OPEN-GRADED DRAINAGE LAYERS: PERFORMANCE PROBLEMS UNDER CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS IN ILLINOIS

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ABSTRACT

Illinois has constructed fourteen pavement sections that contain open-graded drainage layers (OGDLs) in the past few years. The pavement types include continuously reinforced concrete pavements (CRCPs), jointed concrete pavements, and full-depth asphalt concrete pavements. Three of the CRCPs have begun to show a higher level of distress than would be expected from pavements of that cross section and age. An in-depth investigation into the cause of the distress has begun. The investigation to date has included: visual distress surveys; core analysis; analysis of Shelby tube samples; analysis of OGDL gradations, separation layer gradations; and subgrade gradations; deflection tests; and inspection of slabs removed in patching operations. The state placed a moratorium on the construction of new OGDLs pending the outcome of the investigation.

The distresses evident on these pavements may be related to the characteristics of the OGDL, separation layer, and subgrade. The bonding of the CRCP to the OGDL, as well as crack spacing, may have contributed to the poor performance of these pavements.

The current maintenance plan includes patching and undersealing of problem areas. Until the investigation is concluded, ODGLs should not be constructed under CRCPs.

INTRODUCTION

Fourteen pavements that contain open-graded drainage layers (OGDLs) have been constructed in Illinois. The pavements include continuously reinforced concrete pavements (CRCPs), jointed concrete pavements, and full-depth asphalt concrete pavements. Nine of these are short experimental sections, while five of them are over 6.4 km (4 mi) in length.

In 1995, several punchouts and deteriorated transverse cracks were noticed on three of the longer pavements, all of which are CRCP. Because the CRCP sections were only two and three years old at the time, concern was raised about the design of CRCPs with OGDLs and the implications of these problems from a maintenance standpoint. Although the shorter sections were not showing distress, in January 1996 the Illinois Department of Transportation placed a moratorium on the construction of OGDLs.

Two of the pavements with distress are located on I-39 in Woodford County, adjacent to each other, and were constructed in 1992. One of the pavements has 255 mm (10 in.) CRCP, 100 mm (4 in.) cement-treated OGDL, and 75 mm (3 in.) dense-graded aggregate base used as a separation layer on 305 mm (12-in.) lime-modified subgrade. The second pavement has the same cross section as the first pavement, except that a separation layer was not included. By the summer of 1996, I-39 had accumulated 3.6 million Equivalent Single Axle Loads (ESALs).

The third pavement with distress is located on I-80 in Grundy County and was constructed in 1993. The cross section consists of 290 mm (11.5 in.) CRCP and 100 mm (4 in.) cement-treated OGDL on 305 mm (12 in.)

lime-modified subgrade. By the summer of 1996, I-80 had accumulated 6.5 million ESALs, or almost twice the number as I-39. Figure 1 shows the location and Figure 2 shows the cross section of the three distressed pavements.

The aggregate used for the OGDL was a standard IDOT CA-11 gradation that was primarily between 25 mm and 9.5 mm (1 in. and 3/8 in.) in size. The CA-11 on I-80 was recycled concrete from the original pavement constructed in 1960. The dense-graded aggregate base used was a CA-06 gradation. This is a well-graded material, with 100 percent passing the 25 mm (1 in.) sieve and up to 12 percent passing the 75Tm (No. 200) sieve.

An investigation was initiated to identify the cause of the problems. The investigation included: visual distress surveys; core analysis; analysis of Shelby tube samples; analysis of the OGDL gradations, separation layer gradations, and subgrade gradations; deflection tests; and inspection of slabs removed in patching operations. The following section details the investigation to date.

INVESTIGATION

Visual Distress Surveys

The PaveTech Video Inspection Van was used in the fall of 1995 to videotape the three pavements. The tapes were viewed in November 1995, and all distresses were recorded. Table 1 includes a summary of the distress types and severities present on the pavements at that time. Pavements of this age should not be showing any distress, and definitely not the amount shown on I-80 eastbound.

As seen in Table 1, the I-39 pavement with a separation layer was showing some transverse cracking and patching by November 1995. Since then, a punchout has occurred and been patched. The I-39 pavement without a separation layer had several transverse cracks that were low, moderate, and even high in severity. Patches had been placed on this pavement as well.

Punchouts are areas enclosed by closely spaced transverse cracks, a short longitudinal crack, and the edge of pavement or a longitudinal joint. In Illinois, transverse cracks on CRCP are not identified until they begin to deteriorate. Low severity transverse cracks are spalled no more than 10 percent along the crack length. Moderate severity transverse cracks are spalled along more than 10 percent and less than 50 percent of the crack length. High severity transverse cracks are spalled along more than 50 percent of the crack length *(1)*.

In addition, the extent of the problem on I-80 can be seen in Table 1. Transverse cracking was low and moderate in severity. Additional distressed transverse cracks and a higher severity of cracking became apparent after the winter of 1995-1996. Patching has been performed since the pavement was videotaped. The eastbound lanes are showing distress while the westbound lanes are not. This is probably due to the eastbound lanes having two-way traffic when the westbound lanes were constructed.

On-site surveys of the pavements were conducted in the spring of 1996. In locations of deteriorated cracks on all three pavements, the pavement was observed to move under heavy loads. Average crack spacing on the pavements was determined. The underdrains were also surveyed to determine the overall condition of drainage. The average crack spacings were between 1.3 and 1.9 m (4.2 and 6.3 ft). The average crack spacing on a CRCP is anticipated to be between 0.9 and 3.1 m (3 and 10 ft) *(2)*. Cracks were commonly seen on all three pavements adjacent to the tied concrete shoulder joints. On I-39, the inside and outside shoulder joints do not line up, causing increased cracking between the shoulder joints. Frequently, there are several cracks close together, then a long stretch of pavement before the next set of cracks.

During the on-site surveys in the spring of 1996, underdrains were surveyed to determine the overall condition of drainage. The underdrains on I-39 appeared to be in fairly good condition. The only potential problem noted was that, in the majority of cases, the soil at the foot of the headwall was higher than the flowline of the outlet, causing water to back up into the outlet pipe. The underdrains on I-80 were also in good condition except the ditch level was even with the outlet pipe at approximately 50 percent of the locations. This condition may impede the ability of the pavement to drain during heavy rain when the ditches may be full.

Cores

Cores were taken at several locations on I-80 in the eastbound lanes in October 1995. Table 2 includes the core results. Most of the cores have some amount of infiltration of the subgrade fines into the OGDL. In several cores, the distinction between the bottom of the pavement slab and the top of the OGDL was difficult to discern. In most cases, the OGDL came out attached to the slab. The pavement concrete from the cores was tested for strength. All concrete strengths were acceptable.

In May 1996, four cores were taken from the I-39 pavement with a separation layer to examine the condition of the OGDL and the separation layer. Three of the cores were located at areas where transverse cracks and punchouts had occurred. The OGDL was bonded to the pavement in all locations. The separation layer at two of the locations was in good condition, although the gradation is coarser now than when it was constructed, indicating that fines have been lost. The separation layer at the other two locations was either non-existent or completely mixed with subgrade fines, either due to the coring operation or degradation of the separation layer after construction.

Shelby Tube Samples

Shelby tube samples were taken from patches that were placed on I-80 in November 1995. Two of these patches were located at failed areas while one was located in a "sound" area. The recovered Shelby tube samples were checked with a phenolphthalein solution to determine if lime could be detected in the soil. Unconfined compressive strengths were also determined. The Shelby tube data are included in Table 3.

In many cases, the phenolphthalein did not detect lime in the soil. This does not mean that lime was not applied, only that the subgrade pH was below the indicator level and the soil-lime reaction was not continuing. The purpose of lime modification is to provide a stable construction platform, not to provide a long-term strength gain. In most cases, the quantity of lime used is less than would be used in stabilization. Often, by-product lime is used for modification.

The unconfined compressive strengths of the Shelby tube samples varied from 29 to 168 kPa (0.30 to 1.75 tons/ft^2). In the failed areas, the strength increases with depth, while the moisture content, density, and soil description remain relatively constant. The two samples from the sound areas do not follow this trend. One of the two samples is stronger in the upper 0.15 m (0.5 ft) while the other sample is approximately uniform in strength.

Analysis of OGDL, Separation Layer, and Subgrade Gradations

The FHWA has recommended that the gradations of drainage components be examined to determine if they are acceptable. Areas of concern are the permeability of the separation layer and the ability of the separation layer to prevent subgrade fines from migrating into the OGDL *(3)*.

The as-placed gradations of the OGDL and the separation layer, as well as the gradation of the subgrade, were obtained for this analysis. The calculations were performed and it was determined that the permeability of the separation layer is low enough to deflect infiltrated water into the underdrains. However, the subgrade is very fine, with 99 percent passing the 75 Tm (#200) sieve, and the separation layer cannot adequately keep the fines from migrating into the OGDL.

Deflection Data

Deflection data have been collected several times on the two I-39 pavements and the I-80 pavement using the Falling Weight Deflectometer. Table 4 contains the dates of testing. On I-80, the November 1995 tests covered the east end of the eastbound lanes that could not be tested in October due to the construction of crossovers for an adjacent project. In December 1995, retesting was conducted because maintenance had been performed on the east end of the eastbound and westbound lanes of the I-80 pavement.

Tests were performed at the edge on the leave side of transverse cracks in the pavement and at the pavement/outside shoulder (true edge) joint. Figure 3 shows the deflection test pattern. Load transfer efficiencies (LTEs) were calculated for both the pavement cracks and true edges. Tables 5 through 8 contain the deflection statistics on the OGDL pavements for all three years.

The deflection data at the leave side of the cracks on I-39 indicate that deflections increased considerably between April 1994 and November 1995. Between November 1995 and April 1996, the deflections unexpectedly decreased. There had been rain in the days prior to testing in 1995, saturating the subgrade, but it had been dry for an extended period in 1996, allowing the subgrade to dry out. The LTE across the transverse pavement cracks is still very good, with values no lower than 91.7 percent in 1996.

The deflection data at the true edge of pavement on I-39 show a similar trend to the crack data. The LTEs, however, are significantly lower. In 1996, the highest average LTE on any of the sections was 80.0 percent while the lowest average LTE was 51.5 percent.

The deflection data on I-80 indicate that the average deflections at the leave side of the cracks increased significantly between 1994 and 1995, but increased only marginally from 1995 to 1996. The average LTEs across transverse cracks are very good, with the lowest average LTE in 1996 at 90.1 percent.

The I-80 deflection data also indicate that the average deflections at the true edge have increased significantly as more ESALs have accumulated. The average LTEs at the pavement/shoulder interface in 1996 are poor at 56.4 percent on the eastbound lanes and 60.9 percent on the westbound lanes.

Patching

Five patches have been placed on I-39 in the pavement with a separation layer. Four patches have been placed on I-39 in the pavement without a separation layer. Three patches have been placed on I-80 in the eastbound lanes. Two of those patches were placed at failed areas while the third one was placed in a sound area to compare the subbase and subgrade on failed and sound areas.

The placement of the I-80 patches was observed in November 1995. Shelby tube samples were taken, as discussed earlier. The OGDL was completely and strongly bonded to the concrete at all three locations. The subgrade under the shoulder was dry in all locations. There was some amount of infiltration of the subgrade into the OGDL at all locations, from about 25 mm (1 in.) to complete infiltration. There was a thin film of mud under the OGDL at all locations.

DISCUSSION OF RESULTS

Once some of the testing had been completed, ideas on the causes of the problems of CRCPs on OGDLs were explored. The distresses evident on these pavements may be related to the characteristics of the OGDL, separation layer, and subgrade. The bonding of the CRCP to the OGDL, as well as crack spacing, may have contributed to the poor performance of these pavements.

OGDL Issues

There are two main issues related to the OGDL design itself. The OGDL and the CRCP may be incompatible and the cement content of the OGDL may have been too high.

Incompatibility Between OGDL and CRCP

Jointed concrete pavements fail mainly due to pumping and faulting. OGDLs were designed to solve those problems *(3, 4, 5, 6, 7)*. Illinois, however, uses predominantly CRCP on its high-volume facilities. CRCPs in Illinois fail primarily due to punchouts *(9)*. Several states have used OGDLs successfully under their jointed pavements, although Michigan has reported some problems *(5, 6, 9, 10)*. Because CRCPs behave differently than jointed concrete pavements, the same drainage features may not work equally well on both pavement types. Also, CRCPs need very good subbase support. No agreement has been reached yet as to the structural value of OGDLs.

At this time, it is difficult to conclude whether or not there is an incompatibility between the CRCP and OGDL. The performance of the other pavement types that have been constructed on open-graded drainage layers should reveal if there is a problem with OGDLs in general, or if the problems are limited to their use with CRCPs.

Cement Content in the OGDL

The cement content used in cement-treated OGDLs varies widely from state to state. Amounts used vary from 107 to 166 kg/m^3 (180 to 280 lb/yd^3) *(3, 11, 12)*. Illinois used 142 kg/m^3 (240 lb/yd^3) on both I-39 pavements and between 118 and 142 kg/m^3 (200 and 240 lb/yd^3) on the I-80 pavement. A water reducing additive was used on I-80 *(13)*. The resulting mixture produced a material that handled well and was stable once cured. The cement content used, however, caused the OGDL to bond to the pavement slab and act as part of the pavement.

Separation Layer and Subgrade Issues

The cross section of the OGDLs in other states differs from that used in several of Illinois' pavements. Most states use a separation layer between the OGDL and the subgrade to prevent fines from infiltrating the OGDL *(3, 4, 5, 6, 11)*. It was not readily apparent from the experimental sections Illinois had constructed that a separation layer was necessary. As a result, the separation layer was omitted and the OGDL was placed directly on a lime-modified subgrade. At the time, it was thought the lime-modified subgrade would be sufficient as a separation layer. If the lime-modified subgrade does not perform well in this function, fines from the subgrade will infiltrate the OGDL, having the effects discussed above.

The deflection data and visual distress surveys indicate slightly better performance on the section including a separation layer, although the performance is still unacceptable. The poor performance on this section could be the result of an incompatible separation layer.

The unconfined compressive strength of the soil in failed areas where patches were placed increased with depth, indicating that the lime-modified subgrade may have been suitable only for construction. The cores show a significant amount of infiltration of the subgrade into the OGDL, indicating that lime modification may be insufficient as a separation layer, according to the FHWA drainage manual *(3)*.

Bonding Issues

The bonding of the OGDL to the CRCP, caused by the cement content of the OGDL, has effects on the pavement behavior and on the steel design.

Effects on Pavement Behavior

The bonding of the OGDL to the CRCP has the effect of making the pavement a slab-on-grade design with the bottom of the slab having 20 to 30 percent voids. This causes the stresses to be concentrated at the top of the subgrade instead of the top of the subbase. This accelerates the infiltration of the subgrade fines into the OGDL. The infiltrated fines prevent OGDL drainage and remove any positive effects the OGDL might have had. Because of the infiltration, the pavement settles into the subgrade.

Effects on Reinforcing Steel Design

The bond between the OGDL and the pavement slab introduces other problems. The effective increase in pavement thickness results in a percentage of steel that is lower than designed. A low percentage of steel leads to cracks that are wider than normal and the possible rupture of steel *(14)*.

According to the design, the steel should be located 89 mm (3.5 in.) from the top of the slab on all three sections. On I-39, this is just below the one-third point in the slab. When the additional thickness of the OGDL is considered, the reinforcement is at the one-quarter point of the slab. On I-80, 89 mm (3.5 in.) is at the one-third point of the slab, but because of the additional thickness of the OGDL, the steel is just above the one-quarter point of the slab. Steel above the one-third point in the slab is higher than FHWA's recommended depth of steel *(15)*. Because of the additional thickness of the OGDL, the geometrics of the stress diagram are changed.

A third complicating factor related to the steel is the epoxy-coating on the steel. Currently, it is unknown if there are any performance differences between epoxy-coated steel and plain steel. The purpose of the steel in CRCP is to hold the cracks tight. If the epoxy reduces the bond, the cracks may widen, lowering the efficiency of the load transfer across the cracks and increasing the stress on the subbase and subgrade, eventually leading to punchouts.

The percentage of reinforcing steel may or may not be part of the problem. Several punchouts have occurred on all three pavements, possibly indicating an insufficient amount of steel. However, the LTEs across

the cracks in the pavements are still quite good, indicating the steel has not yet been overstressed as a result of insufficient reinforcement.

Previous research in Illinois indicates that the depth of the reinforcement, 89 mm (3.5 in.) from the surface, is probably not contributing to the failure of these pavements *(16)*. Good LTEs across the cracks in the pavements indicate that the bond between the concrete and the epoxy-coated rebar may not be contributing to the problems.

Crack Spacing Issues

The cracking patterns noticed when visual distress surveys were conducted caused concern that the design of the pavement and shoulders could be contributing to the problems. The pavement is CRCP, but the shoulders are jointed and tied to the pavement with #15 bars at 760 mm (#5 at 30 in.) centers. Because the CRCP was designed without the shoulders contributing any structural value, the pavement should be adequate.

The design of the CRCP and shoulders do not appear to be part of the problem. The cracking patterns on the CRCP have been influenced to some degree by the joints in the shoulders. While the LTEs between the pavement and the shoulder are poor, this would not lead to the transverse cracking and punchouts that have been observed.

MAINTENANCE ALTERNATIVES

Because failures were becoming apparent, maintenance alternatives were explored. An adjacent construction project required two-way traffic on the east end of the I-80 pavement in 1996, and because repair would be impossible if the pavement failed under traffic, maintenance was needed before the adjacent project began. This area was undersealed in the fall of 1995. The undersealing operation consisted of drilling holes through the pavement and pumping grout into the voids of the OGDL.

Because of high deflections throughout the pavement, the eastbound lanes of I-80 were entirely undersealed in the fall of 1996. Areas of high deflection in the westbound lanes were also undersealed. The undersealing resulted in a considerable reduction of the deflections; however, recent deflection testing of the 1995 undersealing revealed that the deflections in that area have returned to pre-undersealing levels. The speed of this increase was probably influenced by having twice the regular traffic on this area when the adjacent project was constructed. Overlaying the pavements does not appear to be an option, unless done in conjunction with undersealing. An overlay does not address the weak support problem.

SUMMARY AND CONCLUSIONS

The use of OGDLs with CRCP designs should be approached with extreme caution. Visual distress surveys and deflection testing of Illinois' CRCP on OGDL have documented deteriorated transverse cracks, patches, and high deflections that would not be expected on CRC pavements of this age and design. Several possible causes of the problems have been investigated through: visual distress surveys; core analysis; analysis of Shelby tube samples; analysis of gradations of the OGDL, separation layer, and subgrade; deflection tests; and inspection of slabs removed in patching operations.

At this time, no firm conclusions can be reached regarding the cause of the problems. The OGDL may be incompatible with CRCP. Performance of other pavement types on OGDLs could prove the validity of this hypothesis. The cement content, leading to bonding of the OGDL to the CRCP and all of the related issues, appears to have impacted the performance of this design. The lack of a separation layer inhibits good performance, but an incorrectly designed separation layer does not completely correct this deficiency. Cracking patterns, while unusual, do not appear to have a major impact on the performance of this pavement design.

RECOMMENDATIONS

The performance of these three pavements should be monitored over time. Deflection testing and visual distress surveys should be performed periodically. The performance of OGDLs under other pavement types should be monitored to provide a comparison.

It is anticipated that, with further time and testing, the source of the problems will become apparent and appropriate solutions for maintenance and rehabilitation will be developed. If further investigation indicates that it is possible, a new policy for the use of OGDLs should be developed. Until then, OGDLs should not be used under CRCPs.

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TABLE 1 Distresses Evident on OGDL Pavements in November 1995

Pavement	Number of Transverse Cracks			Patches	
	Low[a]	Moderate[b]	High[c]	Number	Area (m^2)
I-39 Northbound with Separation Layer	0	1	0	1	17.8
I-39 Southbound with Separation Layer	2	1	0	2	21.2
I-39 Northbound without Separation Layer	1	1	0	0	0
I-39 Southbound without Separation Layer	5	2	3	3	31.2
I-80 Eastbound	30	1	0	0	0
I-80 Westbound	0	0	0	0	0

[a] Spalled along > 0% and ≤ 10% of crack length.
[b] Spalled along > 10% and ≤ 50% of crack length.
[c] Spalled along > 50% of crack length.

TABLE 2 Summary of Core Data from I-80 Eastbound, October 1995

Attribute	Range	Average
Thickness (mm)	241 – 311	278
PCC Strength (kPa)	37,096 – 44,399	41,113
Depth of Rebar (mm)	70 – 108	89
Soil Depth of Infiltration into OGDL from bottom (mm)	0 – 102	33.2
PCC Depth of Infiltration into OGDL from top (mm)	0 – 19	4.1

TABLE 3 Shelby Tube Data on I-80 from November 1995

Depth (m)	Strength[a] (kPa)	Water (%)	Density (kg/m^3)	Description	Lime Detection
Station 1028+50 107 cm from Edge of Pavement					
0.15	33.5	27.1	1861	Black, Gray SiC[b]	Not Detected
0.30	140.7	27.9	1874	Black SiC	Not Detected
Station 1028+50 211 cm from Edge of Pavement					
0.15	49.8	25.3	1884	Black, Gray SiC	Not Detected
0.30	167.5	28.2	1879	Black SiC	Detected Top 1/3
Station 1035+10 97 cm from Edge of Pavement					
0.15	77.5	27.0	1903	Black SiC	Not Detected
Station 1035+10 236 cm from Edge of Pavement					
0.15	35.4	27.0	1768	Black, Gray SiC, visible lime pockets	Detected
0.30	67.9	28.2	1821	Black, Gray SiC, visible lime pockets, top 1/4, to Black SiC	Not Detected Bottom 3/4
Station 1040+00 56 cm from Edge of Pavement[c]					
0.15	124.4	25.9	1876	Black, Gray SiC	Detected
0.30	28.7	26.4	1756	Black, Gray SiC, top 1/2, to Black SiC	Not Detected Bottom 1/2
0.45	155.0	24.8	1916	Black SiC	Not Detected
Station 1040+00 206 cm from Edge of Pavement[c]					
0.15	68.9	25.2	1933	Black, Gray SiC	Not Detected
0.30	61.2	25.0	1901	Black SiC	Not Detected
0.45	—[d]	25.1	1954	Black SiC	Not Detected

[a] Unconfined compressive strength
[b] SiC is silty-clay soil
[c] Area had not failed when tubes were extracted
[d] Data not available

TABLE 4 Dates of Deflection Testing

Location	Dates Tested
I-39 Section 1	April 1994, November 1995, April 1996
I-39 Section 2	April 1994, November 1995, April 1996
I-80 Not Undersealed	April 1994, October 1995, April 1996
I-80 Undersealed	December 1995, April 1996, July 1996

TABLE 5 I-39 Crack Load Transfer Efficiency and Deflection Data

Year	Number of Tests	Load Transfer Efficiency			Deflection		
		AVG[a] (%)	STD[b] (%)	COV[c]	AVG[a] (mm)	STD[b] (mm)	COV[c]
Northbound with Separation Layer							
1994	11	92.6	4.1	4.4	0.099	0.018	18.2
1995	82	88.5	7.2	8.1	0.145	0.036	24.8
1996	86	93.0	3.5	3.4	0.132	0.030	22.7
Southbound with Separation Layer							
1994	12	90.7	6.4	7.1	0.076	0.010	13.2
1995	68	90.1	9.0	10.0	0.150	0.038	25.3
1996	87	92.9	8.3	8.9	0.099	0.020	20.2
Northbound without Separation Layer							
1994	12	91.7	3.5	3.8	0.091	0.010	11.0
1995	110	87.5	13.9	15.9	0.168	0.117	69.6
1996	97	91.7	4.5	4.9	0.109	0.025	22.9
Southbound without Separation Layer							
1994	11	93.9	2.2	2.3	0.094	0.013	13.8
1995	97	91.9	10.1	11.0	0.269	0.150	55.8
1996	107	94.8	4.1	4.3	0.170	0.081	47.6

[a] Average value
[b] Standard Deviation
[c] Coefficient of Variation

TABLE 6 I-39 True Edge Load Transfer Efficiency and Deflection Data

Year	Number of Tests	Load Transfer Efficiency			Deflection		
		AVG[a] (%)	STD[b] (%)	COV[c]	AVG[a] (mm)	STD[b] (mm)	COV[c]
Northbound with Separation Layer							
1994	10	77.4	9.9	12.8	0.099	0.020	20.2
1995	8	56.2	8.4	14.9	0.137	0.041	29.9
1996	10	54.4	7.2	13.2	0.119	0.025	21.0
Southbound with Separation Layer							
1994	11	90.5	7.1	7.8	0.079	0.010	12.7
1995	10	75.8	12.0	15.8	0.114	0.036	31.6
1996	11	80.0	8.8	11.0	0.086	0.008	9.3
Northbound without Separation Layer							
1994	12	76.1	9.1	12.0	0.097	0.010	10.3
1995	12	46.5	11.1	23.9	0.142	0.025	17.6
1996	12	56.5	11.6	20.5	0.109	0.015	13.8
Southbound without Separation Layer							
1994	12	91.8	7.1	7.7	0.081	0.008	9.9
1995	14	42.0	12.9	30.7	0.175	0.053	30.3
1996	12	51.5	4.7	9.1	0.124	0.015	12.1

[a] Average value
[b] Standard Deviation
[c] Coefficient of Variation

TABLE 7 I-80 Crack Load Transfer Efficiency and Deflection Data

Year	Number of Tests	Load Transfer Efficiency AVG[a] (%)	STD[b] (%)	COV[c]	Deflection AVG[a] (mm)	STD[b] (mm)	COV[c]
		Eastbound to 1158+00 (not undersealed)					
1994	50	93.0	6.5	7.0	0.097	0.025	25.8
1995	328	93.0	9.9	10.6	0.165	0.117	70.9
1996	275	91.2	7.9	8.7	0.180	0.102	56.7
		Eastbound 1158+00 to 1180+00 (undersealed)					
1994[d]	—	—	—	—	—	—	—
1995	23	96.8	4.1	4.2	0.074	0.015	20.3
1996	6	93.8	1.7	1.8	0.081	0.013	16.0
		Westbound to 1164+00 (not undersealed)					
1994	60	94.9	4.4	4.6	0.076	0.013	17.1
1995	175	88.3	6.6	7.5	0.157	0.064	40.8
1996	131	90.1	12.2	13.5	0.170	0.114	67.1
		Westbound 1164+00 to 1180+00 (undersealed)					
1994[d]	—	—	—	—	—	—	—
1995	15	94.4	3.6	3.8	0.069	0.013	18.8
1996	6	91.9	4.0	4.4	0.076	0.013	17.1

[a] Average value
[b] Standard Deviation
[c] Coefficient of Variation
[d] Undersealing had not been performed when pavement was tested in 1994

TABLE 8 I-80 True Edge Load Transfer Efficiency and Deflection Data

Year	Number of Tests	Load Transfer Efficiency AVG[a] (%)	STD[b] (%)	COV[c]	Deflection AVG[a] (mm)	STD[b] (mm)	COV[c]
Eastbound to 1158+00 (not undersealed)							
1994	50	84.3	18.4	21.8	0.097	0.041	42.3
1995	58	58.8	27.8	47.3	0.145	0.086	59.3
1996	275	56.4	28.1	49.8	0.180	0.102	56.7
Eastbound 1158+00 to 1180+00 (undersealed)							
1994[d]	—	—	—	—	—	—	—
1995	4	90.3	3.3	3.7	0.074	0.015	20.3
1996	6	87.7	9.6	10.9	0.081	0.013	16.0
Westbound to 1164+00 (not undersealed)							
1994	60	94.6	7.2	7.6	0.076	0.010	13.2
1995	66	77.8	19.6	25.2	0.112	0.038	33.9
1996	131	60.9	25.1	41.2	0.173	0.114	65.9
Westbound 1164+00 to 1180+00 (undersealed)							
1994[d]	—	—	—	—	—	—	—
1995	3	103.0	6.0	5.8	0.064	0.010	15.6
1996	6	93.9	12.5	13.3	0.076	0.013	17.1

[a] Average value
[b] Standard Deviation
[c] Coefficient of Variation
[d] Undersealing had not been performed when pavement was tested in 1994

LIST OF FIGURES

FIGURE 1 Location Map of the OGDL Pavements

FIGURE 2 Cross Section of the OGDL Pavements

FIGURE 3 Falling Weight Deflectometer Test Pattern

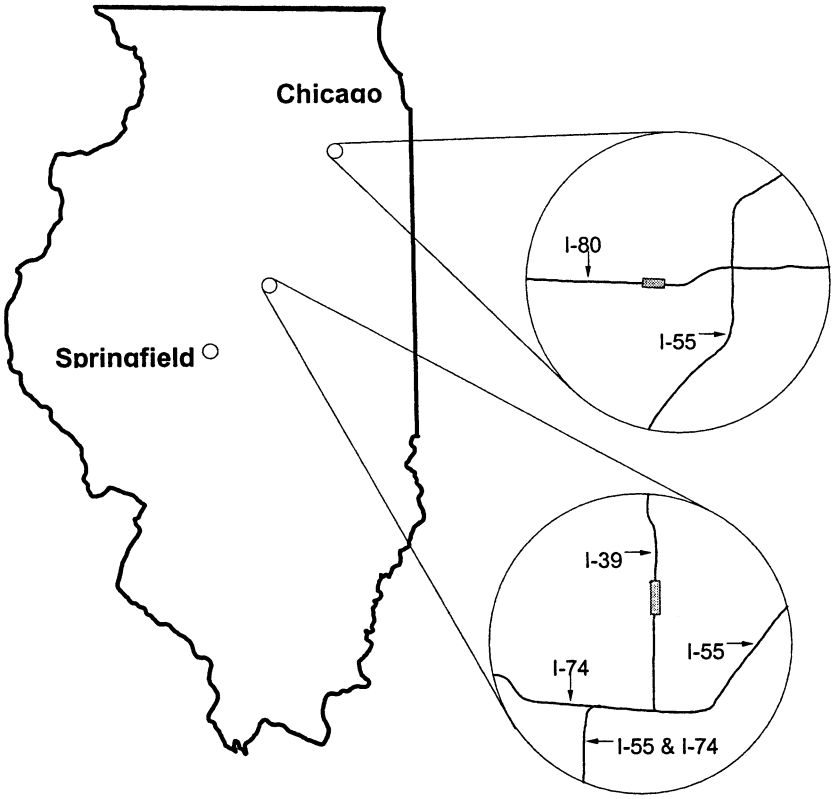
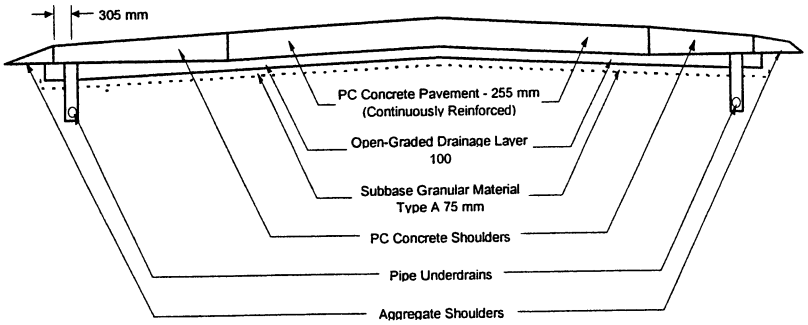
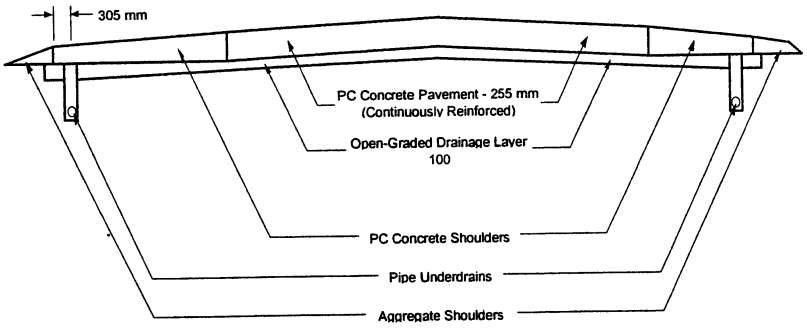


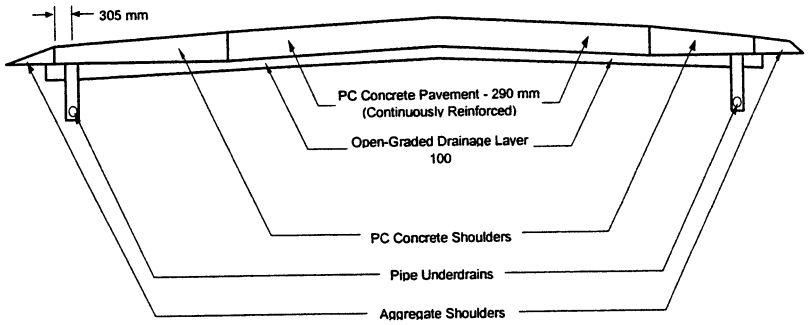
FIGURE 1 Location Map of the OGDL Pavements



(a) Cross section of I-39 with a separation layer



(b) Cross section of I-39 without a separation layer



(c) Cross section of I-80

FIGURE 2 Cross Section of the OGDL Pavements

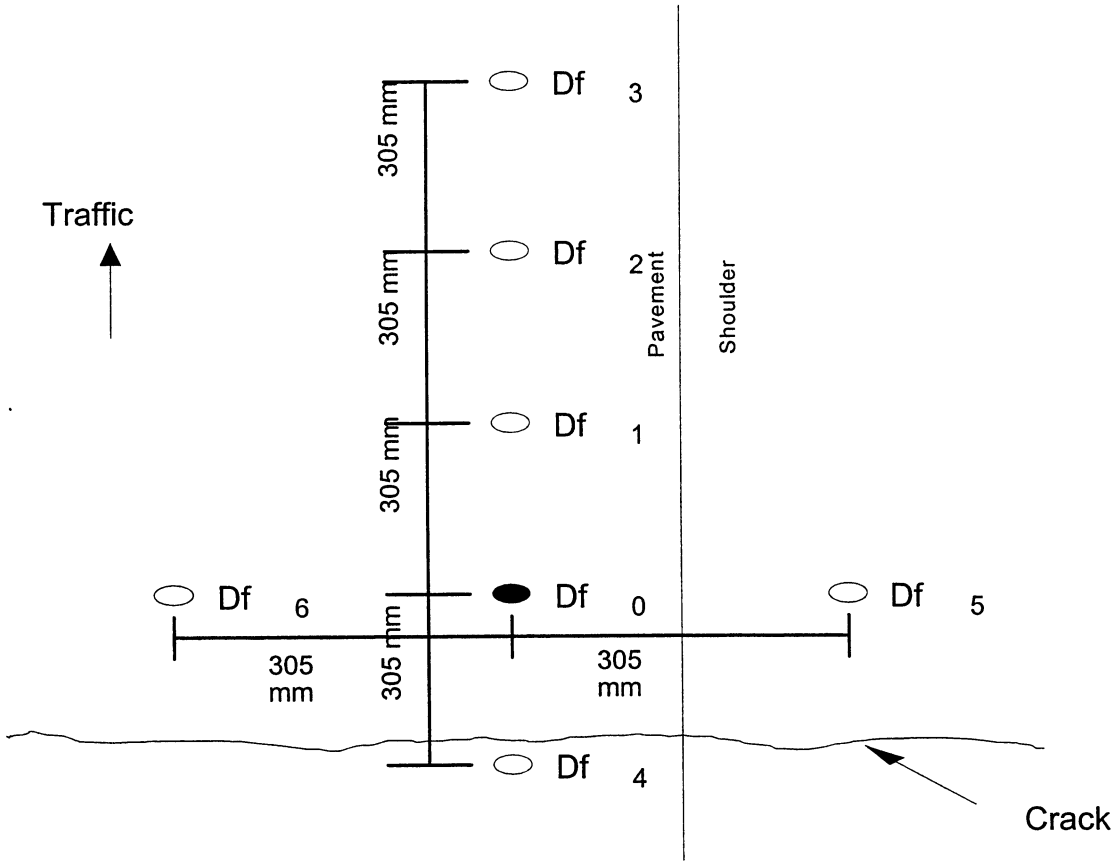


FIGURE 3 Falling Weight Deflectometer Test Pattern

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