Automated Plate Load Testing on Concrete Pavement Overlays with Geotextile and Asphalt Interlayers: Poweshiek County Road V-18

Test Report
April 2018

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16. Abstract

Automated plate load testing (APLT) was conducted on County Road V-18 in Poweshiek County, Iowa, to assess and compare performance of unbonded concrete overlay sections constructed in 2008–2009. The unbonded overlays on County Road V-18 were constructed in selected areas using an asphalt concrete (AC) interlayer or a non-woven geotextile fabric interlayer. Wiegand et al. (2010) documented the construction techniques and materials used to build the test sections (project TR-600). The results of the study documented here provide a new assessment of the in situ deformation and composite modulus of the test sections.

Test results showed that the core thicknesses varied between 8.8 and 10.2 in. in sections with the geotextile interlayer, and 7.3 and 7.6 in. in sections with the AC interlayer. The geotextile fabric was about 0.1 in. thick and the AC layer was about 0.5 in. thick. Cyclic APLT results indicated that, on average, the composite resilient modulus ($M_{r\text{-}comp}$) was 40 percent higher, permanent deformation (δ_p) was lower, and the exponent in the power model (d) that defined number of cycles vs. δ_p was lower in the geotextile sections than in the AC layer sections. Because the data set obtained in this study did not include the mechanistic properties of the underlying layers, additional APLT testing is recommended. Future testing should also assess the in situ drainage difference between sections and the ride quality (e.g., international roughness index (IRI) and pavement condition index (PCI)) between different pavement interlayer types.

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AUTOMATED PLATE LOAD TESTING ON CONCRETE PAVEMENT OVERLAYS WITH GEOTEXTILE AND ASPHALT INTERLAYERS: POWESHIEK COUNTY ROAD V-18

Test Report
April 2018

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Personnel from the National Concrete Pavement Technology (CP Tech) Center and Poweshiek County, Iowa coordinated access to the project site. Xuhao Wang with the National CP Tech Center performed coring operations. Poweshiek County personnel provided traffic control during field testing. Lyle Brehm (Tama County engineer) and Makr Bair (superintendent) provided coordination and input. Ingios Geotechnics provided automated plate load testing (APLT) services.

EXECUTIVE SUMMARY

This report presents results from cyclic plate load testing conducted on County Road V-18 in Poweshiek County, Iowa, comparing and assessing the performance of unbonded concrete overlay sections constructed with geotextile fabric and AC interlayers. The sections were constructed in 2008–2009. Cyclic automated plate load tests (APLTs) were conducted with 250 cycles using five cyclic stress levels ranging between 50 and 150 psi. In addition, pavement cores were collected at each test location to obtain the overlay thickness. Testing was performed at four locations with geotextile fabric interlayer and two locations with the AC interlayer.

The key findings from the testing and analysis were as follows:

- The core thicknesses varied between 8.8 and 10.2 in. in sections with the geotextile interlayer, and 7.3 and 7.6 in. in sections with the AC interlayer. The geotextile fabric was about 0.1 in. thick and the AC layer was about 0.5 in. thick. The effect of overlay thickness on the cyclic APLT results could not be isolated here because of the limited data set.

- Cyclic APLT results indicated that, on average, the composite resilient modulus ($M_{r\text{-}comp}$) was 40 percent higher, permanent deformation (δ_p) was lower, and the exponent in the power model (d) that defined the number of cycles vs δ_p was lower in the geotextile sections than in the AC layer sections.

- Student t-test analysis indicated that at the 95% significance level, δ_p showed a statistically significant difference between the two sections with lower δ_p in the geotextile sections than in the AC layer sections at the end of the test.

The results presented in this report serve as preliminary assessment and comparison of support conditions for the two interlayer conditions. The following recommendations are provided for additional testing and analysis:

- The data set obtained in this study did not include the mechanistic properties of the underlying layers. If the underlying foundation layer properties are isolated, the benefits of using different interlayers can be better assessed. Layered testing protocols and analysis should, therefore, be included with future field testing.

- Cyclic APLT can be used to quantify the underlying layer mechanistic properties by using a special sensor kit measuring the pavement deflection basin. To complement multiple layer field testing, tests directly on the foundation layer are recommended, preferably by performing selected tests through a 14 in. diameter core. It is recommended that at least 8 to 12 test points for each of these different conditions be obtained with future testing.

- Drainage should be quantified in situ by directly measuring the drainage characteristics of the interlayers. This can be achieved by using the core hole permeameter (CHP) test device developed or using the rapid air permeameter test (APT) test device.

- The ride quality of the test sections, i.e., international roughness index (IRI) and pavement condition index (PCI), with and without the geotextile fabric interlayers, should be monitored and analyzed.

INTRODUCTION

In this field study, automated plate load testing (APLT) was conducted on County Road V-18 in Poweshiek County, Iowa, to assess and compare performance of unbonded concrete overlay sections constructed in 2008–2009. The unbonded overlays on County Road V-18 were constructed with an asphalt concrete (AC) interlayer or a non-woven geotextile fabric interlayer in selected areas. Wiegand et al. (2010) documented the construction techniques and materials used to build the test sections (project TR-600). The results of the study documented here provide a new assessment of the in situ deformation and composite modulus of the test sections.

Traditionally, AC interlayer (1 to 2 in.) has been used in practice for concrete overlays to act as a bond breaker for stress relief and to reduce reflective cracking. If geotextile fabric is used as an interlayer, in addition to acting as a bond breaker, it could help improve drainage due to its relatively high permeability characteristics (Lederle et al. 2013). The use of a geotextile fabric interlayer was initiated in the US after positive experiences in Germany were reported during the Federal Highway Administration's (FHWA) European scanning study (Hall et al. 2007). Several field trials have been initiated in the US since 2008 by including a geotextile fabric interlayer in lieu of the AC interlayer in concrete overlay designs (Rasmussen and Garber 2009, Wiegand et al. 2010, Torres et al. 2012, Burwell et al. 2014).

The results presented in this report serve as preliminary assessment and comparison of support conditions for the two interlayer conditions. Recommendations are provided near the end of the report for additional detailed field testing and analysis to more fully characterize the differences in the mechanistic properties of the concrete overlays with and without the geotextile fabric.

TEST SECTION CONSTRUCTION

Wiegand et al. (2010) summarized the geotextile bond breaker construction procedures followed on County Road (CR) V-18 in Poweshiek County. An overview of the procedures is provided below.

Before overlay operations in 2008–2009, the existing pavement was a 7-in. by 22-ft Portland cement concrete (PCC) pavement, built 30 to 35 years ago, and experiencing joint deterioration at the time of construction. A PCC unbonded overlay was planned for this project. The overlay construction involved placing a 1-in. thick unbonded AC interlayer between the PCC overlay and the underlying existing PCC pavement. The research team at the time chose three areas where a geotextile fabric could be substituted for the AC interlayer in an effort to measure cost and performance differences between the two options. The geotextile fabric was placed on both north and southbound lanes of the pavement at the three locations selected. The sections were located between Station 20+00 to 22+94 (flat or tangent grade – Site 1), Station 384+00 to 389+91 (negative grade – Site 2), and Station 36+00 to 38+94 (positive grade – Site 3). Two different fabric material suppliers were used for this project. The first material, HATE B 500-PP, was supplied by Huesker of Charlotte, North Carolina. The second material, Tencate Mirafi 1450 BB, was supplied by Tencate Geosynthetics of North America. Both materials met the material specifications outlined by Rasmussen and Garber, (2009) and were supplied in rolls that were 15 ft wide x 300 ft long. The Huesker material was utilized on Sites 1 and 2 and the Tencate Mirafi material was used on Site 3.

Based on the installation instructions included in Appendix A of Weigand et al. (2010), the fabric was overlapped by no more than 6 in. at the centerline and the excess width was laid flat on the shoulder lane. The fabric was attached to the existing pavement with nails using Hilti-ramset-type guns. They were nailed in an approximate 5.25-ft transversely by 5-ft longitudinal grid pattern with one row of nails 3 in. from each pavement edge, one at the centerline, and one at each mid-panel location.

FIELD TESTING METHODS

Automated Plate Load Testing

Ingios Geotechnics, Inc. recently developed rapid in situ testing and analysis methods and equipment using automated plate load testing (APLT) to characterize the mechanistic properties of pavement and its foundation layer. The results are being used to verify pavement and foundation design input parameter values and forecast long-term cyclic loading performance by simulating vehicle-loading conditions expected during the service life of a pavement system. The APLT field testing and evaluation program was designed to characterize the composite resilient modulus, and the permanent and resilient deformation characteristics on the overlay test sections. Testing involved conducting cyclic APLTs with 250 cycles at each test point using five cyclic stress levels ranging between 50 and 150 psi 12 in. diameter (flat plate). In addition, pavement coring was performed at each location to obtain the overlay thickness measurements. Testing was performed at four locations with geotextile fabric interlayer sections and two locations within the AC interlayer sections.

The cyclic test process uses a controlled load pulse duration and dwell time (e.g., as required in the laboratory AASHTO TP 62 and AASHTO T 324 methods for asphalt pavements and as required in the laboratory AASHTO T 307 resilient modulus test methods for foundation layers) for selected cycle times depending on the field conditions and measurement requirements. The advantage of cyclic tests is that the modulus measurements better represent the true field stiffness values. This finding is well documented in the literature and is considered a major shortcoming of other testing methods that only apply a few cycles/dynamic load pulses on the pavement layers.

The APLT system has the capability to measure inputs to develop in situ elastic modulus for the PCC layer, dynamic modulus master curve models for the AC layer, and in situ stress-dependent constitutive models for the foundation layers (i.e., base and subgrade) as used in the AASHTOWare Pavement ME Design (2015). The major advantage of in situ testing is that it does not suffer from the effects of sample preparation, sample size, equipment, and boundary conditions associated with laboratory tests.

Because the APLT test system is automated, the test methods are highly repeatable and reproducible (i.e., no operator bias). Operators only need to input the desired loading conditions (cyclic stress levels, load pulse duration and dwell time, and number of cycles), which are then tightly controlled by the machine feedback control system.

Figure 1 shows the operator station, controls, and the on-board display monitor for real-time visualization of results.

Figure 1. Automated plate load test (APLT) equipment setup on the CR V-18 project

The results of cyclic deformation, permanent deformation, elastic modulus, stiffness, resilient modulus, cyclic stresses, and number of cycles are calculated in real-time and are available for reporting immediately (see illustration of key parameters in Figure 2).

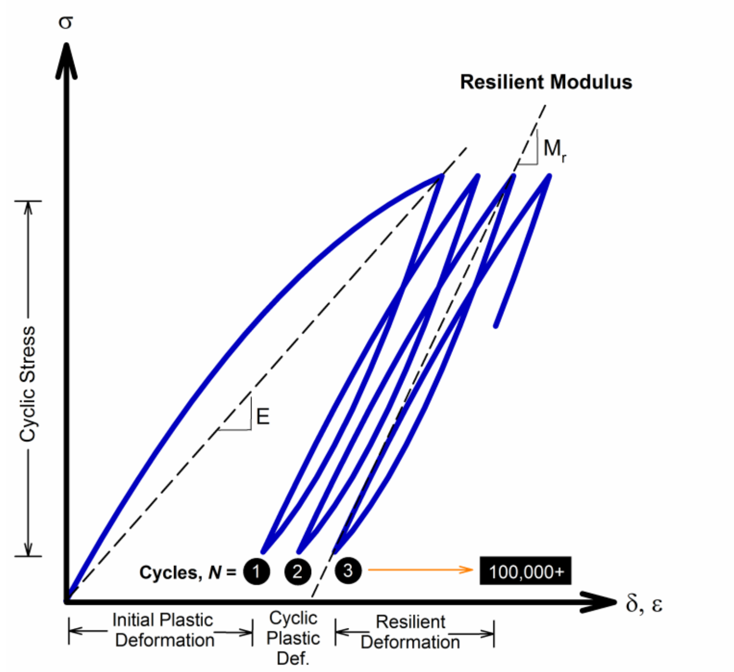


Figure 2. Illustration of the parameters measured from APLT cyclic plate load tests.

Resilient Deformation and Composite Resilient Modulus

In this field study, cyclic APLTs were performed using a 12 in. diameter plate on the PCC surface to obtain composite resilient moduli measurements ($M_{r\text{-}comp}$) and resilient deformation (δ_r) values. A picture of the test setup is shown in Figure 3.

Figure 3. 12 in. diameter plate setup with reference beam for plate deflection measurements

The composite resilient moduli ($M_{r\text{-}comp}$) provide a measure of composite response of the pavement layer and the supporting layers under dynamic loading. This value can be used to quickly compare the support conditions between the test points. The $M_{r\text{-}comp}$ values from APLT were calculated using the modified Boussinesq's elastic half space solution equation shown in Eq. (1).

$$M_{r-comp} = \frac{(1-\nu^2)\sigma_0 a}{\delta_r} \times f \qquad (1)$$

where

$M_{r\text{-}comp}$ = in situ composite resilient modulus

δ_r = the resilient deflection of plate during the unloading portion of the cycle (determined as the average of three measurements along the plate edge, i.e., at a radial distance r' = r)

ν = Poisson ratio (assumed as 0.4)

σ_o = cyclic stress

a = radius of the plate

f = shape factor selected as 8/3

Permanent Deformation

Permanent deformation (δ_p) results from cumulative plastic shear strain, compaction, and consolidation during loading. δ_p was monitored during cyclic APLT. From the number of load cycles (N) versus δ_p plot, a deformation performance prediction model was developed. A power model was selected to represent the permanent deformation versus number of cycles as shown in Eq. 2:

$$\delta_p = CN^d \qquad (2)$$

where coefficient *C* is the plastic deformation after the first cycle of repeated loading, and *d* is the scaling exponent.

Monismith et al. (1975) described a similar power model relationship for relating permanent strain to cycle loadings for repeated triaxial laboratory testing. It is expected that regression coefficients *C* and *d* depend on the material and stress conditions.

Pavement Coring

Pavement coring was performed using a 4 in. diameter core to the bottom of the fabric/AC interlayer.

RESULTS AND ANALYSIS

Cyclic APLTs were performed at six test locations. Four test locations (#1 to 4) were in sections with geotextile fabric interlayer and two test (#5 and 6) locations were in sections with AC interlayer. Figure 4 shows the October 27, 2016, APLT test locations on Powashiek CR V-18.

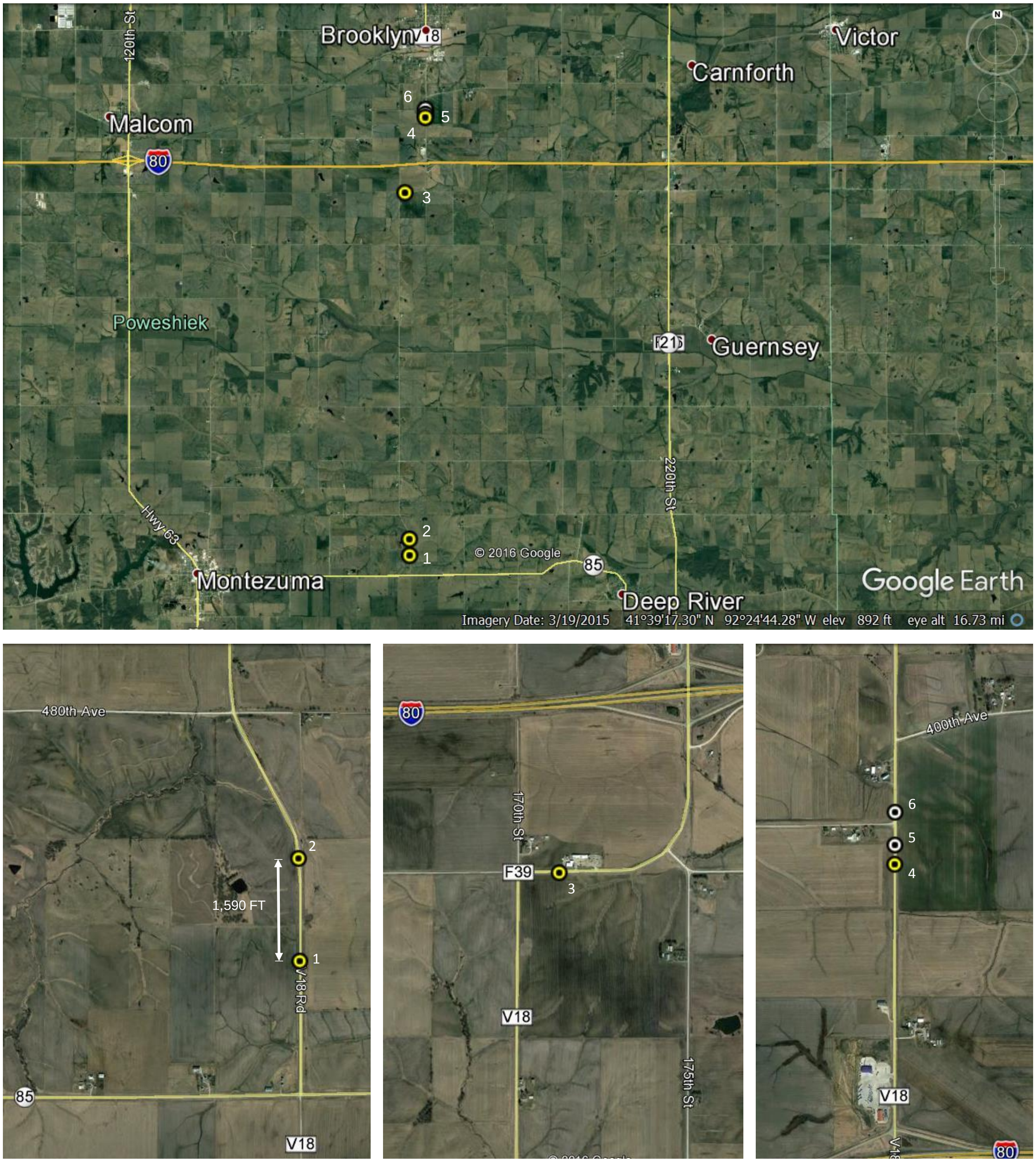


Figure 4. In situ APLT test locations on CR V-18 in Poweshiek County

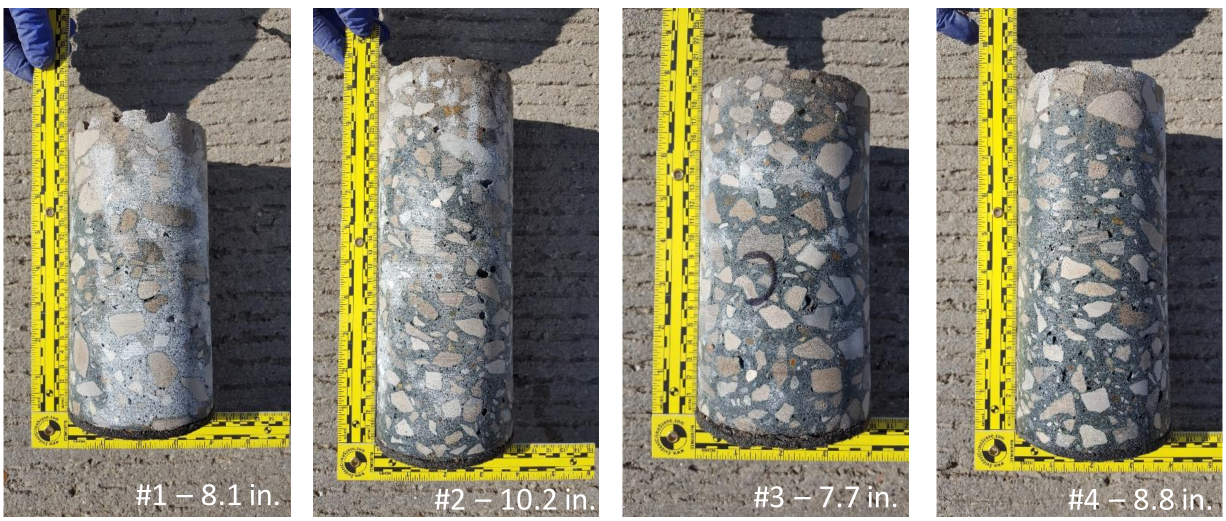
The locations are based on an average of 2 Hz autonomous GPS measurements at each test location.

Tests were conducted with a total of 250 loading cycles in 5 loading sequences using a 12-in. diameter rigid loading plate. The loading sequences included applying 50, 80, 100, 125, and 150 psi nominal cyclic stress for 50 cycles in each sequence.

It must be noted that test location #2 was in an area with a relatively steep slope, which likely resulted in poor seating between the plate and the pavement at the lower cyclic stress sequences. Therefore, the results at that test location must be reviewed with consideration for the influence of the difficult test conditions on sloping pavement. This test location was predetermined.

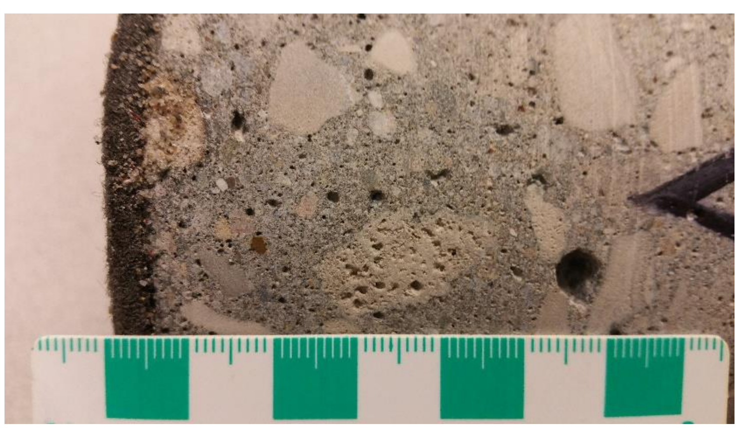
Pavement Coring Results

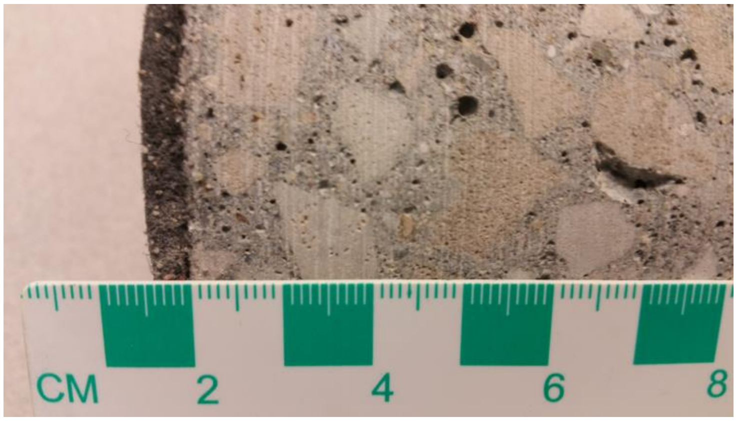
Images of pavement cores from the geotextile fabric and AC interlayer sections, respectively, at the six test locations are shown in Figure 5 and Figure 6.



Thicknesses noted are thickness of PCC + fabric

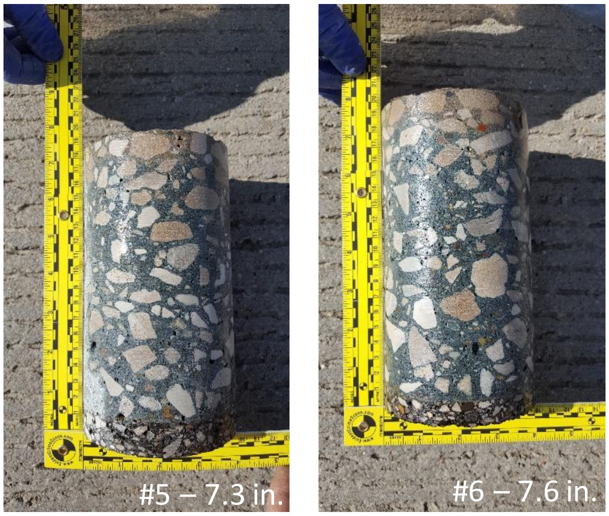
(a)





(b)

Figure 5. PCC overlay cores (a) from test locations 1 to 4 with geosythetic fabric interlayer and (b) laboraotry collected images from cores #1 (top) and #4 (bottom)



Thicknesses noted are thickness of PCC + fabric

Figure 6. PCC overlay cores from test locations 5 and 6 with AC interlayer

The core thicknesses, which ranged between 8.8 and 10.2 in. at test points with the fabric interlayer, and 7.3 and 7.6 in. at test points with the AC interlayer, are also noted in the figures. The fabric was about 1/10-in. thick and the AC layer was about 1/2-in. thick.

Figure 7 shows the geotextile firmly attached to the concrete core.

(a)

(b)

Figure 7. Images show (a) peeled back geotextile and (b) close-up view of fibers bonded to concrete

The geotextile could be peeled off the core, but the fibers of the geotextile were firmed bonded to the concrete and had to be broken to be removed.

APLT Results and Analysis

Cyclic APLT results in the geotextile and AC interlayer sections with resilient deformation (δ_r), permanent deformation (δ_p), and $M_{r\text{-}comp}$ values for the 250 cycles are compared in Figure 8, Figure 9, and Figure 10, respectively.

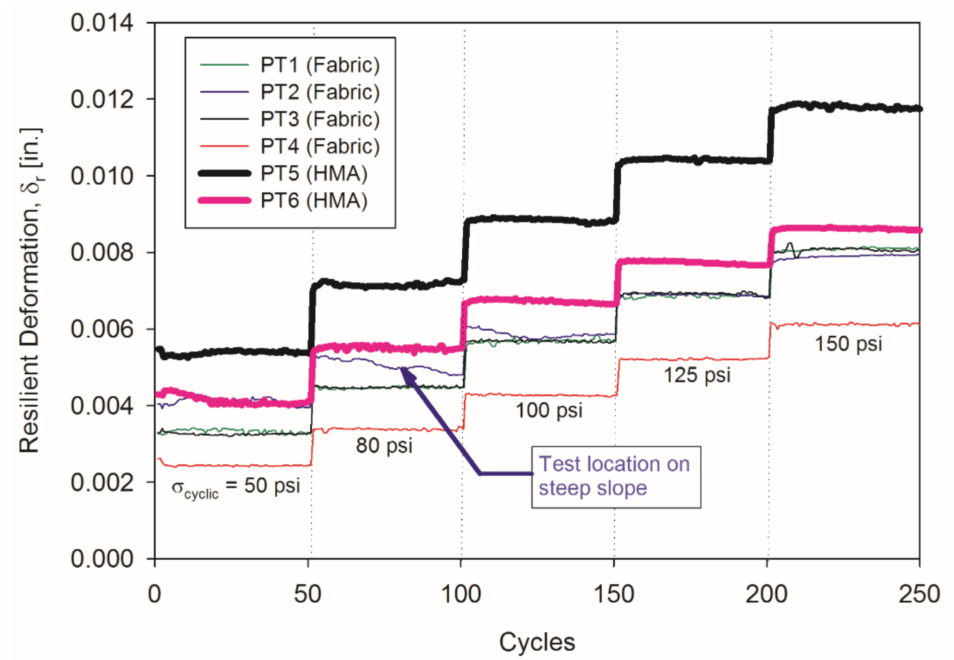


Figure 8. Resilient deformation (δ_r) results for the five stress sequences at all test points

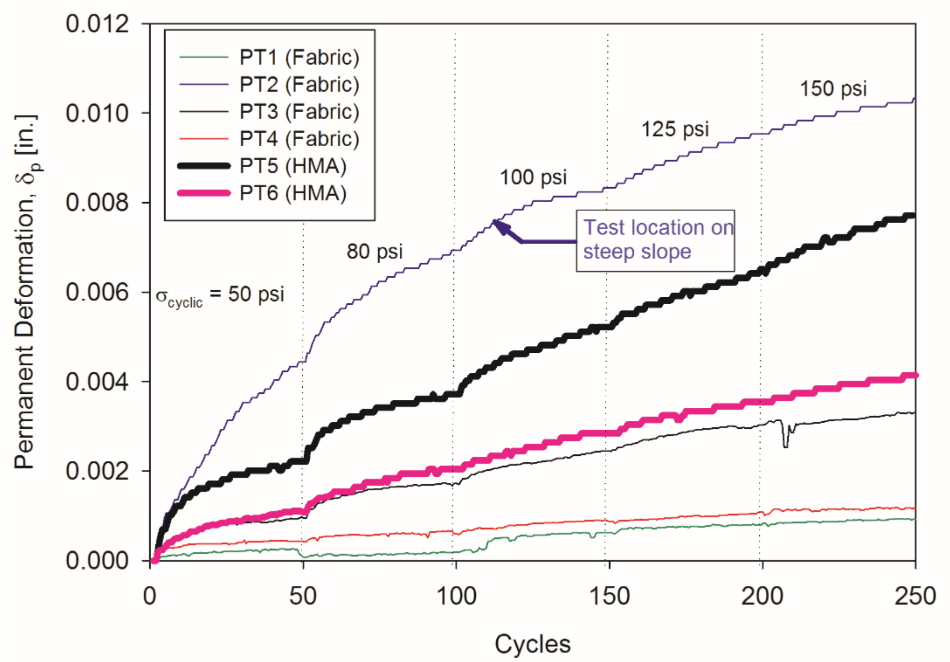


Figure 9. Permanent deformation (δ_p) results for the five stress sequences at all test points

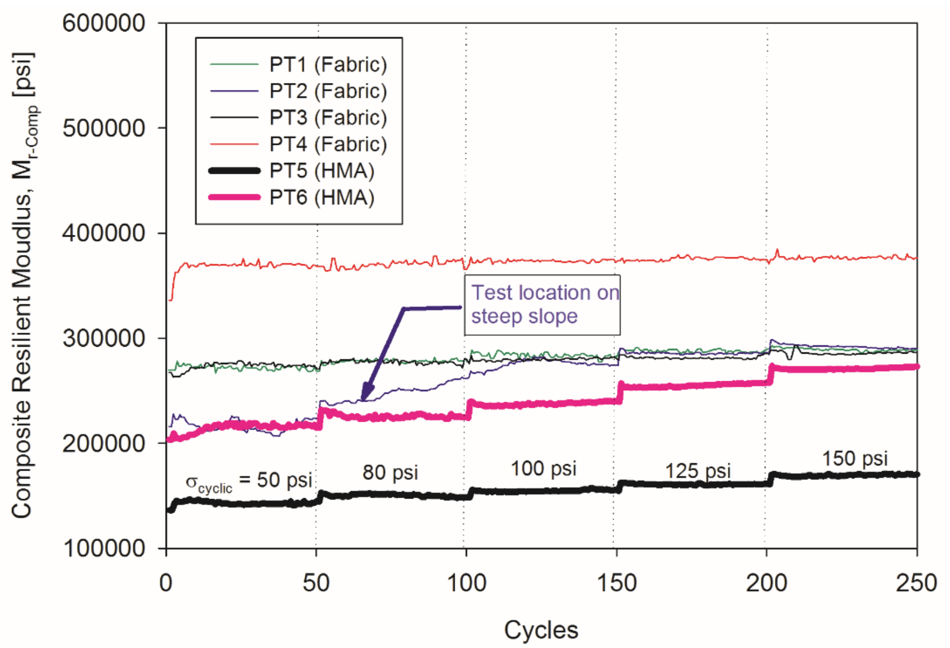


Figure 10. Composite resilient modulus ($M_{r\text{-}comp}$) results for the five stress sequences at all test points

A summary of the test results with core thicknesses, power model *C* and *d* parameters, δ_p at the end of the test, difference in δ_p from the start and end of the last sequence (201st and 250th cycle), and average $M_{r\text{-}comp}$ of the last five cycles is provided in Table 1.

Table 1. Summary of test results

Test Point	Interlayer	Core thickness (in.)	*C*	*d*	$\Delta\delta_p$ for last seq. (mils) [δ_p at 250 cycle – δ_p at 201 cycle]	δ_p at 250 cycles	$M_{r\text{-}Comp}$ (psi) [Avg. of last 5 cycles]
1	Geotextile	8.07	0.0016	0.1503	0.085	3.65	288,859
2*	Geotextile	10.24	0.0058	0.1964	0.751	17.26	290,321
3	Geotextile	7.72	0.0031	0.1942	0.267	9.04	286,613
4	Geotextile	8.78	0.0030	0.0701	0.119	4.40	376,587
Avg.	Geotextile	8.70	0.0034	0.1528	0.305	8.59	310,595
5	AC	7.28	0.0026	0.3379	1.252	16.74	170,564
6	AC	7.64	0.0040	0.2074	0.575	12.59	272,859
Avg.	AC	7.46	0.0033	0.2727	0.914	14.67	221,712
Student t-test results [one-tailed condition with unequal mean and unequal variances]		0.055	0.475	0.141	0.145	0.091	0.151
		0.069**	0.241**	0.120**	0.130**	**0.033****	0.135**

*Test on steep slope; **Excluding test point 2

Results show that on average, the $M_{r\text{-}comp}$ was higher, δ_p was lower, and the *d* parameter was lower in the geotextile section compared to the AC layer. The composite resilient modulus in the geotextile sections (311 ksi) was about 40 percent higher in the AC sections (222 ksi). At test point #2 in the geotextile interlayer section, the test was located on a section of pavement with steep slope that showed higher δ_p and *d* values. The average comparative values showed overall improved mechanistic values (see averages in Table 1), even when results from #2 were included in the calculations.

The core thicknesses at all test points in the geotextile interlayer sections were higher on average than in the AC layer sections (8.70 in. in geotextile sections versus 7.46 in. in AC sections). The effect of overlay thickness could not be isolated statistically because of the limited data set.

The student *t*-test was conducted on the data set, which involved both including and excluding results from test point #2 on the results summarized in Table 1. The *t*-test was conducted assuming unequal sample mean and variances, and for a one-tailed condition. The *p*-values from the *t*-test are summarized in Table 1. Analysis results indicated that, at the 95% significance level, only one parameter (δ_p at the end of the test) showed a statistically significant difference between the two sections with lower δ_p in the geotextile section compared to the AC layer section, when test point #2 was excluded from the analysis. To strengthen the results of the *t*-test analysis, additional testing is recommended (target minimum of 8 to 12 tests per section).

SUMMARY OF KEY FINDINGS AND RECOMMENDATIONS

In this report, results were presented from cyclic plate load testing conducted on County Road V-18 in Poweshiek County, Iowa, comparing and assessing the performance of unbonded concrete overlay sections constructed with geotextile fabric and AC interlayers. The sections were constructed in 2008–2009. Cyclic APLTs were conducted with 250 cycles using five cyclic stress levels ranging between 50 and 150 psi. In addition, pavement cores were collected at each test location to obtain the overlay thickness. Testing was performed at four locations with the geotextile fabric interlayer and at two locations with the AC interlayer.

The key findings from the testing and analysis are presented below. Recommendations are also provided for future field testing programs and monitoring to characterize the difference in the mechanistic properties of the concrete overlays with and without the geotextile fabric.

Key Findings

- The core thicknesses varied between 8.8 and 10.2 in. in sections with the geotextile interlayer, and 7.3 and 7.6 in. in sections with the AC interlayer. The geotextile fabric was about 0.1 in. thick and the AC layer was about 0.5 in. thick. The effect of overlay thickness on the cyclic APLT results could not be isolated here because of the limited data set

- Cyclic APLT results indicated that, on average, the composite resilient modulus ($M_{r\text{-}comp}$) was 40 percent higher, permanent deformation (δ_p) was lower, and the exponent in the power model (*d*) that defined number of cycles vs δ_p was lower in the geotextile sections than in the AC layer sections.

- Student t-test analysis indicated that at the 95% significance level, δ_p showed a statistically significant difference between the two sections, with lower δ_p in the geotextile sections than in the AC layer sections at the end of the test.

Recommendations

The results presented in this report constitute a one-of-a-kind data set that compared the in situ mechanistic properties of concrete overlays with AC and geotextile fabric interlayers. However, the findings presented should be assessed as showing potential for performance differences given a limited data set. The following additional testing and monitoring activities are recommended to provide a statistically robust dataset to quantify the differences between interlayer materials.

Mechanistic Evaluation of Pavement and Foundation Layers

The data set obtained in this study did not include the mechanistic properties of the underlying layers. It is well known that the resilient and performant deformation characteristics of composites (all layers) measured at the surface are influenced by the underlying foundation layer support conditions. If the underlying foundation layer properties are isolated, the benefits of using different interlayers can be better assessed. Layered testing protocols and analysis were not included this report because of limited time and budget to complete the field testing.

Cyclic APLT can be used to quantify the underlying layer mechanistic properties by using a special sensor kit that measures the pavement deflection basin. However, the theory behind analyzing deflection basins to extract foundation layer properties assumes the presence of a fully bonded pavement layer, which is not the case in these unbonded overlay test sections. Therefore, to complement multiple layer field testing, performing selected tests through a 14 in. diameter core directly on the foundation layer is recommended.

Further, the literature suggests that the geotextile interlayer offer an added benefit over the AC layer by providing enhanced drainage. This should be quantified in situ by directly measuring the drainage characteristics of the interlayers. This can be achieved by using the core hole permeameter (CHP) test device developed as part of the TR-554 project or by using the rapid air permeameter test (APT) test device developed as part of the TR-482 project. A 6-in. diameter core is required for the CHP test and a 14-in. diameter core is required for the APT.

Statistically Valid Data Set

The variables that affect the surface deformation characteristics under cyclic loading include: 1) foundation layer mechanistic properties (i.e., resilient modulus or modulus of subgrade reaction), 2) thickness of overlay, 3) thickness of the original pavement, 4) overlay age, and 5) condition of the pavement. To statistically assess the influence of these different variables, a statistically valid data set must be obtained. It is recommended that at least 8 to 12 test points for each of these different conditions be obtained with future testing.

The future test locations can be selected based on the historic IRI/PCI ride quality data, as-built plans and construction records, and annual falling weight deflectometer (FWD) test results.

Ride Quality Monitoring

The ride quality of the test sections, i.e., IRI and PCI, with and without the geotextile fabric interlayers, should be monitored annually. The Iowa DOT, with the aid of the CPTech Center, should consider compiling information regarding the different test sections built across Iowa with AC and geotextile interlayers to aid in conducting this monitoring.

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