Open Graded Drainage Layer Performance in Illinois

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16. Abstract

The sustained presence of free water in the foundation layers of a pavement can be detrimental to the entire pavement structure. The presence of water can lead to a loss of substructure support, fatigue cracking, stripping, faulting, pumping, and various other surface distresses. The challenge of removing this water from the foundation layers of a pavement has confronted pavement designers and engineers since the construction of the first hard surfaced road.

Many concepts and materials have been produced to address the issue of water in pavement structures. Pipe underdrains, french drains, impermeable subbase materials, geotextile fabrics, pavement sealers, and other products have been developed to try and keep water out of the pavement structure. In addition to these products, the concept of an open graded drainage layer was developed as a foundation layer that could effectively move water from beneath the pavement and into an underdrain system.

Illinois experimented with the use of open graded drainage layers during the late 1980's and early 1990's. Four projects were constructed to monitor the effectiveness of the drainage layer and the performance of the pavement. Five additional projects were constructed based on the early performance of the monitored projects. However, continued monitoring of the initial projects, and additional projects, indicated two of the pavements were quickly deteriorating. Superficial pavement distress, severe lane to shoulder settlement, and high pavement deflections for these two projects indicated a failure of the pavement structure. Based on the performance of these projects, a moratorium on the construction of open graded drainage layers was issued for Illinois in January of 1996.

This report covers the construction, performance, and rehabilitation for six of the nine projects. In addition, the project costs, traffic volumes, modes of failure, and maintenance activities will be addressed. Finally, conclusions on the performance of these pavement sections and recommendations for future projects are included.

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Final Report

Open Graded Drainage Layer Performance in Illinois

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ABSTRACT

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DISCLAIMER

The contents of this paper reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views, or policies, of the Illinois Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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INTRODUCTION

It is no great mystery to the construction industry that one of the largest contributors to the destruction of our buildings and highways are the natural elements. The action of moisture, freezing and thawing, sunlight and heat, and ultra-violet radiation can be detrimental to some of the most sophisticated construction materials. Millions of dollars are spent each year in an attempt to counteract the effects of these natural elements.

Significant importance in the highway construction industry is placed on surface and subsurface drainage of water. If the water is not effectively removed from the foundation layers of the pavement, significant damage will result and the life of the pavement will be reduced. In addition, rain water must be effectively removed from the surface of the pavement to avoid ponding and hydroplaning. These concepts were recognized as early as 1824 by John MacAdam, "…after having secured the soil from under water (subsurface water) the roadmaker should then secure it from rainwater."

Many concepts and materials have been produced to address the issue of free water in pavement structures. Pipe underdrains, french drains, impermeable subbase materials, geotextile fabrics, and pavement sealers have all been developed to try and keep water out of the pavement structure. In addition to these products, the concept of an open graded drainage layer (OGDL) was developed as a pavement layer that could effectively move water from beneath the pavement and into an underdrain system.

The OGDL consists of a uniform size aggregate that may be bound together as a lean concrete mixture or low asphalt cement content bituminous mixture. The concept of an open graded aggregate consists of only the coarse fraction of a gradation. Removal of the finer fractions creates an interconnected pore structure that allows free water to flow through the material. Figure 1 illustrates the concept of an open graded aggregate versus a well graded aggregate.

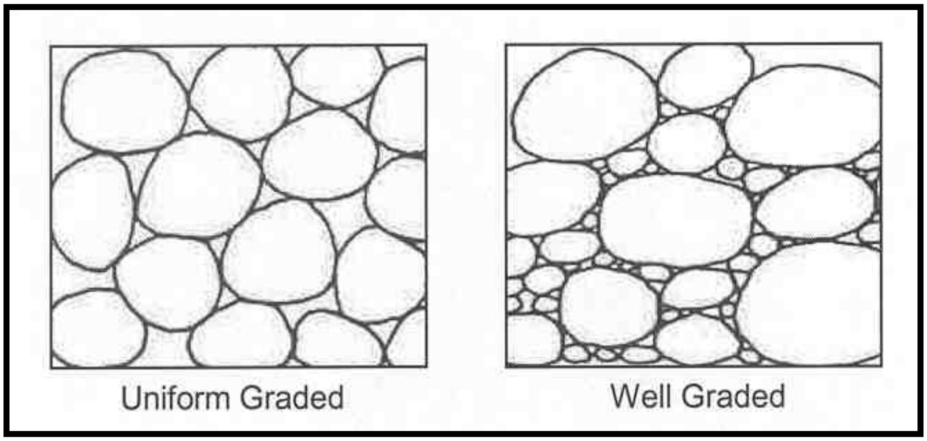


Figure 1(1)

Uniform (Open) Graded versus Well Graded Aggregate

The bound OGDL mixtures, both cement treated and asphalt treated, are produced by conventional means of producing normal concrete or bituminous mixtures. The material is placed as one layer between 3 and 6 inches thick. Conventional paving equipment and steel drum rollers for compaction can be used. The layer is allowed to cure for a specified amount of time before subsequent layers of the pavement structure are constructed.

Illinois experimented with the use of OGDLs during the late 1980’s and early 1990’s. Two experimental projects and two demonstration projects were constructed for monitoring purposes. Three of these projects were incorporated into the construction of Interstate 39 between Bloomington and LaSalle, while the fourth was constructed on Illinois State Route 161 east of St. Louis. The construction information and early performance data for these four projects may be found in Physical Research Report No. 114 (2).

Following these four projects, five additional projects were constructed with an OGDL. Two of those projects will be expanded upon within this report, while the remaining three were all non-highway applications such as rest area ramps and parking lots. The two projects that will be expanded upon were constructed on Interstate 80 near Morris and Macon County Highway 1 near Decatur.

The construction activities and performance of these projects has been periodically monitored by the Illinois Department of Transportation. Construction documentation included construction sequencing, mixture designs, problems encountered, and early performance problems. Performance monitoring has included Falling Weight Deflectometer (FWD) measurements, International Roughness Index (IRI) values, visual distress surveys, and Condition Rating Survey (CRS) values.

CONSTRUCTION

The Illinois Department of Transportation (IDOT) constructed four projects with OGDLs between 1989 and 1992. These projects were monitored extensively during construction and for early performance. Monitoring included pavement distress surveys, FWD analysis, pressure transducers, and tipping bucket water outflow data for the underdrains.

Physical Research Report Number 114 was written in 1993 to document the construction and early performance of these four projects. Complete construction details and initial performance results are summarized in the 1993 report. A summary of each project location and the typical cross section is listed below as a quick reference for the purposes of this final report.

INTERSTATE 39 AT BLOOMINGTON

The first experimental section with an OGDL in Illinois was constructed as part of Interstate 39, three miles north of Bloomington. The test and control sections are both located in the northbound lanes. The control section is 1,000 feet long, while the test section is 1,220 feet long. This project was constructed in the fall of 1989. A complete project location map may be found in Appendix A.

The typical cross section for this project consists of a 16-inch lime modified subgrade beneath a 4-inch lean concrete base and a 10.75-inch hinge jointed plain concrete pavement. The cross section of the OGDL section included the same 16-inch lime modified subgrade beneath a 6-inch cement treated OGDL (CTOGDL) and the 10.75-inch hinge jointed plain concrete pavement. The OGDL extends 18 inches out under the tied plain concrete shoulders. Geocomposite underdrains were placed at the shoulder to mainline joint with outlet drains every 500 feet.

INTERSTATE 39 AT LOSTANT

The second experimental section with an OGDL was also constructed as part of Interstate 39, near the town of Lostant. The test and control sections are located in both the northbound and southbound lanes. The monitored sections are all 500 feet in length. The total experimental project length is approximately 4,000 feet in each lane. This project was constructed in the fall of 1990. A complete project location map may be found in Appendix A.

The typical cross section for the control section consists of a 16-inch lime modified subgrade beneath a 4-inch lean concrete base and a 10-inch continuously reinforced concrete (CRC) pavement. Plastic pipe underdrains were placed at the shoulder to mainline joint with outlet drains every 500 feet.

This project experimented with the thickness and type of OGDL used under the pavement. The northbound lanes used an asphalt treated OGDL (ATOGDL), while the southbound lanes used a CTOGDL. Test sections with 4-inch and 5-inch OGDLs were used in both directions and placed directly on the 16-inch lime modified subgrade. An additional section in each direction included a 4-inch OGDL placed directly on 3 inches of dense graded aggregate material, atop the 16 inches of lime modified subgrade. A 10-inch CRC pavement was used in both directions. Plastic pipe underdrains were placed 1 foot in from the outside shoulder edge with drains every 500 feet.

INTERSTATE 39 AT EL PASO

The first demonstration project was constructed in 1992 on Interstate 39 near El Paso. This is the first OGDL project with considerable length, as the project extends for 9.5 miles in the northbound and southbound lanes. Due to the length of this project, eighteen 500-foot test sections were randomly selected for the visual distress surveys. There is no control section associated with this project.

The limits of this project are roughly from the town of Kappa on the south to the town of Panola on the north. The project was divided into two different test sections, with the dividing line falling just south of the intersection between Interstate 39 and U.S. Highway 24. A complete project location map may be found in Appendix A.

The typical cross section for the southern section consists of a 16-inch lime modified subgrade beneath a 3-inch layer of aggregate material, a 4-inch CTOGDL, and a 10-inch

CRC pavement. This cross section was used in both the northbound and southbound lanes. The typical cross section for the northern section consists of a 16-inch lime modified subgrade beneath a 4-inch CTOGDL and the 10-inch CRC pavement. This cross section was also used in both the northbound and southbound lanes. Plastic pipe underdrains were placed 1 foot in from the outside shoulder edge with drain outlets every 500 feet.

ILLINOIS ROUTE 161

The second demonstration project was constructed in 1992 near Fairview Heights on Illinois State Route 161. The project is located in the westbound lanes only. A complete project location map may be found in Appendix A. This project is three miles in length; however, it is divided into two different cross sections. Six randomly selected monitoring sections of 500-feet in length were selected for the visual distress surveys. There is no control section with this project.

The typical cross section for this project consists of a 12-inch lime modified subgrade beneath a 4-inch ATOGDL and a 14-inch full-depth HMA pavement. The second test section consists of the 12-inch lime modified subgrade beneath a 3-inch aggregate layer, the 4-inch ATOGDL, and the 14-inch full-depth HMA pavement. Plastic pipe underdrains were placed 1.0 foot in from the outside edge of the shoulder with drain outlets every 250 feet.

INTERSTATE 80

Interstate 80 is a major east-west route across the northern half of the United States. In Illinois, this interstate stretches from Chicago on the east to Moline on the west. The majority of this interstate, in Illinois, was originally constructed in the early 1960’s as a 10-inch jointed concrete pavement. By the early 1990’s, several sections of the interstate were in need of rehabilitation or reconstruction.

One such section was located between mileposts 105 and 111 just west of Morris as shown in Figure 2. This section of Interstate 80 was originally constructed in 1960 as a 10-inch jointed concrete pavement on a 6-inch aggregate base. Prior to the 1993 reconstruction, a minor maintenance contract for concrete pavement restoration was completed in 1983. In addition, two patching contracts were awarded in 1985 and 1988.

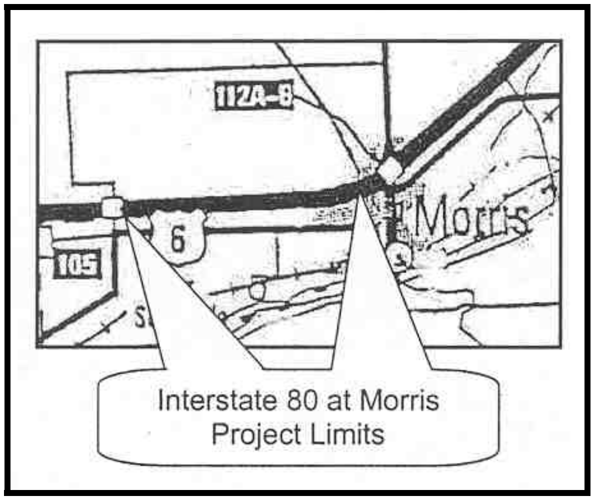


Figure 2

Interstate 80 Reconstruction Project Location

The decision was made to completely reconstruct this section of Interstate 80 in 1993. In addition, this project would utilize a CTOGDL for subsurface drainage. The typical cross section for this project consists of a 12-inch lime modified subgrade beneath the 4-inch CTOGDL and an 11.5-inch CRC pavement.

Pavement break-up and removal started in May of 1993. All traffic was routed to the westbound lanes as the eastbound lanes were reconstructed, and vice versa for the reconstruction of the westbound lanes. Figure 3 illustrates the broken pavement prior to removal. The entire existing pavement structure was removed down to the subgrade soils. The existing pavement was crushed and stockpiled for use as the coarse aggregate in the OGDL.

Figure 3

Broken Pavement Prior to Removal

Reconstruction began with the lime modification of the subgrade soils to a depth of 12 inches. The eastbound lanes were modified with lime slurry, while the westbound lanes were modified with dry hydrated lime. The application of dry hydrated lime and the condition of the subgrade soils may be seen in Figure 4. Several wet spots were encountered during the lime modification process. Approximately one mile of the eastbound lanes and nearly 1.5 miles of the westbound lanes were lime modified at least twice. The wet spots occurred along the entire length of the project. The only concentrated area of multiple applications of the lime was at the west end of the westbound lanes. This area is approximately one mile in length.

Figure 4

Application of Dry Hydrated Lime

Following the lime modification process, the plastic pipe underdrains were trenched into place. The pipe underdrains were placed two feet from the outside edge of the shoulder under both the median and outside shoulders. The underdrain trench was wrapped in a geotextile fabric as shown in Figure 5.

Figure 5

Geotextile Wrap of Underdrain Trench

The median through this section of Interstate 80 is very shallow and very flat. To help compensate for this, the underdrain system was raised from the standard 30-inch depth to 22 inches below the pavement surface. However, several of the median underdrain outlet pipes and headwalls were still placed at the bottom of the median ditch with a zero percent slope on the outlet pipe. Figure 6 illustrates the shallow median ditch and placement of the headwall at the bottom of the ditch.

Figure 6

Shallow Median Ditch with Underdrain Headwall

The CTOGDL was placed directly on the lime modified subgrade. The decision was made not to use a separation layer of aggregate or geotextile fabric between the OGDL and the subgrade. This decision was based on initial material cost and no documentation of the long term benefits of the separation layer. As mentioned previously, the existing pavement was crushed and recycled as the coarse aggregate in the OGDL. The gradation of the recycled concrete used in the OGDL was an Illinois CA 07. This gradation is outlined in Table 1 below.

Table 1

Coarse Aggregate 07 Gradation

Sieve Size	1 ½”	1”	½”	No. 4
Percent Passing	100	95 ± 5	45 ± 15	5 ± 5

The contract mixture specifications outlined a cement content of not less than 200 pounds per cubic yard, and not more than 280 pounds per cubic yard, while maintaining a water-cement ratio of 0.50. The majority of the OGDL placed on this project had 240 pounds of cement per cubic yard and a water-cement ratio of 0.60. The increased water-cement ratio was necessary to account for the high absorption rate (5.0%) of the recycled concrete pavement.

The OGDL was placed 4 inches thick with a CMI Autograde machine. This machine was equipped with an auger and screed extension to cover the median shoulder along with the two traveling lanes in one pass. In addition, vibrating pans on the rear of the machine were used to seat the material. Placement of the material with this machine worked well. Placement of the outside shoulder was done as a separate operation. Figure 7 illustrates the autograde machine and the process used to place the material.

Figure 7
CMI Autograde Machine

The 11.5-inch CRC pavement was placed directly on the OGDL. Two spreading machines and one paving machine were used to pave the two lanes full-width. This process did not work very well, as the first spreading machine did not leave a uniform thickness for the second spreading machine. Also, the second spreading machine and paving machine could not keep the same pace as the first spreading machine. Paving of the CRC pavement was completed by late summer.

MACON COUNTY HIGHWAY 1

County Highway 1 in Macon County connects Illinois State Route 48 with Faries Parkway on the east side of Decatur as shown in Figure 8. This county highway serves as a major tractor-trailer truck entrance for the Archer Daniels Midland (ADM) facility located in Decatur on County Highway 1. The Macon County Highway Engineer stated that, “If ADM is the Supermarket to the World, then County Highway 1 is the front door. (3)”

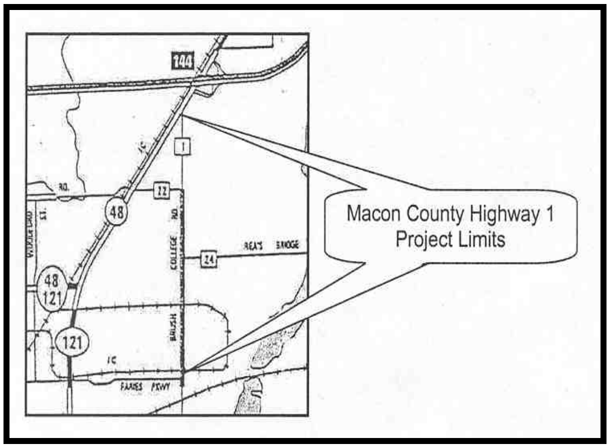


Figure 8

Macon County Highway 1 Construction Project Location

This 3-mile project was constructed as three sections between the years of 1994 and 1997. The pavement cross section for each section, however, is the same. The cross section includes a 12-inch lime modified subgrade beneath a 4-inch ATOGDL. The 12-inch jointed reinforced concrete pavement was constructed with a doweled joint spacing of 40-feet, and 6-inch by 12-inch welded wire fabric pavement reinforcement.

The majority of this project is five lanes with curb and gutter to control drainage. A short section at the north end of the project is four lanes. Due to the curb and gutter cross section, no underdrains were placed on this project.

Construction details for this project are limited. The project was constructed in three stages, and over the course of three years as three separate contracts. Due to the length of the construction process, and that this is a county highway, construction records and documentation for this project were not kept for this research effort.

PERFORMANCE

The performance of these OGDL projects has been periodically monitored since the construction of each one. The monitoring process included visual distress surveys, FWD measurements, IRI values, and CRS values.

The visual distress surveys were performed on the entire project for smaller projects, and on randomly selected short sections for larger projects. The objective of these surveys is to document the distress that is present, assign it a severity level, and monitor the deterioration throughout the life of the project. The type of distress and severity of the distress are based on the “Distress Identification Manual for the Long-Term Pavement Performance Project.” (4) Details of the results from the 2003 visual distress surveys are included within this report.

FWD measurements were taken to monitor the pavement deflection, subgrade support rating, and the load transfer efficiency for each project. The FWD data was monitored to determine if the OGDL has provided adequate pavement support, and to determine if the underlying subgrade has migrated up into the OGDL.

The IRI is an indication of the deviation of a given pavement surface from an ideal smooth pavement. (5) This value is measured in inches per mile, with higher IRI values indicating increased pavement roughness. Statewide data is collected using digital collection vehicles and sorted from smoothest to roughest pavements. An average of all the data is found, and comparisons to this statewide average may be used.

The CRS is a computerized mathematical model used to rate the pavement based on the type, severity, and extent of the visual pavement distress. Statewide data is collected using the digital collection vehicles and rated manually before entry into the computer model. The following scale is used to categorize the current condition of the pavement based on the pavement distress. (5) A CRS rating of 6.5 or less for an interstate pavement generally indicates that it will be programmed for rehabilitation. The CRS rating for interstates and state primary routes is performed on a biennial basis in opposing years.

CRS Range	Category
1.0 to 4.5	Poor
4.6 to 6.0	Fair
6.1 to 7.5	Satisfactory
7.6 to 9.0	Excellent

INTERSTATE 39 AT BLOOMINGTON

The project on Interstate 39 at Bloomington is a 10.75-inch hinge jointed plain concrete pavement on a 6.0-inch CTOGDL built in 1989. This project has performed very well to date. The 2003 visual distress survey indicated that three joints showed some minor spalling, as shown in Figure 9, and two joints indicated an adjacent crack. Approximately 50 percent of the joints also exhibited a fault of 0.13 inch, or less. There are a total of 81 pavement joints in the test section.

Figure 9
Minor Joint Spalling

The control section for this project is also a 10.75-inch hinge jointed plain concrete pavement. However, the control section was constructed on top of a 4.0-inch lean concrete base material. The 2003 visual distress survey indicated no joints with spalling or cracking present. Approximately 10 percent of the joints exhibited a fault of 0.13 inch or less. There are a total of 66 pavement joints in the control section.

The underdrain outlets were all open and flowing with minor sediment accumulations noted at some of the outlets. There has been no patching performed for either the control or test sections.

The FWD data for this project indicates that the pavement deflections at the center of each panel have remained constant between 2.0 and 3.0 mils for both the test and control sections. Figure 10 illustrates the FWD test results and a two point moving average trend line for those results. In addition, the load transfer efficiencies for the pavement joints have remained constant between 85.0 and 90.0 percent since construction for both sections.

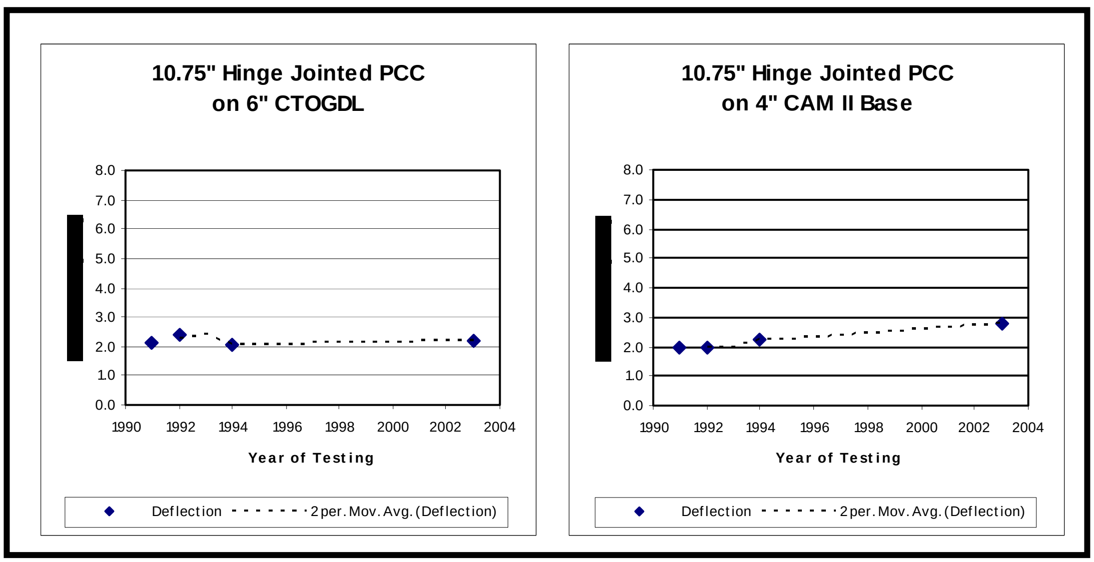


Figure 10

Average FWD Deflections for I-39 at Bloomington

The IRI data for this project indicates a general increase in roughness for the test section compared to a relatively consistent value of roughness for the control section. When compared to the statewide average, both sections were less than the statewide average after construction but since have increased to a level greater than the statewide average. The graph below in Figure 11 indicates these trends.

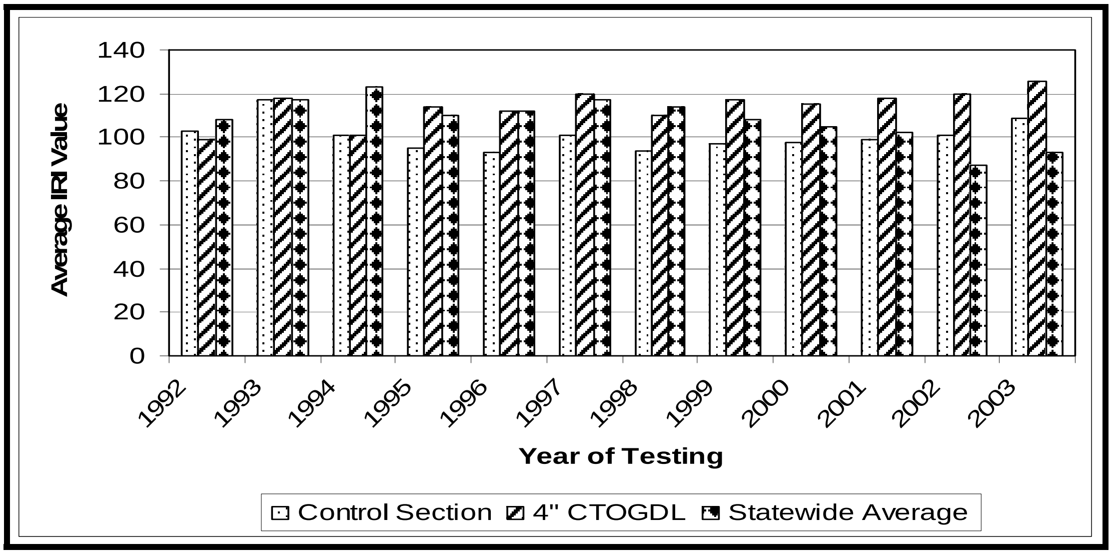


Figure 11

Average IRI Values for I-39 at Bloomington

The CRS data indicates a general decline in the overall condition of the pavement since construction. However, this decline is well within the limits of normal decline for a hinge-jointed concrete pavement with a 20-year design life. The CRS value remained within the "Excellent" category for the first 10 years. The CRS values given in Table 2 illustrate the rate of decline.

Table 2

CRS Values for I-39 at Bloomington

Year	1994	1996	1998	2000	2002
CRS Value	8.7	8.4	7.6	7.5	7.1

INTERSTATE 39 AT LOSTANT

The experimental pavement section at Lostant is a 10.0-inch CRC pavement constructed over various OGDL sections. The project was completed in 1990. The northbound lanes utilized a 4.0-inch and 5.0-inch asphalt treated open graded drainage layer (ATOGDL) constructed directly on the lime modified soil, and a 4.0-inch ATOGDL constructed on a 3.0-inch aggregate separation layer. The southbound lanes were constructed with the same thickness of OGDL for each test section, however a CTOGDL was used for these lanes. The control section for this project consists of the same 10.0-inch CRC pavement; however, it was constructed on a 4.0-inch lean concrete base over a lime modified soil.

The 2003 visual distress surveys indicate only the normal low severity cracking that is designed for and expected with continuously reinforced concrete. There is no indication of any medium severity distress or spalling at any of the transverse cracks. The figures in Table 3 indicate the average transverse crack spacing for each of the test and control sections.

Table 3

Average Pavement Crack Spacing for I-39 at Lostant

Pavement Section	Northbound (Asphalt Treated OGDL)	Southbound (Cement Treated OGDL)
4.0” OGDL on 3.0” Aggregate	4.0 feet	3.8 feet
5.0” OGDL	3.7 feet	3.7 feet
4.0” OGDL	3.9 feet	2.8 feet
Control (4” Lean Concrete)	2.7 feet	2.6 feet

There is a significant amount of surface grinding that was done to the surface of the driving and passing lanes in both directions. The underdrain outlets were open and flowing for each of the sections with only minor sediment accumulations noted. There has been no patching performed in any of the test or control sections.

The FWD data for these sections indicates that both the test and control sections have remained constant between 2.0 and 5.0 mils since the time of construction. The only exception to this is the 4-inch CTOGDL that is on 3 inches of aggregate material. The 1998 deflection for this section is approximately 7.0 mils. The FWD results and a two point moving average of the results for all the sections may be found in Figures 12 and 13.

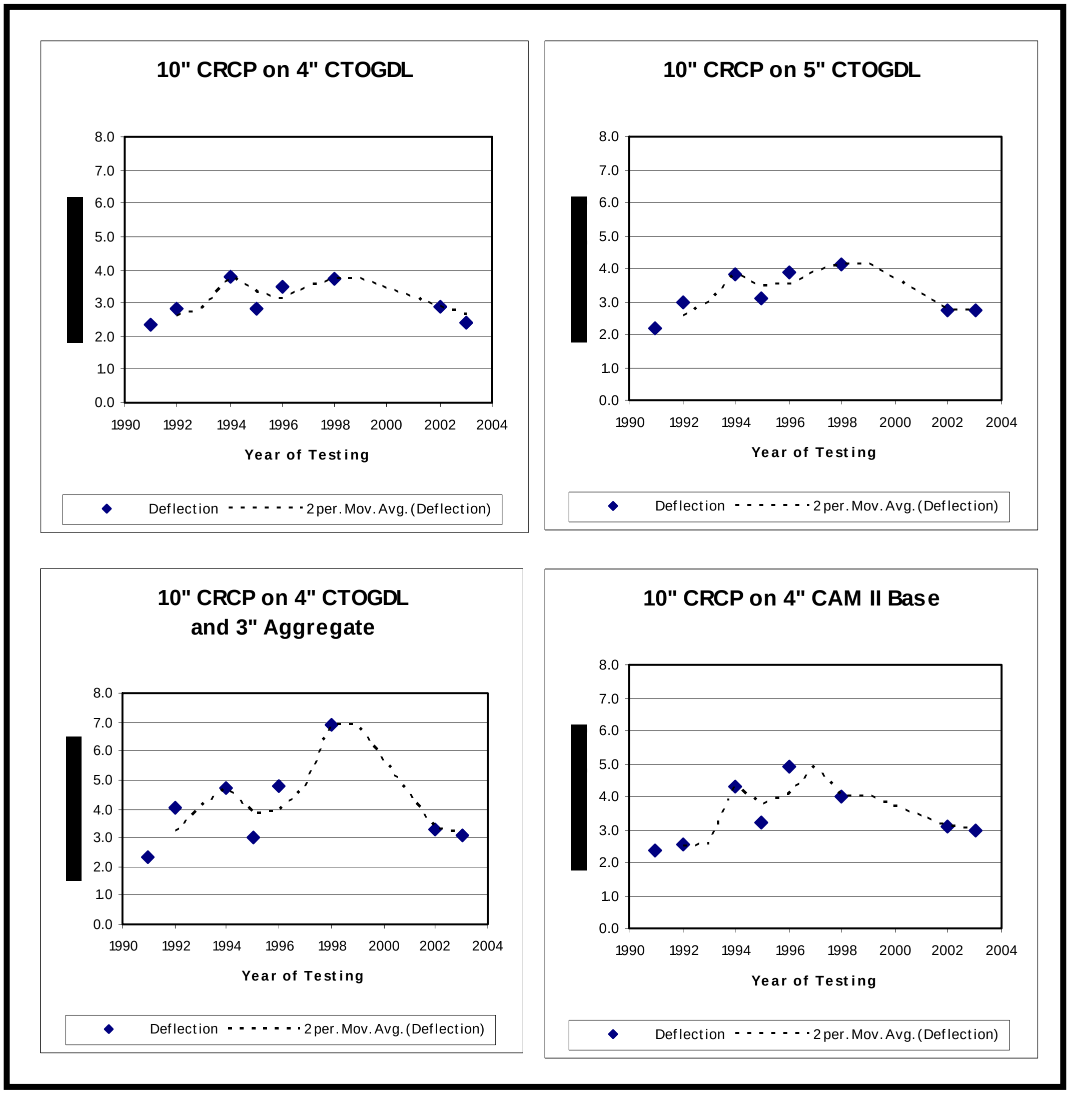


Figure 12

Average FWD Deflections of CTOGDL for I-39 at Lostant

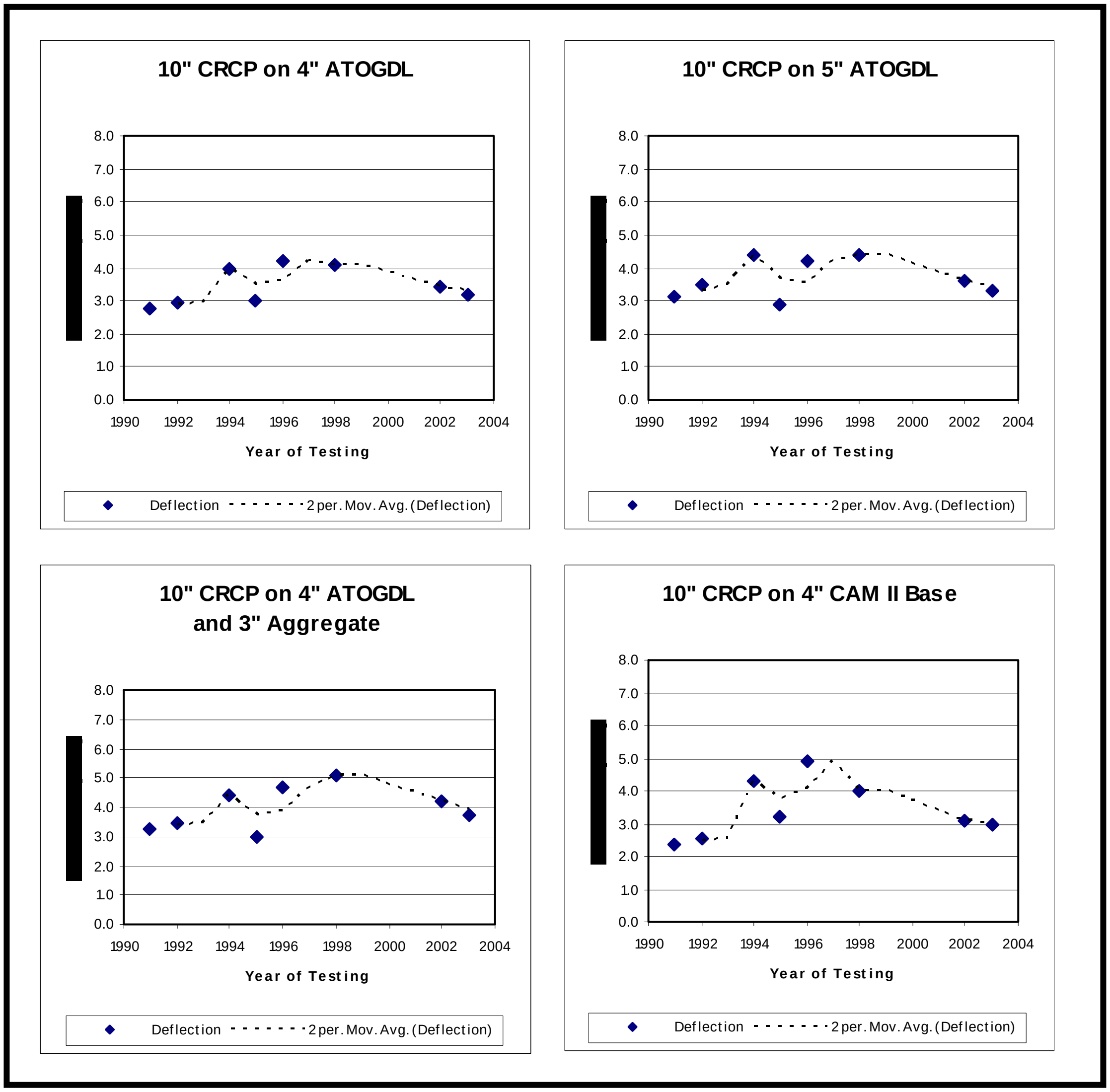


Figure 13

Average FWD Deflections of ATOGDL for I-39 at Lostant

The FWD results for these sections indicate that there is no significant difference between the CTOGDL, the ATOGDL, and the control section. The results also indicate that there is no significant difference based on the thickness of the OGDL, or the addition of an aggregate separation layer below the OGDL. The load transfer efficiency of the transverse cracks has also remained consistently above 90 percent for all of the test sections at Lostant. The FWD results for this project may be biased, however, due to the short length (500 feet) of the test sections.

The IRI data for these test and control sections indicates a wide variety of trends. The best performing (smoothest) sections are the 4- and 5-inch CTOGDL sections. The worst performing (roughest) sections are the 4-inch ATOGDL and 4-inch CTOGDL on aggregate material. Also, it is clearly shown that the 4- and 5-inch CTOGDL sections are smoother than the 4- and 5-inch ATOGDL sections. Finally, the ATOGDL sections tend to follow the statewide average IRI values, while the CTOGDL sections are well below the statewide average. The exception to this is the 4-inch CTOGDL on aggregate material section. Figure 14 on page 21 illustrates the IRI values for the various test and control sections.

The CRS data for this project is misleading due to the short length of the test sections. Individual CRS values were not determined for each test section. The CRS value was determined for the entire pavement project which encompassed several miles on either side of the experimental test locations. Therefore, the CRS values have not been included for this project.

INTERSTATE 39 AT EL PASO

The 1992 El Paso project on Interstate 39 is divided into two separate test sections. The northern section consists of a 10.0-inch CRC pavement over a 4.0-inch CTOGDL and lime modified soil. The southern section also consists of the 10.0-inch CRC pavement and 4.0-inch CTOGDL; however, there is a 3.0-inch aggregate separation layer present between the OGDL and the lime modified soil. Both test sections are approximately 4.5 miles in length, and there is no control section for this project.

Due to the extended length of this experimental project, random sections were selected for the 2003 visual distress survey. Eight 500-foot sections were selected for the pavement cross section with the aggregate separation layer beneath the OGDL. Ten 500-foot sections were selected for the pavement cross section with the OGDL placed directly on the lime modified soil.

Normal low severity transverse cracking was noted throughout all 18 of the surveyed continuously reinforced concrete pavement sections. No medium severity cracks were noted in any of the selected test sections, and no spalling at the transverse cracks was

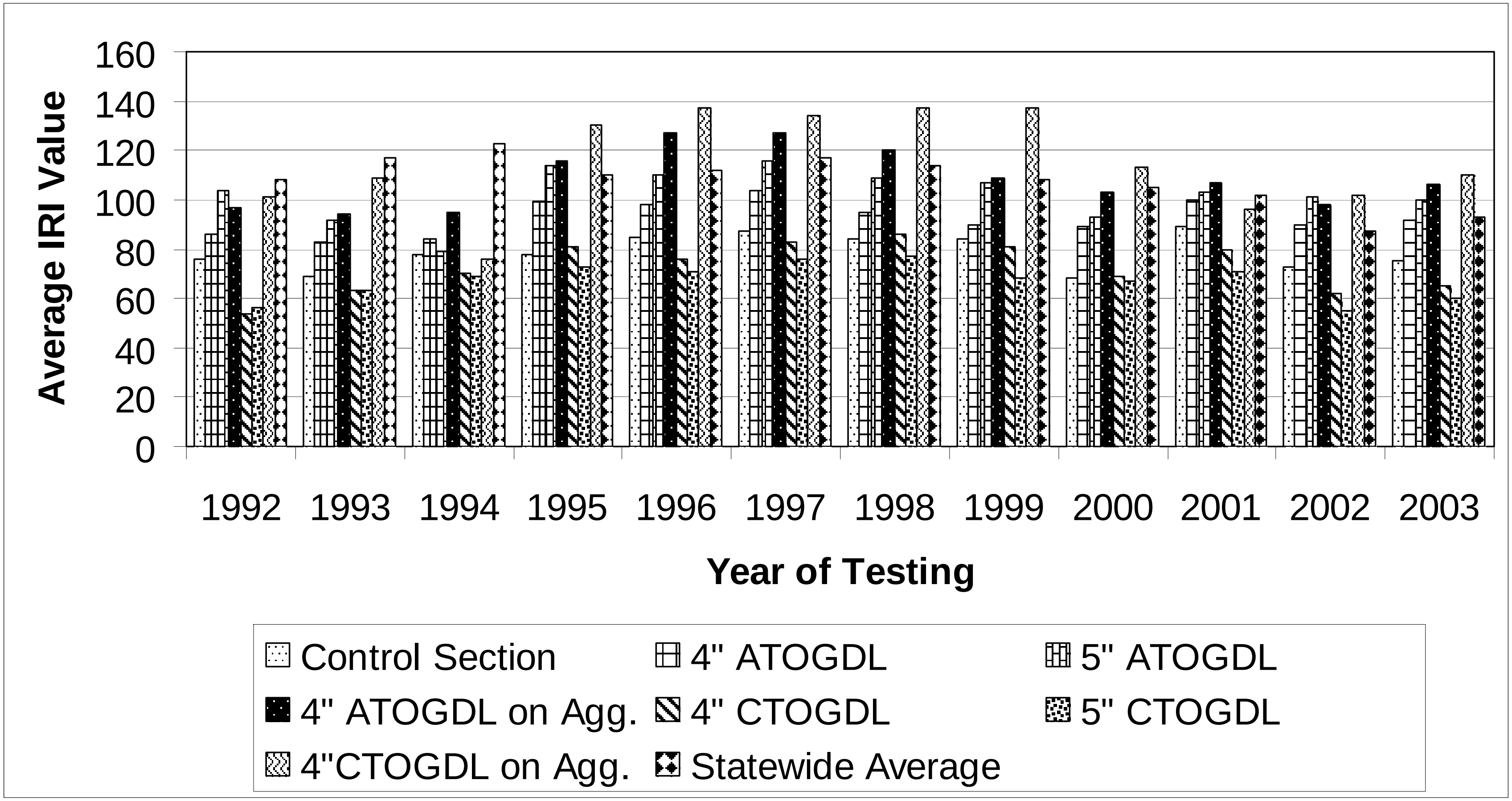


Figure 14
Average IRI Values for I-39 at Lostant

found. The figures in Table 4 indicate the average transverse crack spacing for the two different test pavement cross sections.

Table 4

Average Pavement Crack Spacing for I-39 at El Paso

Pavement Section	Northbound	Southbound
4” OGDL	3.9 feet	4.4 feet
4” OGDL on 3” Aggregate	5.3 feet	4.3 feet

Several areas of lane to shoulder settlement (lane lower than shoulder) were noted throughout the project; however, it was especially apparent in the southbound lanes of the OGDL placed directly on the lime modified soil. In 1999 the southbound lanes of this section were undersealed to try and correct this phenomenon. The undersealing process was designed to fill in the voids of the OGDL and prevent the settling of the pavement cross section into the subgrade. The process of undersealing the pavement also resulted in the filling of the median underdrain outlets. The underdrains on the outside of the pavement lanes were not filled and continue to function.

The FWD deflections for this project are relatively high for both of the test sections. There was no control section on this project, so no comparison can be made to standard construction practice. Figure 15 illustrates the average FWD deflections and a two point moving average for both the test sections. Comparison of the results indicates that the CTOGDL on the aggregate separation layer performed better than the CTOGDL placed directly on the modified subgrade. The reduction in deflection values that occurs after 1998 is due to the undersealing of the pavement and extensive patching efforts for both sections. The load transfer efficiency of the cracks has remained between 90 and 95 percent for the entire project even with the high deflections.

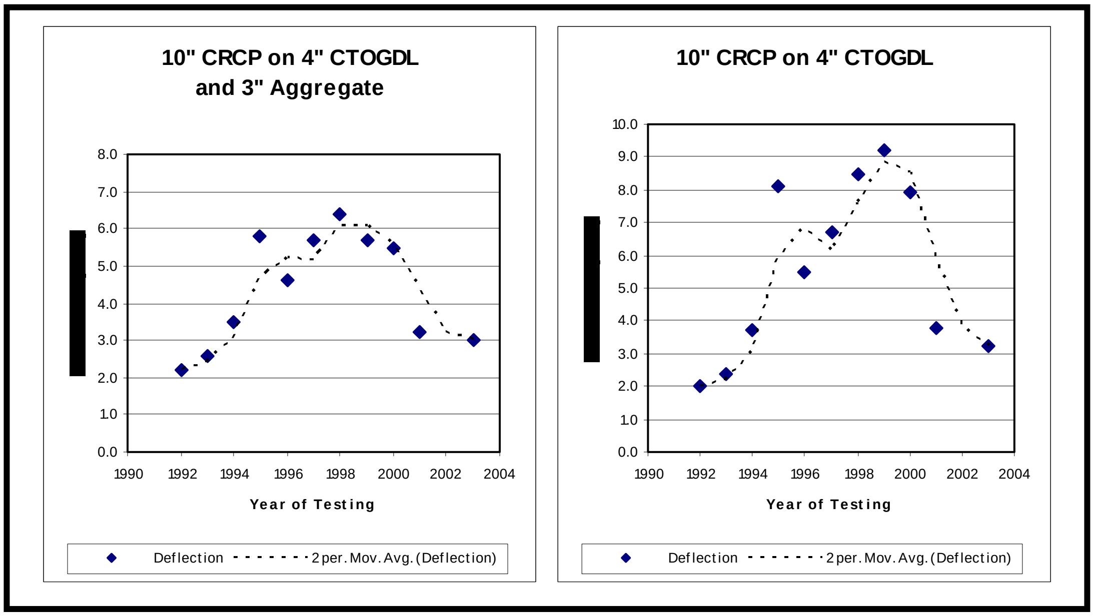


Figure 15

Average FWD Deflections for I-39 at El Paso

The average IRI values for this project indicate that both test sections were well below the statewide average after construction. This trend continued for most of the last eight years; however, in 2002 the average IRI for the test sections did surpass the statewide average. Additionally, the OGDL test section that was placed on the aggregate separation layer was less rough than the OGDL test section placed on lime modified soil in all years except 1992. Figure 16 below indicates the average IRI values for these test sections as well as the statewide average.

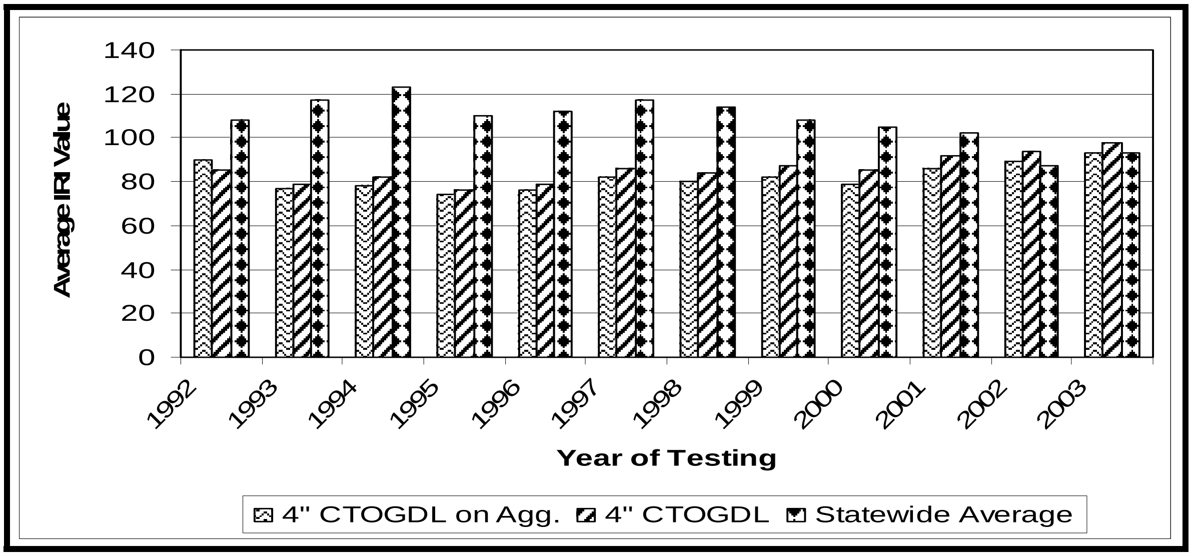


Figure 16

Average IRI Values for I-39 at El Paso

The CRS data for this project indicates a general decline in the overall condition of the pavement since construction. The decline of the CRS value has been very gradual, except for a large step down between 1994 and 1996. It was during this time frame that initial patches were placed and the lane to shoulder settlement was discovered. However, the project remained in the “Excellent” category for the first seven years of the 20-year design life. The CRS values given in Table 5 illustrate the rate of decline.

Table 5

CRS Values for I-39 at El Paso

	1994	1996	1998	2000	2002
Northbound CRS Value	8.9	8.2	8.0	7.6	7.4
Southbound CRS Value	8.9	8.3	8.0	7.6	7.4

ILLINOIS ROUTE 161

The experimental project on Illinois Route 161 is three miles in length, and is located in the westbound lanes only. There is no control section with this 1992 project. The first cross section for this project is a 14-inch HMA pavement on a 4-inch ATOGDL and lime modified soil. The second cross section includes all of the above items as well as a 3-inch aggregate separation layer between the OGDL and the lime modified soil. This second cross section encompasses the center mile of this three mile project.

The visual distress survey performed in 2003 revealed no major distress. There has been no patching and only minor maintenance activities performed on this project to date. The majority of the distress that was found included low severity block cracking and low severity longitudinal cracking at the centerline joint and the center of the driving lane. The underdrain outlets were open and free of debris or buildup.

The FWD deflections for this project are very consistent between the two test sections. There is no control section for this project, so no comparison can be made to standard construction practice. Figure 17 illustrates the average deflections and a two point moving average of the results for the two test sections.

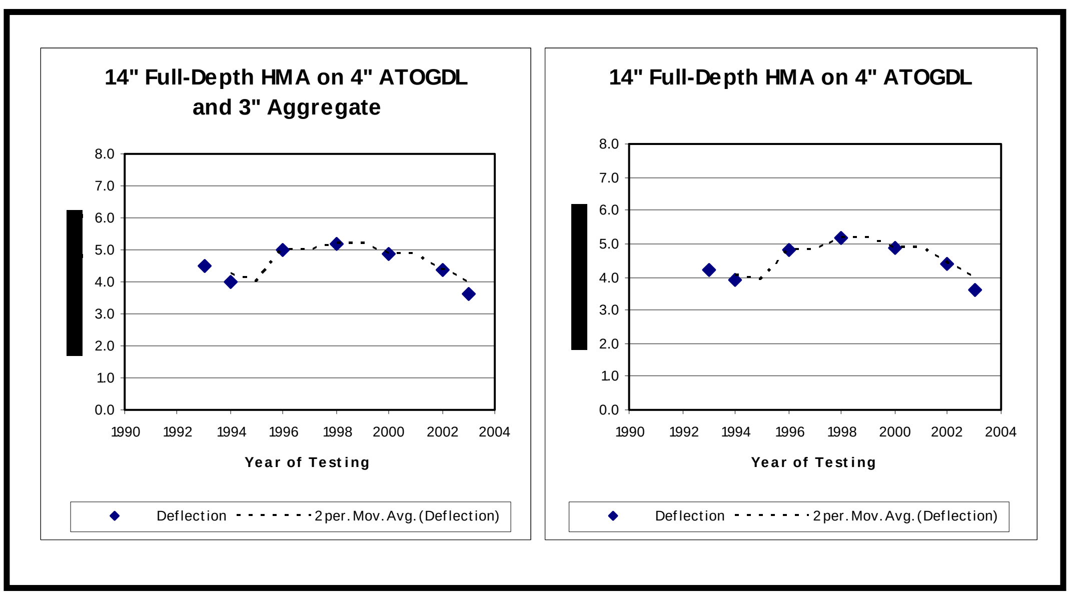


Figure 17

Average FWD Deflections for Illinois Route 161

The IRI data for this project was only collected during the even numbered years, as is standard for the state primary routes. Also, the IRI data was not separated for the two different pavement cross sections. The IRI data that is available indicates this project was constructed smooth and has remained smooth compared to the statewide average IRI values. This trend is displayed in the following figure, Figure 18.

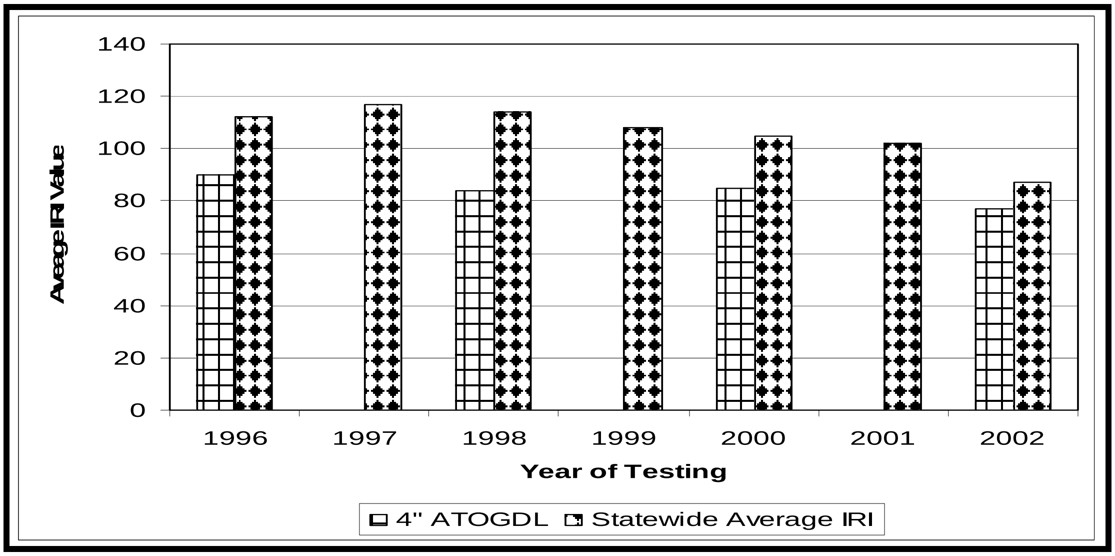


Figure 18

Average IRI Values for Illinois Route 161

The CRS data for this project was also collected for the same even numbered years. The CRS values have remained within the "Excellent" category since construction of the project. The values in Table 6 indicate the CRS values since 1996 and the very slow decline in the condition of the pavement.

Table 6

CRS Values for Illinois Route 161

Year	1996	1998	2000	2002
CRS Value	8.9	8.5	8.4	8.4

INTERSTATE 80

The Interstate 80 project was constructed in 1993 and incorporated the use of recycled concrete as the coarse aggregate in the OGDL. The project is approximately 6.5 miles in length and there is no control section with this project. A complete project location map may be found in Appendix A. The typical cross section for this project includes an 11.5-inch CRC pavement constructed over a 4-inch CTOGDL and lime modified soil.

Due to the extended length of this experimental project, random sections were selected for the 2003 visual distress survey. Six 500-foot sections were selected for both the eastbound and westbound directions.

The visual distress survey indicated normal, low severity, transverse cracking throughout all of the surveyed sections. However, in the westbound direction approximately 10 percent of the transverse cracks were moderate severity with between 10 and 50 percent of the joint spalled. The eastbound direction displayed approximately 20 percent moderate severity cracking. The average transverse crack spacing for the eastbound and westbound lanes may be found in Table 7. In addition to the transverse cracking, a pattern of regular longitudinal cracking was also noted in every section. The longitudinal cracking was spaced at approximately 3.0 feet across both the driving and passing lanes.

Table 7

Average Pavement Crack Spacing for I-80

Pavement Section	Eastbound	Westbound
4” CTOGDL	2.5 feet	3.2 feet

Approximately half of the underdrains in the westbound lanes were plugged with debris, and foreign materials. However, the eastbound underdrains were open and free of debris build up.

The average FWD deflections for this project jumped from 3.4 to 6.4 mils within the first year after construction. Due to the sudden increase in pavement deflection, the eastbound and westbound lanes were undersealed to arrest the deflection problems. The average FWD deflections showed an immediate response by dropping down to 5.0 mils within the next year. The general trend of the average deflections has continued to decrease since 1996. Figure 19 illustrates the sudden rise and decline of the average FWD deflections for this project. The load transfer efficiency of the cracks has remained between 90 and 95 percent for the entire project even with the high deflections.

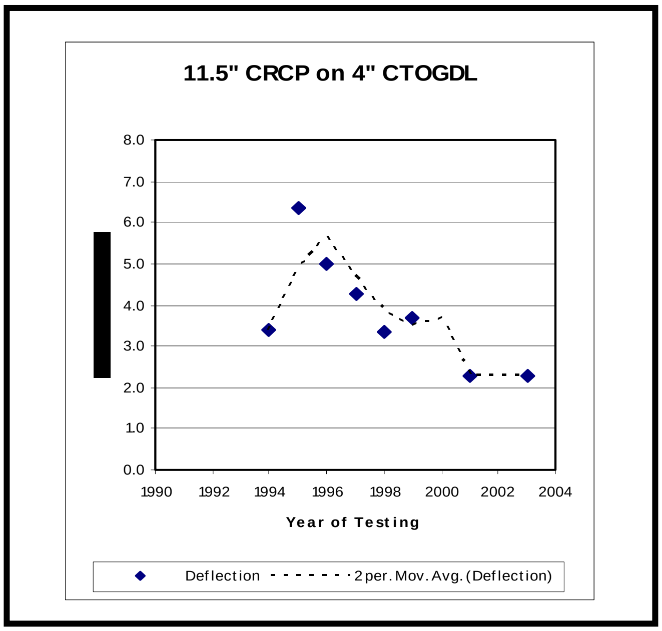


Figure 19

Average FWD Deflections for I-80

A side effect of the pavement undersealing has been the increase in transverse and longitudinal cracking of the pavement surface. The severity level for some of the transverse cracks has also increased since the undersealing was performed. The development of longitudinal cracks at a regularly spaced interval is alarming due to the potential formation of punchouts at the pavement edge. In addition, the combination of longitudinal and transverse cracks creates a grid pattern of small rectangular blocks across the pavement surface. These small blocks may begin to move independently and fail as the load transfer efficiency of the surrounding cracks is reduced.

Although the average FWD deflections quickly spiked after construction, the ride quality of this project has been very good since the time of construction. The average IRI values for this project started low, and have remained low, when compared to the statewide average. Only recently, has the average IRI value reached the level of the statewide average. This trend is displayed in Figure 20.

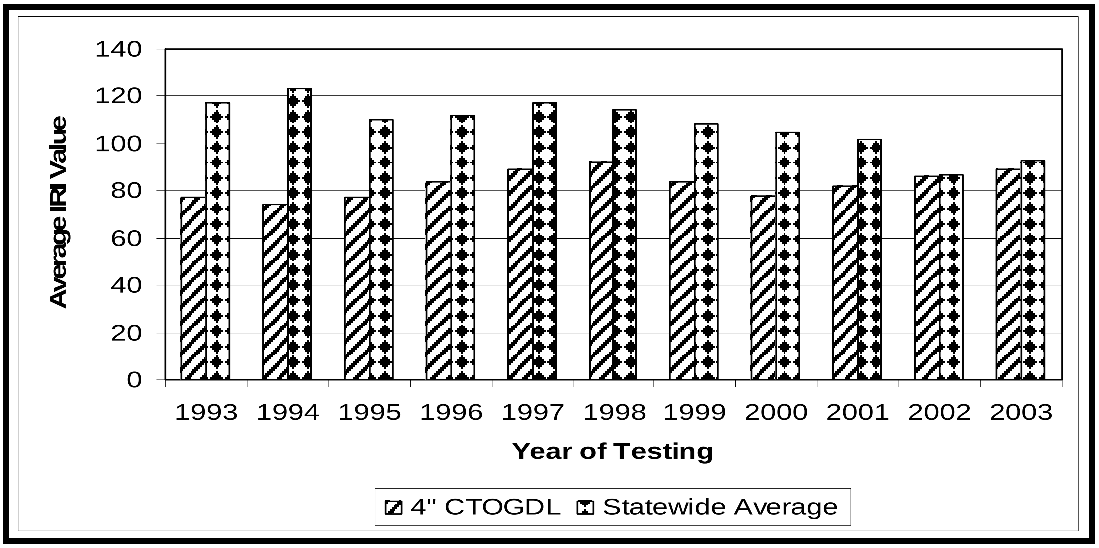


Figure 20

Average IRI Values for I-80

The CRS values for this project also made a sharp decline soon after construction was complete. The CRS value dropped from a perfect 9.0 to a 7.8 for both the eastbound and westbound lanes within the first two years after construction. However, after the large initial decline the CRS values stabilized and have only slightly declined in the last six years. Table 8 below displays the CRS value for both lanes since the time of construction.

Table 8

CRS Values for I-80

Year	1994	1996	1998	2000	2002
Eastbound CRS Value	9.0	7.8	7.7	7.3	7.0
Westbound CRS Value	9.0	7.8	7.7	7.3	7.0

MACON COUNTY HIGHWAY 1

The Macon County Highway 1 project was constructed in three stages between 1994 and 1997. The project is approximately three miles in length, and there is no control section. A complete project location map may be found in Appendix A. The typical cross section for this project consists of a 12-inch jointed reinforced concrete pavement. The doweled joint spacing is 40 feet, and the reinforcement includes a 6-inch by 12-inch welded wire fabric. The pavement was constructed over a 4-inch ATOGDL and a lime modified soil.

The visual distress survey performed in 2003 indicated that 99 percent of the 40-foot slabs had a mid-panel crack. Nine percent of those mid-panel cracks were considered medium severity. The remaining cracks were all low severity. Five percent of the mid-panel cracks had positive faulting of at least 0.25 inch and some low severity spalling. The doweled joints were in good condition with no spalling or faulting present. The design of jointed pavements with a 40-foot joint spacing has been abandoned since the time of this project. The current IDOT standard is to construct jointed pavements with a 15-foot joint spacing.

The FWD data for this project is limited. IDOT does not routinely test county highways for investigative FWD deflections, IRI, or CRS values. Figure 21 illustrates the data that is available and a two point moving average for the limited FWD deflection results. The data indicates that the average deflection has fluctuated between 4.0 and 7.0 mils. The majority of the average values fall within the 4.0 to 5.0 mils range, except for the spike value of 6.5 mils in 1999. This outlying average test value may be attributed to poor conditions during the actual testing, and a limited number of tests.

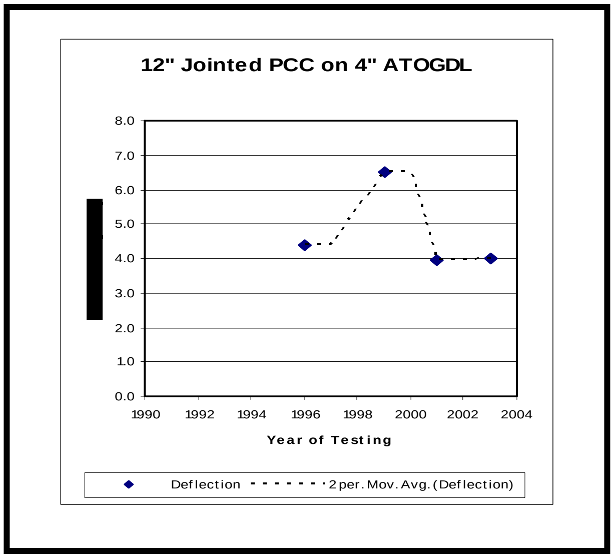


Figure 21

Average FWD Deflections for Macon County Highway 1

REHABILITATION AND MAINTENANCE

INTERSTATE 39 AT BLOOMINGTON

The 14 year old OGDL experimental project on Interstate 39 at Bloomington has received no rehabilitation or maintenance to date. The 2003 visual distress survey indicated three spalled joints, two transverse cracks, and approximately 50 percent of the joints with some degree of faulting. These items are not severe enough at this time to require maintenance activities. The survey of the control section indicated no joints with spalling or cracking, and only 10 percent of the joints with some degree of faulting. There has been no patching in either section.

The underdrain outlets at the median and outside shoulders are open and flowing as designed. There were some minor sediment accumulations at the underdrain outlets; however, it was not impeding the flow of water from the underdrain. Also, there was some vegetation growth around the underdrain outlets; however, this was trimmed with the annual mowing of the interstate shoulders and median.

INTERSTATE 39 AT LOSTANT

The 13 year old experimental project on Interstate 39 at Lostant has received no rehabilitation or maintenance to date. Only normal low severity transverse cracking of the CRC pavement was noted during the 2003 visual distress survey. The same observation was made for the control section on this project. Low severity, normal transverse cracking was noted throughout the section.

The underdrain outlets at the median and outside shoulders are open and flowing as designed. There were some minor sediment accumulations at the underdrain outlets; however, it was not impeding the flow of water from the underdrain. Also, there was some vegetation growth around the underdrain outlets. This was trimmed with the annual mowing of the interstate shoulders and median.

INTERSTATE 39 AT EL PASO

The experimental project on Interstate 39 at El Paso has had numerous rehabilitation and maintenance activities since construction in 1992. The 2003 visual distress survey indicated normal low severity transverse cracking throughout the surveyed sections. However, a review of the entire project length indicated extensive undersealing of the southbound lanes as well as numerous full-depth concrete patches. In addition, several areas of lane to shoulder settlement were noted.

In 1999 a large portion of the southbound lanes in the area of CTOGDL placed directly on lime modified subgrade was undersealed. The undersealing process was aimed at filling the voids of the OGDL to prevent further intrusion of the subgrade fines. At the same time, the undersealing was used to lift the pavement and correct the lane to shoulder settlement which had occurred in several areas. In all, nearly 2,300 square yards of pavement were undersealed in the southbound lanes, and 150 square yards in the northbound lanes. The pavement was raised an average of 0.80 inch, and as much as 1.75 inches in one location, to correct the settlement. One side effect to undersealing the pavement was the filling of the underdrain system and the outlets. Several of the median underdrain outlets of the southbound lanes were filled as shown in Figure 22. Ironically, the outside shoulder underdrain outlets at the same locations were not filled.

Figure 22

Sealed Median Underdrain Outlet on I-39 at El Paso

In addition to the undersealing, numerous full-depth concrete patches have been placed throughout the project in the driving lane. All of the patches for the entire project length were recorded as part of the 2003 visual distress survey. These patches were placed between the years of 1994 and 2002, with the majority of the patches placed in 2001. Figure 23 illustrates an area of the southbound lanes that has been patched several times.

Figure 23
Patching on I-39 at El Paso

The OGDL section placed on the 3-inch aggregate separation layer has had approximately 468 square yards patched, or roughly 0.42 percent of the total pavement area. The OGDL section placed directly on the lime modified subgrade has had approximately 2,240 square yards patched, or roughly 1.43 percent of the total pavement area. There are several areas within this OGDL section that have been patched and re-patched several times over the last eight years.

There was no control section constructed with this experimental project. Therefore, comparison cannot be made to a control section for this project, only comparison between the two different types of subbase.

ILLINOIS ROUTE 161

The 11 year old experimental project on Illinois Route 161 has experienced only minor maintenance activities. Maintenance activities included routing and sealing of some longitudinal and transverse cracks. The longitudinal cracking occurred predominantly at the centerline joint and at the center of the driving lane. The crack at the center of the lane may be attributed to the location of the gear box on the screed of the paving machine during construction. The transverse cracking was very infrequent and low severity in nature where it did occur.

The underdrain outlets at the outside shoulder are open and flowing as designed. There was no sediment accumulation at the underdrain outlets.

There was no control section constructed with this experimental project. The overlay of the adjacent eastbound lanes exhibited similar distresses and received the same maintenance activities as the experimental sections.

INTERSTATE 80

The experimental project on Interstate 80 has had numerous rehabilitation and maintenance activities since construction in 1993. The 2003 visual distress survey indicated normal low severity transverse cracking as well as 10 and 20 percent moderate severity transverse cracking for the westbound and eastbound lanes, respectively. The entire project length in the eastbound lanes has been undersealed, as well as several areas of the westbound lanes. There was no evidence of broken steel, faulting, or pavement settlement noted during the survey.

In 1995, a small portion of the pavement at the east end of the project was undersealed in both directions to reduce the chance of pavement failures under two-way traffic during an adjacent construction project. Based on FWD deflection improvements for these areas, the entire eastbound direction was undersealed in 1996. At the same time, specific areas of high deflection in the westbound direction, as determined by FWD analysis, were also undersealed.

In addition to the undersealing, several full-depth concrete patches have been placed throughout the project. All of the patches for the entire project length were recorded as part of the 2003 visual distress survey. The westbound lanes have had approximately 35 square yards patched, or merely 0.04 percent of the total westbound pavement area. The eastbound lanes have had approximately 309 square yards patched, or roughly 0.35 percent of the total eastbound pavement area. Figure 24 illustrates a bituminous patch that has been placed within an area of depression in the eastbound driving lane. Lane-to-shoulder and lane-to-lane settlement was noted at this area during the final distress survey.

Figure 24
Bituminous Patch on I-80

There was no control section constructed with this experimental project. Comparisons to a typical pavement cross section of the same age are not available for this project in this geographic area.

MACON COUNTY HIGHWAY 1

The 9 year old project constructed on Macon County Highway 1 has had no maintenance or rehabilitation work completed since construction. Mid-panel cracking of the 40-foot slabs, as well as some minor spalling and faulting of the cracks and joints were noted during the 2003 visual distress survey. The majority of these cracks and spalls do not require maintenance attention at this time. Approximately 10 percent of the cracks were considered medium severity and will require attention in the near future.

There are no underdrains on this project for inspection due to the curb and gutter configuration. The gutter drop inlets were open and free of debris build up.

There was no control section constructed with this experimental project. Again, there is not a typical pavement cross section of the same age within this geographic area that comparisons can be made too.

MODES OF FAILURE

The poor performance of the projects on Interstate 39 at El Paso and Interstate 80 has presented many questions about the modes of failure for a pavement cross section with an OGDL. More specifically, questions have surfaced about the performance of an OGDL under a CRC pavement. The isolation of one cause for the poor performance is not possible. It is believed that the combination of several small contributing factors has led to the poor performance on these two projects.

One of the largest known contributing factors to failure is the infiltration of fines into the OGDL, or the settlement of the OGDL into the subgrade. The most common practice of subgrade preparation in Illinois is lime modification. Dry, by-product or hydrated, lime is added and worked into the soil with a disc at the optimum moisture content. The modified soil is then compacted and trimmed to the proper grade. This modified soil provides a good stable platform on which to construct the new pavement. However, questions remain about the longevity of the lime modification to the subgrade soils.

Continuous exposure to a wet environment, either through surface water runoff or the presence of a high ground water elevation, will alter the lime modified soil. Eventually, the presence of water and the working action of traffic loads will move the subgrade fines either into the OGDL or out from under the pavement structure. This is especially true in extremely wet areas and areas with a soil composition that is not highly reactive with the lime modification.

Core samples and Shelby tube samples were taken from failed areas of Interstate 80. The core samples revealed that subgrade fines were indeed migrating up and into the OGDL. The Shelby tube soil samples were tested for pH and the results indicated that the lime was not reacting with the subgrade soils. Samples were also taken from the area of Interstate 39 at El Paso with the aggregate separation layer. Cores in this area indicated that the subgrade fines were also infiltrating the aggregate separation layer beneath the OGDL.

In order for the subgrade fines to migrate up and into the OGDL, or aggregate separation layer, there needs to be a carrier such as water. The objective of the OGDL is to move water quickly and effectively to the underdrain system and away from the pavement substructure. Tipping bucket results from earlier research (2) indicated that the OGDL does effectively move water. However, results also indicated that the OGDL did not move the water as fast as the control sections did. In fact, it is reasonable to believe that the "open" structure of the OGDL actually traps more water and holds it within the pavement substructure for longer amounts of time than a dense graded or stabilized subbase. The trapping and extended duration of water exposure provides the means for migration of the subgrade fines.

A second mode of failure is centered on the bond between the pavement and the open graded drainage layer. The pavement design for the Interstate 39 and 80 projects details a CRC pavement constructed on top of the OGDL. The assumption is that the pavement will not fully bond to the underlying OGDL due to the cold joint that is formed from different paving dates. However, the "open" surface structure of the open graded drainage layer allows for the fresh pavement concrete to flow down and into some of the voids within the OGDL. The core samples pulled from the pavement surface, and all of the patching work that has been done on both projects, revealed that the OGDL was fully bonded to the underside of the pavement. Therefore, the design of a CRC pavement on top of the OGDL became a full-depth CRC pavement constructed on a lime modified soil.

The third suspected mode of failure is a side effect of the bonding between the open graded drainage layer and the pavement. The bond of the OGDL and the pavement simulates a full-depth pavement, which in turn changes the depth of steel placement and the effective percentage of steel for a CRC pavement. The CRC pavement is designed to perform independently of any supporting layer.

In Illinois, the longitudinal steel is typically placed at a depth of 3.0 inches for pavements 8.0 inches or less in thickness, and at a depth of 3.5 inches for pavements greater than 8.0 inches. The CRC pavement design thickness for Interstate 39 was 10.0 inches and 11.5 inches for Interstate 80. The combined pavement thickness with the OGDL for the Interstate 39 project was 14.0 inches, and for the Interstate 80 project was 15.5 inches. The general effects of steel placement include the quantity and severity of transverse cracks in the pavement surface. Placing the steel low in the pavement cross section will result in fewer cracks, however the crack opening will be increased. Placing the steel high in the pavement cross section will result in more cracks, however the crack opening will be reduced. The optimum crack spacing for a continuously reinforced concrete pavement is between three and five feet. A short crack spacing will eventually lead to poor load transfer and punchouts. The visual distress surveys of both projects indicate a crack spacing in areas that is below three feet.

The percentage of steel in the pavement cross section of a continuously reinforced concrete pavement also plays a role in the pavement performance. The longitudinal steel works to control the width and spacing of transverse cracks as they appear. IDOT design standards indicate a minimum steel percentage of 0.70 percent for CRC pavements. The Interstate 39 and Interstate 80 projects were both designed with 0.70 percent longitudinal steel. However, if the OGDL was fully bonded to the pavement during construction, the Interstate 39 and Interstate 80 steel percentages effectively become 0.51 percent. The reduction in steel percentage allows for the severity of the cracks that do develop to increase rapidly.

MATERIAL COSTS

The cost effectiveness of any experimental material is a major factor in the decision to continue using the material. The experimental material must be able to perform as specified, while at the same time be economical to the construction industry. The material cost must be comparable to the current alternative, or the superior performance must outweigh any additional cost when compared to current alternatives.

The figures in Table 9 outline the costs for furnishing and placing the OGDLs on five of the six projects. Material costs were not available for the Macon County Highway 1 project.

Table 9

Material Costs for Open Graded Drainage Layers

Project	Pay Item	Quantity (sq. yds.)	Unit Price
Interstate 39 at Bloomington	CT OGDL 6"	4,500	$11.24
	Stabilized Subbase 4"	142,561	$4.25
Interstate 39 at Lostant	ATOGDL 4"	8,975	$7.17
	ATOGDL 5"	4,578	$8.15
	CTOGDL 4"	8,975	$4.10
	CTOGDL 5"	4,578	$4.88
	Aggregate Separation Layer	8,680	$1.54
	Stabilized Subbase 4"	396,950	$3.45
Illinois Route 161	ATOGDL 4"	87,151	$7.05
	Aggregate Separation Layer	27,632	$2.50
	Lime Modified Soil 12"	101,614	$1.60
Interstate 39 at El Paso	CTOGDL 4"	441,533	$5.16
	Aggregate Separation Layer	169,184	$2.18
Interstate 80	CTOGDL 4"	299,282	$3.33
	Lime Modified Soil 12"	306,572	$1.00

Several observations can be made from the values presented in Table 9. First, the unit price for an ATOGDL is typically higher than for a CTOGDL. This relationship is expected, as the price for a unit of asphalt cement is typically higher than for a unit of portland cement. In addition, the procedure for production of an ATOGDL is more complex than for a CTOGDL.

Second, the unit price for the materials decreased as more projects were completed and more construction knowledge was gained. In addition, the unit price decreased as the quantity of the material placed increased. This is especially true for the CTOGDL projects.

Finally, the price of an OGDL is typically higher than the price of a stabilized subbase, and much higher than the price for lime modification of subgrade soils. A stabilized subbase or lime modified subgrade currently are the accepted construction platforms for both portland cement concrete and HMA pavements.

TRAFFIC VOLUMES

The successful performance of any pavement cross section is ultimately dependent on two variables, the environment and traffic loading. The OGDLs constructed in Illinois cover a wide range of values for both variables, especially traffic loading. The extreme cases are Interstate 80 on the high end of the scale, and Illinois Route 161 on the low end of the scale.

The tables presented below represent the estimated traffic loadings for each project based on actual traffic counts taken at various times. The highlighted rows in each table represent the years in which an actual traffic count was performed and Equivalent Single Axle Loading (ESAL) values were calculated. The remaining values were interpolated based on the actual traffic data.

The 18-kip ESAL for each year, expressed in millions, has been calculated using the following equations for rigid and flexible pavement design. The cumulative ESAL value for each project through the end of 2002 is also presented.

Rigid Pavement Design (5)

$$TF = DP\left(\frac{(0.15 * P * PV) + (143.81 * S * SU) + (696.42 * M * MU)}{1{,}000{,}000}\right)$$

Flexible Pavement Design (5)

$$TF = DP\left(\frac{(0.15 * P * PV) + (132.50 * S * SU) + (482.53 * M * MU)}{1{,}000{,}000}\right)$$

Where:

TF = Traffic Factor (18-kip ESAL expressed in millions)

DP = Design Period (Equals 1.0 for this calculation)

P, S, M = percent of PV, SU, and MU vehicles in the design lane expressed as a decimal

PV, SU, MU = structural design traffic expressed as the number of Passenger Vehicles, Single Unit vehicles, and Multiple Unit vehicles.

Interstate 39 was constructed in multiple sections along the existing alignment of U.S. Highway 51 from Bloomington to Rockford. Therefore, some of the early traffic figures for the projects on Interstate 39 may have been taken from traffic counts on U.S. Highway 51. The following tables, Tables 10, 11, and 12, represent the traffic and ESAL calculations for the three projects constructed on Interstate 39.

Table 10

Traffic Volumes for I-39 at Bloomington

Year	ADT	SU	MU	PV	Year's ESALs	Cum. ESALs
1990	10350	120	500	9730	0.16	0.16
1991	10100	125	450	9525	0.15	0.31
1992	12350	130	570	11650	0.19	0.50
1993	14400	285	1265	12850	0.42	0.91
1994	15500	440	1950	13110	0.64	1.55
1995	16600	595	2650	13355	0.87	2.42
1996	17300	750	3350	13200	1.10	3.52
1997	18000	840	3750	13410	1.23	4.75
1998	18800	925	4125	13750	1.35	6.10
1999	19600	1010	4500	14090	1.48	7.58
2000	20500	1100	4900	14500	1.61	9.19
2001	21400	1000	5400	15000	1.76	10.95
2002	22200	1050	5950	15200	1.93	12.88

Table 11

Traffic Volumes for I-39 at Lostant

Year	ADT	SU	MU	PV	Year's ESALs	Cum. ESALs
1991	8200	335	2400	5465	0.77	0.77
1992	9900	370	2630	6900	0.85	1.62
1993	11600	410	2915	8275	0.94	2.56
1994	12950	450	3200	9300	1.03	3.59
1995	14300	490	3485	10325	1.12	4.72
1996	15250	530	3770	10950	1.22	5.93
1997	16200	600	4275	11325	1.38	7.31
1998	17150	670	4780	11700	1.54	8.85
1999	18100	740	5285	12075	1.70	10.56
2000	17950	810	5790	11350	1.87	12.43
2001	17800	800	5700	11300	1.84	14.26
2002	17500	780	5600	11120	1.81	16.07

Table 12

Traffic Volumes for I-39 at El Paso

Year	ADT	SU	MU	PV	Year's ESALs	Cum. ESALs
1993	11500	365	2885	8250	0.93	0.93
1994	12725	400	3150	9175	1.01	1.94
1995	13950	435	3415	10100	1.10	3.04
1996	14775	470	3680	10625	1.18	4.23
1997	15600	510	4010	11080	1.29	5.52
1998	16000	555	4340	11105	1.40	6.91
1999	16400	595	4670	11135	1.50	8.42
2000	17025	640	5010	11375	1.61	10.03
2001	17650	700	5500	11450	1.77	11.80
2002	18250	750	6025	11475	1.94	13.73

As can be seen from the tables, the cumulative 18-kip ESALs for each of the projects is very near the same. In addition, it should be noted that the 10-year cumulative ESAL values are low for an interstate facility in Illinois. The good performance of the projects at Bloomington and Lostant can be attributed, in part, to the low traffic volumes.

The project constructed on Illinois Route 161 between Fairview Heights and Belleville is an urban section. This four-lane facility predominately carries passenger vehicles and a few light trucks. Table 13 summarizes the traffic volumes for this project. The ESAL values in Table 13 indicate very light traffic on this facility. The low ESAL volume has aided in the excellent performance of this project.

Table 13

Traffic Volumes for Illinois Route 161

Year	ADT	SU	MU	PV	Year's ESALs	Cum. ESALs
1994	16150	410	160	15580	0.06	0.06
1995	17900	420	170	17310	0.06	0.12
1996	18800	430	170	18200	0.06	0.19
1997	19700	610	240	18850	0.09	0.28
1998	20250	790	310	19150	0.12	0.39
1999	20800	970	380	19450	0.14	0.53
2000	19150	1140	460	17550	0.17	0.70
2001	17500	500	200	16800	0.07	0.77
2002	16600	450	180	15970	0.07	0.84

Interstate 80 is a major east-west shipping and travel route across northern Illinois. The OGDL project on Interstate 80 has carried more ESALs in a shorter amount of time than any of the other OGDL projects. This rural section of interstate has averaged more than two million ESALs per year over the life of the project. Table 14 below illustrates the traffic volumes for the project. These extremely high traffic volumes have contributed to the early problems and poor performance of this project.

Table 14

Traffic Volumes for I-80

Year	ADT	SU	MU	PV	Year's ESALs	Cum. ESALs
1994	19550	1400	5600	12550	1.85	1.85
1995	20300	1420	5680	13200	1.87	3.72
1996	21050	1440	5760	13850	1.90	5.62
1997	22000	1610	6440	13950	2.12	7.74
1998	22900	1780	7120	14000	2.35	10.09
1999	23800	1950	7800	14050	2.57	12.66
2000	24350	2120	8480	13750	2.80	15.46
2001	24900	1600	7900	15400	2.58	18.04
2002	25500	1750	7000	16750	2.31	20.35

The project on Macon County Highway 1 has a surprising amount of traffic, especially tractor-trailer traffic, due to the ADM facility. This highway project was constructed over the course of three years, however the traffic values have been given since the completion of the first section. The high number of tractor-trailers has resulted in an average annual ESAL value of nearly one million. Table 15 outlines the traffic volumes for the Macon County Highway 1 project.

Table 15

Traffic Volumes for Macon County Highway 1

Year	ADT	SU	MU	PV	Year's ESALs	Cum. ESALs
1995	9100	200	2300	6600	0.73	0.73
1996	9000	200	2375	6425	0.76	1.49
1997	8900	210	2450	6240	0.78	2.27
1998	8700	220	2525	5955	0.81	3.08
1999	8500	220	2600	5680	0.83	3.90
2000	8800	230	2675	5895	0.85	4.76
2001	10000	240	2760	7000	0.88	5.64
2002	11500	280	2900	8320	0.93	6.57

SUMMARY

The Illinois Department of Transportation experimented with the use of an OGDL as part of the pavement cross section during the late 1980's and early 1990's. Two experimental projects and two demonstration projects were constructed to monitor the construction and early performance of the drainage layer. The two experimental projects were constructed on Interstate 39 at Bloomington and Lostant. Both projects are short in length, and the Lostant project compares the two types of OGDLs in different configurations. The first demonstration project was constructed on Interstate 39 near El Paso with a CTOGDL. The second demonstration project was constructed on Illinois Route 161 near Fairview Heights with an ATOGDL.

Based on the initial performance of these projects, five additional projects were constructed throughout the state. Two of these projects were monitored as part of this research, while the remaining three were non-highway related applications. The first monitored project was constructed on Interstate 80 near Morris with a CTOGDL. The second project was constructed on Macon County Highway 1 near Decatur with an ATOGDL.

Performance monitoring was continued through the fall of 2003 for these projects. Monitoring included visual distress surveys, FWD testing, IRI values, and CRS values. A final visual distress survey was conducted for each project in 2003. The entire project was surveyed for the shorter projects, and random test sections were selected for the longer projects. Normal low severity distresses were recorded for the majority of the projects. Moderate severity distress was noted on the Interstate 80 and Macon County Highway 1 projects. Patch quantities were recorded for the Interstate 39 at El Paso and Interstate 80 projects.

FWD testing was conducted on a routine basis for the majority of the projects. Deflection trends for the Interstate 39 at Bloomington and Lostant, Illinois Route 161, and Macon County Highway 1 projects have been consistent and steady since the time of construction. Deflection trends for the Interstate 39 at El Paso and Interstate 80 projects both spiked shortly after construction. Maintenance activities and some minor rehabilitation have corrected the deflection problems.

Annual testing for IRI was conducted on the interstate projects, and biennially for the project on Illinois Route 161. The same general trend was common among all of the projects. The projects were constructed very smooth when compared to the statewide average; however, as time and traffic impacted the projects the IRI values have slowly risen to the level of the statewide average and slightly beyond.

The CRS value was compounded every two years for all of the projects except Interstate 39 at Lostant and Macon County Highway 1. The project on Illinois Route 161 has remained in the "Excellent" category since construction. The projects on Interstate 39 at Bloomington and El Paso have gradually declined since construction, but both still remain in the top of the "Satisfactory" category. The project on Interstate 80 quickly declined after construction, but with the undersealing and patching efforts, the pavement remains in the "Satisfactory" category.

The CRC pavements for the Interstate 39 at El Paso and Interstate 80 projects both experienced problems shortly after construction. Relatively high FWD test results and physical evidence of pavement settlement were observed. Pavement undersealing was used to arrest the pavement settlement and correct the pavement profile. Areas with moderate to severe distress were patched with full-depth concrete patches. Repeat patching operations have continued for both of these projects. Based on the poor performance of these two projects, a moratorium on the construction of OGDLs under state maintained highways was issued in January of 1996.

There are several contributing factors to the premature failure of these two interstate projects. The largest contributor to the pavement failure was the intrusion of subgrade fines into the pore structure of the OGDL. In conjunction with this process were the pavement settlement and the increased pavement deflections. Material testing indicated the presence of silty soils that were non-reactive to the lime modification process.

Another contributing factor was the unexpected bond between the OGDL and the CRC pavement. The open structure of the OGDL allowed for the plastic concrete to filter in and permanently bond to the OGDL. The side effects of this bond include a decreased effective steel percentage and a variation in the design steel placement depth. The decreased steel percentage for the pavement cross section decreases the CRC crack spacing. The unexpected high steel placement also decreases the CRC crack spacing resulting in low severity cracks at the surface and higher severity cracks at the bottom of the pavement cross section.

The material costs were also evaluated as part of the research. In general, the bid price for a unit of ATOGDL is more expensive than the same unit of CTOGDL. Also, the bid price for OGDL materials was significantly higher than the prices for stabilized subbase and lime modification of subgrade soils.

Finally, the traffic volumes and ESAL quantities for all of the projects was collected and analyzed for the life of each project to date. Very low ESAL quantities were noted for the urbanized project on Illinois Route 161. Typical traffic and ESAL volumes were recorded for the three projects on Interstate 39. Higher than normal volumes were recorded for the Macon County Highway 1 project, and very high ESAL volumes were noted on the Interstate 80 project.

CONCLUSIONS

Nine experimental projects with an OGDL were constructed in Illinois to investigate the use and effectiveness of the OGDL as a pavement substructure drainage material. Six of these nine were monitored periodically since the time of their construction. The remaining three projects were not pavement related, and therefore were not evaluated. Of the six, three used a CTOGDL, two used an ATOGDL, and one project used both materials. Also of those six, three of the projects were constructed on a lime modified subgrade; and the remaining three were constructed over sections of lime modified subgrade with an aggregate separation layer.

The following conclusions were made after monitoring the construction and performance of these OGDL projects:

1) The use of an OGDL is more expensive than the use of a standard stabilized base material or lime modified soil.

2) The intrusion of fines from the subgrade and the aggregate separation layer into the OGDL resulted in settlement, faulting, and eventually premature failure.

3) An unexpected permanent bond between the CRC pavement and the OGDL, which reduced the steel depth with regards to the total pavement cross section, and reduced the effective steel percentage within the pavement aided in the premature CRC pavement failures.

4) The benefits of using either type of OGDL (cement treated or asphalt treated) over the other could not clearly be determined.

5) The limited benefits of using an OGDL do not outweigh the increased costs, construction difficulties, and maintenance requirements on CRC pavements.

RECOMMENDATIONS

The following recommendations are made concerning the construction and performance of OGDLs:

1) It is recommended to properly select projects for use of an OGDL. Consideration should be given to subgrade soil analysis, topography and surface drainage, and pavement type.

2) The use of an OGDL under a CRC pavement is not recommended.

3) The use of a geotextile fabric or dense graded aggregate filter under the OGDL to prevent the intrusion of subgrade fines is recommended.

4) The use of an autograde machine for placement of a CTOGDL is recommended due to the coarse texture of the mixture.

5) The use of a bond breaker between a CTOGDL and a concrete pavement is recommended.

REFERENCES

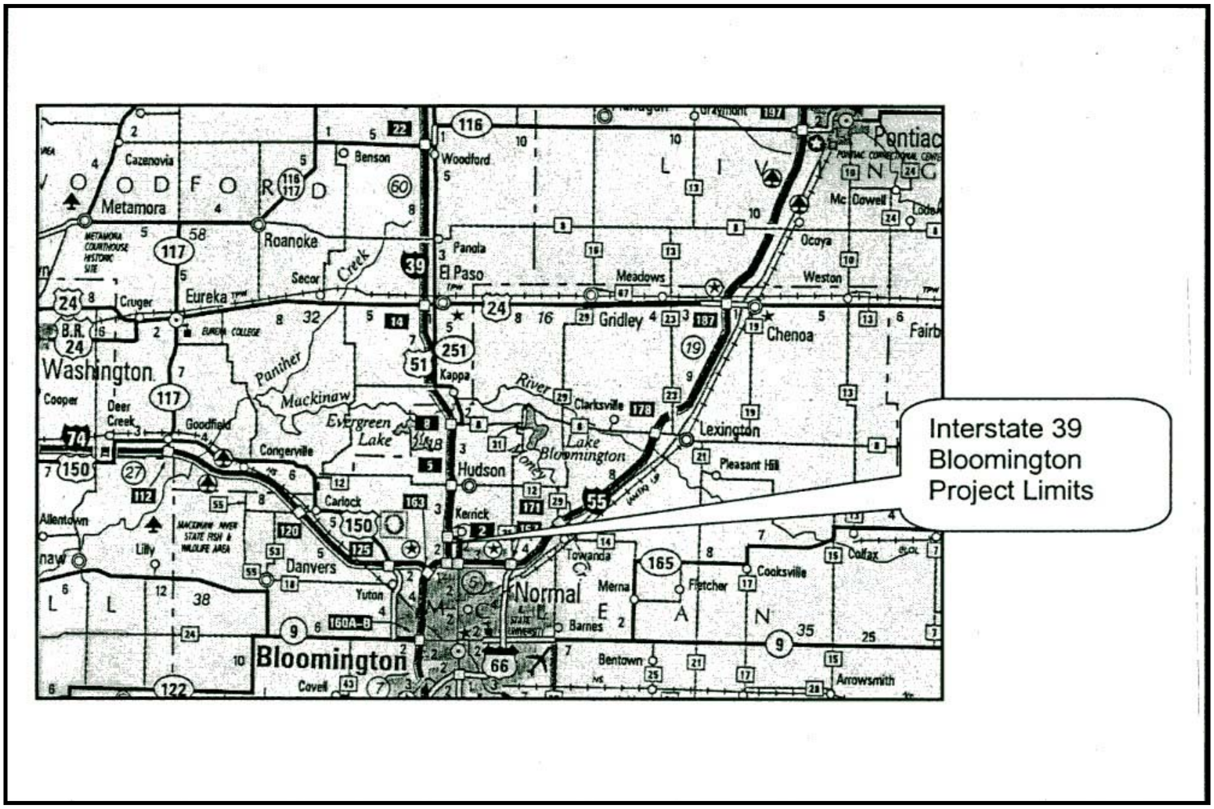
1. Herubin, C.A., Marotta, T.W., “Basic Construction Materials,” Fifth Edition, Prentice-Hall Inc., Copyright 1997, Page 45, Figure 2-16.
2. Reed, C.M., “Design and Construction of Open-Graded Base Courses,” Physical Research Report No. 114, Illinois Department of Transportation, 1993.
3. Byrd, B., Macon County Highway Engineer, 2003.
4. Strategic Highway Research Program, “Distress Identification Manual for the Long-Term Pavement Performance Project, Stategic Highway Research Program, Publication No. SHRP-P-338, Washington, D.C., 1993.
5. Illinois Department of Transportation, Bureau of Design and Environment, Pavement Design Manual, November 1999.

APPENDIX
A

PROJECT LOCATION
MAPS

Interstate 39 at Bloomington

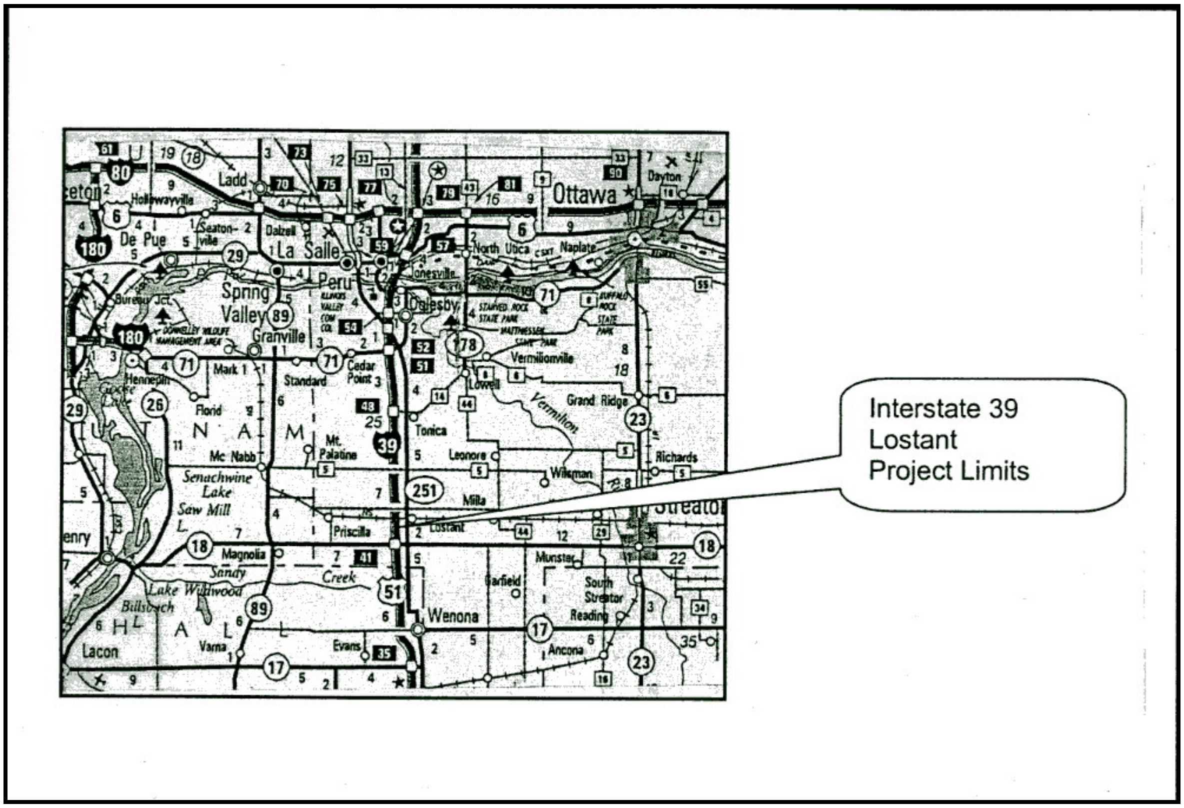
Project Location



This project is located on Interstate 39 just north of Bloomington-Normal. The experimental sections are located in the northbound lanes between mileposts 2 and 3.

Interstate 39 at Lostant

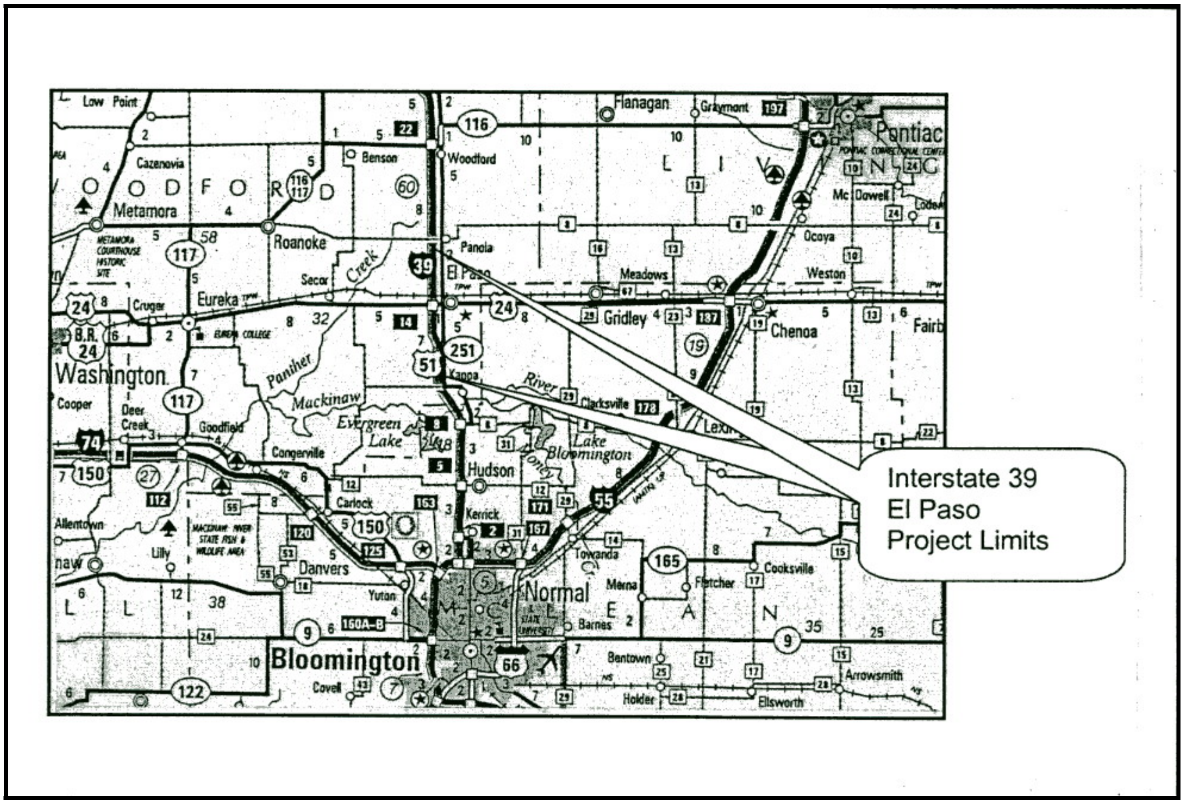
Project Location



This project is located on Interstate 39 just north of the intersection between Interstate 39 and Illinois Route 18, near Lostant. The experimental sections are located in the northbound and southbound lanes between mileposts 41.9 and 42.5.

Interstate 39 at El Paso

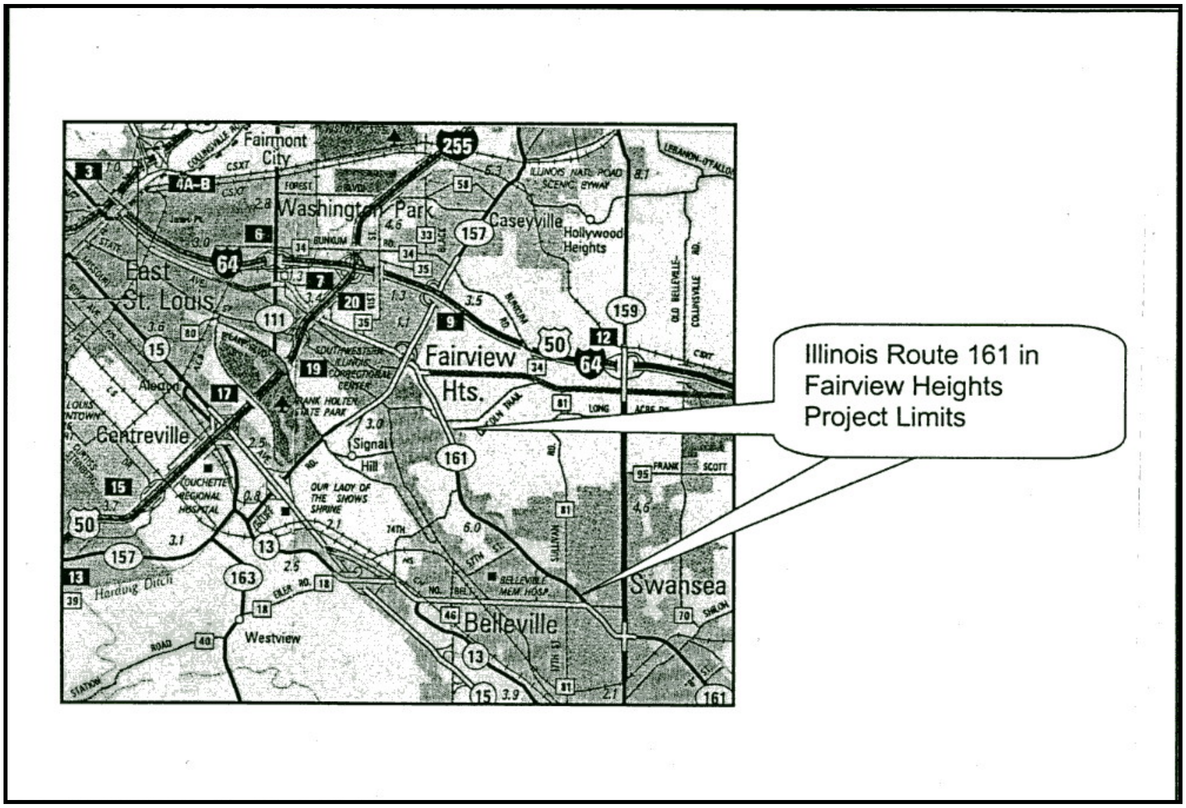
Project Location



This project is located on Interstate 39 around the intersection of Interstate 39 and U.S. Highway 24, near El Paso. The experimental sections are located in the northbound and southbound lanes between mileposts 9.7 and 19.3.

Illinois Route 161

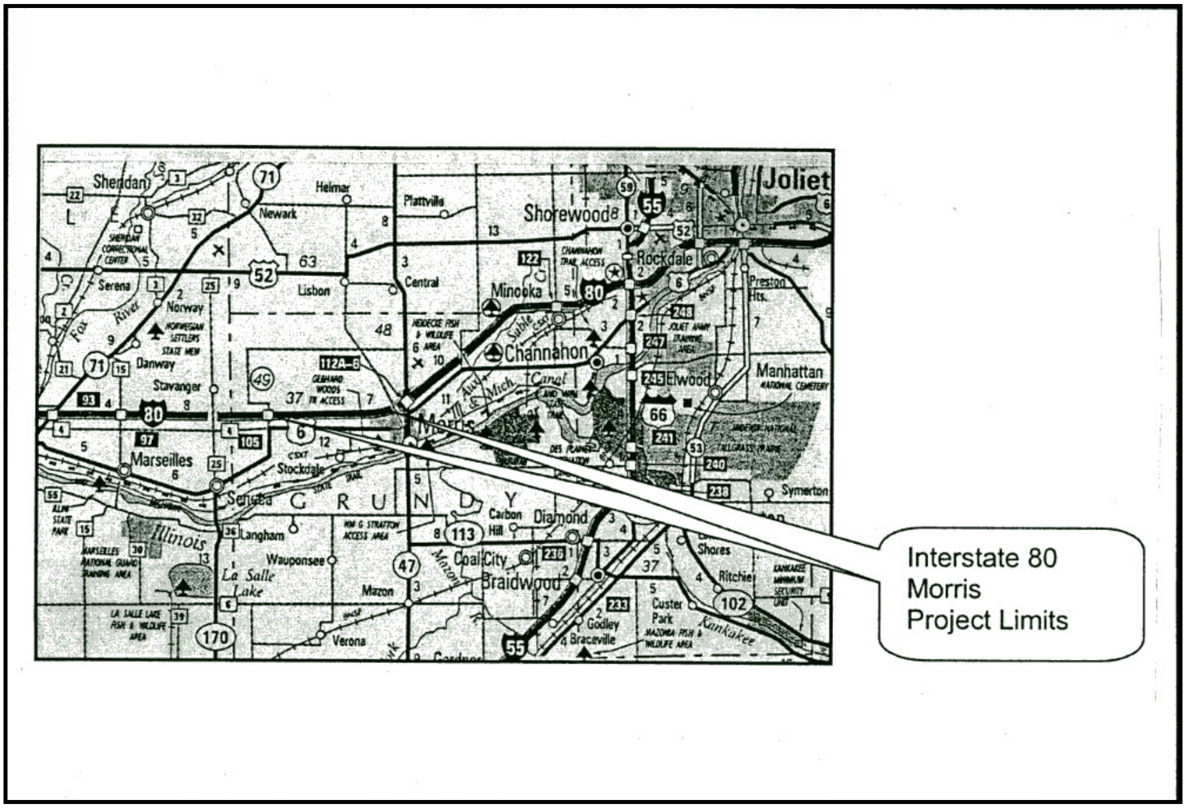
Project Location



This project is located on Illinois Route 161 between Illinois Routes 157 and 159 in Fairview Heights. The experimental sections are located in the westbound lanes only.

Interstate 80

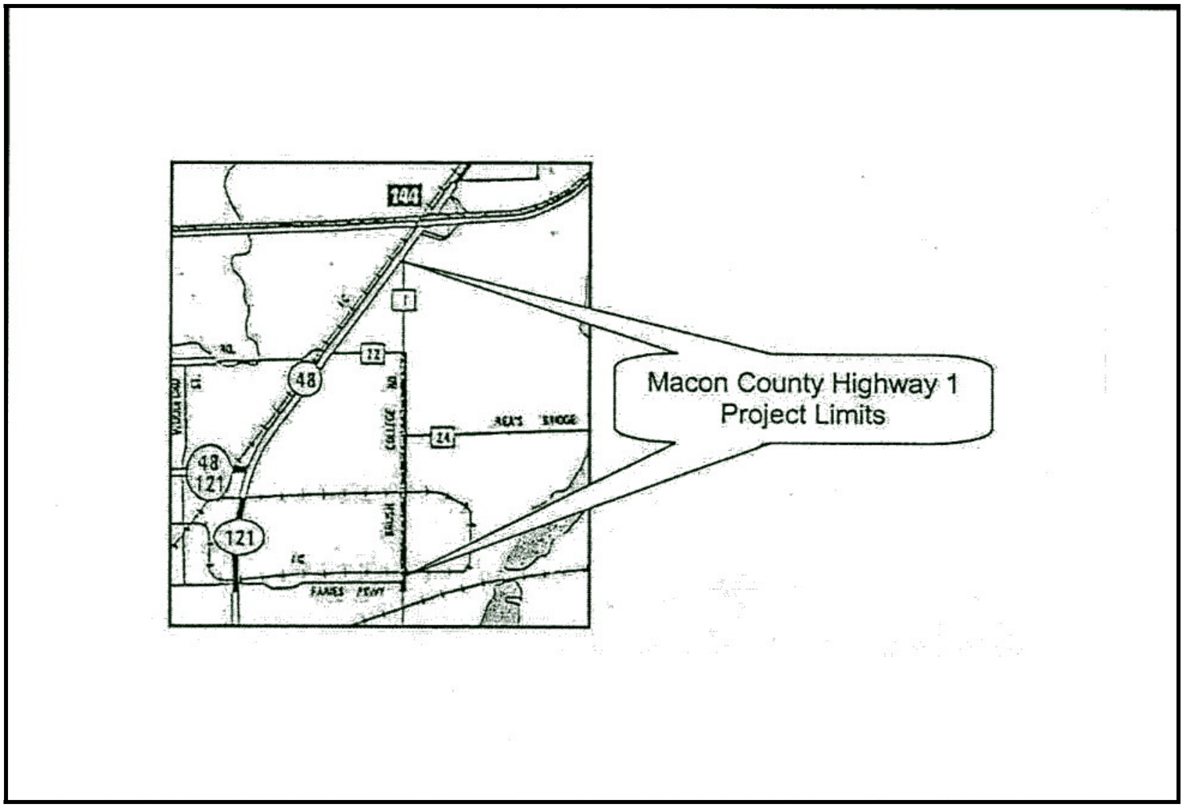
Project Location



This project is located on Interstate 80 near Morris. The experimental sections are located in the eastbound and westbound lanes between mileposts 105.3 and 111.6.

Macon County Highway 1

Project Location



This project is located on Macon County Highway 1 (Brush College Road) on the east side of Decatur. The experimental sections are located in the northbound and southbound lanes between the intersections with Illinois Route 48 and Faries Parkway.