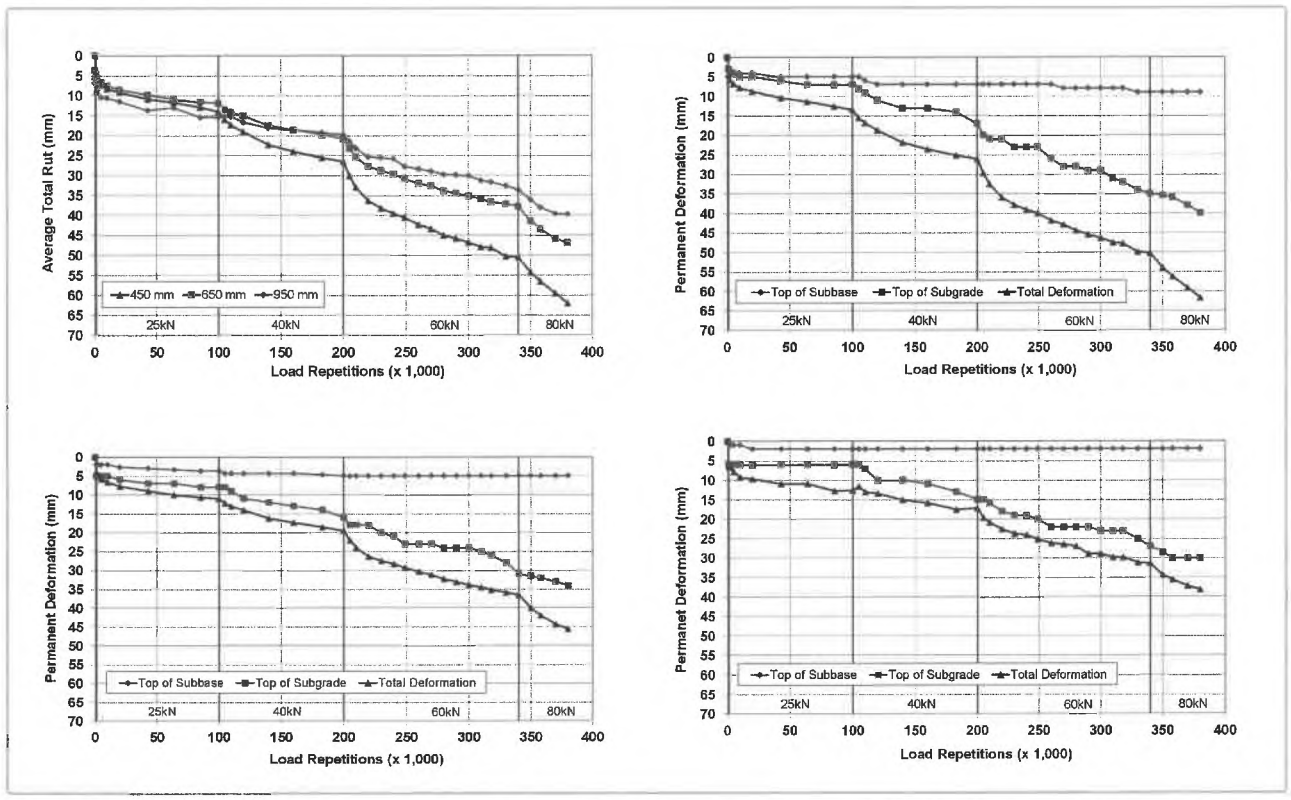
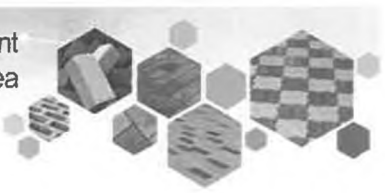


Figure 3. 679HC wet test: (a) Average maximum total rut depth; (b) Permanent deformation of 450 mm subbase; (c) Permanent deformation of 650 mm subbase;(d) Permanent deformation of 950 mm subbase



Average maximum total rut depth (Figure 3) was significantly quicker compared to the rut depths under dry conditions. During each wheel loading, the test ended with much deeper ruts compared to the dry test. The rate of rut depth increase was faster than the rate recorded with the 25 kN load and with the 40 kN load on the dry test and accelerated compared to the 40 kN loading cycle, and to the dry test. Permanent deformation in the underlying layers was recorded in each subsection for the 450 mm, 650 mm, and 950 mm subbase sections, respectively.Permanent deformation measured in 450 mm subbase layer at the end of the test was 9.0 mm, significantly more than the 3.8 mmrecorded on the dry test, and consistent with the deformation recorded in the subbase. With the load increasing, there was a considerable, but similarly trending rate of increase in permanent deformation in both the subbase and subgrade. Onthe 650mm subbase layer, the combined bedding and base layer had less permanent deformation at the end of the test compared to the thinner section. Apart from minor embedment at the start of the test, permanent deformation of 950mm subabase in the combined bedding and base layer (2 mm) did not increase during the test. The trend of total permanent deformation was not linear, with considerably more permanent deformation on the thin subsection compared to the thicker subsections, implying that thicker subbase layers will be necessary if water levels are maintained in the subbase.

Drained Test (Section 680HC) was included to compare rate of rut increase on the section with no water in the subbase with rate of rut increase on the dry and wet tests. This section did not contain pressure cells or permanent deformation gauges. A limited number of load repetitions were applied, sufficient to compare surface rutting trends with those on the other two sections. Rutting trends and rut depths were similar to those recorded on the dry section. Permanent deformation in the underlying layers was not measured in this drained test.

4. Conclusion

This paper summarizes the main results from HVS APT testing and reveals the structural performance of PICP under heavy traffic loading. There was a significant difference in rutting performance and rutting behavior between the wet and dry tests, as expected. During testing under wet conditions, rutting in the bedding and base layers was dependent on the thickness of the subbase.Rutting occurred in both the subbase and the subgrade on all subsections, with rutting in the subbase consistent across all three sections. The sensitivity of the pavement structure to water and to load is clearly evident. Although only limited testing was undertaken under drained conditions, rutting behavior appeared to show similar trends and behavior to the test under dry conditions. The thickness of the subbase influenced rut depth in the subgrade, as expected, but did not influence the rutting behavior in the subbase itself. Rutting in this layer therefore appears to be governed by the aggregate properties, and construction methods and quality. The increase in rate of rut depth increased with increasing load, indicating that the pavement structure was load sensitive, especially at load levels close to and above the legal load limit.

Acknowledgements

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