PAVEMENT OVERLAYS IN VIRGINIA

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ABSTRACT

This paper describes the installation and performance of three hydraulic cement concrete overlays in Virginia. Two of the overlays were placed on continuously reinforced concrete pavement, and the other was placed on rutted asphalt pavement. The overlays were placed to increase the flexural strength of the pavement and demonstrate the feasibility of concrete overlays for extending the service life of pavements. One of the overlays was also placed to prevent spalling caused by a shy cover over the reinforcement.

The concretes used in the overlays were strong and highly resistant to the intrusion of solutions, characteristic of high performance concretes. Hooked-end steel, polyolefin, and monofilament and fibrillated polypropylene fibers were added to the concrete used in 31-m test sections to improve its toughness and ability to control cracks.

The overlay thicknesses are as follows: 51 mm for project A, 102 mm for project B, and sections of 51 mm, 76mm, and 102 mm for project C. Each of the test section was 610 m long. Concretes were tested in the unhardened state for slump and air content and in the hardened state for compressive strength, permeability to chloride ions, freeze-thaw durability, length change, and shear bond strength. The fiber-reinforced concrete was tested in flexure in accordance with ASTM C1018. The overlays were tested for tensile bond strength, skid resistance, and stiffness measured by a falling weight deflectometer.

Tests revealed that all of the overlay concretes were strong and had low to very low permeabilities. Freeze-thaw resistance and shear and tensile bond strengths were all acceptable. Pavement stiffness and skid resistance were improved with the addition of the overlays. The addition of fibers to the overlay concretes improved their toughness and appears to be restricting crack widening at 1 year after placement.

Key Words: hydraulic cement concrete, overlay, fiber, strength, shrinkage, skid resistance, stiffness

INTRODUCTION

Pavements are susceptible to several types of distress. Surface deterioration such as spalling, scaling, and loss of surface texture occurs due to freezing and thawing and abrasion. Intrusion of water and solutions from the top surface of the pavement also causes deterioration of the pavement and corrosion of the reinforcing steel, especially when there is shy cover. Cracks develop due to shrinkage, traffic loadings, and temperature changes.

The types of distress associated with deteriorating pavements can be ameliorated by placing an overlay. Hydraulic cement concrete overlays, generally of high quality compared to regular concretes, are an accepted method of rehabilitation for transportation structures in the United States. In Virginia, high-quality concrete overlays have been shown to increase the service life of bridges by providing a strong, low-permeability topping to a bridge deck *(1, 2)*. The overlays constructed for this project are considered high performance concrete (HPC) overlays because they contain fly ash or slag and have low permeability. HPCs with high strengths and low permeability have a high resistance to abrasion and infiltration of harmful solutions. Properties of a pavement such as flexural strength, stiffness, ride quality, and skid resistance are expected to

improve with the placement of a concrete overlay. The addition of steel or plastic fibers provides control over crack growth that is characteristic of an HPC overlay *(3)*.

The need for durable pavements has become a critical issue in recent years because of the aging of the interstate system, increased traffic volumes and weights, and higher traffic speeds. Concrete overlays can be placed on concrete or asphalt pavements. To develop an effective and durable method of pavement rehabilitation using concrete overlays, each phase from the selection of materials to placement must be examined carefully. The mechanical properties of the concrete, surface preparation, base material, paving techniques, overlay thickness, curing methods, and joint spacing are all factors affecting the performance of a concrete overlay. HPC is expected to provide the longevity needed for cost-effective rehabilitation.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the feasibility of placing HPC overlays on continuously reinforced concrete pavements and asphalt pavements in Virginia. For this study, three hydraulic cement concrete pavement overlays were placed in the summer of 1995. Concrete mixture design, base material, and overlay thickness were variables in the three projects. The mechanical properties of the concrete were tested during the year after placement of the overlays, and the performance of the pavements was evaluated at 1 year. The results of this study will allow correlation between overlay performance and variables and provide a guideline for HPC overlay construction in the future.

DESCRIPTION OF PROJECTS

In projects A and B, overlays were placed on I-295 SBL (near mile marker 29) and I-85 SBL (near mile marker 51) in Virginia, respectively. Both interstates are continuously reinforced concrete pavement. The overlays were placed to prevent spalling caused by a shy cover over the reinforcement. In project C, an overlay was placed on rutted asphalt pavement located on Rt. 29 NBL (1.6 km south of Charlottesville) in Virginia. The overlay thicknesses are as follows: 51 mm for project A, 102 mm for project B, and sections of 51 mm, 76mm, and 102 mm for project C as shown in Table 1. Class f fly ash was used in projects A and B, and Grade 120 ground-granulated blast-furnace slag was used in project C. The length of the test sections for all projects was 610 m. Four fiber-reinforced concrete sections 31 m long were placed within each test section.

Mixture Proportions

Mixture proportions and ingredients meeting ASTM and VDOT specifications varied between the three overlays as shown in Table 2. The concretes were mixed in accordance with ASTM C192. Two different concrete mixtures were used in project C because of differences in maximum aggregate size. C (13 mm max size) corresponds to the concrete placed in the 51-mm-thick section of the overlay, and C1 (25 mm max size) corresponds to the concrete placed in the 76-mm and 102-mm-thick sections of the overlay.

PLACEMENT AND TESTING

The continuously reinforced concrete pavements were shotblasted to remove an average of 3 mm of the top surface. The asphalt pavement was milled to remove the asphalt that would be replaced by the concrete overlay. Prior to milling the asphalt, the asphalt pavement consisted of 102 mm of base mix and 75 mm of surface mix. The prepared surfaces were maintained in a saturated surface-dry condition as the overlays were placed. Ready-mixed concrete trucks were used for the mixing and delivery of concrete. The concretes were tested in the freshly mixed state for slump (ASTM C143), air content (ASTM C231), and temperature (ASTM C1064). Specimens were then prepared for tests in the hardened state as shown in Table 3.

Each mold was filled with concrete in accordance with ASTM C192 and was consolidated using a vibrating table. Vibrating time depended on the workability of the mix and was limited to 5 to 10 seconds to avoid segregation of the constituents. After 24 hours, the specimens were removed from the molds and moist cured in accordance with ASTM C192 until tested.

The concrete was placed with a paving machine and tined for skid resistance. The concrete was cured with a white pigmented liquid membrane curing compound. The pavements were opened to traffic after 6 days of cure.

TESTS AND RESULTS

Properties of Fresh Concrete

Slump

Slump ranged from 32 to 114 mm, most of the concretes meeting the VDOT overlay paving concrete specification of 0 to 76 mm.

Air Content

The air contents of the concretes ranged from 4% to 8%, all of them meeting the VDOT paving concrete specification of 6±2%.

Properties of Hardened Concrete

Compressive Strength

The results of compressive strength tests of concretes without fibers are summarized in Figure 1.

The 24 hour compressive strengths were very similar for all projects. At 28 days, the values were about 30 MPa and higher, and at 1 year, the values exceeded 40 MPa. Compressive strengths in these projects were much higher than those of conventional paving concrete where the minimum 28-day design compressive strength is 21 MPa (*4*). At 6 days to 1 year, the slag concrete of Project C had compressive strengths 5 to 10 MPa higher than the fly ash concretes of Projects A and B.

Permeability

The results of permeability of concretes without fibers are given in Figure 2. At 28 days, fly ash concretes had high permeability values and slag concretes had moderate to low permeability. However, at 1 year the permeability values of all concretes were low to very low, which is characteristic of HPC *(5, 6)*. In conventional concretes at 28 days, high permeability values are expected, which reduce to moderate range with time.

Shear Bond Strength

Shear bond specimens were prepared by placing a 51-mm-thick slice of a 102-mm-diameter cylinder of either concrete or asphalt in the bottom of a 102-mm-diameter mold and placing a 51-mm-thick overlay on the sawn surface of the base. The cured specimens were placed in a guillotine shear jig, and the overlays sheared from the base to provide shear bond strength values and failure mode. The results of shear bond strength data for concretes without fibers are summarized in Figure 3.

Shear bond strengths were satisfactory in all projects. However, strengths were significantly higher in Projects A and B where the base material was concrete pavement. Project C demonstrated lower shear bond values because of the relative weakness of the concrete-asphalt interface as compared to a concrete-concrete interface.

Tensile Bond Strength

Three cores, 57 mm diameter by 102 to 152 mm long, were taken from each of the overlay test sections. The cores were saw cut parallel to the bond interface, 25 mm above and below the bond line, and metal caps were epoxied onto the sawn surfaces. The specimens were pulled in direct tension to provide an indication of tensile bond strength and failure mode. Results of tensile bond strength tests of concretes without fibers are given in Figure 4.

The results for tensile bond strength were satisfactory and similar to those obtained in the shear bond strength test. Projects A and B demonstrated much higher tensile bond values than Project C. As shown previously for shear bond strength, this variation between projects was due to the relative weakness of the concrete-asphalt interface as compared to a concrete-concrete interface.

Shrinkage

Results of the shrinkage tests of concretes without fibers are displayed in Figure 5.

In all three projects, concrete shrinkage showed normal trends and magnitudes. C demonstrated the highest shrinkage, and C1 demonstrated the lowest. When smaller size stone was used, water and paste contents were higher which contributed to higher shrinkage. Projects A and B had similar shrinkage trends and magnitudes. The reported water content was lower in Project A but the aggregate size was larger in Project B.

Shrinkage of fiber-reinforced concretes (FRC) were also determined. Values were mixed; some FRC had similar shrinkage values as the controls and some had higher values depending on the additional amount of water added to FRC for workability.

Freeze-Thaw Tests

The results of freezing and thawing tests on concretes without fibers are shown in Table 4.

The results indicated acceptable resistance to cycles of freezing and thawing for all specimens. There was more scaling in the slag concretes with the small maximum size aggregate.

Flexural Strength and Toughness of FRC

The results of flexural strength and toughness index are given in Tables 5 through 7 for the different projects.

To determine the first crack strength and toughness values in accordance with ASTM C1018 and eliminate the effects of settlement of the supports and crushing at the load points, a Japanese yoke was used in combination with a closed loop, servo controlled, universal testing machine.

As expected, the addition of fibers resulted in large improvements in flexural toughness. The addition of steel fibers at amounts of 29.7 and 44.5 kg/m^3 provided larger improvements in toughness than the addition of polypropylene fibers at 0.9 to 3.0 kg/m^3; 25-mm and 51-mm-long polyolefin fibers added at amounts of 11.9 kg/m^3 and 14.8 kg/m^3 produced toughness values approaching those of steel fibers at 29.7 kg/m^3.

Pavement Stiffness

The stiffness of the pavements obtained by a falling weight deflectometer (FWD) before and after the placement of the overlays is summarized in Figures 6 through 8 for the different projects.

Stiffness of the pavement was improved with the placement of an overlay in all three projects. However, the overall stiffness of the Project C pavement with asphalt and concrete was low because of the presence of the asphalt layer. No difference in stiffness could be attributed to the addition of fibers.

Skid Resistance

The skid numbers obtained by the skid trailer are summarized in Table 8.

Results indicate that the skid numbers of the overlay sections are above 40 and are satisfactory. The placement of the overlay in Project B led to large improvements in skid numbers compared to the existing pavement, which had low skid numbers in the 20's. Some existing sections in Project A had higher numbers than the overlay test section because of surface deterioration and resulting roughness.

Field Evaluations at 1 year

Project A

Transverse cracks had reflected through the overlay, and it appeared they were tighter in the fiber section. The highest frequency of transverse cracking was observed in the middle lane, followed by the outside and inside lanes. There was limited scaling mainly attributable to the presence of a thin crust formed during finishing.

Project B

Transverse cracks had reflected through the overlay but were tight. Transverse cracks were spaced between 1.5 and 3 meters. In general, there was no scaling of the top surface of the overlay except limited areas with light loss of texture.

Project C

In the 76 and 102-mm thickness overlay sections, cracking was minimal and the surface was free of scaling and spalling. The 51-mm thick section was in good condition, but some areas had spalling, scaling, and loss of texture. In this section, joints were cut in 1.8 m by 1.8 m or 0.9 m by 0.9 m squares, and corner cracks were prevalent. At the end of the test section, there was extensive cracking attributed to loads applied by drum weights during the asphalt paving of the shoulders. These cracks do not appear to have increased in number over the year since overlay placement but have increased in width. Cracks in the fiber sections appear to be narrower than those in the plain concrete sections.

DISCUSSION AND CONCLUSION

The HPC overlays were successfully placed on continuously reinforced concrete and on asphalt pavements. The 1-year evaluation of concretes and the overlays indicate that:

1. Strong and low permeability concretes were obtained.
2. Addition of fibers increased the toughness index of the concretes. In the overlays, the presence of fibers appeared to control the widening of cracks.
3. Resistance to cycles of freezing and thawing of air-entrained concretes was satisfactory.
4. Stiffness of the pavements was improved with the addition of the overlays.
5. Satisfactory skid numbers were achieved in all test sections.

TABLE 1 Summary of the three projects

Project	A	B	C
Location	I-295, VA	I-85, VA	Rt. 29, VA
Mineral Admixture	Fly Ash	Fly Ash	Slag
Overlay Thickness (mm)	51	102	51/76/102
Base Material	Continuously Reinforced Concrete Pavement	Continuously Reinforced Concrete Pavement	Asphalt Pavement

TABLE 2 Summary of mixture proportions

Project	A	B	C	C1
Cement, kg/m^3	320	344	251	226
Fly Ash, kg/m^3	75	81	0	0
Slag, kg/m^3	0	0	167	151
Coarse Aggregate, kg/m^3	908	1036	880	1051
Coarse Aggregate Size	# 7's	#57's	#7's	#57's
Fine Aggregate, kg/m^3	745	632	792	758
Water, L/m^3	153	178	188	153
Air Entraining, L/ m^3	0.232	0.232	0.4	0.4
Water Reducer, L/ m^3	0.77 - 3.9	0.83	0.77	0.77
Air, %	6	6	6	6
Slump, mm	51	51	76	51
w/cm	0.39	0.42	0.45	0.41

TABLE 3 Hardened concrete tests

Test	Designation	Size of Sample	# of Samples*	Test Age
Compressive Strength	ASTM C39	100 x 200 mm	3	24 hours, 6 days, 28 days, 1 year
Shear Bond		100 x 100 mm	3	6 days, 28 days, 1year
Permeability	ASTM C1202	100 x 100 mm	2	28 days, 3 months, 1 year
Length Change	ASTM C157	76 x 76 x 280 mm	3	Monthly
Freeze Thaw Durability	ASTM C666A	76 x 100 x 406 x mm	3	28 days
Flexural Strength, Toughness	ASTM C1018	100 x 100x 355 mm	4	28 days

* per test age

TABLE 4 Freezing and thawing data

Project	Weight Loss (%)	Durability Level	Surface Scaling
A	1.56	103	1.16
B	0.72	112	1.00
C	3.10	104	2.06
C1	1.53	111	1.15

TABLE 5 Flexural strength and toughness index data for Project A

Fiber Type	Fiber Length (mm)	Diameter (mm)	Amount (kg/m^3)	First Crack (MPa)	I5	I10	I20	R5,10	R10,20	Japan.
Plain	--		0	3.76	1	1	1	0	0	------
Polyolefin	25	0.40/0.57*	11.9	3.41	3.97	7.19	13.38	64.5	61.8	116
Polyolefin	51	0.66/1.00*	14.8	3.27	4.42	7.68	14.05	65.1	63.5	114
Fib. Polypropylene	19	-	1.8	3.55	2.91	4.79	7.69	37.6	29.1	55
Steel	30	0.5	29.7	3.64	4.29	7.82	15.09	70.7	72.7	157
Steel	30	0.5	44.5	4.02	4.77	9.37	18.88	91.9	95.1	193

*Fibers have elliptical cross section (Diameter 1/ Diameter 2)

TABLE 6 Flexural strength and toughness index data for Project B

Fiber Type	Fiber Length (mm)	Diameter (mm)	Amount (kg/m^3)	First Crack (MPa)	I5	I10	I20	R5,10	R10,20	Japan.
Plain	--		0	3.65	1	1	1	0	0	------
Mono. Polypropylene	19	5.33E-4	0.9	4.05	1.61	2.26	3.54	12.9	12.8	20
Mono. Polypropylene	19	5.33E-4	3.0	4.53	2.36	3.64	5.84	25.4	21.7	39
Steel	30	0.5	29.7	3.87	3.62	6.63	12.2	60.2	55.8	128
Steel	30	0.5	44.5	4.34	4.23	7.85	14.96	72.3	71.1	182

TABLE 7 Flexural strength and toughness index data for Project C

Fiber Type	Fiber Length (mm)	Diameter (mm)	Amount (kg/m³)	First Crack (MPa)	I5	I10	I20	R5,10	R10,20	Japan.
C	--		0	4.94	1	1	1	0	0	------
C1	--		0	4.67	1	1	1	0	0	------
Polyolefin	25	0.40/0.57	11.9	4.86	3.38	6.14	11.64	55.2	56.1	160
Mono. Polypropylene	19	5.33E-4	3.0	4.83	1.65	2.45	3.88	16.1	14.4	35
Steel	30	0.5	29.7	5.12	3.44	6.37	12.31	58.5	59.4	186
Steel	30	0.5	44.5	5.50	3.99	7.66	15.72	73.5	80.6	262

TABLE 8 Skid resistance data

Project	Lane	Existing Pavement Upstream of Overlay	Overlay Section	Existing Pavement Downstream of Overlay
A	IL	58.0	48.6	50.9
	ML	52.2	48.4	45.6
	OL	51.6	53.2	48.6
B	IL	34.7	53.7	40.6
	OL	22.3	48.4	28.6
C	IL	---	52.4	---
	OL	---	42.4	---

Note: Bald tire test was used for all lanes

FIGURE 1 Compressive strength data

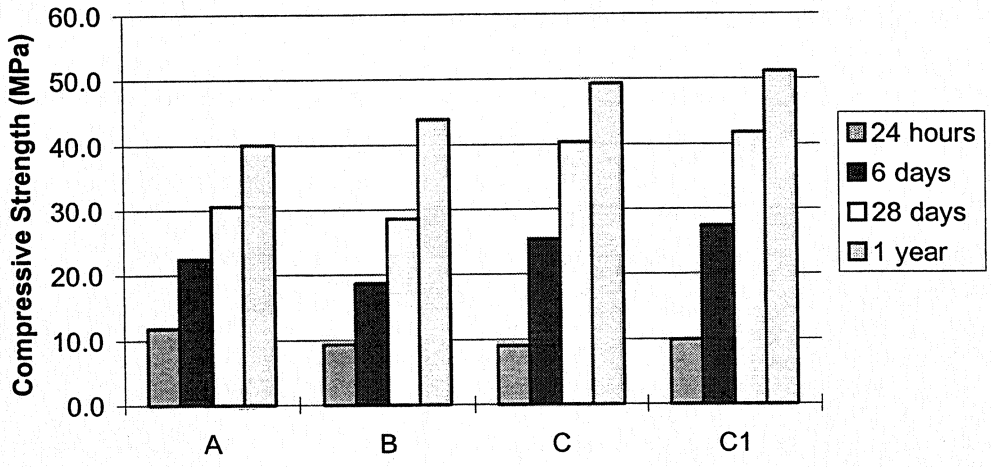


FIGURE 2 Permeability data

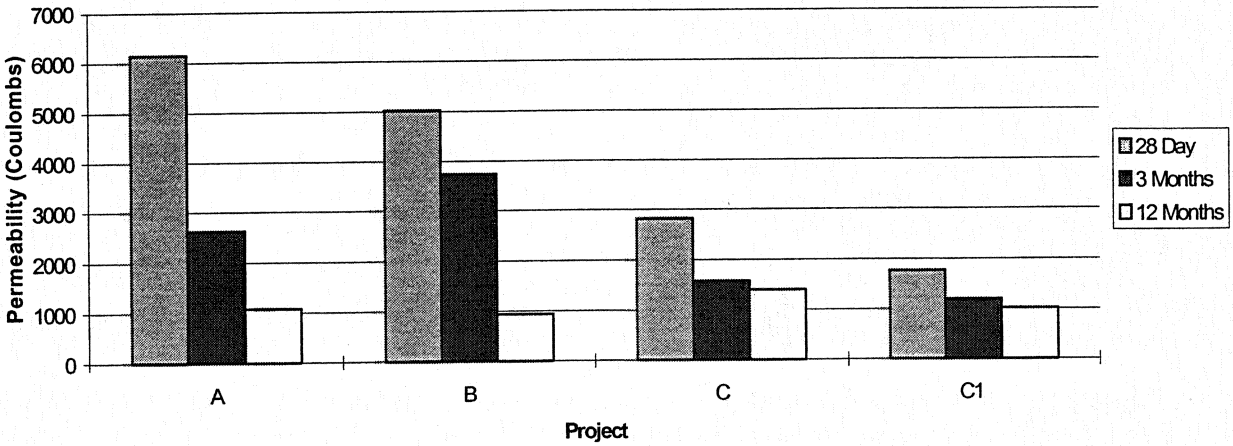


FIGURE 3 Shear strength data

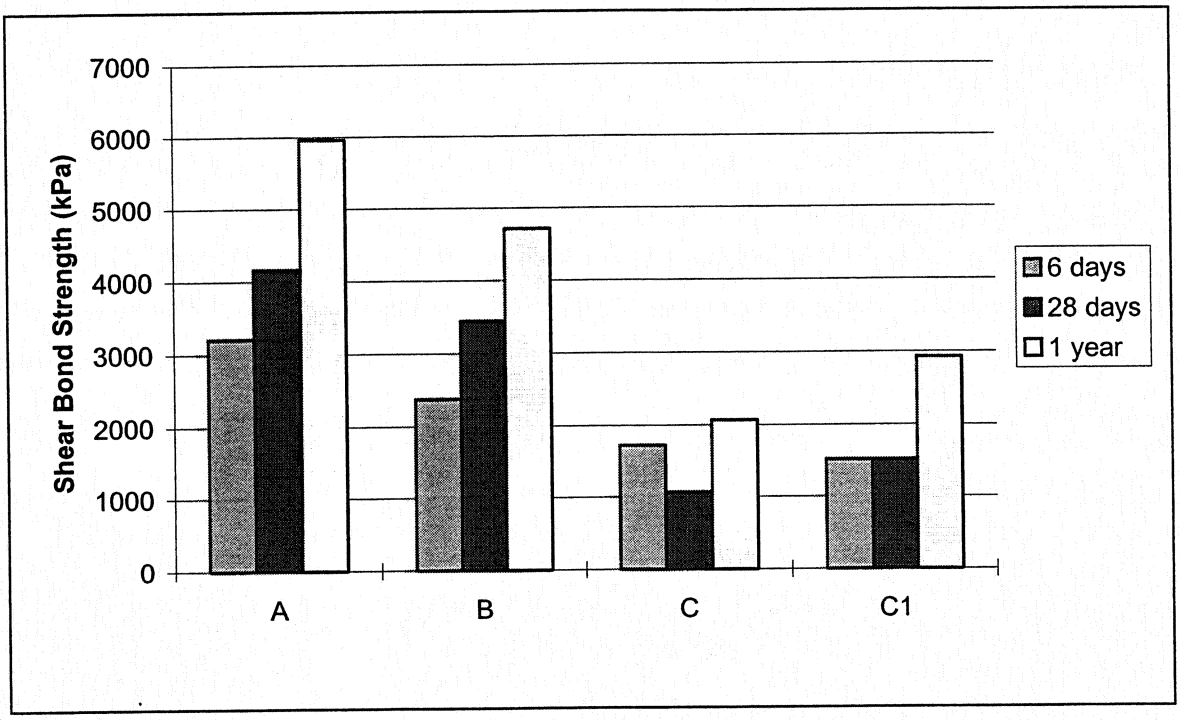


FIGURE 4 Tensile bond strength data

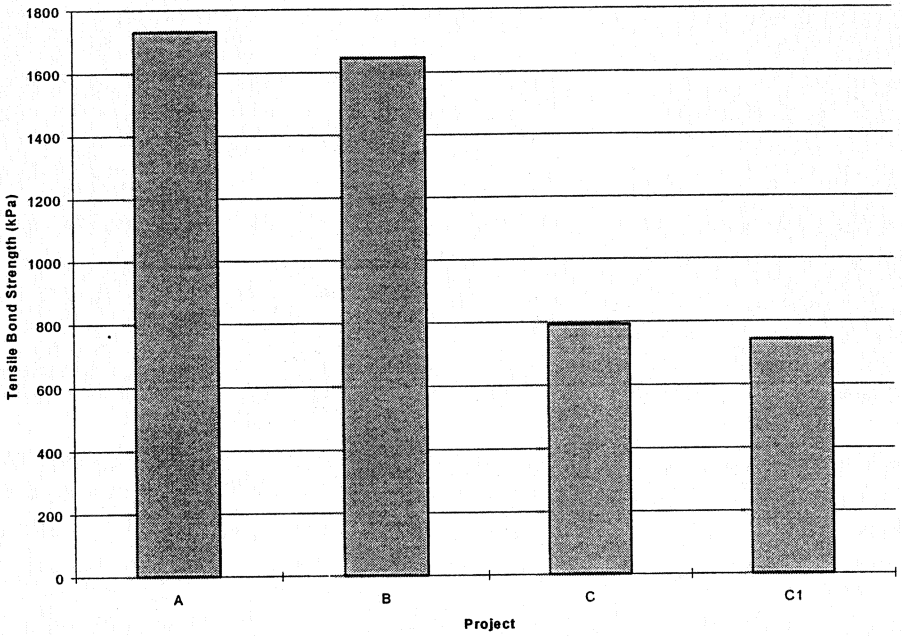


FIGURE 5 Shrinkage data

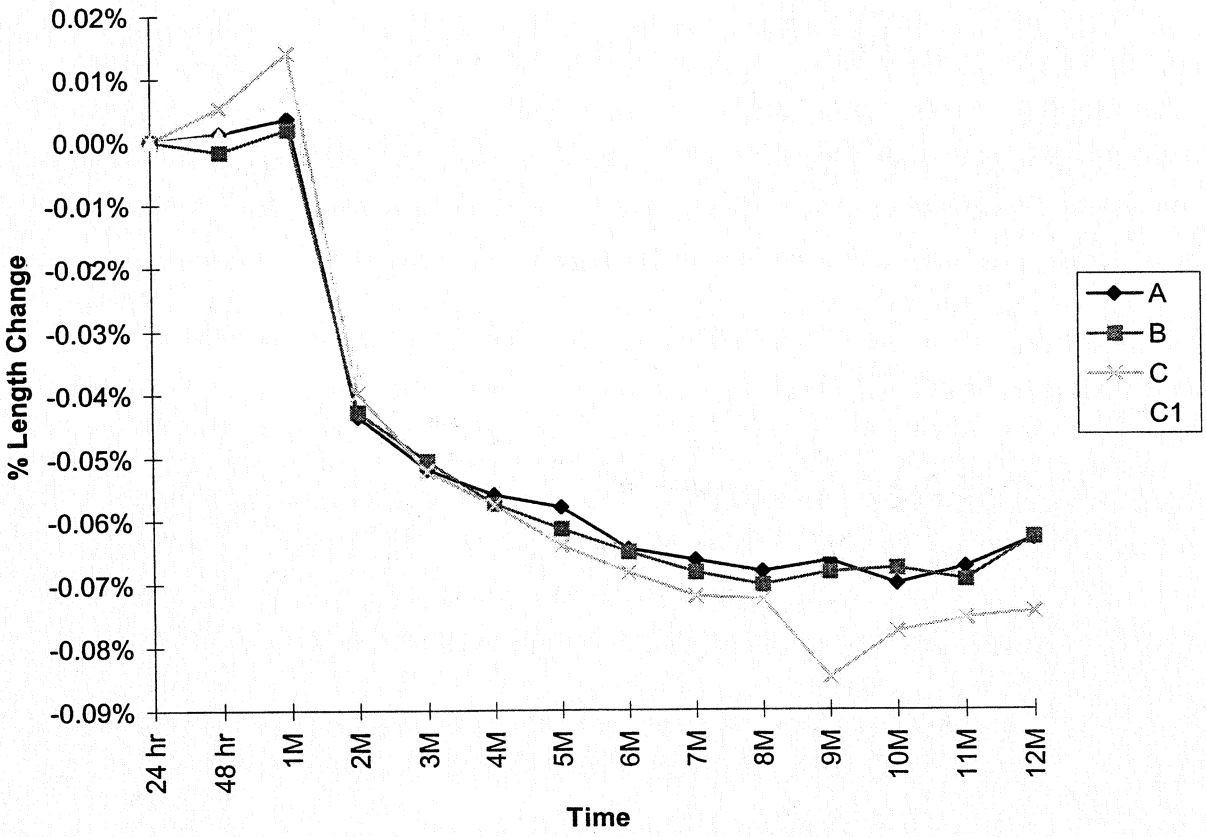


FIGURE 6 Pavement stiffness for Project A

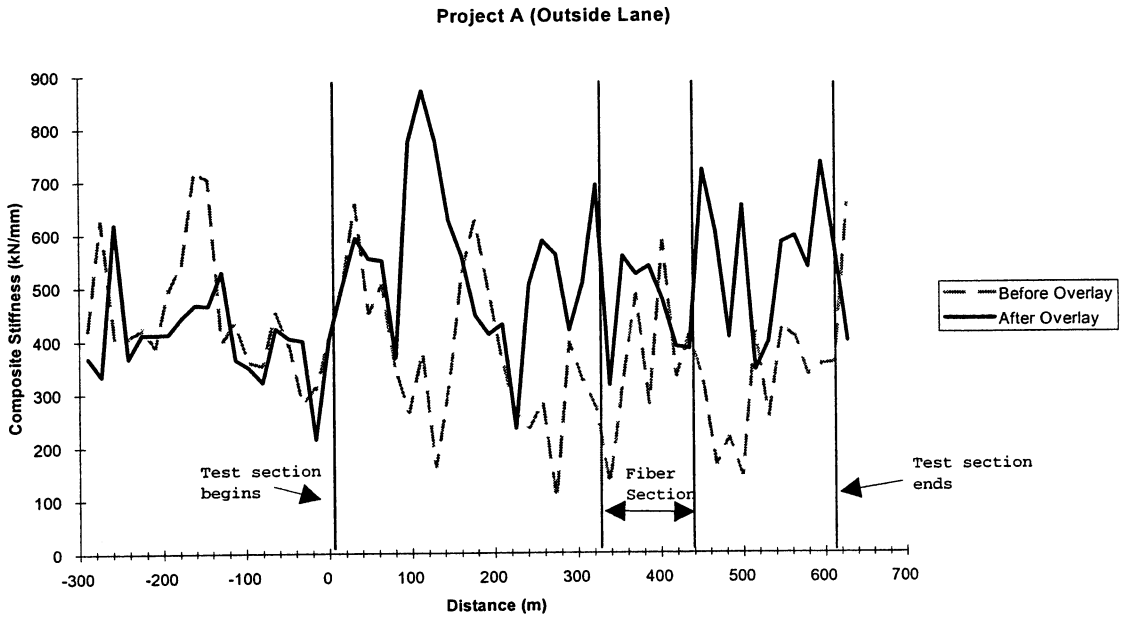


FIGURE 7 Pavement stiffness for Project B

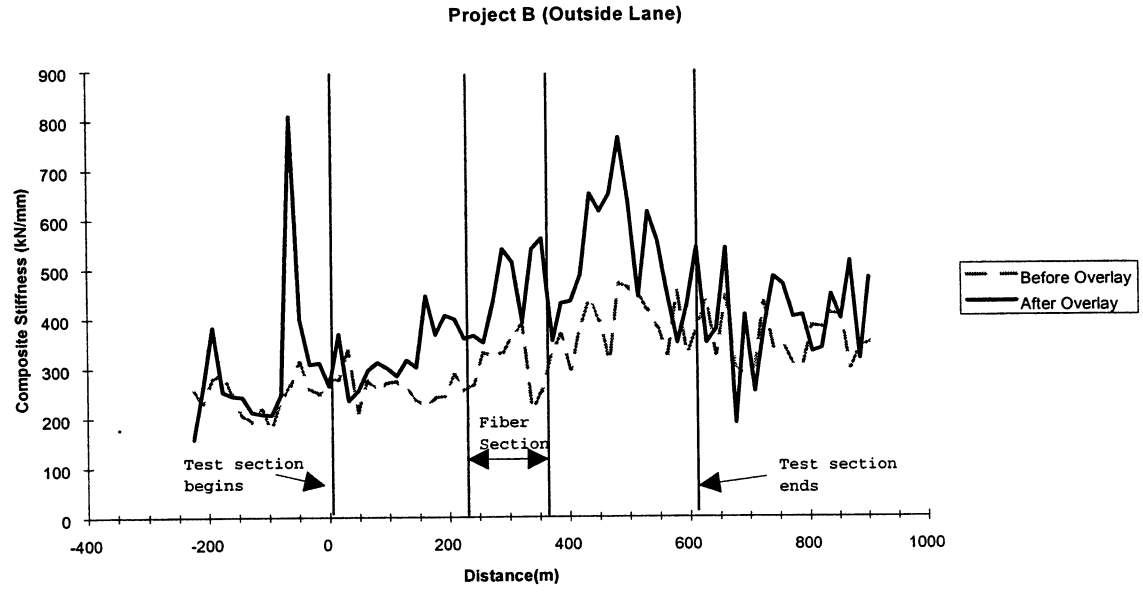
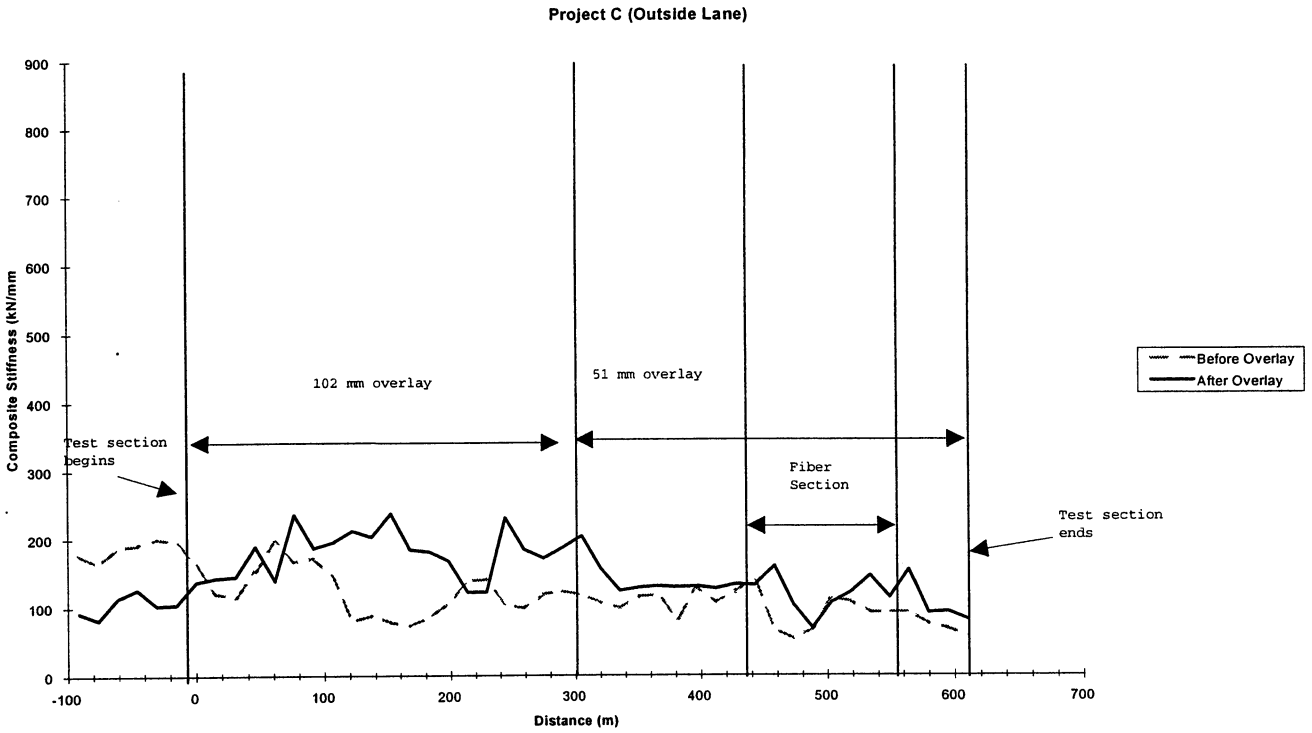


FIGURE 8 Pavement stiffness for Project C



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