Accelerated Load Testing to Compare the Performance of Full-Depth Reclamation with Foamed Asphalt Under Three Environmental Conditions

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Full-depth reclamation (FDR) with foamed asphalt has been successfully used as a rehabilitation strategy in California since 2001. Long-term field monitoring on several projects, combined with a comprehensive laboratory study, resulted in the preparation of guidelines and specification language in 2008. However, the design criteria were essentially empirical, in line with California's design procedures for this level of rehabilitation project. There has been growing interest in the use of cement, engineered emulsion, and no-stabilizer full-depth reclamation strategies in addition to foamed asphalt, and in the use of mechanistic design in a greater range of rehabilitation projects. Consequently, the research initiative was extended to a second phase, to include accelerated load testing on an instrumented test track constructed with these four FDR strategies. The second phase gathered data for the development of performance models that can be included in mechanistic–empirical rehabilitation design procedures. This paper summarizes the results of three of the 11 tests in this accelerated loading study, which compared the performance of foamed asphalt under three environmental conditions (dry, wet, and at elevated temperature). All three sections performed well; however, performance was clearly influenced by wet conditions and higher asphalt concrete surface temperatures. As a consequence, good drainage and appropriate binder selection need to be considered when undertaking rehabilitation designs with full-depth reclamation.

Full-depth reclamation (FDR), or recycling of damaged asphalt concrete pavements to provide an improved base for a new asphalt concrete wearing course, is a pavement rehabilitation strategy of increasing interest worldwide. FDR offers a rapid rehabilitation process, with minimal disruption to traffic. Most importantly, it reuses the aggregates already in the pavement, thereby minimizing the environmental and social impacts associated with removal of old pavement layers and extraction and transport of new aggregates.

The California Department of Transportation (Caltrans) built its first FDR project with foamed asphalt and cement in 2001 in a 15-km pilot study. Based on the early apparent advantages this technology, Caltrans approved a University of California Pavement Research Center (UCPRC) study in 2004 to investigate the use of this technology under California pavement, material, traffic, and environmental conditions, with a special focus on the rehabilitation of thick, severely cracked asphalt pavements. Most Caltrans FDR projects are undertaken on thick, cracked pavements, which distinguishes California practice from that of many other states and countries in the investigation and use of this rehabilitation strategy. Pavement technology in South Africa and Australia, where much of the early research was undertaken on FDR with foamed asphalt (FDR-FA), typically relies on good quality granular material or cement-treated base and subbase layers for the primary load-carrying capacity of the pavement, with the thin asphalt concrete (< 50 mm) or surface treatment layers (chip seals) providing little or no structural integrity. Consequently, in those countries, the recycled material consists mostly of recycled natural aggregate or cracked cement-stabilized layers, which was reflected in their research, experience, and guideline documentation at the time the California study was initiated (*1–4*). Practice in Europe has been intermediate between that of California and South Africa, with the recycled material generally consisting of a mix of asphalt bound and natural aggregate materials.

The first phase of the research focused on foamed asphalt and included a comprehensive laboratory study and long-term field performance monitoring on several projects (*5*). The project culminated in 2008 with the preparation of a guideline document (*6*) and specification language. The design criteria were essentially empirical, in line with California's design procedures for this level of rehabilitation project. Since the completion of this phase of the research, FDR-FA has been widely used as a rehabilitation strategy in the state.

Recently, there has been growing interest in the use of other stabilizers in FDR projects, including cement and engineered emulsion. There have also been experiments with FDR without a stabilizer (FDR-NS, i.e., pulverizing the old asphalt concrete layers and recompacting the material as a new, unbound base course). And there is growing interest in the use of mechanistic design approaches in FDR projects. Consequently, the California research initiative was extended to a second phase, to include these additional stabilization strategies and investigate the development of mechanistic–empirical performance models for them. This research study entailed monitoring additional field projects with the different strategies, laboratory testing, and accelerated load testing on an instrumented test track constructed with the four FDR strategies (*7*). The data collected during this research are being used for the development and calibration of performance models that can be included in mechanistic–empirical rehabilitation design procedures.

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This paper summarizes one part of the Phase 2 accelerated load tests, conducted on three separate FDR-FA sections to compare performance under dry and wet conditions, and at elevated surface temperatures (i.e., temperature at the top of the FDR-FA layer was maintained at 50°C for the duration of this test compared with 30°C for the other two tests).

STUDY AND PAPER OBJECTIVES

The objective of the second phase of the California FDR study was to develop a comprehensive guideline for the rehabilitation design of pavements with full-depth reclamation techniques. This objective was achieved through the following tasks (*7*):

1. A literature review on research related to the topic;
2. Long-term monitoring of field experiments to assess stiffness, cracking, rutting or densification, freeze-thaw, moisture sensitivity, and other observed distresses;
3. Construction of a test track to compare full-depth cement, foamed asphalt with cement, and engineered asphalt emulsion stabilization against two sections with no stabilization in accelerated load tests (the two sections with no stabilizer have different asphalt concrete surface layer thicknesses);
4. Laboratory testing to refine mix-design procedures and identify suitable criteria for mechanistic–empirical design procedures and performance models; and
5. Preparation of guidelines for full-depth recycling in California.

This paper discusses the results of three of the 11 accelerated load tests listed in Task 3 (*7*). The results of tests on the unstabilized and cement stabilized sections were published elsewhere (*8–10*).

LITERATURE REVIEW

Although more than 60 publications related to full- and partial-depth reclamation were reviewed (*7*), they mostly documented project-level field or laboratory tests, and did not directly address the objectives of this study. Although some documents in the search implied guidance (*11, 12*), the information listed was based on the results of department of transportation surveys, and no actual guidance was provided. Useful approaches to mechanistic–empirical design of FDR pavements were covered in the revised *Wirtgen Cold Recycling Manual* (*4*), and several other publications referred to analysis of laboratory test results with mechanistic approaches (*13–15*). The literature review located three references on accelerated load testing of FDR projects: Louisiana (*16*), New Zealand (*17*), and Alabama (*18*). Although many publications were located on the monitoring of individual field projects, no published research was located on the comprehensive monitoring of a series of FDR field sections with different design parameters.

TEST TRACK DESIGN AND CONSTRUCTION

The test track for the accelerated load test is located at the UCPRC in Davis, California. The test track, which is 110 m long and 16 m wide, was originally constructed to assess the performance of seven warm-mix asphalt technologies in rubber-modified asphalt concrete. The test track consisted of 400 mm of aggregate base, surfaced with 60 mm of conventional hot-mix asphalt underneath 60 mm of gap-graded rubberized asphalt concrete. This track was tested over a period of two years (*19–21*). After completion of testing, the test track was recycled in place. Conventional full-depth reclamation procedures were followed, with each of four lanes of the test track subjected to a different stabilization strategy [no stabilization, foamed asphalt with cement (termed FDR-FA in this paper), engineered emulsion with no active filler, and portland cement only].

Milling depth was set at 250 mm for all the strategies, which is typical of milling depths on California rehabilitation projects (200 to 300 mm). A 60 mm–thick conventional dense-graded asphalt concrete overlay was placed over the full track. An additional 60 mm layer of asphalt concrete was placed over half the length of Lane 1 (no stabilizer) to quantify the differences in performance of the unstabilized base with different thicknesses of asphalt. The additional layer was also used to determine whether the unstabilized recycled base with thicker asphalt provided similar performance to a stabilized base with thinner asphalt. In addition, data were collected for life-cycle cost and environmental life-cycle analyses. Mix designs were undertaken by UCPRC in consultation with the California–Nevada Cement Association and manufacturers of engineered emulsions. The FDR-FA section mix design was 3% asphalt and 1.5% cement by mass of aggregate.

Conventional FDR construction procedures were followed. On the FDR-FA section, cement was first spread onto the pavement, after which the recycling train (binder tanker, recycler, and water tanker) made a single pass (Figure 1*a*). Some water was added to raise the

(a)

(b)

FIGURE 1 Test track construction: (*a*) pulverization and mixing and (*b*) water addition and compaction.

moisture content to a suitable level for compaction. Compaction and finishing followed the same process as that for the unstabilized section (Figure 1*b*). The test sections were allowed to cure for 10 days before the asphalt was placed. The FDR-FA section was kept moist during the curing period.

TEST TRACK INSTRUMENTATION AND MEASUREMENTS

The test section layout is shown in Figure 2. Each accelerated load test section was instrumented with two strain gauges (transverse and longitudinal positions) on top of the base, one pressure cell (embedded to be level with the top of the base), and a multidepth deflectometer (MDD), with linear variable differential transformers (LVDTs) set at 60 mm (top of the recycled base), 310 mm (interface between recycled and existing layers), 480 mm (bottom of old base), and 750 mm (subgrade). Pavement temperatures were measured with thermocouples on the surface, and at 25 mm intervals to a depth of 150 mm. In addition to the embedded instrumentation, surface deflections were measured with an electronic Benkelman Beam [road surface deflectometer (RSD)], and surface profile was measured with a laser profilometer. Falling weight deflectometer (FWD) measurements were taken on each section before and after testing, to evaluate changes in stiffness caused by traffic and moisture content in the underlying layers. Moisture contents were taken from cores and augured material from the core holes (to subgrade depth) before and after each test.

ACCELERATED LOAD TESTING PROGRAM

Accelerated load testing on the three separate FDR-FA sections was carried out with a heavy vehicle simulator (HVS). All trafficking was conducted with a dual tire configuration (720 kPa tire pressure) in a wandering bidirectional mode. Identical loading programs, selected on the basis of 20 years of HVS testing experience at UCPRC to provide a realistic accelerated loading pattern (i.e., starting with a standard axle load and then increasing to higher loads as pavement responses are understood) were followed and are summarized in Table 1. Failure criteria were set at 13 mm average maximum rut or 2.5 m/m^2 of cracking. Loading on the FDR-FA dry test was terminated after 1.37 million load repetitions in the interests of completing the testing within the project time and financial constraints.

Pavement temperature at 50 mm depth was maintained at 30°C (±4°C) on the dry and wet tests and at 50°C (±4°C) on the elevated temperature test with an environmental chamber surrounding the equipment. The lower temperature was selected to assess rutting and cracking potential in the recycled layer under typical pavement con-

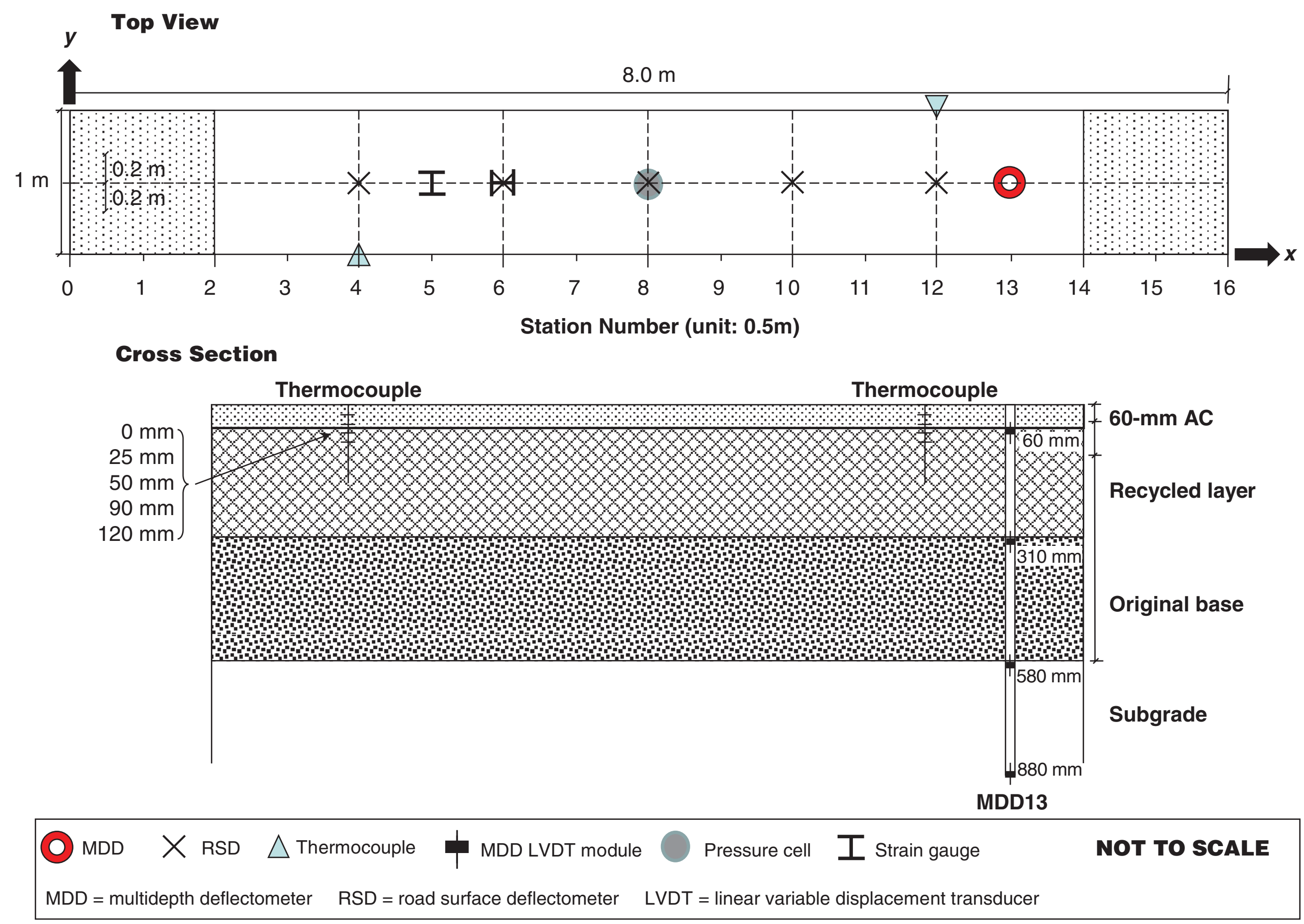


FIGURE 2 Test section layout.

TABLE 1 Loading Program

		Number of Repetitions			Rut Depth (mm)			Cracking (m/m^2)		
Phase	Load (kN)[a]	Dry	Wet	Hot	Dry	Wet	Hot	Dry	Wet	Hot
1	40	315,000	315,000	315,000	1.7	2.2	2.4	None	0.2	None
2	60	200,000	200,000	200,000	2.3	6.7	3.4	None	1.9	None
3	80	250,000	235,000	250,000	3.2	24.6	7.4	None	11.9	None
4	100	596,000	0	235,000	4.3	—	15.9	None	—	1.6
Total		1,371,000	750,000	1,000,000						
Total ESALs[b]		33,971,500	5,732,133	17,033,768						
ESALs to fail		Did not fail	3,434,737	12,811,065						

[a]Half-axle wheel load (40 kN = 9,000 lb; 60 kN = 13,500 lb; 80 kN = 18,000 lb.; 100 kN = 22,500 lb).
[b]Equivalent single-axle loads, calculated by $(\text{axle load}/18{,}000)^{4.2}$.

ditions, and the higher temperature was selected to assess whether FDR-FA layers are susceptible to rutting under relatively thin asphalt concrete surfacings trafficked at summer temperatures. The chamber also protected the sections from any rainfall.

In the wet test, the test section was soaked with water for 10 days prior to HVS testing, to accelerate the onset of any potential moisture damage and represent typical conditions on roads in heavily irrigated agricultural areas. The soaking period was based on previous studies to determine optimal soaking times for soaked HVS testing (*22*). A row of holes was drilled in the bottom of the asphalt concrete layer on the side of each test section, to facilitate water ingress into the base. The holes were 25 mm in diameter, 250 mm from the edge of the HVS test section, and 250 mm apart. A wooden dam, 200 mm high and 300 mm from the edge of the test section, was then glued to the pavement with silicone, to provide a head of water (Figure 3). The dam was kept full of water for the duration of the soaking period. During HVS testing, a constant flow of water at approximately 1.5 L/h was maintained through irrigation tubes positioned in each hole in the asphalt layer, to ensure that the base remained in a soaked condition. Excess water was allowed to flow across the surface, thereby allowing infiltration through any cracks in the asphalt concrete. This water was maintained at a temperature of 30°C ±4°C to prevent cooling of the pavement surface. This testing condition was considered to be an extreme worst case to illustrate the importance of ensuring good drainage on rehabilitated roads, something that may be overlooked in some rehabilitation designs, especially in areas with irrigated agriculture (e.g., rice).

FIGURE 3 Presoak before HVS testing.

TEST SECTION PERFORMANCE

HVS testing started on the dry section, followed by the wet section, and then the high-temperature section. The moisture contents recorded in the recycled layer, original aggregate base, and subgrade on each test section were as follows:

- Dry test. Moisture contents in the three layers were 3.2%, 4.5%, and 12.9% of the dry weight of the materials, respectively, at the start and did not change during the test.
- Wet test. Moisture contents in the three layers were 6.8%, 6.2%, and 15.5% of the dry weight of the materials, respectively, at the start, considerably higher than were those recorded on the dry test. Moisture contents did not change significantly during the test.
- High-temperature test. Moisture contents in the three layers were 5.0%, 5.9%, and 15.2% of the dry weight of the materials, respectively, at the start. These moisture contents were higher than were those recorded on the dry test, which was attributed to moisture ingress from the wet tests on the adjacent FDR-NS section. Moisture contents did not change significantly during the test.

Test section performance is summarized in the following subsections for the various measurements that were taken.

Permanent Deformation on Surface

Permanent surface deformation (average maximum rut being the measurement from the bottom of the rut to the top of the displaced material on the side of the wheelpath) measured on the three sections is shown in Figure 4.

Significantly more rutting was noted on the wet and high-temperature sections compared with the dry section, as expected, with the higher rate of rutting on the high-temperature section primarily attributed to the higher layer moisture contents rather than to the higher test temperature. Average maximum rut recorded on the dry section after 1.371 million load repetitions [equivalent to 34 million equivalent single-axle wheel loads (ESALs); see Table 1 for loads applied during the test] was about 5.0 mm, well below the terminal

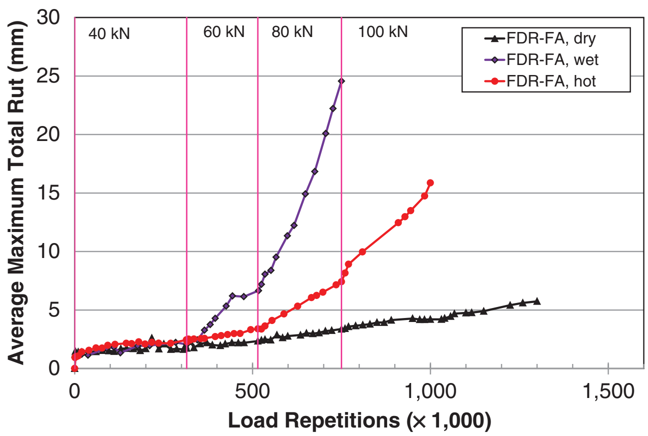


FIGURE 4 Surface permanent deformation.

average maximum rut of 13 mm. Terminal rutting was recorded on the wet and high-temperature sections after 625,000 and 910,000 wheel repetitions, respectively, which equates to 3.5 million and 12.8 million ESALs, respectively. The wet and high-temperature test sections were also load sensitive, with each load change resulting in an embedment phase and increased rut rate per load repetition. Performance on the dry section did not appear to be load sensitive.

Contour plots of the surface deformation are shown in Figure 5. Rutting on all three sections appeared to be predominantly downward compression or densification, with very little displaced material on the edges of the wheelpath.

Permanent Deformation in Underlying Layers

Permanent deformation in the underlying layers, recorded with MDDs, compared with the surface layer (recorded with a laser profilometer)

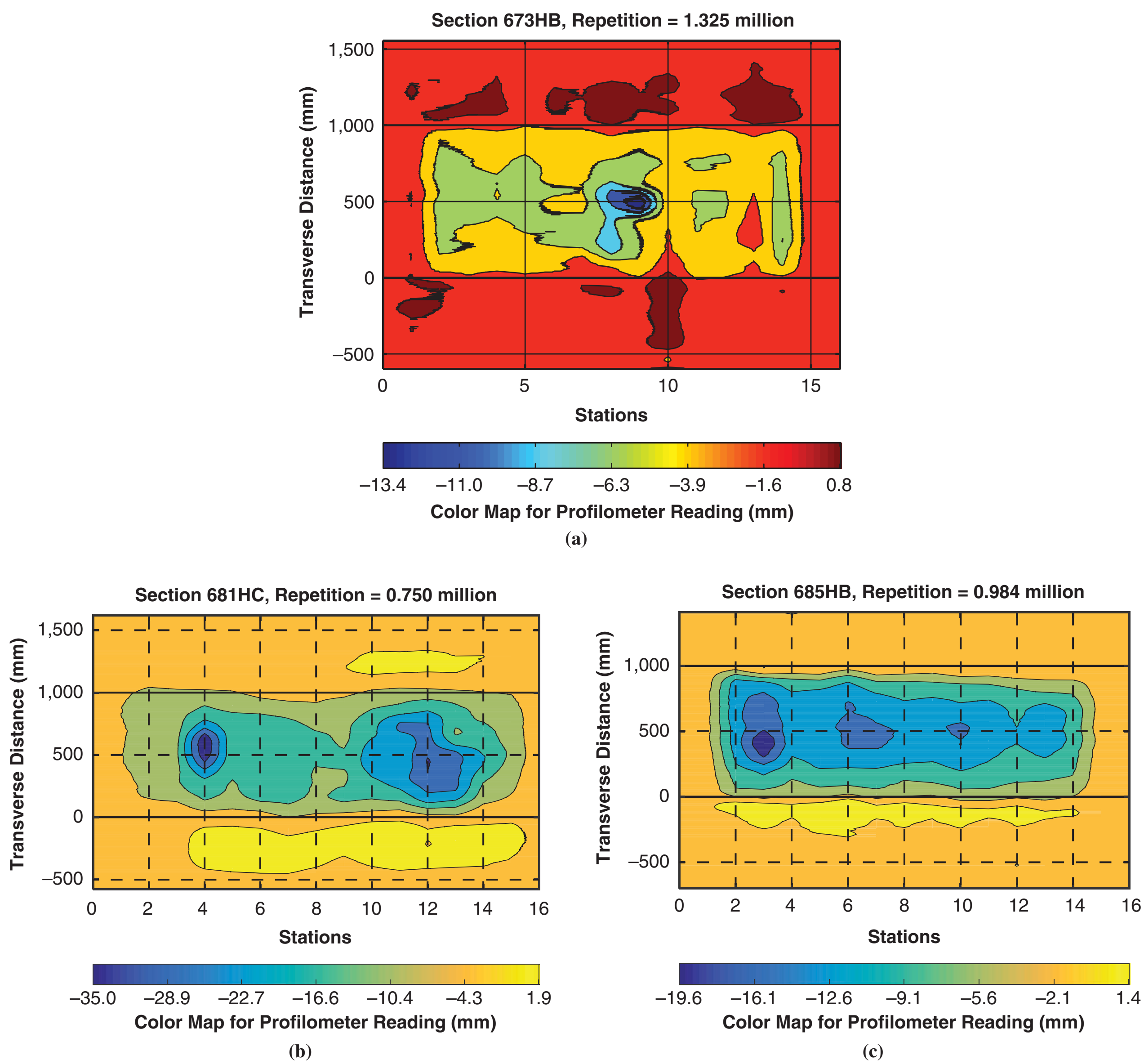


FIGURE 5 Contour plots of surface permanent deformation (negative is downward deformation): *(a)* FDR-FA, dry; *(b)* FDR-FA, wet; and *(c)* FDR-FA, hot.

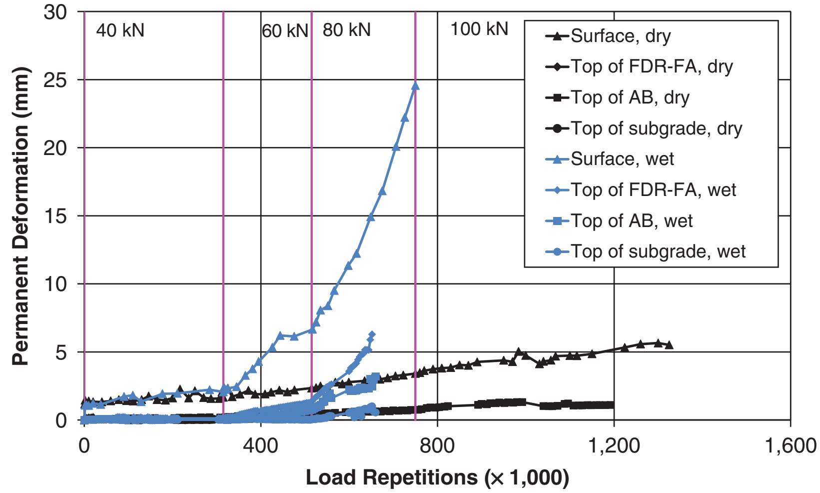


FIGURE 6 Permanent deformation in surface and underlying layers.

is shown in Figure 6 for the dry and wet tests. Although LVDTs were installed in the high-temperature test, they failed early (lost contact with the hole) due to higher than optimal moisture conditions caused by soaking on the adjacent wet tests. Some LVDT failures also occurred on the dry and wet tests under trafficking, and consequently a full set of data could not be collected. However, the MDD measurements that were collected were consistent with the laser profilometer measurements. On the dry test, the limited permanent deformation appeared to be primarily in the surfacing. On the wet test, the deformation appears to have been distributed between the surfacing, recycled layer, and existing aggregate base. Rutting in the subgrade was similar in both sections and very limited (about 1 mm). Given that limited data were collected from the MDDs, the extent of permanent deformation was carefully evaluated during the forensic investigation, which is discussed in the next section of the paper.

Transverse and Longitudinal Strain at Top of Recycled Base

Strain readings on the wet and high-temperature tests became erratic in the early stages of the test, attributed to debonding of the instruments under the very wet conditions. On the dry test, relatively constant transverse strain readings were recorded for the first 200,000 load repetitions, with a slight decrease thereafter until the load change to 60 kN, suggesting gradual layer stiffening resulting from densification caused by the HVS trafficking. Strains increased after the load change, but then showed similar decreasing trends, indicating continued densification under loading. Longitudinal strain remained fairly constant throughout the test, apart from a small decrease during the first 20,000 load repetitions and some small spikes when the wheel load was increased. No surface distresses directly associated with the change in strain measurements in the recycled layer were noted during the testing.

Vertical Pressure at Top of Recycled Base

Pressure readings were stable and sensitive to load changes in the early stages of each test. Initial pressure was higher on the dry test compared with the wet test, which was expected based on layer elastic theory and considering the higher stiffness of the dry section. In the later stages of testing, readings from the instruments were erratic, which was attributed to changes in the support conditions under the pressure cell, as evidenced by circular cracks in the asphalt concrete directly above the cells, indicating that the cells were moving under the wheel load. It was concluded that 60-mm surfacings are probably too thin for satisfactory performance of the relatively large pressure cells and strain gauges.

Elastic Deflection in Underlying Layers

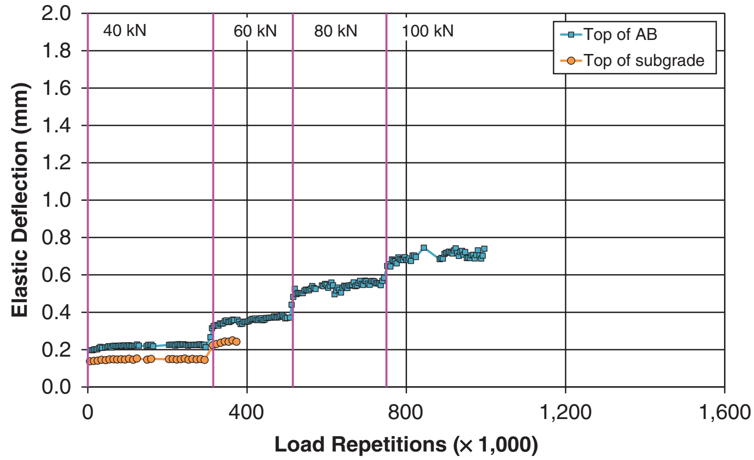
Figure 7 shows the history of in-depth elastic deflections, measured by the LVDTs in the MDDs, for the dry and wet test sections. These readings are consistent with the surface deflections measured with the RSD shown in Figure 8.

On the dry test, there was a consistent increase in vertical deflections measured at the different depths after each load change, but no significant changes during testing at each load. These results suggest a general decrease in overall stiffness of the pavement structure over the duration of the test. Similar results were observed at the top of the existing aggregate base, and at the top of the subgrade on the wet test; however, deflections increased significantly at the top of the FDR layer, which was attributed to debonding between the asphalt concrete and the FDR layer.

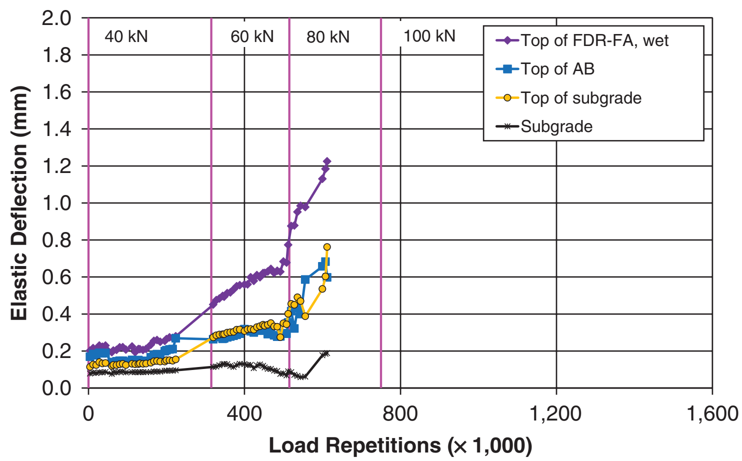
Surface Deflection Measured with Road Surface Deflectometer

Figure 8 compares elastic surface deflections measured with an RSD on the three sections under a 40 kN half-axle load. The RSD measurements were taken under a creep-speed load and would not be the same as those recorded under normal traffic or under an FWD.

Surface deflections on the dry test were constant in the range between 250 and 500 microns for the duration of trafficking, with no changes in deflection measurements after the load changes. Deflections on the wet and high-temperature tests were notably higher than those recorded on the dry test, and continued to increase



(a)



(b)

FIGURE 7 Elastic deflection in the underlying layers (MDD): (*a*) FDR-FA, dry; and (*b*) FDR-FA, wet.

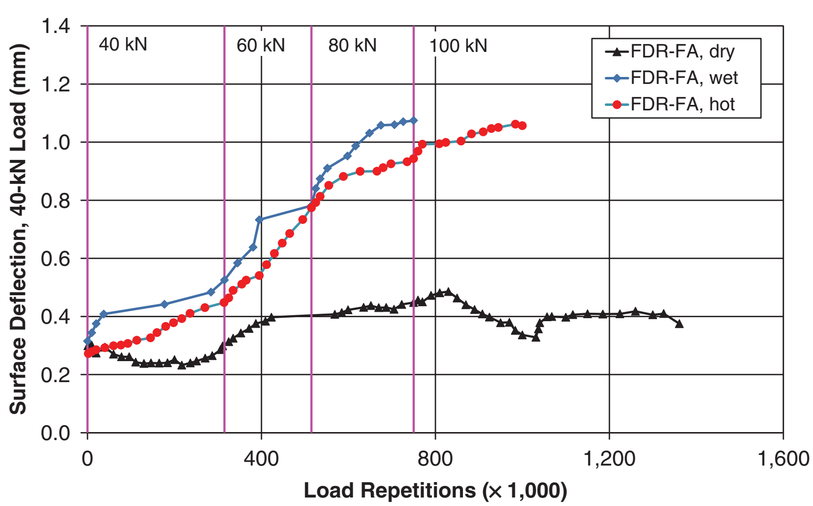


FIGURE 8 Surface deflection measured with RSD.

for the duration of the tests. In the wet test, this behavior was attributed to the high moisture content in the underlying layers and to potential debonding of the asphalt concrete surfacing from the FDR layer (confirmed in the forensic investigation). On the high-temperature test, behavior was attributed to the higher temperatures at which the deflection testing was carried out (50°C versus 30°C) and to the damage caused to the asphalt concrete layer, and potentially to the FDR-FA layer, by trafficking at the higher temperature. The higher deflections on this test were also attributed in part to the higher moisture content in the underlying layers. Load changes appeared to have had an effect on deflection on both tests.

FWD Measurements Before and After Testing

FWD testing was conducted on each section before and after HVS testing, to evaluate the change in stiffness caused by trafficking. Testing was undertaken on the trafficked and adjacent untrafficked areas (i.e., 5 m on either end of the 8 m test section) at 500 mm intervals. Two sets of tests were undertaken on each day to obtain a temperature range. The results are summarized in Figure 9, *a* and *b*. The results are consistent with the RSD measurements discussed in the previous section, with all sections showing higher deflections on the surface after completion of trafficking, as expected. Average surface deflection on the dry test increased by 40 microns after completion of HVS trafficking, compared with 250 and 110 microns on the wet and high-temperature tests, respectively, indicating that moisture had a greater influence on stiffness than higher temperatures did. Although not indicated in the figures, deflections in the subgrade did not appear to change during the course of testing and were similar on all sections.

The recycled layer stiffnesses were backcalculated from the deflection measurements using the CalBack software package. The results are summarized in Figure 9*c*. On the dry test, there was a notable drop (~ 3.400 MPa) in stiffness of the recycled layer after trafficking, which was attributed to some breaking of the cement bonds under loading and consequent damage in the form of microcracking. The presence of the recycled asphalt concrete material did not appear to affect the stiffness of the layer. After wet testing, the stiffness of the FDR-FA layer was an order of magnitude lower than at the start of the test (drop from ~ 10 GPa to 350 MPa), attributed in part to the same reasons cited for the dry test, but primarily to debonding and moisture-related damage caused by trafficking under wet conditions.

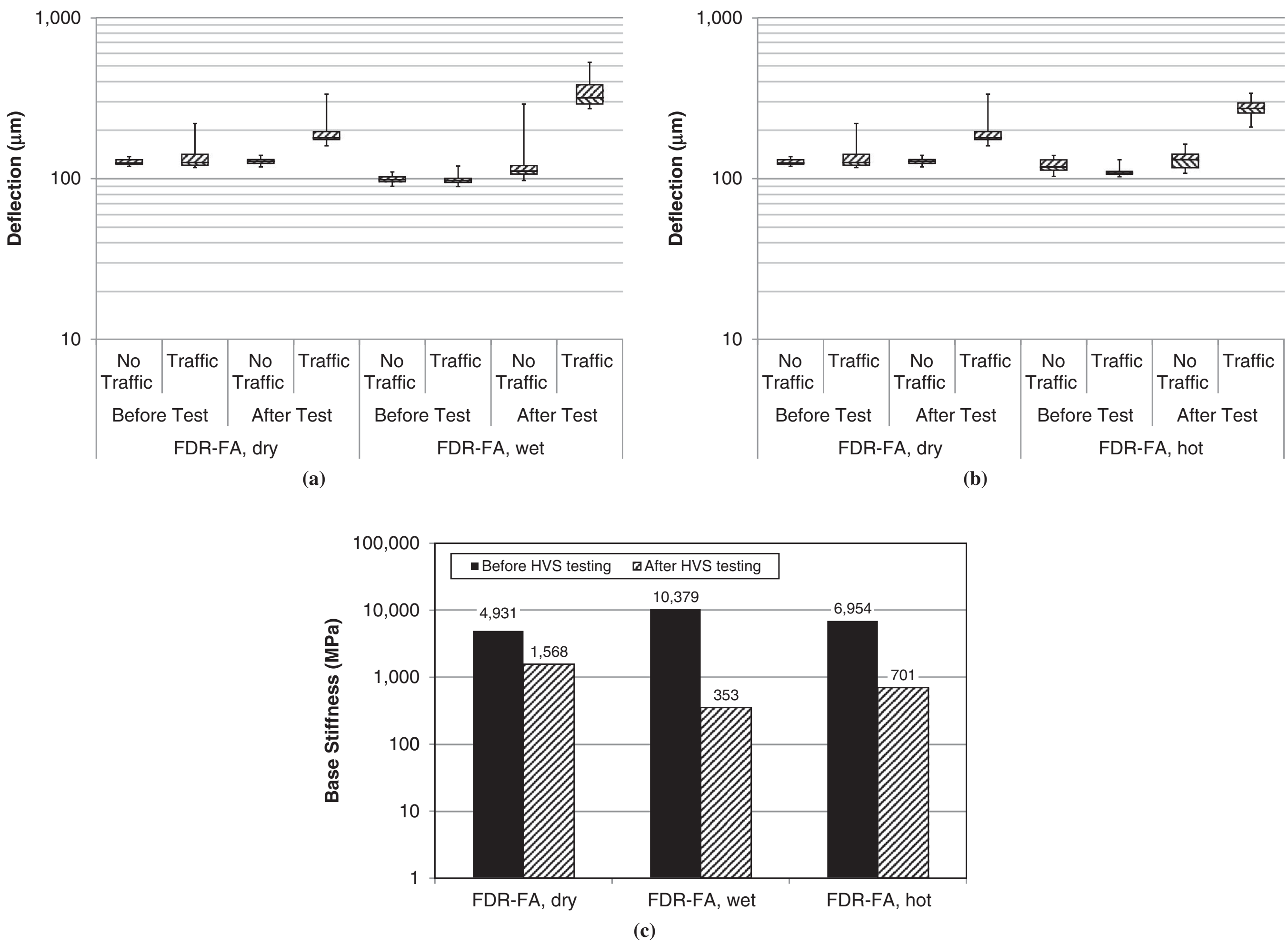


FIGURE 9 Elastic deflection and backcalculated stiffnesses in the recycled layer (FWD): (*a*) dry and wet test deflections, (*b*) dry and high-temperature test deflections, and (*c*) backcalculated stiffness. *Y*-axes are log scales.

There was also a significant drop in the stiffness of the recycled layer after HVS trafficking on the high-temperature test (~ 6,000 MPa). This drop was attributed to some breaking of the asphalt and cement bonds under loading, and consequent damage in the form of microcracking in the early stages of the test, but also to damage in the asphalt concrete and FDR layers caused by trafficking at higher temperatures. The higher moisture contents in the underlying layers would also have influenced the stiffness of the pavement structure. Unlike testing on the dry and wet tests, the relatively high-foamed asphalt content coupled with the presence of the relatively unaged recycled asphalt concrete material appeared to have an effect on the stiffness of the layer when trafficked at higher temperatures (i.e., ~1,570 MPa after the dry test compared with ~700 MPa after the high-temperature test).

FORENSIC INVESTIGATION

Photographs of the test sections after completion of HVS testing, and the test pits excavated on each section are shown in Figure 10. Moisture in the FDR layer is evident in the test pit faces of the wet and high-temperature tests. This observation supports the conclusion from the data analysis that higher moisture content had a larger impact on the performance of the high-temperature test than testing at the elevated temperature. Debonding and the void caused by pumping on the wet test are also clearly visible. Measurements in the test pits also confirmed or supplemented the measurements from the instruments discussed in the preceding sections.

SUMMARY AND CONCLUSIONS

This paper summarized the results of three of 11 accelerated loading tests conducted as part of a larger study to understand and model the behavior of pavements rehabilitated with FDR. The three tests discussed were conducted on three sections on the foamed asphalt stabilized lane, and compared performance under three environmental conditions (dry and wet at intermediate surface temperature, and dry at high surface temperature). As expected, the dry test outperformed the wet and high-temperature tests in all aspects that were measured. The key results include the following:

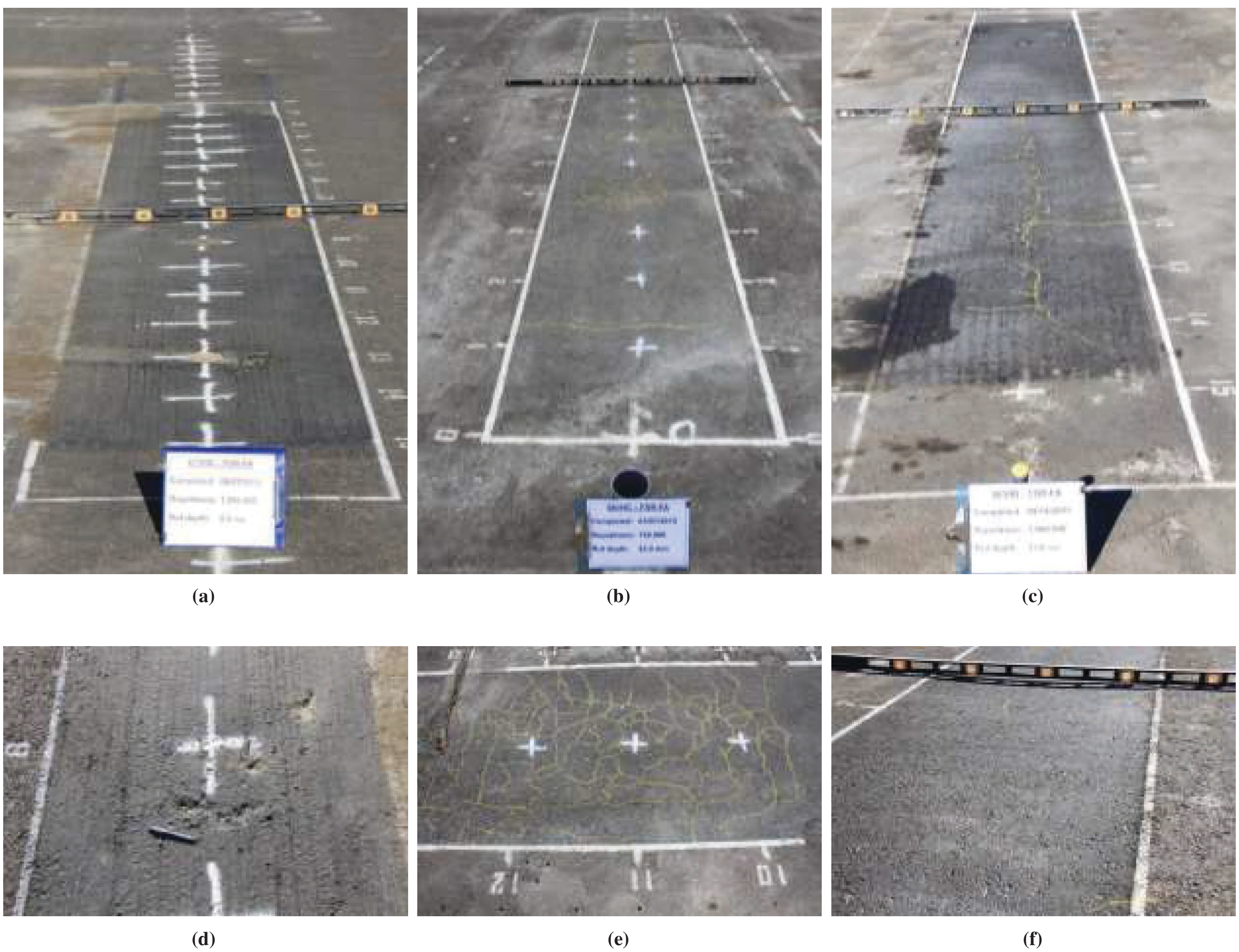


FIGURE 10 Views from end of test section: (*a*) FDR-FA, dry, (*b*) FDR-FA, wet, and (*c*) FDR-FA, hot. Close-up views of test section: (*d*) FDR-FA, dry, (*e*) FDR-FA, wet, and (*f*) FDR-FA, hot.

(continued)

(g) (h) (i)

FIGURE 10 *(continued)* **Forensic investigation test pits: (*g*) FDR-FA, dry, (*h*) FDR-FA, wet, and (*i*) FDR-FA, hot.**

- Terminal rut depths of 13 mm were recorded on the wet and high-temperature test sections after approximately 3.5 million and 12.8 million ESALs had been applied, compared with only 5.0 mm on the dry test after 34 million ESALs. Testing was halted on the dry test at this point in the interests of testing the other sections within the time and financial constraints of the project. Permanent deformation was primarily in the asphalt surfacing layer of all three test sections.
- Measured and backcalculated stiffnesses were significantly higher after completion of HVS trafficking on the dry test compared with the wet and high-temperature tests. This finding indicates that high-layer moisture contents will be detrimental to performance, and moisture had a greater impact on performance than temperature did. Although the stiffness dropped considerably in the recycled layer on the dry test after trafficking, it was still orders of magnitude higher than on the other two sections, despite having been subjected to considerably more axle loads.
- A forensic investigation confirmed the results from instrumentation. Test pits revealed that distresses on the wet and high-temperature tests were primarily caused by moisture in the underlying layers. Debonding of the asphalt and pumping of fines from the top of the FDR layer into the asphalt was evident in the wet test.

The test results discussed in this paper confirm earlier test results from a previous phase of the study, and further support the findings that in-place recycling with foamed asphalt and cement is an appropriate rehabilitation strategy for pavements with low-strength or failed bases that have led to severe cracking or rutting in asphalt concrete surfacings. Diminished performance during HVS testing under extreme wet conditions illustrated the importance of taking appropriate measures to ensure that the recycled base remains dry during the service life of the pavement (i.e., ensuring that good drainage is always provided along the length of the rehabilitated road). Testing under elevated temperatures had minimal impact on the performance of the recycled layer. The results of this research are being used to prepare guidelines on full-depth reclamation in California, which will include mechanistic–empirical design criteria and parameters.

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