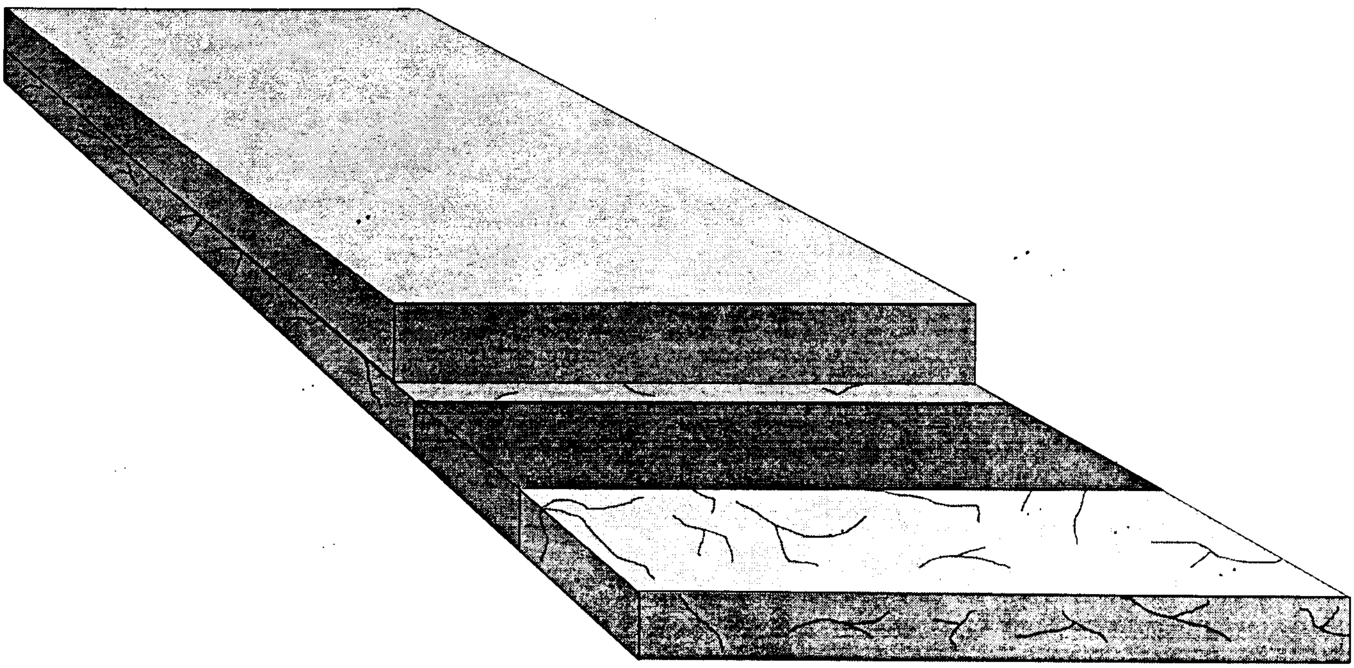
Thin Bonded Concrete Overlay and Bonding Agents



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16. Abstract

This report presents the construction procedures and initial performance evaluation of a four-inch Bonded Concrete Overlay placed on Interstate 80 near Moline, Illinois. Preconstruction testing consisted of Falling Weight Deflectometer, permeability to chloride, and distress surveys. Surface preparation included: full-depth patching, partial-depth patching, bituminous material removal, shot blasting, and sand blasting. During construction of the overlay, concrete temperature, air temperature, wind speed, relative humidity, rate of evaporation, concrete slump, concrete air content, water-cement ratio, placement time, and overlay thickness were recorded. Testing conducted after construction of the overlay included: compressive strength, split tensile strength, distress surveys, location of delamination, Falling Weight Deflectometer, California Profilograph, International Roughness Index, friction, drying shrinkage of concrete, and bond strength.

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INTERIM REPORT

THIN BONDED CONCRETE OVERLAY AND BONDING AGENTS

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June, 1996

Physical Research Report No. 123
Illinois Department of Transportation
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DISCLAIMER

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This paper is based on the construction and initial performance of the thin bonded concrete overlay and bonding agents. The study, "Thin Bonded Concrete Overlay and Surface Laminates," was sponsored by the Illinois Department of Transportation (Division of Highways) and the U. S. Department of Transportation (Federal Highway Administration).

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EXECUTIVE SUMMARY

New road construction in Illinois is decreasing and the main focus has shifted to rehabilitating existing pavements. Use of portland cement concrete (PCC) to resurface pavement started in 1913. Asphalt concrete (AC) overlays are the most common type of rehabilitation. However, this improves the structural capacity of the pavement only slightly. Illinois is experimenting with the bonded concrete overlay (BCO) as a means of rehabilitating roadways. This project is located on Interstate 80 near Moline, Illinois, between mileposts 1.67 and 3.37.

The BCO consists of the existing pavement with a layer of PCC placed directly on top. This overlay relies on a clean, rough PCC surface to achieve maximum bond strength between the existing pavement and the overlay. Once the overlay has been placed, the new slab thickness is adequate to support the current and future design traffic loadings.

A laboratory study was conducted in December, 1993 and January, 1994 to determine percentages of microsilica and the necessity of grout. This experimental feature project studies six combinations of microsilica and grout. Three percentages of microsilica were added to the concrete mix design: zero, three, and five percent. The necessity of using grout as a bonding agent was also studied.

Field testing performed before the overlay included distress surveys, Falling Weight Deflectometer (FWD) testing, and coring for chloride ion permeability. Data from these tests are to be used as a baseline to study overlay performance. Surface preparation for the overlay required full-depth patching, partial-depth patching, bituminous material removal, shot blasting, and sand blasting.

Paving was completed during the fall of 1994 for the eastbound lanes and in the spring of 1995 for the westbound lanes. Data was also collected during the paving of the overlay. Recorded information included concrete temperature, air temperature, wind speed, and relative humidity. From this data, the rate of evaporation was calculated. Also, the quality of the paving mix was studied through compressive strength and split tensile strength testing.

Testing completed after the placement of the overlay consisted of distress surveys, delamination testing, FWD testing, ride quality measured by both California

Profilograph and South Dakota Profilometer, friction testing, drying shrinkage of concrete, and bond strength. Performance monitoring will continue for five years.

The edge of pavement along the gore area of the eastbound weigh station entrance ramp had to be patched in the spring of 1995. A crack developed in the driving lane approximately six to eight inches in from the edge. The cause of the distress is unknown; however, theories of frost heave or disturbance by a vibratory roller during gore paving were considered. Rehabilitation consisted of removing the overlay between the crack and the edge of pavement and replacing it. The patch is performing well at present.

The following conclusions were made after observing the construction and early performance of the BCO:

1. Surface preparation for the BCO is crucial to obtaining a good overlay.
2. Bond strength of the overlay did not vary significantly either with or without grout as a bonding agent.
3. Placing the grout was cumbersome and slowed down the paving process.
4. Addition of microsilica did not improve the strength of the mix greatly.

Recommendations for paving a BCO are as follows:

1. Tarps should be required if trucks or other equipment will be driving on the cleaned surface.
2. Eliminate the use of grout, since the bond strength was not increased significantly and to keep from slowing down the paving process.
3. The addition of microsilica to the mix could be eliminated if the permeability of chloride is no drastically affected.
4. Do not allow shot blasting fines to be piled along the side of the road.
5. Keep shot blasting/sand blasting near the paving operation.

INTRODUCTION

Construction of new roads on the Illinois highway network is ending. Cost-effective maintenance and rehabilitation are now main focus points for the Illinois Department of Transportation (IDOT). Illinois maintains a large highway transportation network consisting of interstates and primary, secondary, and urban roadways. Maintenance costs are continuously increasing, reducing the amount of rehabilitation that can be performed with available funds.

The most common rehabilitation method is the asphalt concrete (AC) overlay. This type of overlay is not designed for thickness. Current IDOT policy requires a thickness of 80 mm (3.25 inches) for interstate resurfacing. Research indicates that this thickness of overlay tends to last approximately 12 years on a pavement with no D-cracking [1]. However, the structural capacity of the pavement is increased only slightly. Structural capacity is the pavement's ability to carry traffic loadings. The portland cement bonded concrete overlay (BCO) is a rehabilitation option that assumes a longer design life than an AC overlay. In addition, the structural capacity of the pavement with a BCO is greater than with an AC overlay. This is shown in Figure 1. IDOT is experimenting with the BCO as an alternative for rehabilitating existing portland cement concrete (PCC) roadways.

BCOs consist of the existing pavement with a layer of PCC placed directly on top. Many concrete pavements outlive their design lives. Once the design traffic loadings have been reached, the pavement often begins to deteriorate more rapidly than normal. This rehabilitation method can be used to increase service life, without removing and replacing the pavement. Another instance in which the BCO may be used is for a pavement on which the volume of traffic has drastically increased. This may be caused by the roadway becoming a major connecting route or by a large business developing along the roadway. Other states that have used the BCO include: Missouri, Texas, Iowa, Wisconsin, South Dakota, Wyoming, Louisiana, Pennsylvania, and New York. Most of the BCOs have performed very well.

The BCO relies on a clean, rough PCC surface to achieve maximum bond strength between the existing pavement and the overlay. Clean means that the pavement surface is free of all foreign materials such as oil stains, tire marks, bituminous material, etc. The overlay material reacts with the surface of the existing pavement to bond the two layers and create a monolithic slab. This new slab has adequate thickness to support higher traffic volume.

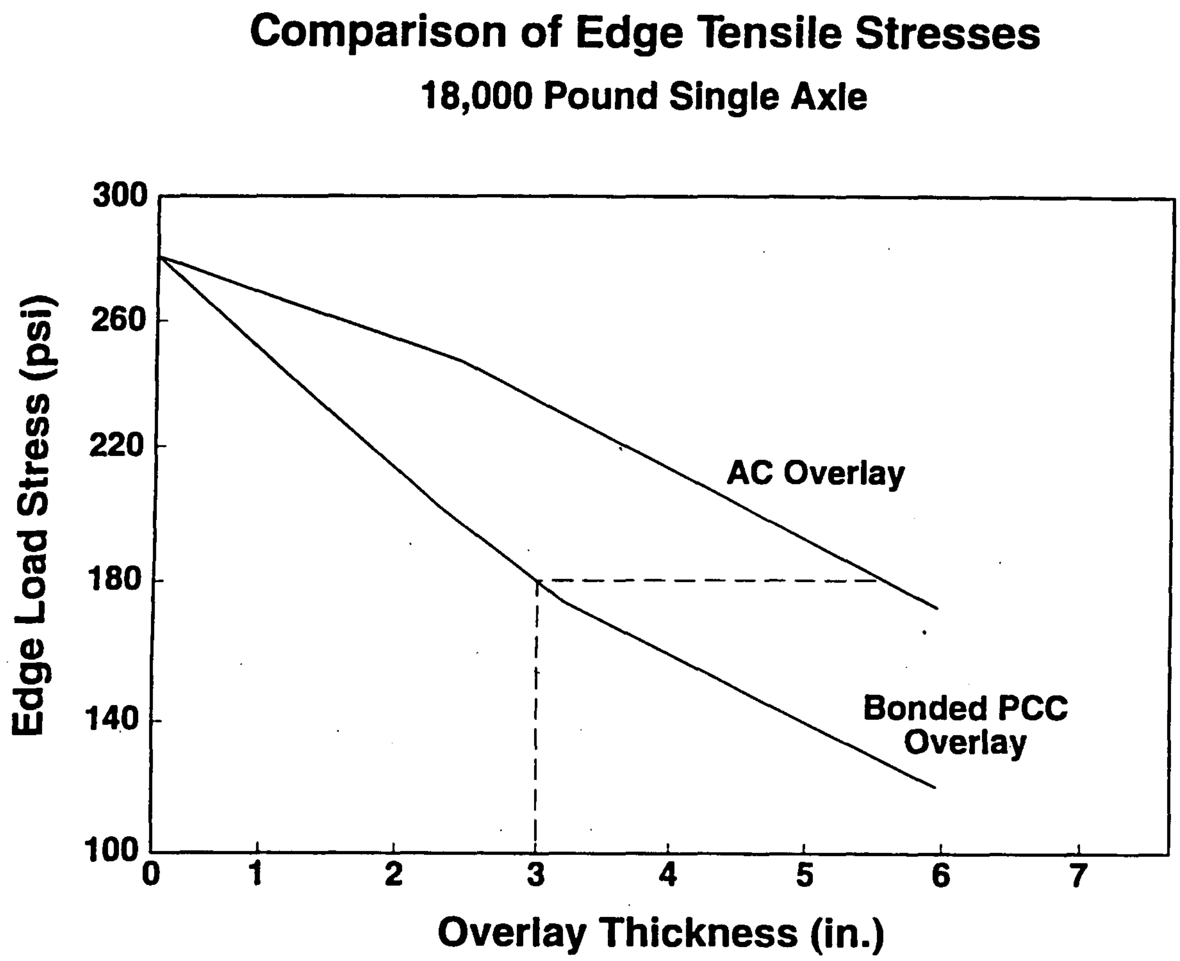


Figure 1. Comparison of Edge Tensile Stresses Between AC Overlays and Bonded Concrete PCC Overlays (Per American Concrete Pavement Association, Technical Bulletin - Guidelines for Bonded Concrete Overlays)

OBJECTIVE

This project is the first of two experimental feature BCOs. An experimental feature work plan entitled "Thin Bonded Overlay and Surface Laminates" was proposed for the project. This report details the construction and initial performance of the BCO. The specific objective of this experimental feature was to evaluate the constructibility and early performance of a thin BCO using several different percentages of microsilica to reduce chloride permeability and using grout as a bonding agent.

HISTORICAL PERSPECTIVE

The practice of using PCC for resurfacing existing pavements is not new. This type of rehabilitation has been used in the United States since 1913. Depending on the design, this type of pavement rehabilitation can give 20 to 40 more years of service at a lower cost than full reconstruction. Many states have previously used this technology; however, not as widely as AC overlays. The limited use of this method was usually due to the higher initial cost.

Similar to other state DOTs, the BCO was first used by IDOT as a method of resurfacing bridge decks. Acceptance of the BCO for pavement rehabilitation is growing. Reasons contributing to increased acceptance include:

- improvements in concrete construction equipment and procedures,
- the rapidly increasing cost of asphalt, and
- the trend toward selection of resurfacing type based on life-cycle costs rather than initial costs [2].

PLANNING AND DESIGN

Many pavements in Illinois are nearing the end of their design lives. IDOT normally uses the AC overlay for pavement rehabilitation. However, this is not a long term solution. A longer-lived rehabilitation method is desirable. Therefore, IDOT investigated the use of the BCO as an alternative for longer rehabilitation life. The design of this overlay uses a 20-year design life with the benefit of minimal maintenance during those years.

In the fall of 1993, the IDOT Pavement Review Team canvassed the interstate system in search of candidates for the BCO. The criteria set for the desired pavement included:

1. a thin pavement [175 to 200 mm (7 to 8 inches) thick],
2. a continuously reinforced concrete pavement (CRCP),
3. a bare concrete surface (no AC overlay),
4. minimal required surface preparation, and
5. a section not currently in the state 5-year program for rehabilitation.

These criteria were developed for the following reasons:

1. Thin pavements do not adequately support traffic loading on heavily traveled routes.
2. Mismatched joints on an overlaid jointed pavement could create more rehabilitation problems than a CRCP.
3. A pavement with an AC overlay would be too deteriorated for this type of rehabilitation.
4. Reflective distresses from a pavement with extensive deterioration are greater.
5. The pavement must be in good condition because the overlay bonds to create a monolithic slab.

Using these requirements, a section of Interstate 80 near the Illinois-Iowa border was chosen. Figure 2 is a map showing the location of the project. This section of pavement was an 8-in. CRCP constructed in 1965. A traffic factor corresponding to this thickness of pavement is approximately 5.0 million Equivalent Single-Axle Loadings

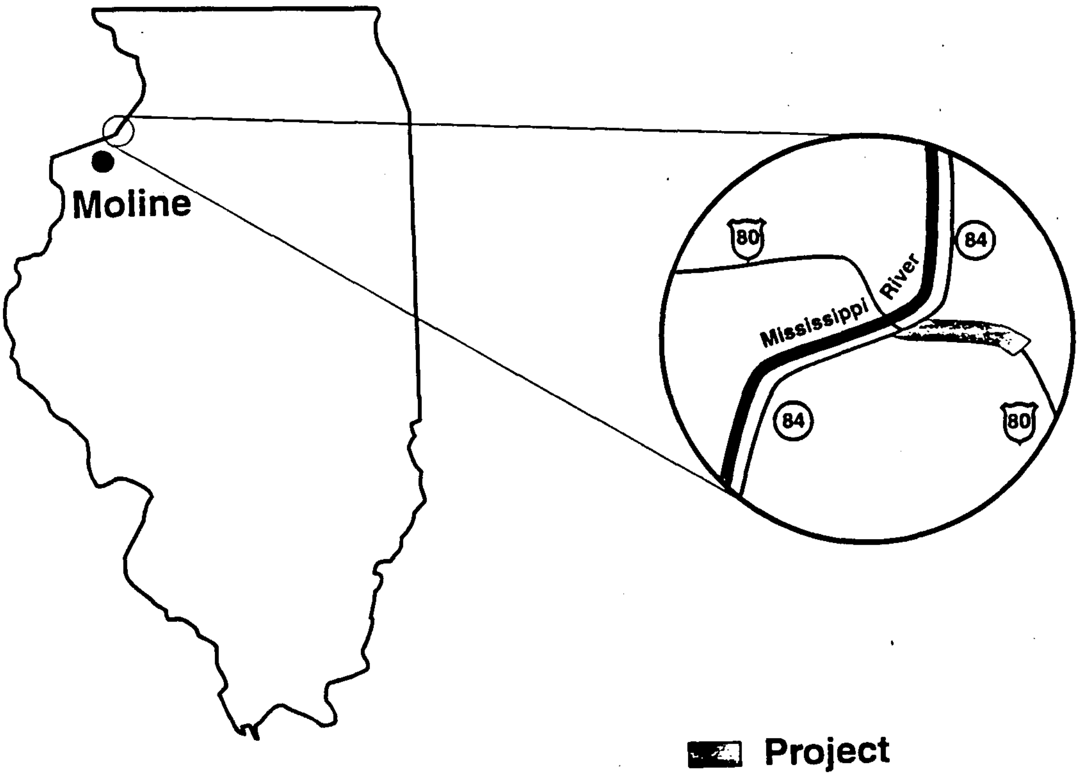


Figure 2. Project Location Map

(ESALs). To date, this section of Interstate 80 has carried nearly 16 million ESALs; over three times the design ESALs. Also, this pavement accumulates an estimated 1.7 million ESALs per year. Therefore, the pavement was in need of rehabilitation to meet future traffic loadings.

The American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures [3], and the National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice 99 [2] were the two methods used for the design of the BCO. Both methods use a 20-year design life. The two-way Average Daily Traffic values used in the calculations included: Passenger Vehicles (PV) = 17,405, Single Units (SU) = 740, and Multiple Units (MU) = 2,955.

AASHTO Design Procedure

$$D_{ol} = D_f - D_{eff} \qquad \text{[Equation 1]}$$

where:

D_{ol} = required thickness of bonded PCC overlay [mm (inches)]

D_f = slab thickness determined from slab, traffic, support, drainage, serviceability loss, reliability and future structural capacity values [mm (inches)]

D_{eff} = effective thickness of existing slab determined from the condition survey method [mm (inches)]

NCHRP Design Procedure

$$h_o = h_d - h_b \qquad \text{[Equation 2]}$$

where:

h_o = required resurfacing thickness [mm (inches)]

h_d = required monolithic thickness of concrete for the design loading [mm (inches)] (determined from regular concrete pavement design analysis)

h_b = thickness of existing pavement [mm (inches)]

Overlay thicknesses generated by the designs were 90 mm (3.5 inches) (AASHTO) and 50 mm (2.0 inches) (NCHRP 99). After consulting with personnel from other states on their experiences with BCOs, a thickness of 100 mm (4.0 inches) was chosen for the project.

LABORATORY EXPERIMENTS

In December, 1993 and January, 1994, the Bureau of Materials and Physical Research (BMPR) conducted a laboratory experiment using microsilica and bonding agents. This investigation examined two variables: (1) the differences in compressive strengths of mix designs using various percentages of microsilica, and (2) the differences in bond strengths using various bonding agents. Three mix designs and three types of bonding agents were used in the experiment. The following combinations were studied:

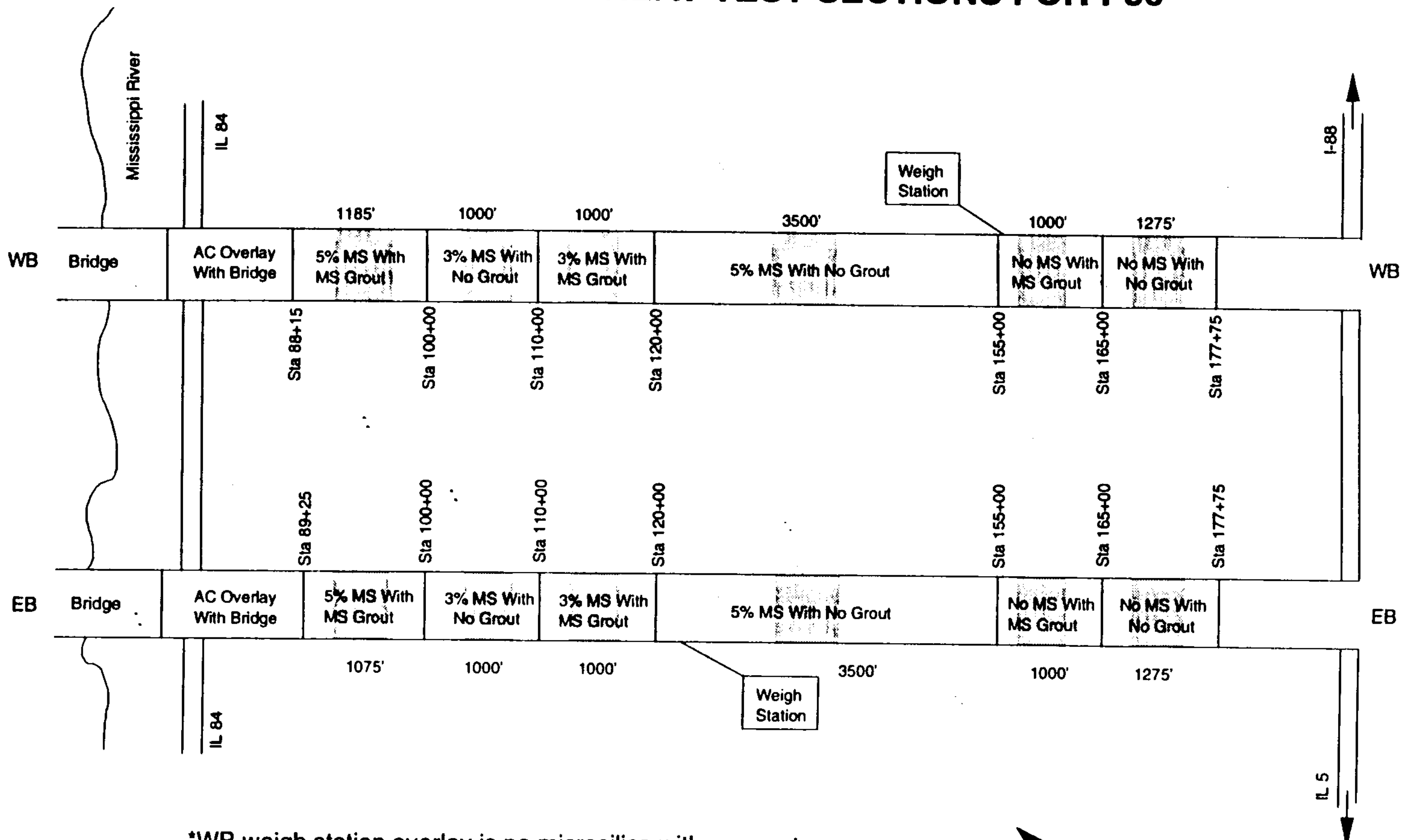
1. no microsilica with no grout
2. no microsilica with plain grout
3. no microsilica with microsilica grout
4. five percent microsilica with no grout
5. five percent microsilica with plain grout
6. five percent microsilica with microsilica grout
7. eight percent microsilica with no grout

Direct tensile and slant shear tests were conducted to measure the bond strengths.

Microsilica in the mix tends to increase the compressive strength of the concrete. It was thought that using a microsilica grout with a microsilica overlay mix would increase the bond strength. However, no significant difference in bond strength was noted between the types of bonding agents. Also, no significant difference in compressive strength of the various mix designs was noted. Test sections for the project were chosen based upon the results of the laboratory experiment. To test the effects of both grout and microsilica in the field, some of the test sections contained microsilica. To reduce costs, only three and five percent microsilica were used in the overlay mixes in addition to plain concrete. The design for each mix is shown in Appendix A. Bonding agents used in the field were no grout and microsilica grout.

Six test section combinations were designated in each direction for the project. Figure 3 is a map showing the location of each test section. The shaded area in each test section is a 150-meter (500-foot) monitoring section. All field testing and observations were conducted within these sections.

BONDED OVERLAY TEST SECTIONS FOR I-80



*WB weigh station overlay is no microsilica with no grout
EB weigh station overlay is 5% microsilica with no grout

**MS = Microsilica

Test Sections

*** Test sections are all 500' in length

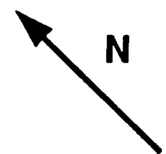


Figure 3. Map of Interstate 80 Test Sections

PRECONSTRUCTION OF EASTBOUND LANES

Testing

Falling Weight Deflectometer

Patching pavement and building crossovers began on August 4, 1994. Prior to any major activities, the Falling Weight Deflectometer (FWD) was used to test the structural capacity of the project pavement. On September 22, 1994, BMPR tested the eastbound lanes with the FWD. The FWD is a device that applies an impulse load, which simulates a moving wheel load, to the pavement in order to determine deflection characteristics. Three loads were applied: 4,000, 8,000, and 12,000 pounds. The project was tested at approximately every 300 feet.

The results from the testing on the eastbound lanes are found in Table 1. Deflection readings were taken both in the center of slab and in the outer wheel path of the driving lane. Data recorded from the 8,000-pound drop were normalized to 9,000 pounds for area calculations. Deflection basin "areas" were calculated to

Table 1. Falling Weight Deflectometer Statistics for Deflections for 09/22/94 on I-80 (Eastbound Lanes)

Test Section	Temp	# of Tests[a]	D0[b] (mils)			D1[b] (mils)			D2[b] (mils)		
			AVG	SD	COV (%)	AVG	SD	COV (%)	AVG	SD	COV (%)
0% w/o GR	73°	3	12.90	1.95	15.10	12.16	1.95	16.04	10.52	1.96	18.67
0% w/ GR	73°	2	13.60	0.05	0.40	12.75	0.19	1.51	11.02	0.20	1.77
3% w/o GR	74°	3	12.52	1.43	1.44	11.77	1.15	9.77	10.14	0.99	9.76
3% w/ GR	74°	4	11.87	0.79	6.65	11.08	0.76	6.83	9.51	0.64	6.77
5% w/o GR	74°	10	10.74	1.75	16.29	9.96	1.75	17.58	8.50	1.68	19.80
5% w/ GR	74°	4	9.79	1.98	20.25	9.49	1.60	16.86	8.09	1.33	16.50

Test Section	Temp	# of Tests[a]	D3[b] (mils)			Area[c] (in)		
			AVG	SD	COV (%)	AVG	SD	COV (%)
0% w/o GR	73°	3	8.51	1.78	20.90	30.95	0.84	2.70
0% w/ GR	73°	2	8.94	0.12	1.33	30.92	0.29	0.95
3% w/o GR	74°	3	8.15	0.72	8.89	30.95	0.48	1.55
3% w/ GR	74°	4	7.70	0.53	6.93	30.71	0.51	1.65
5% w/o GR	74°	10	6.86	1.59	23.20	30.35	0.97	3.20
5% w/ GR	74°	4	6.54	1.05	16.08	31.74	1.18	3.71

a Tests were conducted in the outer wheel path.

b D0, D1, D2, and D3 are surface deflections at 0-, 12-, 24-, and 36-inch offsets (respectively) from the center of the loading plate.

c Area (inch) = 6 (1 + 2(D1/D0) + 2(D2/D0) + D3/D0) [4] measure the pavement's ability to distribute load. The area can range between 6 and 36 inches. Low basin areas indicate weak pavement structure. Load distribution is more effective as the area increases. Areas in the higher end of the range indicate the pavement has the ability to distribute traffic loadings well. The data indicates the capacity of the pavement to carry traffic is good.

Area calculations for the eastbound lanes showed that the pavement was distributing the load well. The average area values ranged from 30.35 to 31.74 inches, with a standard deviation between 0.51 and 1.18 inches. This indicates the pavement is in good condition, which is necessary for this type of rehabilitation. Without a good existing pavement, the overlay will deteriorate prematurely under traffic loadings.

Permeability to Chloride Testing

Since microsilica was used in some of the test sections on this project, permeability tests would be conducted before and after placement of the overlay. Cores for permeability testing were taken in the eastbound driving lane for this purpose. Testing of these cores is not completed to date. Test results will be included in the final report.

Distress Surveys

On September 30, 1994, a distress survey was conducted on each of the monitored sections. These surveys will be used to monitor the progression and effect of various distresses on the overlay. The questions to be answered by these surveys are how quickly and to what extent will the existing distresses reflect through the overlay. All major distresses located in the monitored areas were recorded. The survey data for all of the sections are located in Table 2. Definitions of each distress are taken from the IDOT Pavement Distress Manual [5].

Punchouts and Local Areas of Distress

A punchout is defined as the area enclosed by two closely spaced transverse cracks and a short longitudinal crack. Typically, these distresses are located at the edge of the pavement; however, they can occur elsewhere in the pavement. As cracks deteriorate, the concrete loses aggregate interlock. The steel ruptures under loading and the concrete within these cracks punches downward.

Low severity means that longitudinal and transverse cracks are fairly tight; low severity spalling or faulting less than 6 mm (0.25 inch) exists. Moderate severity is

Table 2. Distress Survey of Eastbound Lanes Prior to Placing the Overlay

Test Section	Distress	Severity	Quantity
0% Microsilica w/ No Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Low	145 m (475 ft)
		High	8 m (25 ft)
	Longitudinal Cracking	High	13 m (43 ft)
0% Microsilica w/ Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Low	152 m (500 ft)
3% Microsilica w/ No Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Edge Punchouts	High	4 m (13 ft)
	Centerline Distress	Low	117 m (383 ft)
		Medium	33 m (107 ft)
		High	3 m (10 ft)
3% Microsilica w/ Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Infrequent
	Centerline Distress	Low	37 m (122 ft)
		Medium	115 m (378 ft)
5% Microsilica w/ No Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Rare
	Centerline Distress	Low	152 m (500 ft)
5% Microsilica w/ Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Low	152 m (500 ft)

spalling or faulting of 6 to 13 mm (0.25 to 0.50 inch) and the cracks interconnect. High severity is when the concrete within the area is punched down by more than 13 mm (0.50 inch); and/or severely spalled or broken. Also, temporary patching is present or is required.

The extent of distress is measured by the number of areas at each severity level. All punchouts were patched.

Longitudinal Cracking

Longitudinal cracks occur generally parallel to the centerline of the pavement, but may meander throughout the lane. This does not include centerline distress.

Low severity consists of a hairline (tight) crack with no spalling or faulting, or a well sealed crack with no visible faulting or spalling. This does not include "Y" or interconnecting cracks. Moderate severity consists of a working crack with a moderate or low severity spalling and/or faulting less than 13 mm (0.50 inch). This includes "Y" and interconnecting cracks with no punchouts or material loss. High severity is a crack with width greater than 25 mm (1 inch); a crack with a high severity level of spalling; or a crack faulted 13 mm (0.50 inch) or more. This includes "Y" and interconnecting cracks with punchouts or material loss. Maintenance patching may be present or is needed.

The cracks are measured in linear feet for each level of severity. The length and average severity of each crack is identified and recorded.

Transverse Cracking

Transverse cracking of continuously reinforced slabs is a normal occurrence and is not in itself considered to be a distress. However, if the steel ruptures or shears, load transfer across the crack is lost and the crack becomes a potential location for major distress. Crack spalling or faulting are an indication of sheared reinforcing bars. Some cracks may have widened substantially after steel rupture. (Note: Sometimes the transverse cracks run diagonally across the pavement and intersect.)

Low severity cracks are tight (hairline) cracks with no faulting, steel rupture, or spalling. Moderate severity means the crack is open, but less than 13 mm (0.50 inch) with no steel rupture, faulting less than or equal to 5 mm (0.2 inch) and/or low severity spalling. High severity consists of a crack with steel rupture, or medium to high severity spalling or crack width greater than 13 mm (0.50 inch).

Low severity cracks are counted for the first 30 m (100 feet) and multiplied by 5 to approximate the number in the entire unit. Medium and high severity cracks are counted individually for the entire unit. Hairline cracks that are less than 2 m (6 feet) long are not rated.

Spalling of Centerline Joints

Centerline deterioration consists of cracking, breaking, chipping, or fraying of slab edges within 0.6 m (2 feet) of the centerline (lane-to-lane) joint.

Low severity deterioration is cracking and/or spalling less than 75 mm (3 inches) wide. Moderate severity deterioration is cracking and/or spalling 75 to 150 mm (3 to 6 inches) wide. High severity deterioration is cracking and/or spalling greater than 150 mm (6 inches) wide.

This deterioration is recorded in meters (feet) along the lane of affected area at each severity level.

High Steel Spalling and Localized Surface Distress

High steel spalling is surface spalling resulting from high steel placement with the steel itself visible. This also includes localized surface distress, an area of slab surface where the concrete has broken into pieces and spalled.

Low severity is an area in which spalling is less than 300 mm (12 inches) in diameter or length. Moderate severity is an area in which spalling is 300 to 455 mm (12 to 18 inches) in diameter or length. High severity is an area in which spalling is over 455 mm (18 inches) in diameter or length.

This distress is measured by the number of high steel spalling and localized surface distress areas at each severity level.

Throughout the test sections transverse cracking was frequent. The majority of this cracking was low severity with some medium severity. Local areas of distress were infrequent. The centerline contained all levels of severity. Most of the sections contained a large amount of low severity with intermittent medium and high severity.

Surface Preparation

A bonded concrete overlay relies on good surface preparation. Without it, proper bond will not be established and the thin overlay will act as an independent pavement. This layer is not thick enough to carry truck traffic on its own, and the overlay will fail prematurely. The preparatory work for this overlay included: full-depth patching, partial-depth patching, bituminous material removal, shot blasting, and sand blasting.

Full-depth Patching

Prior to overlaying the section, full-depth patching was completed on the necessary areas. Eleven patches for a total of 143.0 sq m (171 sq. yd.) of Class A patches were placed in the eastbound lanes. This quantity is 0.72 percent of the eastbound lanes surface area. Class A patches consist of full depth pavement removal and CRCP replacement. Before traffic could be moved to the westbound lanes, full-depth patching was completed on these lanes as well. The patching in the westbound lanes consisted of 10 patches totaling 105.5 sq m (126.2 sq. yd.) of Class A patches. This quantity is 0.53 percent of the westbound lanes surface area. The combined total for the project was 0.62 percent.

Partial-depth Patching

The special provision for the BCO, Appendix B, required a partial-depth patch to be placed over any random longitudinal crack. These areas were cold milled to a depth of 60 mm (2.5 inches) or to the depth required by the Resident Engineer. The width of milling had to be a minimum of 0.9 m (3 feet). After the area was milled and just prior to paving, #15 (#5) epoxy coated tie bars 750 mm (30 inches) in length were placed at right angles to the crack on 750-mm (30-inch) centers as shown in Figure 4. The tie bars were fastened securely to the pavement with metal bands and power driven nails. The eastbound lanes contained one partial-depth patch that was 13.2 sq m (15.8 sq. yd.).

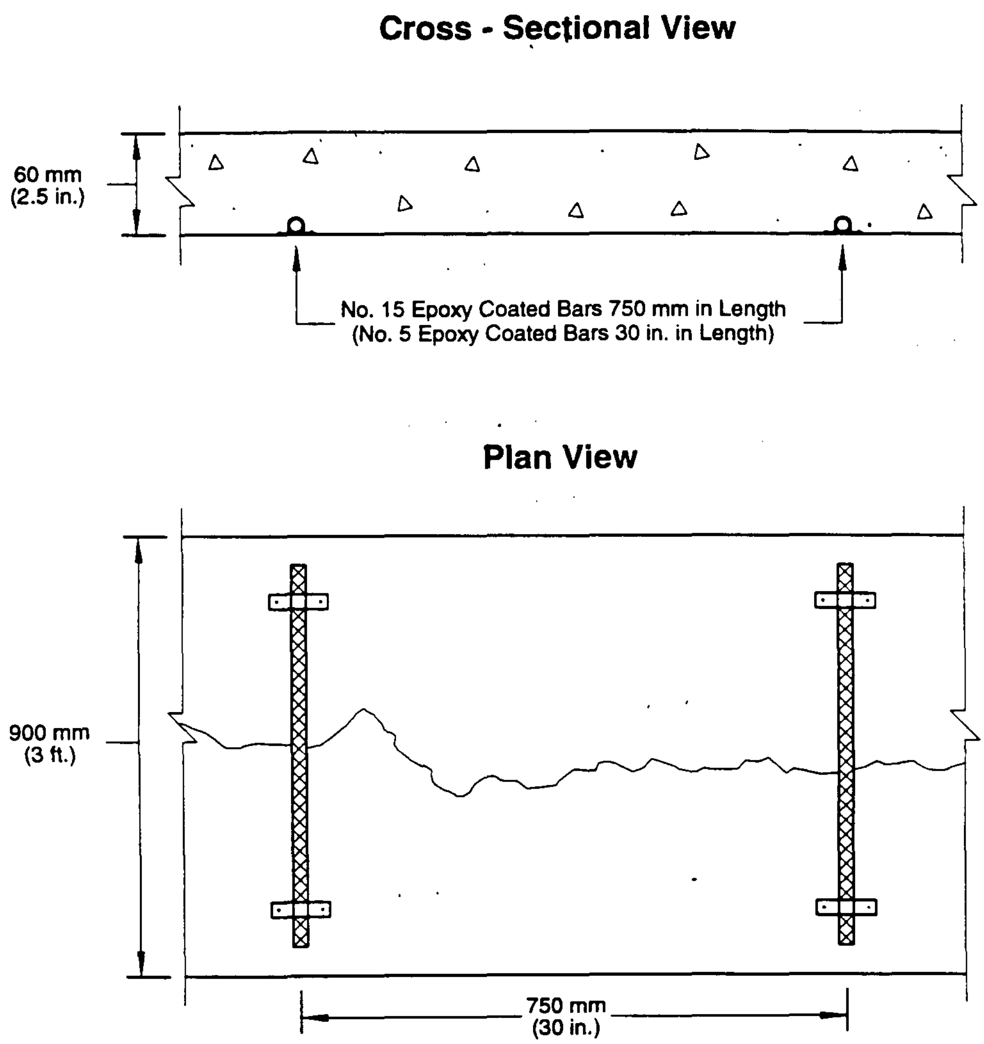


Figure 4. Cross-Sectional and Plan Views of Longitudinal Crack Reinforcement

Bituminous Material Removal

All bituminous material had to be removed from the surface before the overlay could be placed. Cold milling was used to remove any large areas of bituminous material. Areas of localized distress were scattered throughout the section. Several of these spalls were filled with cold patch material. Milling these areas would have been impractical; therefore, the contractor removed the material with jackhammers. Also, any loose or unsound concrete adjacent to the spall was removed during this process. Jackhammers were also used to remove the raised pavement reflectors along the centerline.

Shot Blasting

The next stage of surface preparation for the pavement was shot blasting. The blasting machines had a 405-mm (16-inch) wide blasting head that propelled steel shot at the pavement to remove any dirt, oil, grease, etc. from the surface. A 50/50 mix of S-390 and S-550 cast steel shot and grit from Ervin Industries was used in this process. The shot blasters moved at 15 m (50 feet) per minute (approximately a walking pace) with the valve wide open. This process removed approximately 3 mm (0.125 inch) of the surface. Most of the shot and the fines that were removed were vacuumed up as the shot blaster moved along the surface. Any shot that remained on the pavement was gathered later with a large magnet.

Sand Blasting

Because the shot blasters had such a narrow head, it was difficult to prepare the surface around spalled areas. If the blasting head could not cover the spall, vacuum seal was lost and the device would not be able to remove the shot or fines. The same problem occurred along the pavement edge. To maintain the vacuum seal, the shot blaster was as close to the spall or edge of pavement as possible, then sand blasters were used to finish the work. Wet bottom boiler slag (WBBS) was used as the blasting agent instead of sand.

CONSTRUCTION OF EASTBOUND LANES

The paving operation began on October 7, 1994 and took a total of five days to complete. Stringlines were set on both sides of the pavement to establish a BCO thickness of 100 mm (4 inches). Any low or high areas were leveled out while maintaining a minimum of 100 mm (4 inches).

The pavement had to be cleaned with compressed air to remove any dirt or WBBS before the overlay could be placed. If this were left on the pavement, it would impede bonding. On the first day of paving, there was a short rain shower while the crews were blowing the pavement clean. Fines on the pavement formed a mud-like paste. The operation was halted until the shower ended. At that point, the pavement was allowed to dry, and the mud was sand blasted off the surface. No more rain occurred during the paving operation.

Shot blasting was completed during consecutive days at the beginning of the paving process. This meant all vehicles used for paving would be driving on the newly cleaned surface. Trucks or equipment driving on this surface left tire residue when turning because of the roughness of the pavement. To minimize tire tracks near the paver, haul trucks turned around at the end of the project and backed down the pavement to the paving operation. Any tracks or oil drips that were caused by construction traffic were sand blasted and the pavement was again blown clean before overlaying.

Fines vacuumed by the shot blaster were deposited along the side of the pavement. Pickups drove through these piles and individuals walked through them. The fines were stirred into the air and the wind blew them back onto the pavement. The contractor had to keep the air compressor near the paving operation to clean the pavement.

Some trucks also dripped oil onto the pavement. Small areas, the size of a half-dollar or less, were cleaned by spraying starting fluid or ether and blotting with a paper towel. Occasionally, a larger spill would occur, such as air brakes blowing grease onto the pavement. In such cases, the paving operation was halted, the shot blaster cleaned the area, and the pavement was blown clean. Paving resumed after the pavement was clean. In the case of brakes spraying oil onto the pavement, buckets were placed under the truck to prevent the spill from recurring.

The grout mixture used in some test sections consisted of portland cement, 15 percent microsilica solids by mass (weight) of cement, and water. The grout was placed immediately in front of the paver and behind the trucks. A pressure sprayer was used to apply the grout to the surface of the pavement. Squeegees were used to leave a thin, even layer. Excess grout in spalls was broomed out.

The overlay was placed monolithically over both lanes. A longitudinal float was used for initial finishing. Finishers followed with bullfloats and other equipment to hand finish the pavement. Microsilica in the mix reduces the amount of bleed water, which makes finishing more difficult. Next, a burlap drag was used to provide longitudinal texture. The drag was attached to the front of the tining machine which was used to provide transverse texture. Finally, when the water sheen disappeared from the surface of the overlay, the curing machine applied a white pigmented membrane curing compound. This type of cure was specified to reduce drying shrinkage cracks resulting from loss of moisture. The curing compound was to be applied in two applications, each at a rate of 0.25 liter per square meter (1.5 gallons per 250 square feet). This application rate is higher than for a standard pavement to ensure retention of moisture in the overlay.

The final stage of construction was to saw the centerline joint. A lightweight saw was used on the project to saw the centerline. This was also an experimental feature, separate from the BCO. A maximum mass (weight) of 136 kg (300 pounds) was specified and the saw was required to have a diamond blade which rotated in an up-cutting motion and maintained a speed of 2500 RPM. An anti-ravel skid plate was to be used in conjunction with the blade. Ideally, the pavement was to be sawed within 0-2 hours after final finishing. However, the cool weather increased set time and delayed the sawing operation. Delays were increased when the curing compound did not dry properly, causing the saw to track. The sawing usually did not begin until approximately 7 to 12 hours after final finishing. To minimize tracking and allow the crew to begin sawing sooner, the amount of curing compound applied was adjusted. The sprayer placed a lighter strip of compound down the centerline, and only one application of compound was applied on the overlay.

The centerline joint was cleaned and sealed one to two days after sawing. Bituminous shoulders were placed along the mainline seven days after the overlay was placed to allow the BCO to cure and gain strength.

Weigh stations were present within the project limits. The entrance ramps of each weigh station were also paved with a BCO. The eastbound weigh station entrance ramp mainline was paved on October 21, 1994. Before paving, the joint between the interstate and the ramp was coated with a two-part epoxy. Exit ramps were paved with a bituminous overlay.

A stringline-guided paver was used with manual finishing, texturing, and curing. A section of the existing pavement at the end of the overlay was milled to taper the overlay down to the existing grade. Figure 5 shows the profile of the taper. The overlay thickness was reduced to 50 mm (2 inches) where it meets the existing grade.

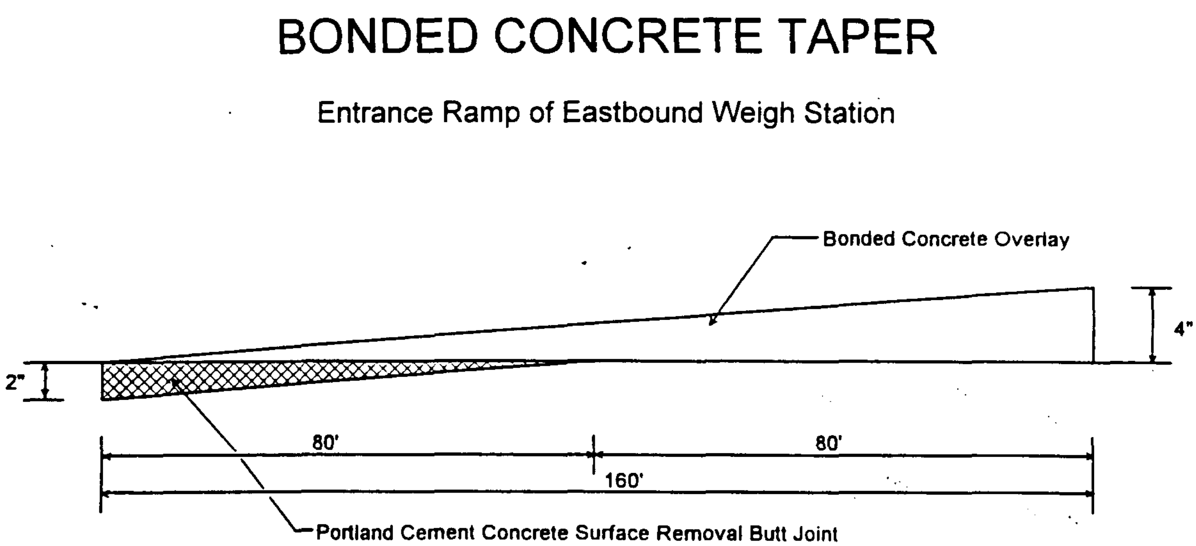


Figure 5. Bonded Concrete Overlay Taper for Eastbound Weigh Station

The outside PCC shoulder of the eastbound weigh station was also paved with a BCO. The outside shoulder was paved on November 1, 1994. The PCC gore area was also supposed to receive the BCO. The anchors tying the gore area to the interstate had failed. Both vertical and horizontal movement was noticed in the longitudinal joint between the gore and the mainline pavement. Therefore, it was overlaid with asphalt concrete to prevent future problems on the gore.

The eastbound lanes were opened to traffic on November 7, 1994. This marked the completion of the first stage of the project. The construction deadline for the first stage of the project was November 23, 1994.

PRECONSTRUCTION OF WESTBOUND LANES

Testing

The westbound lanes were supposed to be tested with the FWD prior to the overlay. However, the FWD was not available for testing before the project restarted in the spring. Structural capacity will only be studied on the eastbound lanes of the project.

Distress surveys were conducted on the westbound lanes prior to placement of the overlay. Summaries of the distresses are located in Table 3.

Table 3. Distress Surveys of Westbound Lanes Prior to Placing the Overlay

Test Section	Distress	Severity	Quantity
0% Microsilica w/ No Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Low	151 m (495 ft)
		High	2 m (5 ft)
0% Microsilica w/ Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Infrequent
	Centerline Distress	Low	105 m (345 ft)
		Medium	40 m (130 ft)
		High	8 m (25 ft)
	Longitudinal Cracking	High	8 m (27 ft)
	Full-depth Patching	N/A	60.8 m^2 (72.7 yd^2)
3% Microsilica w/ No Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Low	30 m (100 ft)
		Medium	122 m (400 ft)
3% Microsilica w/ Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Low	76 m (250 ft)
		Medium	55 m (180 ft)
		High	21 m (70 ft)
	Full-depth Patching	N/A	32.8 m^2 (39.3 yd^2)
5% Microsilica w/ No Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Low	152 m (500 ft)
5% Microsilica w/ Grout	Transverse Cracking	Low	Frequent
		Medium	Infrequent
	Localized Areas of Distress	High	Very Infrequent
	Centerline Distress	Medium	68 m (225 ft)
		High	84 m (275 ft)

Similar to the eastbound lanes, transverse cracking was frequent throughout all of the test sections in the westbound lanes. The majority of this cracking was low severity with some intermittent medium severity. Localized areas of distress were very infrequent. The distress surveys were conducted after patching, which accounts for the patching quantities listed in the table. Centerline distresses varied throughout the test sections. Most of the centerline showed low severity distress. Some sections contained medium and high levels of severity. The westbound lanes contained more longitudinal cracking than the eastbound lanes.

Surface Preparation

The westbound lanes were prepared in the same manner as the eastbound lanes. Full-depth patching was required once traffic had been completely shifted to the eastbound lanes. Eighteen more patches totaling 238.5 sq m (285.3 sq. yd.) of full-depth patches were placed prior to overlaying. These patches repaired areas that deteriorated from the increased traffic driving on the westbound lanes during the first stage of construction. This was an additional 1.19 percent of the westbound lanes surface area. Eight partial-depth patches were placed in the westbound lanes for a total of 99.75 sq m (119.30 sq. yd.). Bituminous material was removed from spalls in the same manner as the eastbound lanes.

The shot blasting operation on the westbound lanes was held to a length equal to the next day paving length instead of completing the entire surface in advance. This helped to minimize the amount of extra sand blasting that had to be done to clean excessive tire tracks and oil drips left by construction vehicles. The sand blasting was handled in the same manner as the eastbound lanes.

CONSTRUCTION OF THE WESTBOUND LANES

The paving operation began on April 21, 1995. Plant breakdowns and rain slowed paving during the first three days. Paving was completed in four days, despite the interruptions.

Special tarps were made for the trucks in order to minimize the amount of oil and other fluids dripping from the concrete trucks. These tarps covered the underside of the truck. Straps to attach the tarps were located on the front and rear of the truck. Most of the contaminants were trapped by this process. A section of the tarp extended under the air brake release to catch the oil spray. This replaced the buckets that were used on the eastbound lanes. The tarps greatly reduced the amount of additional clean up. The only contaminant that had to be cleaned was the tire residue.

To limit the amount of dust blown onto the pavement by the wind, fines from shot blasting were not left at the edge of the pavement. Once a large pile of fines had accumulated, the contractor used a large vacuum truck to remove the pile.

The remainder of the paving continued in the same manner as the eastbound lanes. Paving of the westbound weigh station entrance ramp was on May 11, 1995. After constructing the eastbound ramp, it was decided that the epoxy used in the joint was unnecessary and was not used on the westbound ramp. Also, the overlay at the end of the ramp section on the eastbound lanes showed severe distresses and was partially delaminated. The design was changed on the westbound ramp. The new profile used is shown in Figure 6.

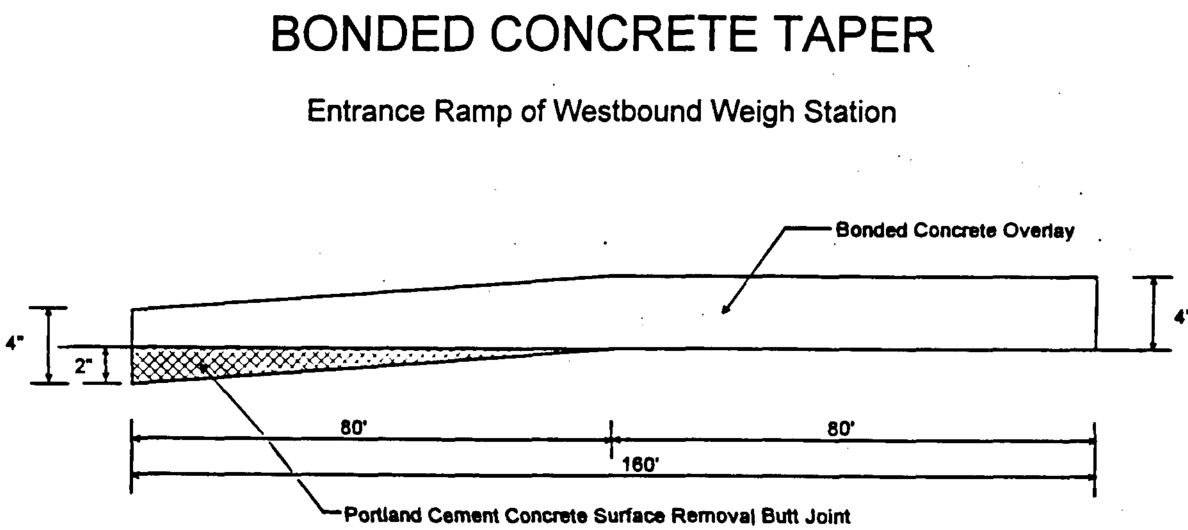


Figure 6. Bonded Concrete Taper for Westbound Weigh Station

The paving operation was similar to that used on the eastbound weigh station entrance ramp. The gore on the westbound ramp did not have the same distresses as the eastbound ramp; therefore, the BCO was placed over this gore. On May 20, 1995, both the gore and inside shoulder of the ramp were paved. The outside shoulder of the ramp was paved on May 26, 1995.

The westbound lanes were open to traffic on May 23, 1995. At this point, traffic was no longer two-way. The contractor had until the completion date of June 30, 1995 to complete slope work and remove the crossovers.

RECORDED DATA

The Rate of Evaporation (ROE) was monitored to determine if moisture was escaping from the overlay too rapidly. Concrete temperature, air temperature, wind speed, and relative humidity were measured during paving in order to calculate the ROE. Other items were monitored to check quality of the overlay: slump, air content, and actual water-cementitious ratio. Placement times and the thickness of the overlay were also recorded.

Concrete Temperature

Concrete temperature was measured while conducting air content and slump tests. Specifications required the concrete be between 10° C (50° F) and 32° C (90° F). These temperatures were maintained at all times. Concrete temperatures measured during paving are shown in Table 4.

Table 4. Concrete Temperature, Slump, and Air Content

Date	Ticket Number	Conc. Temp., ° C (° F)	Slump, mm (in)	Air Con., %
10-07-94	123378	22 (72)	25 (1.00)	6.9
	123380	–	38 (1.50)	5.4
	123381	–	64 (2.50)	7.0
	123384	–	57 (2.25)	6.8
	123395	23 (74)	32 (1.25)	6.5
	123411	23 (74)	44 (1.75)	5.6
	123431	–	51 (2.00)	5.6
	123455	23 (74)	32 (1.25)	5.0
	123475	–	57 (2.25)	5.2
	123490	24 (76)	44 (1.75)	6.1
10-10-94	123527	15 (60)	51 (2.00)	5.7
	123530	–	51 (2.00)	6.7
	123532	18 (64)	44 (1.75)	6.2
	123545	–	38 (1.50)	6.1
	123553	–	38 (1.50)	7.0
	123560	–	44 (1.75)	7.2
	123581	18 (65)	44 (1.75)	6.7
	123599	20 (68)	32 (1.25)	5.3
	123602	21 (71)	38 (1.50)	6.4
	132605	20 (68)	38 (1.50)	5.3
	123618	21 (70)	44 (1.75)	5.2
	123633	21 (70)	44 (1.75)	6.3
	123657	21 (70)	57 (2.25)	7.0
	123680	21 (70)	51 (2.00)	5.9
	123692	20 (68)	51 (2.00)	5.8
10-11-94	123704	18 (64)	38 (1.50)	5.0
	123708	16 (61)	38 (1.50)	5.9
	123709	19 (66)	44 (1.75)	5.3
	123728	–	57 (2.25)	8.0
	123747	18 (64)	44 (1.75)	6.3
	123762	18 (64)	51 (2.00)	5.0
	123780	21 (70)	44 (1.75)	6.9
	123802	21 (70)	51 (2.00)	6.6
	123824	22 (72)	44 (1.75)	5.5
	123845	22 (72)	64 (2.50)	6.0
	123868	21 (71)	44 (1.75)	6.8
	123888	21 (71)	51 (2.00)	5.8
10-12-94	123921	15 (60)	38 (1.50)	5.1
	123927	18 (64)	51 (2.00)	6.3
	123928	–	51 (2.00)	6.0
	123941	17 (62)	57 (2.25)	6.6
	123949	17 (62)	51 (2.00)	5.7
	123950	16 (61)	51 (2.00)	5.8
	123978	17 (63)	44 (1.75)	7.0
10-12-94	124005	20 (68)	64 (2.50)	5.9
	124035	21 (70)	70 (2.75)	7.4
	124059	22 (72)	38 (1.50)	5.7
	124087	23 (74)	51 (2.00)	7.7
	124108	24 (75)	57 (2.25)	6.9
	124139	–	38 (1.50)	6.4

Table 4. Concrete Temperature, Slump, and Air Content (Continued)

Date	Ticket Number	Conc. Temp., °C (°F)	Slump, mm (in)	Air Con., %
10-13-94	124164	19 (66)	51 (2.00)	5.9
	124168	17 (62)	44 (1.75)	5.9
	124170	16 (61)	51 (2.00)	5.9
	124182	18 (64)	57 (2.25)	6.8
	124196	19 (66)	44 (1.75)	6.8
	124197	17 (63)	51 (2.00)	6.4
	124201	18 (65)	38 (1.50)	5.0
	124229	18 (65)	38 (1.50)	6.9
	124252	20 (68)	51 (2.00)	5.6
	124273	–	44 (1.75)	6.9
	124303	21 (70)	57 (2.25)	6.8
10-21-94	124989	18 (64)	44 (1.75)	5.1
	124995	18 (64)	38 (1.50)	6.0
	124997	19 (66)	44 (1.75)	6.1
	125046	21 (70)	44 (1.75)	7.0
	125084	24 (76)	13 (0.50)	6.7
	125087	–	19 (0.75)	6.8
11-01-94	126033	23 (74)	32 (1.25)	5.0
	126063	–	32 (1.25)	5.8
	126079	–	38 (1.50)	5.1
04-21-95	130876	21 (70).	38 (1.50)	5.3
	130877	–	38 (1.50)	6.6
	130878	–	44 (1.75)	5.9
	130907	–	51 (2.00)	6.4
	130927	–	32 (1.25)	5.3
	130949	19 (66)	38 (1.50)	6.0
	130969	18 (64)	51 (2.00)	6.9
	130990	18 (64)	51 (2.00)	6.9
	130992	19 (66)	25 (1.00)	5.1
	131018	17 (63)	44 (1.75)	5.9
	131040	16 (61)	38 (1.50)	6.2
	131060	16 (61)	57 (2.25)	6.1
04-24-95	131132	15 (60)	51 (2.00)	5.4
	131133	15 (60)	32 (1.25)	6.0
	131144	15 (60)	51 (2.00)	7.5
	131162	17 (63)	64 (2.50)	6.6
	131179	17 (62)	70 (2.75)	7.2
	131201	17 (63)	57 (2.25)	6.8
	131223	17 (62)	51 (2.00)	6.3
	131257	17 (63)	51 (2.00)	7.6
	131261	17 (62)	38 (1.50)	5.6

Date	Ticket Number	Conc. Temp., °C (°F)	Slump, mm (in)	Air Con., %
	131292	17 (63)	64 (2.50)	8.4
	131300	–	–	5.7
	131311	17 (63)	57 (2.25)	6.3
04-25-95	131340	15 (59)	51 (2.00)	6.2
	131341	–	44 (1.75)	7.2
	131379	18 (65)	44 (1.75)	6.0
	131411	17 (63)	51 (2.00)	7.9
	131443	19 (67)	38 (1.50)	7.0
	131478	19 (66)	51 (2.00)	6.8
	131511	20 (68)	70 (2.75)	7.0
04-28-95	131631	15 (60)	38 (1.50)	5.0
	131632	–	38 (1.50)	6.0
	131649	–	32 (1.25)	5.6
	131686	17 (63)	44 (1.75)	6.2
	131702	18 (64)	38 (1.50)	6.3
	131720	18 (65)	44 (1.75)	6.2
	131723	19 (66)	38 (1.50)	5.2
	131748	18 (64)	38 (1.50)	5.1
	131766	19 (66)	32 (1.25)	5.6
	131786	–	38 (1.50)	5.0
	131793	–	–	6.5
	131810	19 (66)	44 (1.75)	5.0
	131830	18 (64)	38 (1.50)	5.6
	131853	18 (64)	38 (1.50)	6.7
	131869	–	44 (1.75)	6.2
	131883	–	38 (1.50)	6.3
	131894	17 (62)	44 (1.75)	6.9
05-11-95	132666	18 (64)	25 (1.00)	4.6
	132667	18 (64)	38 (1.50)	5.4
	132702	21 (70)	32 (1.25)	5.0
	132709	19 (67)	44 (1.75)	7.4
	132729	21 (70)	70 (2.75)	6.7
	132748	21 (70)	38 (1.50)	6.8
	132754	–	44 (1.75)	6.2
05-20-95	133370	21 (70)	32 (1.25)	7.5
	133376	20 (68)	19 (0.75)	6.0
	133397	22 (72)	44 (1.75)	5.0
05-26-95	133715	20 (68)	32 (1.25)	5.7
	133726	21 (70)	38 (1.50)	5.2
	133740	21 (70)	38 (1.50)	6.6
	133770	22 (72)	38 (1.50)	5.1

Concrete temperatures were also measured at the paver in order to determine rate of evaporation. These readings are listed in Table 5. A standard thermometer was used while paving the eastbound lanes, and a Barnant Company Tri-Sense meter with a thermocouple probe was used during the westbound lanes paving operation to increase data accuracy.

Air Temperature

Air temperature was also monitored. Air temperature readings were taken near the paver. Table 5 lists the readings taken for this purpose. A standard thermometer was used for eastbound paving and a temperature probe on the Tri-Sense meter was used for the westbound lanes. The air temperature during paving in the fall was in the range of 16 - 21° C (60 - 70° F) throughout the day. The temperature cooled off considerably in the evening. While paving in the spring, the air temperature was mainly between 10 and 18° C (50 and 65° F) during the day. Evening temperatures were cooler, but not to the extreme that occurred in the eastbound lanes.

Table 5. Concrete Temperature, Air Temperature, Wind Speed, Relative Humidity, and Rate of Evaporation (ROE)

Date	Time	Conc. Temp., ° C (° F)	Air Temp., ° C (° F)	Wind Speed km/hr (mph)	Relative Humidity (%)	ROE kg/m^2/hr (lb./ft^2/hr.)
10-07-94	10:37 AM	25.6 (78.0)	23.0 (73.5)	24 (15)	58	0.83 (0.17)
	12:45 PM	25.8 (78.5)	27.0 (80.7)	26 (16)	57	0.73 (0.15)
	4:30 PM	24.7 (76.5)	25.8 (78.4)	16 (10)	57	0.44 (0.09)
10-10-94	8:30 AM	16.9 (62.5)	7.2 (44.9)	0 (0)	100	0.10 (0.02)
	11:30 AM	19.6 (67.2)	16.2 (61.1)	2 (1)	38	0.20 (0.04)
	1:25 PM	21.1 (70.0)	18.6 (65.5)	3 (2)	36	0.24 (0.05)
	4:05 PM	21.1 (70.0)	18.9 (66.0)	5 (3)	31	0.34 (0.07)
	5:55 PM	20.8 (69.4)	13.9 (57.1)	3 (2)	37	0.29 (0.06)
10-11-94	9:05 AM	16.1 (61.0)	16.4 (61.5)	6 (4)	73	0.15 (0.03)
	12:30 PM	20.9 (69.7)	19.3 (66.8)	6 (4)	38	0.29 (0.06)
	1:37 PM	21.8 (71.3)	18.6 (65.5)	8 (5)	45	0.39 (0.08)
	5:45 PM	21.1 (70.0)	15.7 (60.3)	10 (6)	42	0.44 (0.09)
10-12-94	8:25 AM	18.9 (66.0)	7.3 (45.1)	3 (2)	78	0.20 (0.04)
	10:57 AM	18.8 (65.8)	16.6 (61.8)	5 (3)	54	0.20 (0.04)
	1:53 PM	22.8 (73.1)	20.9 (69.6)	5 (3)	28	0.39 (0.08)
10-13-94	8:17 AM	17.7 (63.9)	8.2 (46.7)	2 (1)	86	0.15 (0.03)
	11:37 AM	19.8 (67.7)	14.7 (58.5)	3 (2)	72	0.20 (0.04)
	1:28 PM	21.1 (70.0)	20.6 (69.1)	3 (2)	42	0.20 (0.04)
	3:30 PM	22.1 (71.8)	24.2 (75.6)	2 (1)	32	0.20 (0.04)
04-21-95	7:55 AM	23.8 (74.8)	6.2 (43.2)	5.0 (3.1)	77.5	0.34 (0.07)
	10:30 AM	19.9 (67.9)	6.4 (43.5)	22.8 (14.2)	69.5	0.78 (0.16)
	12:50 PM	19.9 (67.9)	6.7 (44.1)	20.1 (12.5)	67.9	0.63 (0.13)
04-24-95	7:00 AM	16.7 (62.1)	6.8 (44.3)	4.5 (2.8)	54.6	0.24 (0.05)
	9:00 AM	16.3 (61.4)	12.2 (53.9)	7.2 (4.5)	34.5	0.29 (0.06)
	11:30 AM	16.0 (60.8)	17.0 (62.7)	9.2 (5.7)	24.7	0.39 (0.08)
04-25-95	8:00 AM	18.4 (65.1)	6.6 (43.9)	5.5 (3.4)	53.8	0.29 (0.06)
	10:30 AM	17.2 (63.0)	12.4 (54.4)	5.5 (3.4)	27.2	0.34 (0.07)
	1:00 PM	18.9 (66.0)	16.6 (61.8)	10.0 (6.2)	23.3	0.49 (0.10)

NOTE: The investigator was not present during paving on April 28, 1995. No readings were taken on that day.

Wind Speed

Wind speed was measured near the paving operation. While paving the eastbound lanes, an Alnor Velometer Jr. was used to measure the wind speed. A Tri-Sense meter with a air velocity probe was used while paving the westbound lanes. The wind speed data taken are listed in Table 5. The wind speed while paving the eastbound lanes was generally between 3.2 and 9.6 km/hr (2 and 6 mph),with gusts up to 25.7 km/hr (16 mph). Wind speed while paving the westbound lanes ranged between 3.7 and 10.0 km/hr (2.3 and 6.2 mph), with gusts up to 22.8 km/hr (14.2 mph).

Relative Humidity

Relative humidity was also measured near the paving operation. A sling psychrometer was used during the eastbound lanes paving operation. Figure 7 is the chart used to determine the relative humidity with the sling psychrometer. A relative humidity probe was used with the Tri-Sense meter while paving the westbound lanes. These readings are also listed in Table 5. The relative humidity was usually above 70 percent in the morning, and between 30 and 50 percent throughout the rest of the day. This was true for paving in both directions.

Rate of Evaporation

The rate of evaporation (ROE) was calculated using Figure 8 to monitor the loss of moisture from the overlay. The ROE is limited to 0.5 kg/m^2/hr (0.1 lb./ft^2/hr.) for bridge deck BCOs. If the rate exceeds this amount, the contractor must take extra precautions to prevent shrinkage cracking. The special provision for the pavement BCO did not specify a limit on the rate of evaporation. The ROE, if greater than 0.5 kg/m^2/hr (0.1 lb./ft^2/hr.), may help to account for excessive shrinkage cracking in the overlay. The measurements are listed in Table 5. Some of the ROEs were greater than the typical 0.5 kg/m^2/hr (0.1 lb./ft^2/hr) limit; however, the contractor was not required to take extra precautions on this project. This occurred on the first day of paving in both directions.

Slump

Concrete slump was measured when the truck checked in on the jobsite. Specifications require the slump to be between 20 and 40 mm (0.75 and 1.5 inches). With microsilica in the mix, the amount of bleed water is limited. For easier paving, the slump was normally between 25 and 64 mm (1.0 and 2.5 inches). The higher slumps increased workability with microsilica in the mix. The recorded slumps are listed in Table 4. The average slumps for the eastbound and westbound lanes were 45 mm (1.79 inches) and 43 mm (1.71 inches), respectively. Standard deviations were 10.2 mm (0.40 inch) and 10.8 mm (0.42 inch), respectively.

Figure 7. Relative Humidity Chart for Use with Sling Psychrometer

Dry Bulb Temperature (°F)

Wet Bulb Temperature (°F) (rows) vs. Dry Bulb Temperature (°F) (columns 41–60)

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
41	100	92	85	78	71	65	59	54	48	43	39	35	31	27	23	20	17	14	11	9
42		100	92	85	78	72	66	60	54	49	45	40	36	32	28	25	22	18	16	13
43			100	93	86	79	72	66	61	55	50	46	41	37	33	30	26	23	20	17
44				100	93	86	79	73	67	61	56	51	47	42	38	34	31	27	24	21
45					100	93	86	79	73	67	62	57	52	48	43	39	35	32	29	26
46						100	93	86	80	74	68	63	58	53	49	44	40	37	33	30
47							100	93	86	80	75	69	63	59	54	50	45	41	38	34
48								100	93	87	81	75	69	64	59	55	50	46	42	39
49									100	93	87	81	75	70	65	60	55	51	47	43
50										100	94	87	81	76	70	65	61	56	52	48
51											100	94	87	82	76	71	66	61	57	53
52												100	94	88	82	76	71	66	62	58
53													100	94	88	82	77	72	67	63
54														100	94	88	82	77	72	68
55															100	94	88	83	78	73
56																100	94	88	83	78
57																	100	94	89	83
58																		100	94	89
59																			100	94
60																				100
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78																				
79																				
80																				

Wet Bulb Temperature (°F) (rows) vs. Dry Bulb Temperature (°F) (columns 61–80)

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	
41	7	4	2																		41
42	10	8	6	4	2																42
43	14	12	10	7	5	3	2														43
44	18	16	13	11	9	7	5	3	1												44
45	22	20	17	15	12	10	8	6	5	3	1										45
46	27	24	21	18	16	14	12	10	8	6	4	3	1								46
47	31	28	25	22	20	17	15	13	11	9	7	6	4	3	1						47
48	35	32	29	26	24	21	19	16	14	12	10	9	7	5	4	3	1				48
49	40	36	33	30	27	25	22	20	18	15	13	12	10	8	7	5	4	3	1		49
50	44	41	37	34	31	29	26	23	21	19	17	15	13	11	9	8	6	5	4	3	50
51	49	45	42	38	35	32	30	25	24	22	20	18	16	14	12	11	9	8	6	5	51
52	54	50	46	43	39	36	33	31	28	25	23	21	19	17	15	13	12	10	9	7	52
53	58	54	50	47	44	40	37	34	32	29	27	24	22	20	18	16	14	13	11	10	53
54	63	59	55	51	48	44	41	38	35	33	30	28	25	23	21	19	17	16	14	12	54
55	68	64	60	56	52	48	45	42	39	36	33	31	29	26	24	22	20	18	17	15	55
56	73	69	64	60	56	53	49	46	43	40	37	34	32	29	27	25	23	21	19	18	56
57	78	74	69	65	61	57	53	50	47	44	41	38	35	33	30	28	26	24	22	20	57
58	84	79	74	70	66	61	58	54	51	48	45	42	39	36	34	31	29	27	25	23	58
59	89	84	79	74	70	66	62	58	55	51	48	45	42	39	37	34	32	30	28	26	59
60	94	89	84	79	75	71	66	62	59	55	52	49	46	43	40	38	35	33	31	29	60
61	100	94	89	84	80	75	71	67	63	59	56	53	50	47	44	41	39	36	34	32	61
62		100	95	90	85	80	75	71	67	64	60	57	53	50	47	44	42	39	37	35	62
63			100	95	90	85	80	76	72	68	64	61	57	54	51	48	45	43	40	38	63
64				100	95	90	85	80	76	72	68	65	61	58	54	51	48	46	43	41	64
65					100	95	90	85	81	77	72	69	65	61	58	55	52	49	46	44	65
66						100	95	90	85	81	77	73	69	65	62	59	56	53	50	47	66
67							100	95	90	86	81	77	73	69	66	62	59	56	53	50	67
68								100	95	90	86	82	78	74	70	66	63	60	57	54	68
69									100	95	90	86	82	78	74	70	67	63	60	57	69
70										100	95	91	86	82	78	74	71	67	64	61	70
71											100	95	91	86	82	78	74	71	68	64	71
72												100	95	91	86	82	79	75	71	68	72
73													100	95	91	87	83	79	75	72	73
74														100	96	91	87	83	79	75	74
75															100	96	91	87	83	79	75
76																100	96	91	87	83	76
77																	100	96	91	87	77
78																		100	96	91	78
79																			100	96	79
80																				100	80

Dry Bulb Temperature (°F)

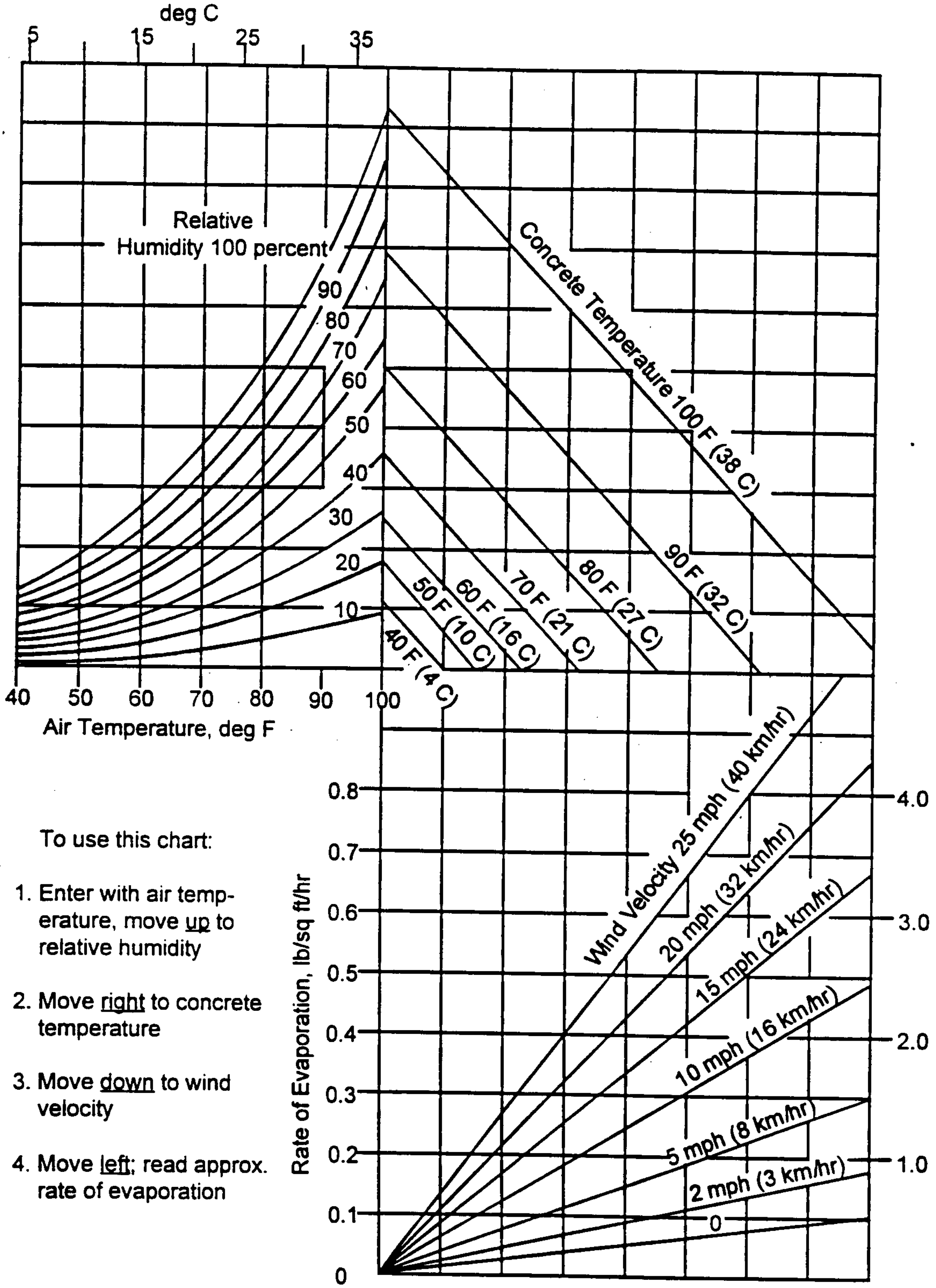


Figure 8. Effect of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete. This chart provided a graphic method of estimating the loss of surface moisture for various weather conditions. To use the chart, follow the four steps outlined above. (Per Illinois Department of Transportation Supplemental Specifications and Recurring Special Provisions Check Sheet #17.)

Air Content

Air content was also measured when the truck checked in on the jobsite. The requirements for air content in the specification is between 5 and 8 percent. Very few readings were outside this limit. Those that were outside the limits were corrected by either adding air entraining agent or mixing the concrete longer. The test results are listed in Table 4. The average air content while paving the eastbound lanes was 6.1 percent, with a standard deviation of 0.72 percent. While paving the westbound lanes, the average air content was 6.2 percent, with a standard deviation of 0.83 percent.

Water-cementitious Ratio

The water-cementitious ratio was recorded for several trucks at the plant before departure to the jobsite. The target value for the water-cementitious ratio was 0.4. The recorded values are shown in Appendix C. The average water-cementitious ratio while paving the eastbound lanes was 0.402, with a standard deviation of 0.013. While paving the westbound lanes, the average water-cementitious ratio was 0.392, with a standard deviation of 0.019.

Placement Time

Placement time was recorded to monitor the amount of time taken to construct the overlay. If placement of the overlay is extremely slow, the cost of traffic control and hindrance to the public may eliminate the BCO from future consideration. Appendix D shows placement times for both the eastbound and westbound lanes. Since this project was an experimental feature, placement times were slow. This was due to changing mixes throughout the day, as well as changing from a grout section to a no grout section. Generally, the paving of a BCO will proceed at a faster pace.

Overlay Thickness

Required minimum overlay thickness was 10 mm (4 inches). When the height of the stringline had to be adjusted to improve rideability, it was always raised instead of lowered. To verify that minimum overlay thickness was placed, inspectors took depth checks every 76.2 m (250 feet). A length of string pulled across the pavement and a fold-up rule were used. The eastbound and westbound lanes had average depths of 112.0 mm (4.41 inches) and 118.1 mm (4.65 inches), respectively. Standard deviations were 9.40 mm (0.37 inch) and 6.60 mm (0.26 inch), respectively.

QUALITY TESTING

Both compressive strength and split tensile strength tests were conducted on the concrete. The test used to conduct the compression tests was ASTM C 39-93a -- Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. 150- by 300-mm (6- by 12-inch) cylinders were used for compressive tests. Results for the compressive tests are located in Appendix E.

The average 7-day compressive strength for the eastbound lanes was 31,848 kiloPascals (kPa) (4,619 psi), with a standard deviation of 5,607.9 kPa (813.4 psi). Average 28-day compressive strength for the eastbound lanes was 42,448 kPa (6,156 psi) with a standard deviation of 5,769.1 kPa (836.7 psi).

For the westbound lanes, the average 7-day compressive strength was 31,474 kPa (4,565 psi), with a standard deviation of 4,561.3 kPa (661.6 psi). Average 28-day compressive strength for the westbound lanes was 41,227 kPa (5,979 psi), with a standard deviation of 5,380.3 kPa (780.4 psi).

Test method ASTM C 496-90 -- Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens was used for determining the split tensile strength. This test was conducted using 100- by 200-mm (4- by 8-inch) cylinders. Results for the split tensile tests are located in Appendix F.

The average 7-day split tensile strength for the eastbound lanes was 4,026.5 kPa (584.0 psi), with a standard deviation of 394.3 kPa (57.2 psi). Average 28-day split tensile strength for the eastbound lanes was 4,660.2 kPa (675.9 psi), with a standard deviation of 461.9 kPa (67.0 psi).

For the westbound lanes, the average 7-day split tensile strength was 4,297.5 kPa (623.3 psi), with a standard deviation of 899.1 kPa (130.4 psi). Average 28-day split tensile strength for the westbound lanes was 4,903.6 kPa (711.2 psi), with a standard deviation of 519.2 kPa (75.3 psi).

Specifications require that the concrete have a compressive strength of 24,000 kPa (3,500 psi) at 14 days. IDOT has no split tensile strength requirement. All specimens met the required strength. Compressive strengths were very comparable between mixes. Microsilica, in the amounts used, did not make a significant difference in strength. This result agreed with compressive tests conducted in the laboratory. The same trend was noticed with the test results for split tensile strength.

MISCELLANEOUS TESTING

Several other tests were conducted on the overlay. These tests include: distress surveys, location of delamination, FWD testing, California Profilograph and International Roughness Index, friction testing, drying shrinkage of overlay concrete, and bond strength testing.

Distress Surveys

On July 17 and July 19, 1995, distress surveys were conducted on all twelve test sections. The following is a description of the crack spacing found in each test section. Only visible cracks were included in the surveys. For the purpose of these surveys, a visible crack is defined as a crack that is easily seen despite the tining of the pavement. Table 6 summarizes the crack spacing for each monitored section. Only the eastbound lanes are included in these descriptions. The westbound lanes had not experienced winter conditions, and the crack spacing at the time of the survey was not a true representation of the final pavement crack spacing.

Table 6. Distress Survey of Eastbound Lanes After Placing the Overlay

Test Section	Number of Cracks	Average Spacing	Minimum Spacing	Maximum Spacing	Standard Deviation
0% MS w/ No Grout	41	3.70 m (12.15 feet)	1.52 m (5.00 feet)	6.10 m (20 feet)	0.99 m (3.24 feet)
0% MS w/ Grout	51	3.01 m (9.88 feet)	1.22 m (4 feet)	11.28 m (37 feet)	1.44 m (4.74 feet)
3% MS w/ No Grout	90	1.69 m (5.54 feet)	0.30 m (1 foot)	4.57 m (15 feet)	0.92 m (3.01 feet)
3% MS w/ Grout	73	2.10 m (6.89 feet)	0.30 m (1 foot)	3.96 m (13 feet)	0.76 m (2.48 feet)
5% MS w/ No Grout	54	2.80 m (9.17 feet)	0.30 m (1 foot)	6.10 m (20 feet)	1.22 m (4.02 feet)
5% MS w/ Grout	68	2.21 m (7.25 feet)	0.30 m (1 foot)	6.10 m (20 feet)	0.97 m (3.19 feet)

The average crack spacing for the plain BCO was 3 to 4 m (9 to 12 feet). BCO mixes containing microsilica had closer crack spacing. The 3 and 5 percent microsilica BCOs had average crack spacings of 1.5 to 2 m (5 to 7 feet) and 2.2 to 2.8 m (7 to 9 feet), respectively. This may indicate that microsilica concrete has higher shrinkage.

Eventually, all transverse cracks, in theory, will reflect through the overlay. All known working cracks were patched. Therefore, the cracks that reflect through should remain tight and not cause significant distresses.

Location of Delamination

On October 26, 1994, the project was surveyed for delaminations on the eastbound lanes before opening to traffic. For this test, a section of reinforcing bar was used to "sound" the pavement. The bar was dropped from a height of approximately 150 mm (6 in.) above the pavement surface. A solid sound indicated a non-delaminated area, while a hollow sound indicated a delaminated area. Several localized areas of delaminations were recorded. These areas were all located along transverse cracks. No signs of other distress were noted in the delaminated areas.

The westbound lanes were tested in a similar manner on May 18, 1995 before opening to traffic. Once again, all areas of delamination were located along transverse cracks and no other signs of distress were apparent. The locations of delamination for eastbound and westbound test sections are shown in Tables 7 and 8, respectively.

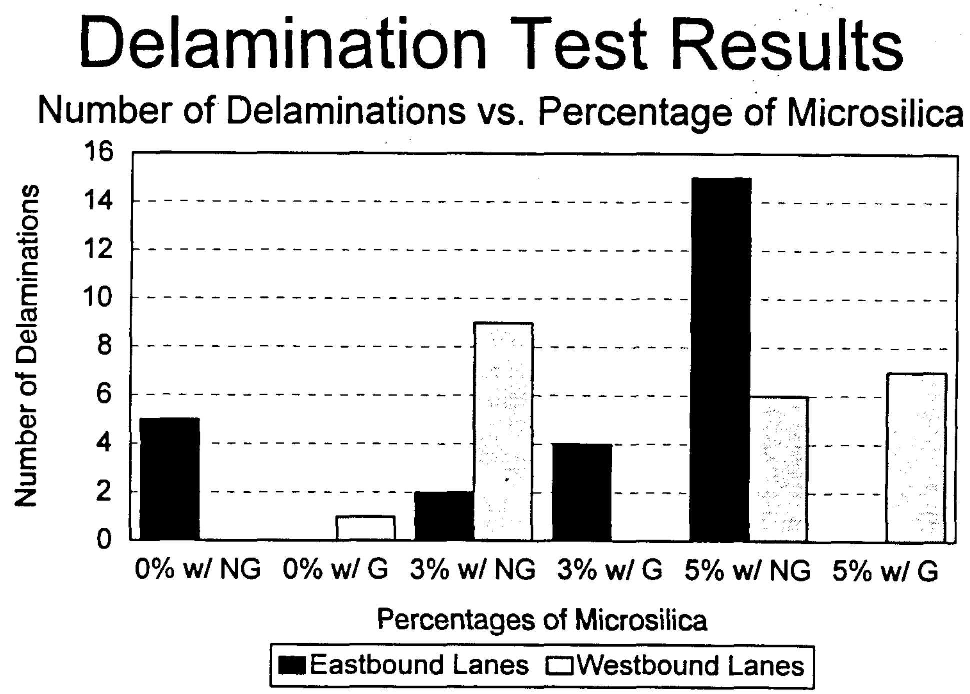
Test results showed increasing delaminations with increasing percentages of microsilica. This trend is shown in Figure 9. A possible explanation for this trend is

Table 7. Locations of Delamination on Eastbound Lanes

Test Section	Station	Length of Delamination
0% MS w/ Grout		No Delaminations
0% MS w/o Grout	167+05	Driving Lane, Outer Wheel Path, ~4'
	171+09	Passing Lane by Centerline
	171+83	Passing Lane
	171+85	Driving Lane, Outer Wheel Path to Shoulder
	171+94	Passing Lane
3% MS w/ Grout	112+91	Both Lanes
	115+36	Driving Lane, 4' from Shoulder to Centerline
	116+48	Driving Lane, Shoulder to Center of Lane
	116+65	Driving Lane, Also Small Amount on Other Side of Centerline
3% MS w/o Grout	104+81	Passing Lane ~8' from Median Side
	105+28	Both Lanes
5% MS w/ Grout		No Delaminations
5% MS w/o Grout	135+05	Both Lanes
	135+25	Driving Lane Only
	135+26	Passing Lane Only
	135+45	Both Lanes
	135+72	Both Lanes
	135+94	Driving Lane Only
	136+36	Driving Lane Only
	136+72	Both Lanes
	137+04	Passing Lane Only
	137+22	Driving Lane, Center of Lane to Shoulder
	138+14	Both Lanes
	138+44	Both Lanes
	138+70	Driving Lane, Center of Lane to Centerline
	138+87	Driving Lane Only
	139+79	Passing Lane

Table 8. Locations of Delamination on Westbound Lanes

Test Section	Station	Length of Delamination
0% MS w/ Grout	161+00	Both Lanes
0% MS w/o Grout		No Delaminations
3% MS w/ Grout		No Delaminations
3% MS w/o Grout	103+85	Right 1/2 of Driving Lane Only
	104+09	Both Lanes
	105+15	Passing Lane Only
	105+30	Both Lanes
	106+11	Passing Lane Only
	106+12	Driving Lane Only
	106+36	Passing Lane Only
	106+89	Passing Lane Only
	107+10	Around Header in Both Lanes, Passing Lane worse (~2-3' wide)
5% MS w/ Grout	92+76	Driving Lane Only
	94+05	Driving Lane Only
	94+25	Driving Lane Only
	94+65	Driving Lane Only
	95+28	Right 1/2 of Driving Lane Only
	96+35	Both Lanes
	96+61	Driving Lane Only
5% MS w/o Grout	135+10	Driving Lane Only
	135+26	Passing Lane Only
	135+36	Both Lanes
	136+23	Both Lanes Until 136+20
	137+26	Driving Lane and 1' Into Passing Lane
	139+60	Both Lanes



NG = No Grout; G = Grout

Figure 9. Number of Delaminations Versus the Percentage of Microsilica in the Mix

thatd concrete containing microsilica absorbs water at a higher rate, causing more shrinkage cracking. Curling stresses can cause the overlay near the shrinkage cracks to pull away from the existing pavement causing delamination. The more cracks, the greater the chance of delamination. Overall, the amount of delamination is minimal compared to the length of each test section. If possible, delamination testing will be conducted at the end of the performance period to monitor the bonding of the overlay.

Falling Weight Deflectometer (FWD) Testing

The eastbound lanes were deflection tested with the FWD on July 25, 1995. Measurements after overlaying were compared to measurements before overlaying. The BCO was expected to increase the structural capacity of the pavement. Results from the second test are in Table 9.

Table 9. Falling Weight Deflectometer Statistics for Deflections for 07/25/95 on I-80 Eastbound

Test Section	Temp	# of Tests[a]	D0[b] (mils)			D1[b] (mils)			D2[b] (mils)		
			AVG	SD	COV (%)	AVG	SD	COV (%)	AVG	SD	COV (%)
0% w/o GR	87°	4	5.51	0.92	16.62	4.99	0.80	15.98	4.49	0.74	16.55
0% w/ GR	87°	3	5.61	1.44	25.64	5.37	1.41	26.28	4.92	1.32	26.80
3% w/o GR	87°	3	6.29	0.43	6.86	5.99	0.39	6.57	5.53	0.39	7.04
3% w/ GR	87°	3	8.19	1.82	22.21	7.79	1.76	22.66	7.20	1.66	23.00
5% w/o GR	87°	11	6.37	1.29	20.21	6.01	1.24	20.68	5.42	1.21	22.32
5% w/ GR	87°	2	5.38	0.25	4.70	5.10	0.17	3.26	4.64	0.08	1.64

Test Section	Temp	# of Tests[a]	D3[b] (mils)			Area[c] (in)		
			AVG	SD	COV (%)	AVG	SD	COV (%)
0% w/o GR	87°	4	3.85	0.62	16.14	30.86	0.58	1.87
0% w/ GR	87°	3	4.33	1.24	28.53	32.52	1.15	3.53
3% w/o GR	87°	3	4.86	0.34	7.01	32.61	0.04	0.13
3% w/ GR	87°	3	6.39	1.57	24.52	32.59	0.50	1.54
5% w/o GR	87°	11	4.72	1.17	24.81	31.90	0.95	2.99
5% w/ GR	87°	2	4.08	0.03	0.82	32.31	0.66	2.04

a Tests were conducted in the outer wheel path.

b D0, D1, D2, and D3 are surface deflections at 0-, 12-, 24-, and 36-inch offsets (respectively) from the center of the loading plate.

c Area (inch) = 6 (1 + 2(D1/D0) + 2(D2/D0) + D3/D0) [6]

Average area calculations after the overlay ranged from 30.86 to 32.61 inches with a standard deviation between 0.50 and 1.15 inch. All test sections showed an increase in deflection basin area. Results from a section of Interstate 39, which is a pavement about the same thickness as the combined thickness of the overlaid pavement, have average area values of 30.5 to 31.7 inch. Therefore, the overlaid pavement is comparable to new construction of a PCC pavement.

Even though the increase in area is slight, in theory, this indicates that the structural capacity of the pavement increased. This pavement was in fairly good condition prior to overlaying. The BCO was placed to prevent the future deterioration of the pavement. Theoretically, the pavement should last another 20 years.

California Profilograph and International Roughness Index

Before a new pavement is open to traffic, the California Profilograph is used to measure a roughness parameter known as the profile index. This apparatus is pushed along each wheel path of the pavement and records the profile on graph paper. Areas requiring grinding are determined using this test. The eastbound lanes were tested and recorded an average profile index of 57.9 mm/km (3.67 inch/mile). The westbound lanes recorded an average profile index of 19.2 mm/km (1.22 inch/mile). The average profile index for the entire project was 38.5 mm/km (2.44 inch/mile). To receive 100 percent pay, our specifications require the contractor produce a minimum profile index of 160 mm/km (10 inch/mile). The average index for the entire project falls within the 36 mm/km (2.25 inch/mile) to 53 mm/km (3.25 inch/mile) limits that resulted in a two percent bonus for the contractor.

Another method used to measure the pavement roughness is the South Dakota Profilometer. This device is mounted on the front bumper of the Video Inspection Vehicle (VIV). The VIV is a van that travels along the pavement at highway speeds video taping the pavement with four cameras. Using these videos, distress surveys and condition rating surveys may be conducted. While the pavement is filmed, the profile of the road is also measured. The number generated by this test is known as the International Roughness Index (IRI). The indices for the eastbound and westbound lanes were 1,073.2 mm/km (68 inch/mile) and 1,041.6 mm/km (66 inch/mile), respectively. Compared to statewide data, these IRI values are considered to be in the smoothest category. Figure 10 is a graph showing the indices of all Illinois pavements in 1994. According to the graph, this project ranks in the smoothest 10 percent of all interstate pavements in Illinois. [6]

IRI QUARTILE ANALYSIS, 1994 DATA

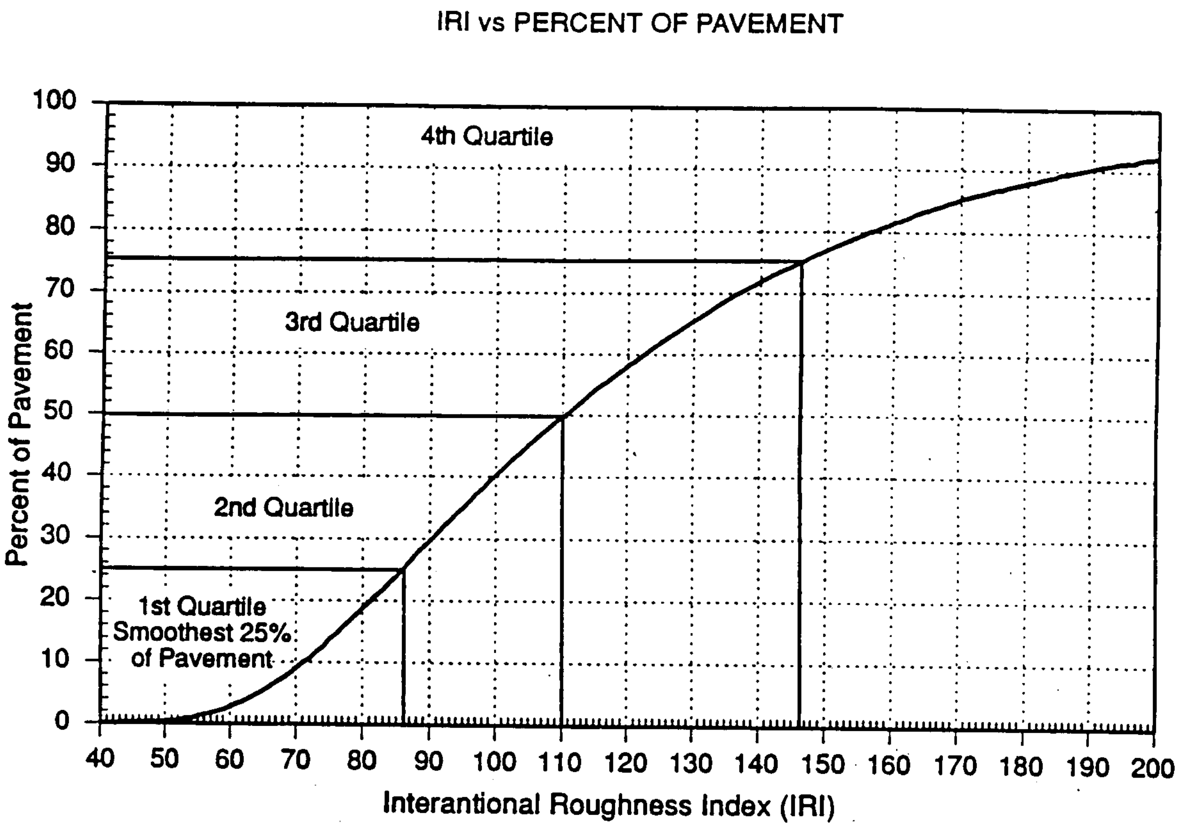


Figure 10. 1994 Ride Quality Data for Interstates in Illinois

Friction Testing

The BMPR friction tester was used to measure the pavement friction of the project on July 25, 1995. This device is designed to obtain a standard measurement of the friction properties of pavement surfaces under wetted conditions. The apparatus is a two-wheeled trailer that is towed along the highway at a predetermined test speed. The test starts when one wheel on the trailer is locked by braking. During braking, a measured amount of water is sprayed on the pavement in front of the tire as it slides along the wetted surface. Friction is generated between the tire and surface which causes a torque to be developed on the trailer axle.

A standard test is at 64 km/hr (40 mph) in the left wheel path with a treaded tire. Each test takes about three seconds. Torque on the trailer axle is measured for a one-second interval. IDOT also performs a test in the right wheel path with a smooth (treadless) tire. Tests are made with alternate wheels as the trailer is towed along the roadway. Data is collected and stored on a personal computer.

Tests were conducted in the driving lane for each direction. The eastbound lanes average friction numbers were 55 for the treaded tire and 49 for the smooth tire. Average friction numbers for the westbound lane were 55 for the treaded tire and 46 for the smooth tire. These results are typical for new concrete pavements.

Drying Shrinkage of Concrete

Concrete drying shrinkage was also measured. ASTM C 157-93 -- Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete test method was used. For the BMPR testing purposes, the size of the test specimens was modified. The molds used to make test specimens were beam boxes with an inside dimension of 152.4 by 152.4 by381 mm (6 by 6 by 15 inches). A small stainless steel bolt was placed in each end of the beam for measuring purposes.

Three beams were made for each mix design on August 16, 1995. Materials from the producers used in the project were used to prepare the specimens and imitate the overlay as closely as possible. The overlay mix was prepared and placed into each mold. A tabletop vibrator was used to consolidate the samples. After curing overnight under wetted burlap, the samples were measured for the initial length. A 609.6-mm (24-inch) caliper was used to take this initial reading. A digital caliper was used to take other readings, but was unavailable to take the initial measurements. Next, the beams were placed in a moist room with 100 percent humidity. After 28 days of moist curing, the beams were removed from the moist room and stored in the laboratory. Lengths were measured at five, seven, 14, and 28 days. Results of the test are summarized in Table 10.

Drying shrinkage during moist curing was the same for all three mixes, 1.6 to 1.7 mm (0.0641 to 0.0654 inch). After air drying in the laboratory, the samples showed additional shrinkage. Shrinkage leveled off after 14 to 28 days, and was again similar for the three mixes.

Distress surveys from the field showed a greater number of cracks in the mixes containing microsilica. However, many factors contribute to crack spacing. These factors include spacing in original pavement, as well as, temperature, relative humidity, and water-cementitious ratio during paving.

Table 10. Drying Shrinkage Test Results

Mix Design	Sample Number	Initial Length mm (in)	Shrinkage After Curing mm (in)	Shrinkage at 5 Days mm (in)	Shrinkage at 7 Days mm (in)	Shrinkage at 14 Days mm (in)	Shrinkage at 28 Days mm (in)
0% MS	X52-1	397.7 (15.6575)	1.6510 (0.0650)	1.7145 (0.0675)	1.7221 (0.0678)	1.7602 (0.0693)	1.7678 (0.0696)
	X52-2	395.5 (15.5715)	1.6281 (0.0641)	1.6840 (0.0663)	1.6942 (0.0667)	1.7297 (0.0681)	1.7450 (0.0687)
	X52-3	397.8 (15.6625)	1.6612 (0.0654)	1.7120 (0.0674)	1.7094 (0.0673)	1.7501 (0.0689)	1.7526 (0.0690)
3% MS	X53-1	396.8 (15.6240)	1.6307 (0.0642)	1.7094 (0.0673)	1.6866 (0.0664)	1.7729 (0.0698)	1.7653 (0.0695)
	X53-2	397.3 (15.6415)	1.6408 (0.0646)	1.6891 (0.0665)	1.6815 (0.0662)	1.7297 (0.0681)	1.7170 (0.0676)
	X53-3	396.6 (15.6130)	1.6281 (0.0641)	1.6485 (0.0649)	1.6840 (0.0663)	1.7043 (0.0671)	1.6993 (0.0669)
5% MS	X54-1	396.3 (15.6025)	1.6586 (0.0653)	1.6866 (0.0664)	1.7018 (0.0670)	1.7170 (0.0676)	1.7221 (0.0678)
	X54-2	396.4 (15.6060)	1.6485 (0.0649)	1.7069 (0.0672)	1.6993 (0.0669)	1.7170 (0.0676)	1.7297 (0.0681)
	X54-3	396.0 (15.5915)	1.6358 (0.0644)	1.6408 (0.0646)	1.6891 (0.0665)	1.7094 (0.0673)	1.7069 (0.0672)

Bond Strength Testing

One of the objectives of the bond strength test is to determine the necessity of a bonding agent with the BCO. To do this, the bond strength of all of the test sections was studied. On August 1, 1995, bond tests were conducted in each of the monitored sections. The test method used was the Virginia Test Method - 92. This test involves coring through the overlay and into the pavement with a 50-mm (2-inch) coring bit. Next, a pipe fitting is epoxied to the surface of the core and allowed to set. A force-measuring device (dynamometer) is attached to the pipe fitting and pulled in tension.

The testing apparatus pulls the overlay away from the pavement as the dynamometer registers the force required to break the bond. During testing, the pipe fitting with epoxy pulled off the surface mortar of the overlay and not the entire overlay. Three tests in each of two monitored sections reacted in this manner. On the second day of testing, a hammer-drill with a chisel bit was used to remove the surface mortar and expose coarse aggregate. Then the overlay was cored and a pipe fitting attached to the surface of the core. Again the pipe fitting with epoxy pulled away from the surface of the core. Three tests in each of two monitored sections reacted in this fashion.

After two unsuccessful days of testing, field testing was abandoned. Instead of conducting a pull-off bond strength test, the Brookhaven National Laboratory (BNL) Guillotine Shear Test Method was used to measure bond strength of the interface. A photograph of the testing apparatus with a sample is shown in Figure 11. This test uses a 100-mm (4-inch) core and applies a load to shear the overlay at the bonding interface. The results of the direct tensile and direct shear tests are summarized in Appendix G. These tests showed that all test sections contained adequate bond strength, defined as anything greater than 1,380 kPa (200 psi) [7]. This indicates that the use of grout for a bonding agent does not increase the bond strength of the overlay.

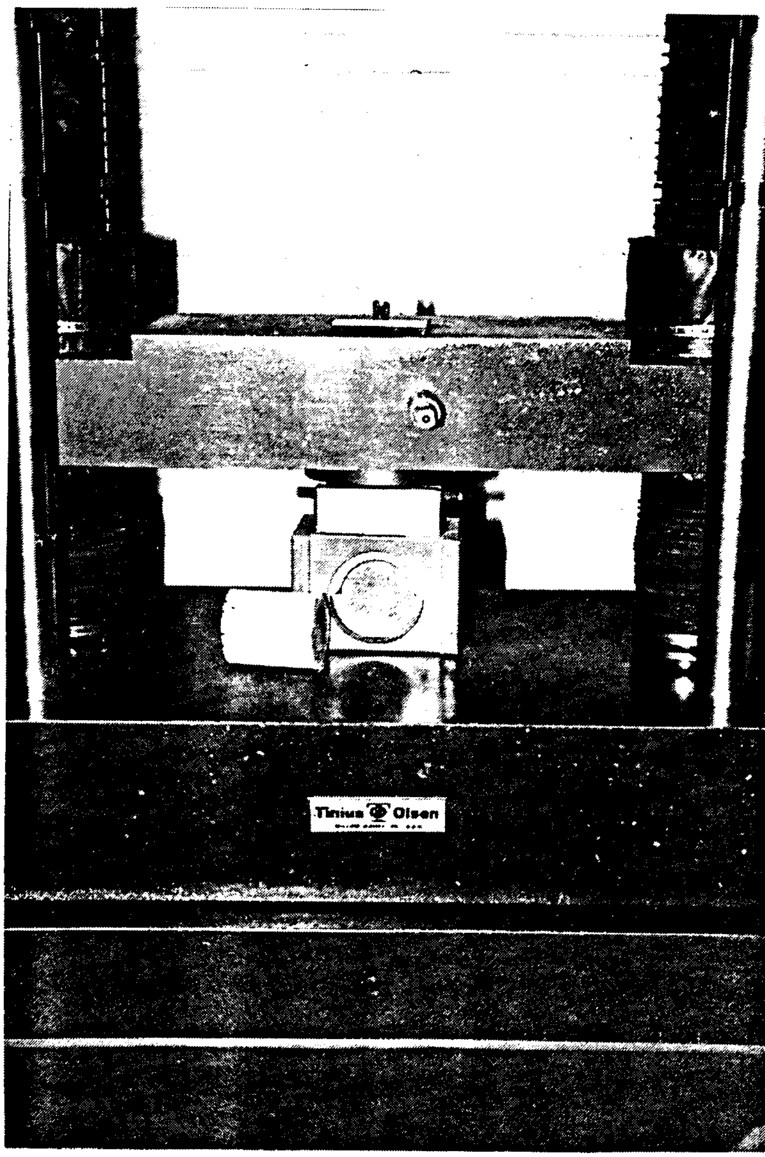


Figure 11. Picture of Guillotine (Direct Shear) Test

PROJECT COSTS

The cost of the BCO was divided into categories. Final costs of the project are not yet complete. Some additional pavement cleaning was required, and the price is still being negotiated between the district and the contractor. Cost to date per two-lane mile were: grading and seeding - $21,219; miscellaneous - $44,594; pavement - $360,208; and traffic control - $35,415. The total two-lane mile cost was $461,436. Final costs will be presented in the final report.

These numbers were compared with an AC overlay from another project. The cost per two-lane mile for the AC overlay was $160,784. The BCO is almost three times the cost of an AC overlay. The BCO is designed for 20 years. AC overlays in Illinois tend to last approximately 13 years. In terms of life-cycle cost, the BCO is only twice the cost of the AC overlay. Also, the BCO should require less maintenance than an AC overlay.

MAINTENANCE

The BCO has already required some maintenance. A longitudinal crack appeared shortly after the pavement was opened to traffic. It was located approximately 150 to 200 mm (6 to 8 inches) in from the edge of pavement along the gore of the eastbound weigh station entrance ramp. The gore area had been overlaid with asphalt concrete because there was a noticeable movement between the pavement and the gore. The cause of this crack has not been positively determined; however a couple of possible answers do exist.

When the pavement near the crack in this area was removed, it was apparent that the overlay had extended anywhere from 13 to 50 mm (0.50 to 2 inches) into the gore over the longitudinal joint. One theory is that frost heave lifted the edge of the pavement up. Interstate traffic riding along the edge then forced the edge of pavement downward abruptly, causing the crack to form. A second theory is that the pavement curled up on the edge slightly. Next, a vibratory roller riding along the edge to pinch the seam caused the pavement to move suddenly, forming the crack. The crack may have not been apparent at first, but through freezing and thawing, the crack spalled making it more visible.

The exact cause is not known. However, precautions were taken to prevent the same occurrence from happening on the westbound lanes. The paver was closely monitored and kept even with the longitudinal joint to prevent the overlay from extending across the joint.

The eastbound lane was patched using standard patching mix with steel fibers added at a rate of 60 kg/cu m (100 lbs./cu. yd.). Also, the joint around the patch was sawed and sealed with hot pour sealant. This same repair was used when another area along the gore cracked in a similar manner. The original patch was extended and both are handling traffic well. One other small area was patched in a similar manner near the exit of the eastbound weigh station. This area appears to be a location where the existing concrete failed, causing the overlay to crack.

Repairs were also made to the joint between the eastbound weigh station entrance ramp and the mainline interstate. The joint was not sawed initially since it is not standard practice in Illinois to saw construction joints. However, several spalls developed along this joint. The spalled areas were squared up, and filled with Rezi-weld 1000 multi-purpose construction epoxy. The repairs seem to be durable. To prevent similar spalls from occurring on the westbound weigh station entrance ramp, the joint was sawed as soon as possible. The epoxy was also used to fill a minor spall along a transverse crack that was deteriorating.

FUTURE MONITORING

The project will be monitored for a minimum 5-year period. During this time, annual distress surveys will be conducted for all the test sections. Also, climatic conditions will be recorded to assist in evaluating environmental effects on the overlay. With weigh stations located within the project limits, attempts will be made to collect weigh-in-motion data. Other tests that are not yet completed include thermal coefficient of both the overlay and the existing pavement, and chloride ion permeability testing.

SUMMARY

Illinois is building fewer new roads. The emphasis has shifted to rehabilitating existing pavements. AC overlays are the most common type of rehabilitation. However, this improves the structural capacity of the pavement only slightly. Illinois is experimenting with the use of the BCO as a means of rehabilitating PCC pavements. The BCO should provide a longer service life.

The BCO consists of the existing pavement with a layer of PCC placed directly on top. This overlay relies on a clean, rough PCC surface to achieve maximum bond strength between the existing pavement and the overlay. Once the overlay has been placed, the new slab thickness is adequate to support the current and future traffic loadings.

This experimental feature is the first of two studies of BCOs. Six test sections were constructed using different combinations of microsilica and grout. Three percentages of microsilica were added to the concrete mix design; 0, 3, and 5 percent. The necessity of using grout as a bonding agent was also studied.

Criteria used to select the project site included:

1. a thin pavement (175 to 200 mm (7 or 8 inches) thick),
2. a CRCP,
3. a bare concrete surface (no AC overlay),
4. minimal required surface preparation, and
5. a section not currently in the state 5-year program for rehabilitation.

A section on Interstate 80 near Moline, Illinois was chosen. Two design methods were used to determine overlay thickness; AASHTO and NCHRP 99. These methods generated thicknesses of 90 mm (3.5 inches) and 50 mm (2.0 inches), respectively. After consulting other states about their experiences with BCOs, a thickness of 100 mm (4.0 inches) was chosen for the project.

In December, 1993 and January, 1994, the BMPR conducted a laboratory experiment using microsilica and bonding agents. This study compared the compressive strength between mixes containing different percentages of microsilica and the bond strength between different types of grouts. Three mix designs and three types of bonding agents were compared. Results indicated no significant difference in either compressive strength or bond strength.

Some field testing was completed prior to overlaying the pavement. Distress surveys were conducted on all test sections to account for distresses that could affect the performance of the overlay. FWD testing was performed on the eastbound lanes. This would give a reference point as to the structural capacity of the pavement prior to the overlay. Finally, cores were taken out of each test section in the eastbound lanes to be used for chloride ion permeability testing. This would be compared with cores taken after the overlay was placed. Microsilica incorporated in the mix tends to lower the permeability of chloride.

Surface preparation for both directions of interstate required full-depth patching, partial-depth patching, bituminous material removal, shot blasting, and sand blasting. The project contained a total of 1.22 percent full-depth Class A patching. One partial-depth patch was placed in the eastbound lanes. This patch was 13.2 sq m (15.8 sq. yd.) in area. The westbound lanes contained eight partial-depth patches totaling 99.75 sq m (119.30 sq. yd.). Jackhammers were used to remove any bituminous material in spalls. Also, raised pavement reflectors were removed using this method. Shot blasters with a 400-mm (16-inch) wide blasting head were used to scarify the surface. This process removed any dirt, grease, oil, or other contaminant from the pavement surface. Fines of the pavement and the steel shot were vacuumed as the shot blaster traveled along the pavement. Vacuum seal was lost if the blasting head could not cover a spalled area. Therefore, shot blasters were as close to the spall or edge of pavement as possible. Then sand blasters were used to finish the work.

Paving of the BCO was very similar to that of a new pavement. The trucks arrived on the site, turned around, and backed down the road to the paving operation. Grout used in some of the test sections was applied using a hydraulic sprayer. This operation was directly in front of the paver and behind the trucks that were discharging concrete. The overlay was placed monolithically over both lanes in each direction. Entrance ramps of weigh stations located within the project limits were also paved with the BCO.

On the eastbound lanes, trucks dripped oil and grease that had to be cleaned before paving could continue. While paving the westbound lanes, the ready mix plant had tarps made for the trucks. These attached to the bottom of the truck, catching any contaminant to prevent additional cleanup. This seemed to increase the efficiency of the paving operation.

The centerline of the pavement was sawed with a lightweight saw. This was a separate experimental feature within the project. Sawing took place immediately after the concrete had set enough to carry the weight of the saw and the operator.

Because the project is an experimental feature, data was recorded throughout the paving process. Variables monitored included: concrete temperature, air temperature, wind speed, and relative humidity. These data were used to calculate the rate of evaporation. Other items that were monitored included: slump, air content, actual water-cementitious ratio, placement times, and thickness of the overlay.

Quality of the paving mixes was determined through compressive and split tensile strength tests. All of the samples met the minimum requirements on strength. The addition of microsilica to the mix tends to increase the strength of the concrete. However, the percentages did not make a significant difference in the strengths.

Distress surveys were conducted on test sections in both directions after the project was open to traffic. Both directions only contained transverse cracking. The eastbound lanes had a higher frequency of cracking. This may have been because those lanes went through one winter season compared to the westbound lanes. Crack spacing was recorded for the eastbound lanes only. The surveys showed that once microsilica was added to the mix, the frequency of cracking increased.

Before opening the lanes to traffic, each test section had a delamination test conducted on it. A reinforcing bar was used to sound for debonded areas. Some delaminated areas were detected. However, all of these areas were located along transverse cracks. These results showed increasing delaminations with increasing percentages of microsilica.

FWD testing was conducted on the eastbound lanes prior to opening the pavement to traffic. Results of area calculations showed a slight increase in the deflection basin area. Even though only a slight increase, theoretically this indicates that the structural capacity of the pavement was increased. These values were comparable to that of a new pavement. The pavement life has been extended to 20 years with the BCO. If no rehabilitation had been done, the pavement would not have lasted that long.

Two devices were used to measure roughness of the pavement; the California Profilograph and the South Dakota Profilometer. Prior to opening the pavement to traffic, the California Profilograph was used to measure the initial roughness of the pavement and give a profile index for that section. The average profile index for the project was 38.5 mm/km (2.44 inch/mile). After the pavement was opened to traffic, the South Dakota Profilometer was used to measure the roughness of the pavement. The IRI for the eastbound and westbound lanes were 1,073.2 mm/km (68 inch/mile) and

1,041.6 mm/km (66 inch/mile), respectively. These indices are among the smoothest 10 percent of pavements in Illinois.

BMPR tested the pavement friction of the project. Driving lanes in each direction were tested. The average friction numbers for the eastbound lanes were 55 for the treaded tire and 49 for the smooth tire. The westbound lanes recorded friction numbers of 55 for the treaded tire and 46 for the smooth tire. These friction numbers are typical of a new PCC pavement.

Beams were made, cured, and measured at several intervals to determine the drying shrinkage of each mix. The addition of microsilica in concrete showed more shrinkage cracking in the field. However, the shrinkage measured in the laboratory showed no significant difference between percentages of microsilica.

Bond strength testing was also conducted. Virginia Test Method - 92 was used to conduct direct tensile testing in the field. This was unsuccessful and abandoned. Cores of the remaining test sections were taken and tested in direct shear. These tests showed that all test sections contained adequate bond strength. This indicates that the use of grout as a bonding agent does not increase the bond strength of the overlay.

Some maintenance has been performed on the overlay. A section of the pavement adjacent to the gore area of the eastbound weigh station entrance ramp has been patched. The cause of the failure is unknown. To date, the patch is performing well. Other small areas of pavement that spalled along a joint and a transverse crack were filled with epoxy. These are also performing well. Measures were taken to improve the paving process to prevent the same problems from occurring in the westbound lanes.

The cost of the BCO was divided into categories. Costs to date per two-lane mile were: grading and seeding - $21,219; miscellaneous - $44,594; pavement - $360,208; and traffic control - $35,415. The total two-lane mile cost was $461,436. Comparing these numbers with an AC overlay, this is almost three times the cost of the AC overlay. In terms of life-cycle cost, the BCO is twice the cost of the AC overlay.

The project will be monitored for at least five years. Annual distress surveys will be conducted to monitor the affect of the existing distresses in the pavement through the overlay. Also, climatic conditions and weigh-in-motion data will be collected if possible. Other tests that will be conducted are thermal expansion coefficient of both the pavement and the overlay, and chloride ion permeability.

CONCLUSIONS

After monitoring construction of the BCO and reviewing the results of the initial performance testing, the following conclusions are made:

1. Surface preparation for the BCO is crucial to obtaining a good overlay.
2. Bond strength of the overlay did not vary significantly either with or without grout as a bonding agent.
3. Placing the grout was cumbersome and slowed down the paving process.
4. Addition of microsilica did not improve the strength of the mix greatly.

RECOMMENDATIONS

1. Tarps should be required if trucks or other equipment will be driving on the cleaned surface.
2. Eliminate the use of grout, since the bond strength was not increased significantly and to keep from slowing down the paving process.
3. The addition of microsilica to the mix could be eliminated if the permeability of chloride is not drastically affected.
4. Do not allow shot blasting fines to be piled along the side of the road.
5. Keep shot blasting/sand blasting near the paving operation.

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APPENDIX A

Mix Designs

0% Microsilica PCC Design Mix[a]

Material	Type	Producer Name	Theoretical Weight, kg (lbs)
Cement	Type I	Dixon-Marquette	195 (430)
Fly Ash	Type C	National Minerals (Portage #2)	61 (135)
Water			112 (247)
Sand	Natural	Moline Consumers (Cordova)	519 (1,145)
Stone	Crushed	Moline Consumers (Midway)	873 (1,925)
		Total Weight of Mix	1,761 (3,882)

Unit Weight of Mix = 2,303.5 kg/m^3 (143.8 lb/ft^3)
Water-Cementitious Ratio = 0.44

3% Microsilica PCC Design Mix[a, b]

Material	Type	Producer Name	Theoretical Weight, kg (lbs)
Cement	Type I	Dixon-Marquette	195 (430)
Fly Ash	Type C	National Minerals (Portage #2)	61 (135)
Microsilica	Slurry	W. R. Grace	8 (17)
Water			104 (230)
Sand	Natural	Moline Consumers (Cordova)	532.(1,172)
Stone	Crushed	Moline Consumers (Midway)	873 (1,925)
		Total Weight of Mix	1,773 (3,909)

Unit Weight of Mix = 2,319.5 kg/m^3 (144.8 lb/ft^3)
Water-Cementitious Ratio = 0.40

5% Microsilica PCC Design Mix[a, b]

Material	Type	Producer Name	Theoretical Weight, kg (lbs)
Cement	Type I	Dixon-Marquette	195 (430)
Fly Ash	Type C	National Minerals (Portage #2)	61 (135)
Microsilica	Slurry	W. R. Grace	14 (30)
Water			104 (230)
Sand	Natural	Moline Consumers (Cordova)	524 (1,156)
Stone	Crushed	Moline Consumers (Midway)	873 (1,925)
		Total Weight of Mix	1,772 (3,906)

Unit Weight of Mix = 2,317.9 kg/m^3 (144.7 lb/ft^3)
Water-Cementitious Ratio = 0.39

[a] All mix designs used water reducing admixture and 6.5% air. Coarse aggregate had a top size of 3/4 inch. All aggregates were assumed to be saturated surface dry.
[b] Mix designs with microsilica also incorporated super plasticizer contained in the slurry.

APPENDIX B

Special Provision

State of Illinois
Department of Transportation

SPECIAL PROVISION
FOR
BONDED PORTLAND CEMENT CONCRETE OVERLAY

Effective: July 1, 1994

Description. This work shall consist of constructing a bonded portland cement concrete overlay over an existing portland cement concrete pavement in accordance with applicable Articles in Section 420 of the Standard Specifications and the following.

Materials. Materials shall meet the requirements of the following Articles of Section 700 of the Standard Specifications:

	Item	Article/Section
a)	Portland Cement Concrete	720 1/
b)	Poured Joint Sealer	750
c)	Preformed Expansion Joint	751
d)	Protective Coat	723.01
e)	Preformed Elastomeric Compression Joint Seals for Concrete	753.01
f)	Grout	2/
g)	Microsilica	3/

Note 1/ The use of high early strength cement will not be allowed. The portland cement concrete shall contain 3 percent and 5 percent microsilica solids by mass of portland cement where shown on the plans. The coarse aggregate shall be the same type of aggregate used in the existing pavement.

Note 2/ The grout for bonding new concrete to old concrete shall be proportioned by mass (weight) and mixed at the jobsite, or it may be ready-mixed. The grout shall have a creamy consistency, allowing it to be scrubbed onto the prepared surface with a stiff brush or broom leaving a thin, uniform coating that will not run or puddle in low spots. The cement-to-water contact time shall not exceed 90 minutes before placement. The grout shall be agitated prior and during its use.

The grout shall consist of equal parts by mass (weight) of portland cement and sand, 15 percent microsilica solids by mass (weight) of cement, and sufficient water to form a creamy slurry. An equivalent approved grout of portland cement, 15 percent microsilica solids by mass (weight) of cement, and water, applied by pressure spray, may be substituted with the approval of the Engineer.

Note 3/ Microsilica shall meet the following requirements:

The microsilica admixture shall be supplied either in a dry, densified form or as a water-based slurry. The Contractor shall submit a notarized manufacturer's certification that the microsilica admixture meets the following requirements. The certification shall include the solids content if the microsilica is furnished as a slurry.

Silica Dioxide (SiO_2), min %	85
Sulfur Trioxide (SO_3), max %	3
Loss on ignition, max %	7
Other ingredients, max %	7
Pozzolanic Activity Index with Portland cement at 7 days min % of control	85

The sum of sulfur trioxide, loss on ignition and other ingredients shall not exceed 15%. The percentage of other ingredients includes high-range water reducers, whether included in the admixture or added separately.

In addition to the above requirements, the supplier of the microsilica admixture shall submit test data from an independent testing laboratory showing that the admixture will reduce the chloride permeability to the very low range (less than 1000 coulombs). The microsilica concrete shall be tested at an age of 28 days using AASHTO T 277 methods.

Equipment. The equipment shall meet the applicable portions of Article 420.03 of the Standard Specifications and the following:

Item	Article/Section
a) Sawing Equipment	1/
b) Shot Blasting Equipment	2/
c) Pavement Milling Equipment	3/
d) Sand Blasting Equipment	4/
e) Light Weight Concrete Saw	5/
f) Air Compressor	6/

Note 1/ Sawing equipment shall be capable of sawing concrete to the specified depth.

Note 2/ Shot blasting equipment shall be power operated and capable of removing all foreign materials and leaving a clean, rough texture surface.

Note 3/ Pavement milling equipment shall meet the requirements of Article 440.03 of the Standard Specifications. In locations of partial depth patching at longitudinal cracks, a 900 mm (3 feet) cold milling width shall be required.

Note 4/ Sand blasting equipment shall be wet sand blasting, shrouded dry sand blasting, or dry sand blasting with dust collectors. Sand blasting equipment shall be capable of removing rust, oil, and concrete laitance from the existing surface of the pavement. Oil traps shall be required.

Note 5/ The concrete sawing equipment shall not exceed a maximum mass (weight) of 13 kg (300 lbs). The concrete saw shall use a diamond blade which rotates in an up-cutting motion and maintains a speed of 2500 RPM. An anti-ravel skid plate shall be used in conjunction with the blade. The plate shall float along the surface to allow cutting of the joint without causing raveling and/or spalling. The concrete saw shall be capable of dry cutting the surface of the pavement to the line and profile shown on the plans.

Note 6/ Compressed air equipment shall have oil traps or filters that prevent oil from being sprayed on the pavement.

CONSTRUCTION REQUIREMENTS

Partial Depth Patches. Areas of random longitudinal cracking shall be cold milled to a depth of 60 mm (2.5 inches) or as indicated by the Engineer, and a width of 900 mm (3 feet). Areas of high steel shall be identified by the Engineer and cold milled to a depth of 50 mm (2 inches), or as directed by the Engineer. The Contractor shall take care not to damage reinforcement bars which are to remain in place. Any significant damage to reinforcement bars shall be corrected at the Contractor's expense.

Surface Preparation. All bituminous material shall be removed prior to surface preparation. The entire pavement surface to be overlaid shall be cold milled to a depth of 6.5 mm (0.25 inch) or shot blasted. All foreign materials, any laitance or loose material, and all pavement marking shall be removed by this process. If cold milling is used for primary surface preparation, a power-operated, mechanical scarifier shall be capable of uniformly scarifying or removing the surface concrete to the depth specified in a satisfactory manner. Other types of removal devices may be used if their operation is suitable and if they can be demonstrated to the satisfaction of the Engineer. The entire surface to be overlaid shall be cleaned after cold milling by sandblasting. All residue shall be removed from the pavement surface.

Partial Depth Patch Reinforcement. In areas of random longitudinal cracking, #15 (#5) epoxy coated tie bars 750 mm (30 inches) in length shall be placed at right angles to the crack on 750 mm (30 inch) centers. The tie bars shall be placed and fastened securely to the pavement with metal bands and power driven nails or other methods approved by the Engineer.

Cleaning and Grouting. The Contractor shall have available an approved mechanical device to remove any tire scuffs, fuel or oil spills or any other contaminant. Immediately prior to paving operations, the entire surface shall be cleaned with compressed air. The pavement surface shall be thoroughly cleaned to a roughened appearance, free from oil, grease, bituminous material, dust, debris and other foreign matter. Particular attention shall be directed to the removal of concrete fines. No vehicles or equipment will be permitted on the existing concrete after cleaning operations except those vehicles necessary for actual paving operations.

The surface shall not be pre-wetted; however, if the surface is damp from rainfall or contractor operations, paving will be allowed if there is no standing water present. After the surface has been cleaned and immediately before placing the concrete, a thin coating of bonding grout shall be scrubbed into or sprayed onto the prepared surface at locations shown in the plans. All specified parts shall receive a thorough and even coating. Excess grout will not be permitted to collect in pools. Grout placement shall be limited so the grout does not become dry before it is covered with the new concrete overlay. The grouted surface shall remain in a tacky and moist condition before the concrete is placed. In areas where the grout becomes dry and chalky, the grout shall be removed and the affected area cleaned by methods approved by the Engineer. New grout shall then be reapplied. The removal of dry grout and the reapplication of new grout shall be at the expense of the Contractor.

Placement and Finishing. The concrete shall be placed the full width and full depth in one operation, including the depressed areas at partial depth patches. Vehicles used for transporting concrete, which are free from contaminants, especially vehicle tires, will be permitted to drive on the pavement being overlaid to deposit concrete directly in front of the concrete pavement being overlaid to deposit concrete directly in front of the concrete paver. Care shall be taken to keep vehicles from tracking concrete that was previously deposited in front of the paver. Vehicles developing oil, grease or other leaks shall be equipped with pans, canvases or other devices to preclude these contaminants from being deposited on the cleaned concrete surface. If the Engineer determines the Contractor is not complying with these specifications, the Contractor shall discontinue paving operations until it can be demonstrated that the vehicles are free of contaminants or the Contractor has and will use alternative hauling methods.

As an alternative, the Contractor will be permitted to use the shoulders as a haul road. A belt placer shall be used to transport the concrete form the trucks to the paver. It will be the Contractor's responsibility to repair the shoulders at no additional cost as deemed necessary by the Engineer.

Curing. The surface shall be protected and cured in accordance with Sections 720 and 722 of the Standard Specifications, except that only Type III curing compound will be permitted and the application rate shall be 0.25 L/m^2 (1.5 gallons per 250 square feet). Curing shall follow the sawing operation. If the air temperature is 85° F or greater, or winds are in excess of 15 mph, a quick drying curing compound shall be applied immediately. All curing compound shall be dry before sawing can commence. The overlay shall be allowed to cure for seven days. If any inclement weather occurs, additional days shall be added to the seven day minimum curing and drying period, as determined by the Engineer. Traffic will not be allowed on the overlay until the end of the curing period.

Transverse Contraction Joints. All transverse contraction joints shall be sawed through the overlay to the existing pavement.

Transverse Hinge Joints and Longitudinal Joints. Sawing of the joint shall commence as soon as the concrete will support the weight of the saw and operator without disturbing the final finish, approximately 0-2 hours after final finishing. After the joint is sawed, the saw cut and adjacent concrete surface shall be cleaned with a vacuum or air jet.

Method of Measurement and Basis of Payment.

(a) Surface Removal

(1) The removal and disposal of bituminous concrete surface course will be measured and paid for at the contract unit price per square meter (square yard) for BITUMINOUS PAVEMENT SURFACE REMOVAL (VARIABLE DEPTH).

(2) The surface preparation, either 6.5 mm (0.25 inch) scarification or shot blasting, will be measured in square yards and paid for at the contract unit price per square meters (square yards) for CONCRETE PAVEMENT SCARIFICATION.

(3) The removal of the concrete for partial depth patches will be measured and paid for at the contract unit price per square meter (square yard) for PORTLAND CEMENT CONCRETE PAVEMENT SURFACE REMOVAL which shall include furnishing and installing the #15 (#5) epoxy-coated tie bars.

(b) Concrete Overlay

The concrete overlay shall be measured and paid for at the contract unit price per square meter (square yard) for BONDED PORTLAND CEMENT CONCRETE OVERLAY of the thickness specified, which price shall include the cost of all material, labor and equipment necessary to clean and prepare the existing pavement for the concrete overlay and all labor and equipment necessary to place to the thickness shown on the plans, finish, tine, and cure the concrete overlay.

The concrete required to fill depressions and partial depth repair areas below the bottom of the quantity overlay shown on the plans will be measured in cubic meters (cubic yards) and will be determined by subtracting 105 percent of the theoretical cubic meters (cubic yards) placed on the pavement. The theoretical cubic meters (cubic yards) of concrete overlay will be determined using the square meters (square yards) placed and the thickness shown on the plans. The actual cubic meters (cubic yards) on concrete placed on the pavement is determined as follows:

The actual cubic meters (cubic yards) of concrete placed on the pavement shall be the cubic meters (cubic yards) shown on the truck tickets. The volume of unused concrete remaining in the last truck will be estimated to the nearest cubic meters (cubic yards) in the truck by the Engineer and will not be measured for payment.

The additional concrete will be paid for at the Contractor's actual cost per cubic meter (cubic yard) plus 15 percent. Article 109.04 of the Standard Specifications will not apply.

APPENDIX C

Water-Cementitious Ratios

Water-Cementitious Ratios

Date	Mix Design	Load Number	Water-Cementitious Ratio
10-10-94	5% MS	1	0.402
		5	0.408
		10	0.429
		15	0.428
		17	0.429
		25	0.430
		31	0.430
		38	0.430
		45	0.415
		54	0.417
		56	0.417
10-11-94	5% MS	1	0.411
		3	0.400
		9	0.402
		22	0.398
		30	0.400
		36	0.405
		44	0.402
		55	0.397
		65	0.402
		81	0.389
		90	0.388
		100	0.392
		112	0.391
		125	0.395
10-12-94	3% MS	1	0.403
		6	0.401
		18	0.395
		26	0.406
		38	0.402
		48	0.394
		59	0.408
		67	0.390
		74	0.390
10-12-94	5% MS	1	0.413
		9	0.413
10-13-94	3% MS	1	0.378
		8	0.380
		13	0.395
10-13-94	5% MS	1	0.391
		7	0.382
		16	0.393
		31	0.399

Water-Cementitious Ratios (Continued)

Date	Mix Design	Load Number	Water-Cementitious Ratio
10-13-94		50 56	0.394 0.383
10-21-94	5% MS	1 4 7 15 24	0.402 0.413 0.412 0.409 0.400
11-1-94	5% MS	1 4 8 12	0.395 0.404 0.404 0.379
04-21-95	5% MS	1 6 15 21 28 35 45 54	0.402 0.417 0.418 0.412 0.396 0.404 0.399 0.405
04-21-95	3% MS	1 -- -- -- --	0.389 0.392 0.398 0.380 0.382
04-24-95	3% MS	1 9 28 33 50 64	0.396 0.401 0.403 0.414 0.382 0.380
04-24-95	5% MS	71 79 95	0.398 0.399 0.412
04-25-95	5% MS	1	0.380
04-28-95	5%MS	1 9 51	0.388 0.374 0.372
04-28-95	0% MS	-- 88	0.347 0.340

APPENDIX D

Placement Times

Placement Times

Date	Time	Station	Yards Placed
10-07-94	10:37 AM	177+75	--
	1:50 PM	175+00	127.0
	4:25 PM	166+00	321.0
	5:45 PM	162+65	98.0
		Total for the day	546.0
10-10-94	8:25 AM	162+65	--
	10:50 AM	159+00	130.0
	1:10 PM	155+30	130.0
	2:34 PM	153+00	78.0
	4:16 PM	149+00	136.5
	6:00 PM	144+51	149.5
		Total for the day	624.0
10-11-94	8:17 AM	144+51	--
	9:25 AM	142+15	97.5
	2:45 PM	130+00	442.0
	5:52 PM	122+31	273.0
		Total for the day	812.5
10-12-94	8:08 AM	122+31	--
	9:10 AM	120+70	71.5
	10:53 AM	117+50	188.5
	3:17 PM	109+00	318.5
	4:12 PM	107+00	71.5
	5:50 PM	102+43	156.0
		Total for the day	806.0
10-13-94	8:17 AM	102+43	--
	9:32 AM	100+30	84.5
	11:32 AM	97+00	123.5
	1:22 PM	93+00	130.0
	3:31 PM	89+25	136.5
		Total for the day	474.5
04-21-95	7:30 AM	88+75	--
	9:35 AM	92+50	149.5
	12:15 PM	99+50	247.0
	3:30 PM	107+10	260.0
		Total for the day	656.5
04-24-95	7:00 AM	107+10	--
	8:40 AM	112+00	169.0
	11:35 AM	120+00	273.0
	2:30 PM	127+00	240.5
		Total for the day	682.5

Placement Times (Continued)

Date	Time	Station	Yards Placed
04-25-95	8:00 AM	127+00	--
	9:45 AM	129+00	91.0
	11:40 AM	135+00	188.5
	1:25 PM	140+00	175.5
	2:10 PM	142+21	65.0
		Total for the day	520.0
04-28-95	7:45 AM	142+21	--
	8:10 PM	177+75	1287.0
		Total for the day	1287.0

APPENDIX E

Compressive Strength Test Results

Compressive Strength Tests on Eastbound Lanes

Cylinder Number	Mix Design	Date Prepared	Date Tested	Strength, kPa (psi)
1	0% MS	10-07-94	10-14-94	25,545 (3,705)
2	|	|	|	29,820 (4,325)
3	|	|	↓	25,180 (3,652)
4	|	|	11-04-94	43,016 (6,239)
5	|	|	|	42,775 (6,204)
6	|	↓	↓	44,671 (6,479)
7	|	10-10-94	10-17-94	28,358 (4,113)
8	|	|	↓	27,744 (4,024)
9	|	|	11-07-94	30,068 (4,361)
10	↓	↓	↓	30,799 (4,467)
11	5% MS	10-10-94	10-17-94	37,887 (5,495)
12	|	|	↓	38,376 (5,566)
13	|	|	11-07-94	39,714 (5,760)
14	|	↓	↓	48,001 (6,962)
15	|	10-11-94	10-18-94	25,669 (3,723)
16	|	|	|	24,807 (3,598)
17	|	|	↓	32,626 (4,732)
18	|	|	11-09-94	41,306 (5,991)
19	|	|	|	45,574 (6,610)
20	↓	↓	↓	45,822 (6,646)
21	3% MS	10-12-94	10-19-94	28,358 (4,113)
22	|	|	|	27,869 (4,042)
23	|	|	↓	30,799 (4,467)
24	|	|	11-09-94	40,445 (5,866)
25	|	|	|	44,602 (6,469)
26	|	↓	↓	47,277 (6,857)
27	|	10-13-94	10-20-94	38,866 (5,637)
28	|	|	↓	37,025 (5,370)
29	|	|	11-10-94	50,056 (7,260)
30	↓	↓	↓	55,124 (7,995)
31	5% MS	10-13-94	10-20-94	39,955 (5,795)
32	|	|	|	40,693 (5,902)
33	|	|	↓	35,804 (5,193)
34	|	|	11-10-94	45,457 (6,593)
35	|	|	|	43,258 (6,274)
36	|	↓	↓	43,258 (6,274)
37	|	10-21-94	10-28-94	27,131 (3,935)
38	|	|	↓	26,890 (3,900)
39	|	|	11-18-94	35,804 (5,193)
40	|	↓	↓	37,887 (5,495)

Compressive Strength Tests on Eastbound Lanes (Continued)

Cylinder Number	Mix Design	Date Prepared	Date Tested	Strength, kPa (psi)
41	|	11-01-94	11-09-94	39,838 (5,778)
42	|	|	↓	31,406 (4,555)
43	|	|	11-29-94	39,838 (5,778)
44	↓	↓	↓	39,107 (5,672)

Compressive Strength Tests on Westbound Lanes

Cylinder Number	Mix Design	Date Prepared	Date Tested	Strength, kPa (psi)
201	5% MS	04-21-95	04-28-95	29,578 (4,290)
202	|	|	↓	28,110 (4,077)
204	|	|	05-19-95	43,016 (6,239)
205	↓	↓	↓	51,986 (7,540)
209	3% MS	04-21-95	04-28-95	30,558 (4,432)
210	|	|	↓	30,799 (4,467)
207	|	|	05-19-95	49,091 (7,120)
208	|	|	|	51,021 (7,400)
211	|	|	|	46,560 (6,753)
212	|	↓	↓	48,125 (6,980)
215	|	04-24-95	05-01-95	28,841 (4,183)
216	|	|	↓	28,599 (4,148)
213	|	|	05-22-95	35,198 (5,105)
214	↓	↓	↓	35,687 (5,176)
219	5% MS	04-24-95	05-01-95	31,778 (4,609)
220	|	|	↓	33,240 (4,821)
217	|	|	05-22-95	35,439 (5,140)
218	|	↓	↓	37,066 (5,376)
223	|	04-25-95	05-02-95	28,110 (4,077)
224	|	|	↓	28,599 (4,148)
221	|	|	05-23-95	37,314 (5,412)
222	|	↓	↓	31,288 (4,538)
225	|	04-28-95	05-05-95	34,591 (5,017)
226	|	|	↓	35,928 (5,211)
227	|	|	05-26-95	35,928 (5,211)
228	↓	↓	↓	43,016 (6,239)
229	0% MS	04-28-95	05-05-95	39,721 (5,761)
230	|	|	|	38,376 (5,566)
231	|	|	↓	38,990 (5,655)
232	|	|	05-26-95	42,775 (6,204)
233	|	|	|	40,817 (5,920)
234	|	↓	↓	41,665 (6,043)
235	|	05-11-95	05-18-95	28,599 (4,148)
236	|	|	↓	34,708 (5,034)
237	|	|	06-12-95	38,128 (5,530)
238	|	↓	↓	41,796 (6,062)
239	|	05-20-95	05-27-95	25,180 (3,652)
240	|	|	↓	23,711 (3,439)
241	|	|	06-17-95	41,182 (5,973)
242	|	↓	↓	40,700 (5,903)
245	|	05-26-95	06-23-95	38,500 (5,584)
246	↓	↓	↓	41,920 (6,080)

APPENDIX F

Split Tensile Strength Test Results

Split Tensile Strength Tests on Eastbound Lanes

Cylinder Number	Mix Design	Date Prepared	Date Tested	Strength, kPa (psi)
101	0% MS	10-07-94	10-14-94	3,571 (518)
102	│	│	│	3,372 (489)
103	│	│	↓	3,571 (518)
104	│	│	11-04-94	5,088 (738)
105	│	│	│	4,599 (667)
106	│	↓	↓	4,737 (687)
109	│	10-10-94	10-17-94	3,647 (529)
110	│	│	↓	3,502 (508)
111	│	│	11-07-94	4,399 (638)
112	↓	↓	↓	4,399 (638)
113	5% MS	10-10-94	10-17-94	4,261 (618)
114	│	│	↓	4,468 (648)
115	│	│	11-07-94	5,088 (738)
116	│	↓	↓	4,944 (717)
117	│	10-11-94	10-18-94	3,916 (568)
118	│	│	│	4,330 (628)
119	│	│	↓	4,192 (608)
120	│	│	11-09-94	4,399 (638)
121	│	│	│	5,364 (778)
122	↓	↓	↓	4,468 (648)
125	3% MS	10-12-94	10-19-94	3,709 (538)
126	│	│	│	4,330 (628)
127	│	│	↓	4,944 (717)
128	│	│	11-09-94	4,737 (687)
129	│	│	│	3,440 (499)
130	│	↓	↓	5,364 (778)
133	│	10-13-94	10-20-94	3,985 (578)
134	│	│	↓	4,399 (638)
135	│	│	11-10-94	4,399 (638)
136	↓	↓	↓	4,737 (687)
137	5% MS	10-13-94	10-20-94	4,261 (618)
138	│	│	│	4,537 (658)
139	│	│	↓	4,330 (628)
140	│	│	11-10-94	4,812 (698)
141	│	│	│	4,537 (658)
142	│	↓	↓	5,019 (728)
143	│	10-21-94	10-28-94	3,778 (548)
144	│	│	↓	3,778 (548)

Split Tensile Strength Tests on Eastbound Lanes (Continued)

Cylinder Number	Mix Design	Date Prepared	Date Tested	Strength, kPa (psi)
145	I	10-21-94	11-18-94	4,192 (608)
146	I	↓	↓	4,054 (588)
147	I	11-01-94	11-09-94	3,916 (568)
148	I	|	↓	3,778 (548)
149	I	|	11-29-94	5,419 (786)
150	↓	↓	↓	4,330 (628)

Split Tensile Strength Tests on Westbound Lanes

Cylinder Number	Mix Design	Date Prepared	Date Tested	Strength, kPa (psi)
301	5% MS	04-21-95	04-28-95	3,985 (578)
302	|	|	↓	3,709 (538)
304	|	|	05-19-95	4,812 (698)
305	|	|	|	4,944 (717)
306	↓	↓	↓	5,433 (788)
309	3% MS	04-21-95	04-28-95	4,123 (598)
310	|	|	↓	7,694 (1,116)
312	|	|	05-19-95	5,633 (817)
313	|	|	|	4,674 (678)
314	|	↓	↓	5,909 (857)
318	|	04-24-95	05-01-95	4,261 (618)
319	|	|	↓	3,916 (568)
317	|	|	05-22-95	5,088 (738)
320	↓	↓	↓	5,157 (748)
323	5% MS	04-24-95	05-01-95	4,192 (608)
324	|	|	↓	4,192 (608)
321	|	|	05-22-95	5,564 (807)
322	|	↓	↓	5,495 (797)
327	|	04-25-95	05-02-95	4,192 (608)
328	|	|	↓	3,571 (518)
325	|	|	05-23-95	4,812 (698)
326	|	↓	↓	4,944 (717)
329	|	04-28-95	05-05-95	3,985 (578)
330	|	|	↓	4,537 (658)
331	|	|	05-26-95	5,364 (778)
332	↓	↓	↓	4,537 (658)
333	0% MS	04-28-95	05-05-95	4,054 (588)
334	|	|	|	4,881 (708)
335	|	|	↓	4,881 (708)
336	|	|	05-26-95	3,440 (499)
337	|	|	|	4,674 (678)
338	|	↓	↓	4,261 (618)
341	|	05-11-95	05-18-95	4,468 (648)
342	|	|	↓	4,261 (618)
343	|	|	06-13-95	4,537 (658)
344	|	↓	↓	4,674 (678)
345	|	05-20-95	05-27-95	3,372 (489)
346	|	|	↓	3,372 (489)

Split Tensile Strength Tests on Westbound Lanes (Continued)

Cylinder Number	Mix Design	Date Prepared	Date Tested	Strength, kPa (psi)
347	|	|	06-17-95	4,944 (717)
348	|	↓	↓	4,537 (658)
351	|	05-26-95	06-23-95	4,537 (658)
352	↓	↓	↓	4,812 (698)

APPENDIX G

Bond Strength Test Results

Bond Strength Test Results

Mix Design	Station	Direction	Location	Load kg (lbs)	Diameter mm (in)	Bond kPa (psi)
0% MS w/ No Grout	169+35*	WB	OWP	268 (590)	50.8 (2.00)	1,295.5 (187.90)
	169+25*	WB	COL	313 (690)	50.8 (2.00)	1,515.0 (219.74)
	169+15*	WB	IWP	286 (630)	50.8 (2.00)	1,383.4 (200.64)
0% MS w/ Grout	158+44*	WB	IWP	340 (750)	50.8 (2.00)	1,646.8 (238.85)
	158+38*	WB	COL	336 (740)	50.8 (2.00)	1,624.9 (235.67)
	158+25*	WB	OWP	268 (590)	50.8 (2.00)	1,295.5 (187.90)
5% MS w/ No Grout	137+60*	WB	OWP	249 (550)	50.8 (2.00)	1,207.7 (175.16)
	137+45*	WB	COL	213 (470)	50.8 (2.00)	1,032.0 (149.68)
	137+35*	WB	IWP	95 (210)	50.8 (2.00)	461.12 (66.88)
3% MS w/ Grout	115+70*	WB	IWP	204 (450)	50.8 (2.00)	988.1 (143.31)
	115+60*	WB	COL	272 (600)	50.8 (2.00)	1,3317.4 (191.08)
	115+50*	WB	OWP	277 (610)	50.8 (2.00)	1,339.4 (194.27)
3% MS w/ No Grout	103+70	WB	IWP	7,031 (15,500)	100.3 (3.95)	8,724.0 (1,265.31)
	103+60	WB	COL	2,939 (6,480)	100.1 (3.94)	3,665.1 (531.58)
	103+50	WB	OWP	5,851 (12,900)	101.6 (4.00)	7,075.7 (1,026.25)
5% MS w/ Grout	95+25	WB	IWP	2,980 (6,570)	95.8 (3.77)	4,059.0 (588.71)
	95+40	WB	COL	4,763 (10,500)	95.8 (3.77)	6,487.0 (940.86)
	95+05	WB	OWP	2,835 (6,250)	95.5 (3.76)	3,882.2 (563.06)

* -- Indicates a tests that was taken in the field using the direct tensile test. However, the sample did not separate at the bond interface, but at the epoxy/concrete interface at the top of the sample; therefore, this is not a true measure of the bond strength. Other samples were cores tested at Bureau of Materials and Physical Research.

MS -- Microsilica
WB -- Westbound driving lane
EB -- Eastbound driving lane
OWP -- Outer wheelpath
COL -- Center of lane
IWP -- Inner wheelpath

Bond Strength Test Results (Continued)

Mix Design	Station	Direction	Location	Load kg (lbs)	Diameter mm (in)	Bond kPa (psi)
5% MS w/ Grout	93+05	EB	OWP	6,359 (14,020)	101.6 (4.00)	7,690.1 (1,115.35)
	93+15**	EB	COL	1,542 (3,400)	105.4 (4.15)	1,732.6 (251.29)
	93+29**	EB	IWP	2,685 (5,920)	105.4 (4.15)	3,016.8 (437.55)
3% MS w/ No Grout	107+03**	EB	OWP	2,644 (5,830)	105.4 (4.15)	2,970.9 (430.89)
	107+12**	EB	COL	2,209 (4,870)	105.7 (4.16)	2,470.7 (358.35)
	107+29	EB	IWP	2,594 (5,720)	95.0 (3.74)	3,591.8 (520.95)
3% MS w/ Grout	113+09	EB	OWP	4,332 (9,550)	95.5 (3.76)	5,932.0 (860.36)
	113+24	EB	COL	4,468 (9,850)	95.5 (3.76)	6,118.3 (887.39)
	113+42	EB	IWP	4,123 (9,090)	95.2 (3.75)	5,676.9 (823.37)
5% MS w/ No Grout	137+27	EB	OWP	2,703 (5,960)	95.2 (3.75)	3,722.2 (539.86)
	137+39	EB	COL	3,089 (6,810)	95.2 (3.75)	4,253.0 (616.85)
	137+53	EB	IWP	3,093 (6,820)	95.2 (3.75)	4,259.2 (617.75)
0% MS w/ Grout	158+33	EB	OWP	4,046 (8,920)	95.5 (3.76)	5,540.6 (803.60)
	158+45	EB	COL	3,520 (7,760)	95.5 (3.76)	4,820.1 (699.10)
	158+59	EB	IWP	3,411 (7,520)	95.5 (3.76)	4,671.1 (677.48)
0% MS w/ No Grout	169+32	EB	OWP	3,996 (8,810)	95.5 (3.76)	5,472.3 (793.69)
	169+48	EB	COL	5,674 (12,510)	95.8 (3.77)	7,728.8 (1,120.97)
	169+67	EB	IWP	3,234 (7,130)	95.2 (3.75)	4,452.8 (645.83)

** -- Indicates a sample that was oversized for the direct shear testing apparatus. The sample did not necessarily break at the bond interface; therefore, this may not be a true measure of the bond strength of that sample.

MS -- Microsilica
WB -- Westbound driving lane
EB -- Eastbound driving lane

OWP -- Outer wheelpath
COL -- Center of lane
IWP -- Inner wheelpath