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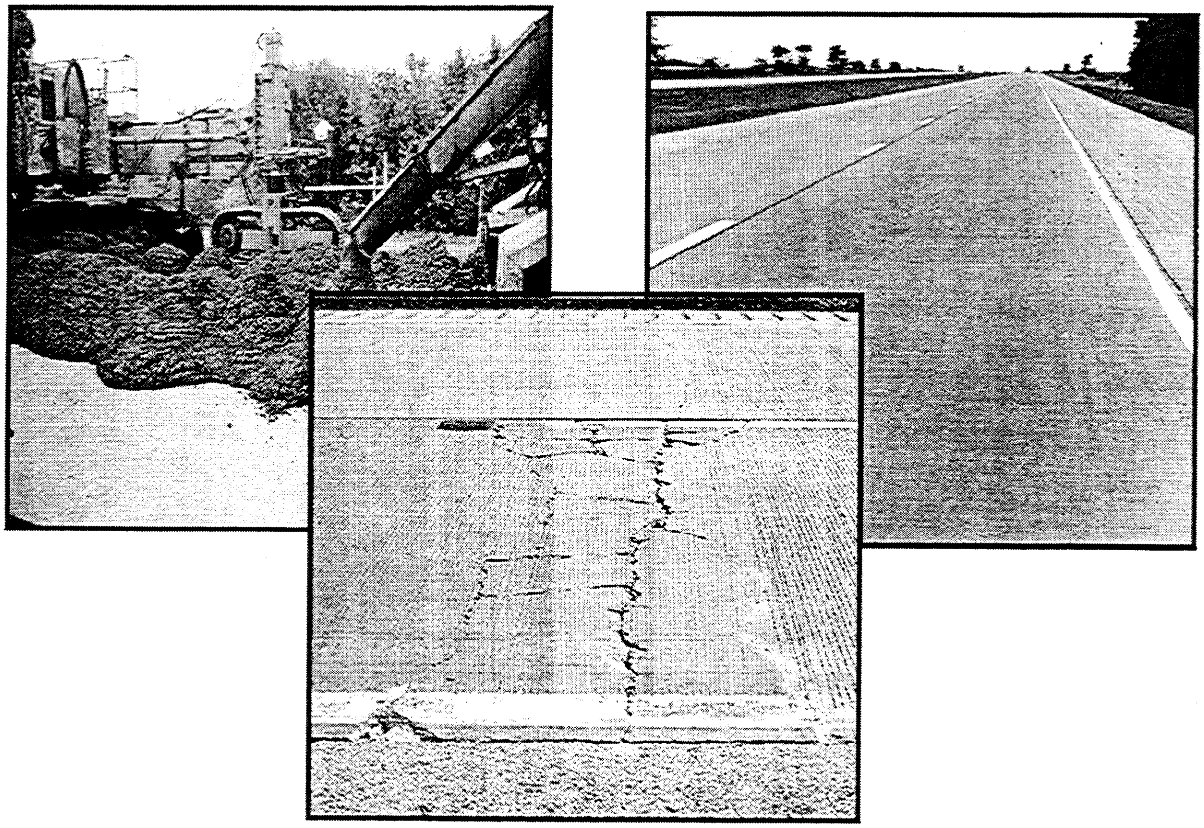
Bonded Concrete Overlay Performance In Illinois



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16. Abstract

Two bonded concrete overlay rehabilitation projects were constructed in Illinois during the 1990's. The first project was constructed in 1994 and 1995 on Interstate 80, east of Moline. The second project was constructed in 1996 on Interstate 88 near Erie. The existing pavements for both the Interstate 80 and Interstate 88 projects were 8-inch thick continuously reinforced concrete pavements. The Interstate 80 rehabilitation was designed as a 4-inch thick plain concrete overlay. This project includes six experimental sections using various percentages of microsilica added to the standard mix design. In addition, microsilica grout was used as a bonding agent between the original pavement and the new bonded concrete overlay in some sections. The Interstate 88 project was designed as a 3-inch thick plain concrete overlay. This project includes two experimental sections, which incorporate different surface preparation methods prior to the overlay placement.

This report summarizes the performance of these two bonded concrete overlays. The design, construction, maintenance, and costs of these projects are addressed. Visual distress surveys were conducted annually for both the Interstate 80 and Interstate 88 projects. In addition, these projects were tested annually for an International Roughness Index value. Condition Rating Surveys were conducted every two years to define the overall condition of the pavement. Results of these tests and visual surveys are included within this report.

The performance of these two projects has been quite different. The Interstate 80 project has shown significant distress, and was in need of maintenance only four years after construction. The Interstate 88 project has not developed significant early distresses. Potential explanations for the difference in performance, including initial pavement condition, traffic volume, and overlay construction are explored.

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Final Report

BONDED CONCRETE OVERLAY PERFORMANCE IN ILLINOIS

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June 2002

ABSTRACT

Two bonded concrete overlay rehabilitation projects were constructed in Illinois during the 1990's. The first project was constructed in 1994 and 1995 on Interstate 80, east of Moline. The second project was constructed in 1996 on Interstate 88 near Erie. The existing pavements for both the Interstate 80 and Interstate 88 projects were 8-inch thick continuously reinforced concrete. The Interstate 80 rehabilitation was designed as a 4-inch thick plain concrete overlay. This project includes six experimental sections using various percentages of microsilica added to the standard mix design. In addition, microsilica grout was used as a bonding agent between the original pavement and the new bonded concrete overlay in some sections. The Interstate 88 project was designed as a 3-inch thick plain concrete overlay. This project includes two experimental sections, which incorporate different surface preparation methods prior to the overlay placement.

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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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EXECUTIVE SUMMARY

The Illinois Department of Transportation constructed two bonded concrete overlays to investigate alternatives to bituminous concrete overlays for the rehabilitation of existing Portland cement concrete pavements. The first bonded concrete overlay was constructed in the fall of 1994 and spring of 1995 on Interstate 80 near Moline. The second overlay was constructed during the summer of 1996 on Interstate 88 near Erie. The Interstate 80 overlay is four inches thick, while the Interstate 88 overlay is three inches thick.

Design information was gathered from the American Association of State Highway and Transportation Officials *Guide for Design of Pavement Structures* and the National Cooperative Highway Research Program *Synthesis of Highway Practice 99.* Design information, construction problems, and performance criteria from other states with bonded concrete overlays were also considered. An overlay thickness of four inches was selected for Interstate 80 based on design criteria and the condition of the existing pavement. Three inches was selected as the overlay thickness for Interstate 88. This project was initially considered for the Federal Highway Administration's Long-Term Pavement Performance program, which required a thickness of three inches, however it was never included in the program.

Experimental research sections were incorporated into each of these projects. The Interstate 80 overlay has six different experimental combinations of microsilica in the concrete mixture and grout for a bonding agent. The experimental microsilica additions were zero percent, three percent, and five percent by mass of total solids. Each of these mixtures was placed in an area with, and without, microsilica grout used as a bonding agent. The entire surface of the Interstate 80 project was prepared with shot blasting. The Interstate 88 project included two experimental types of surface preparation for the existing pavement. The eastbound lanes were cold milled and shot blasted, while the westbound lanes were shot blasted only. No grout was used on the Interstate 88 project.

The necessary patching and surface preparation was completed on both projects prior to the overlay placement. This included the removal of all foreign material such as paint, tire residue and bituminous spot patches from the surface. Full-depth and partial-depth patches were placed in areas with moderate to severe distress and in areas with unsound surface material. Construction for both projects included slip-form paving of the driving and passing lanes monolithically. The fresh concrete was dumped directly in front of the paving machine on Interstate 80, while the Interstate 88 project incorporated the use of a belt placer.

The initial construction cost for these bonded concrete overlays was nearly twice that of a standard bituminous concrete overlay. However, the anticipated design life of the bonded concrete overlays was nearly twice that of a bituminous concrete overlay. Optimum performance from both types of overlays would produce an equivalent cost if based on a life cycle cost.

The design traffic loading for the Interstate 80 and Interstate 88 projects were 19.5 and 13.1 million Equivalent Single-Axle Loads, respectively. These traffic volumes were based on a 20-year design life. The actual total traffic loading for each of these routes, to date, is slightly higher than the design projected total loading by 2002.

Performance of the bonded concrete overlay on Interstate 80 has been unsatisfactory. Transverse cracking of medium to high severity appeared within three years after construction. Patching contracts were awarded in 1998, 2000, and 2001 for the repair of this project. Many of the concrete patches placed in 1998 and nearly all of the concrete patches placed in 2000 were replaced in the subsequent patching contract due to poor performance. These concrete patching contracts included a combination of both full-depth and partial-depth patches. Based on the number and area of these patches, the experimental sections with no microsilica additions have performed the best, followed by those with three percent added and five percent added. In addition, the sections with microsilica grout used as a bonding agent performed better than those without the grout in two out of three cases. The margin of improvement of the grouted sections, however, was minimal, which questions the benefit of using the grout as a bonding agent. The International Roughness Index and Condition Rating Surveys for this project have shown a steady decline in pavement performance.

The Interstate 88 project has displayed very good performance to date. There have been no patching contracts awarded for this overlay. The International Roughness Index and Condition Rating Surveys have shown consistently good pavement performance since the time of construction.

In conclusion, the performance of the Interstate 80 bonded concrete overlay has been unsatisfactory. The project has not been cost effective due to the amount of patching required. The addition of microsilica to the concrete mixture did not prove to be beneficial, and may have initiated some of the early age distress by producing a more brittle concrete pavement. Also, the use of microsilica grout as a bonding agent did not prove to be effective. The performance of the Interstate 88 project has been very good to date. No patching or maintenance has been required.

Based on the observations of these two projects, the Illinois Department of Transportation does not recommend bonded concrete overlays for high volume interstates. If this type of rehabilitation is performed, it is recommended to focus extreme attention on the condition of the existing pavement and the surface preparation of that pavement. In addition, the use of microsilica as a concrete admixture and the use of microsilica grout as a bonding agent are not recommended.

INTRODUCTION

A primary focus for the Illinois Department of Transportation (IDOT) is the rehabilitation and maintenance of existing interstates, state highways, and local agency roadways. Many of these facilities have surpassed their design lives and they are beginning to deteriorate rapidly. Rising construction costs and tighter constraints on material selection and construction practices have hindered the amount of rehabilitation that may be accomplished each year.

The current IDOT policy for rehabilitation of interstate concrete pavements is a 3.25-inch bituminous concrete overlay. Research indicates that this type of overlay will last approximately 10 to 12 years on a pavement with no concrete D-cracking [1]. The structural capacity, or ability of the pavement to carry traffic, is only slightly increased with this type of rehabilitation. An alternative option is the Portland cement bonded concrete overlay (BCO). The theoretical design life of the BCO is nearly twice that of a bituminous concrete overlay, because the structural capacity is increased.

The bonded concrete overlay consists of placing a layer of Portland cement concrete (PCC) directly on top of the existing PCC pavement. Any existing failed pavement joints, cracks, and serious distresses should be patched before placement of the BCO. The existing pavement surface should be textured by milling or abrasive blasting before the overlay is placed. The existing pavement should also be free of all contamination such as dirt, oil stains, paint markings, and tire marks. The overlay concrete will react with the rough surface of the existing pavement to bond the two layers as one monolithic slab [2]. This new monolithic slab should hinder the deterioration of the existing pavement and increase the structural capacity of the facility.

IDOT has experimented with two bonded concrete overlays. These overlays were both plain concrete overlays of continuously reinforced concrete pavements. Experimentation included concrete mixtures with various percentages of microsilica added, microsilica grout as a bonding agent, and surface texturing. The constructibility and performance of these projects were evaluated. Previous reports have covered the preliminary laboratory research, construction and interim performance of these projects [2,3].

This report briefly covers the site selection, planning, and design for both of these projects. In addition, the pre-construction requirements, construction practices, and construction costs are reviewed. Finally, the performance over the last five years of each project is evaluated through the use of visual distress surveys, maintenance requirements, and traffic considerations. Performance was also monitored through the International Roughness Index and Condition Rating Surveys.

Conclusions on the general performance of these two projects are included. Based on these conclusions and the performance of each project, recommendations are made concerning the construction of bonded concrete overlays.

PLANNING AND DESIGN

In 1992 and 1993, IDOT's Bureau of Materials and Physical Research (BMPR) and Pavement Review Team searched the interstate system for a section of pavement that would be suitable for an experimental feature BCO rehabilitation. The desired pavement criteria for the experimental section included each of the following:

- a thin pavement (7 – 8 inches thick),
- a continuously reinforced concrete pavement (CRCP),
- a bare concrete surface (no bituminous concrete overlay),
- minimal required surface preparation, and
- a section not currently in the state's 5-year program for rehabilitation.

These criteria were set for several reasons. A thin pavement was desired in order to see the increased serviceability of the new monolithic slab under increased traffic loadings. A CRCP was desired to reduce the number of distresses and possible faulted joints that might reflect through the BCO. Also, if a jointed pavement were selected, all of the joints would have to be sawed into the BCO. Typically, a pavement that has a bituminous concrete overlay would be too deteriorated for a BCO. In addition, the increased surface preparation of milling the bituminous overlay is expensive. Finally, a section in the state's 5-year program for rehabilitation may be too deteriorated for a BCO.

In 1993, a portion of Interstate 80 was selected as the first project, and in 1994 a section of Interstate 88 was selected as the second project. These pavement sections are both located in the northwest portion of Illinois near the city of Moline. The selected section of Interstate 80 is an 8-inch thick CRCP constructed on a 4-inch thick bituminous aggregate mixture (BAM) subbase. Original construction was in 1965. The selected section of Interstate 88 is also an 8-inch thick CRCP constructed on a 4-inch thick BAM subbase. Original construction was in 1975.

The American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures* [4], and the National Cooperative Highway Research Program (NCHRP) *Synthesis of Highway Practice 99* [5] were the manuals used for designing the thicknesses of these bonded concrete overlays. These methods use the following equations.

AASHTO Design Procedure

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

where:

- D_{ol} = required thickness of the BCO
- D_f = future slab thickness determined from existing slab conditions, future traffic projections, sub-structure support, sub-structure drainage, serviceability loss, and design reliability
- D_{eff} = effective thickness of the existing slab determined from the condition survey method

NCHRP Design Procedure

$h_o = h_d - h_b$ [Equation 2]

where:

- h_o = required thickness of the BCO
- h_d = required monolithic thickness of a concrete pavement for the design loading (determined from regular concrete pavement design analysis)
- h_b = thickness of the existing pavement

The design overlay thickness for Interstate 80 was 3.5 inches according to AASHTO and 2.0 inches according to the NCHRP design. Due to the existing pavement condition and a desired factor of safety, a final thickness of 4.0 inches was selected.

The Interstate 88 designs were 2.0 inches according to AASHTO and 1.5 inches according to NCHRP. This project was initially intended to be included in the Federal Highway Administration's Long Term Pavement Performance (LTPP) program as a Specific Pavement Study 7 site. The requirements for inclusion in this study were to study thickness (3.0 inches and 5.0 inches), bonding agents (neat grouts and no grout), and surface preparation (cold milling, sand blasting, and shot blasting). The BMPR did not want to pursue the study of bonding agents and thickness, and therefore the project was rejected from the LTPP program. A final thickness of 3.0 inches was selected for Interstate 88.

The Interstate 80 project was constructed as an experimental feature, which incorporates additional federal funding for the experimentation of new materials and construction practices. Therefore, this project includes experimental sections with three different amounts of microsilica added to the concrete mix. In addition, microsilica grout was used as a bonding agent between the existing pavement and the new concrete overlay. A total of six experimental combinations, listed below, were incorporated into both directions of the Interstate 80 overlay:

- no microsilica in the overlay mix with no bonding agent,
- no microsilica in the overlay mix with a microsilica grout bonding agent,
- 3% microsilica in the overlay mix with no bonding agent,
- 3% microsilica in the overlay mix with a microsilica grout bonding agent,
- 5% microsilica in the overlay mix with no bonding agent, and
- 5% microsilica in the overlay mix with a microsilica grout bonding agent.

Prior to construction, the BMPR conducted several laboratory experiments with the addition of microsilica into concrete mixtures, and the use of grouts for bonding agents. The goals of this investigation were to determine: 1) the difference in compressive strengths for mixture designs with various percentages of microsilica, and 2) the bond strengths for various types of bonding agents. Bond strengths were determined through direct tensile and slant shear tests.

Concrete mixtures with 0 percent, 5 percent, and 8 percent microsilica were tested in the laboratory. No significant differences were noted from the compressive strength testing of these mixtures. Bond strength tests were performed with no grout, a plain grout, and a microsilica grout. No significant differences were noted between the bond strength testing of these various combinations. To fulfill the experimental feature's project requirements, field testing of concrete mixtures with microsilica and the various bonding agents were tried on the Interstate 80 overlay. Figure 1 illustrates the project layout and the locations of the experimental and research test sections. The mixture design for each experimental section may be found in Appendix A. The laboratory testing is discussed in detail in the 1996 construction report [2].

The Interstate 88 project incorporated two experimental sections. The eastbound lanes were cold milled, followed by a light shot blasting, before the overlay was placed. The westbound lanes were shot blasted only before the overlay placement. No grout was used as a bonding agent for this project and no microsilica was added to the concrete mixture. Figure 2 illustrates this project's layout and the locations of the research test sections. The mixture design for this project may also be found in Appendix A. Table 1 summarizes the locations and paving dates for both projects.

Table 1

Interstate 80 and Interstate 88 Bonded Concrete Overlays

Marked Route	Contract Number	Direction	Milepost Limits	Paving Dates
Interstate 80	84815	Eastbound	1.0 to 2.7	October 7 – October 13, 1994
		Westbound	2.7 to 1.0	April 21 – April 28, 1995
Interstate 88	84988	Eastbound	13.3 to 16.4	April 18 – May 1, 1996
		Westbound	16.4 to 13.3	June 4 – June 14, 1996

Interstate 80 Bonded Concrete Overlay Test Sections

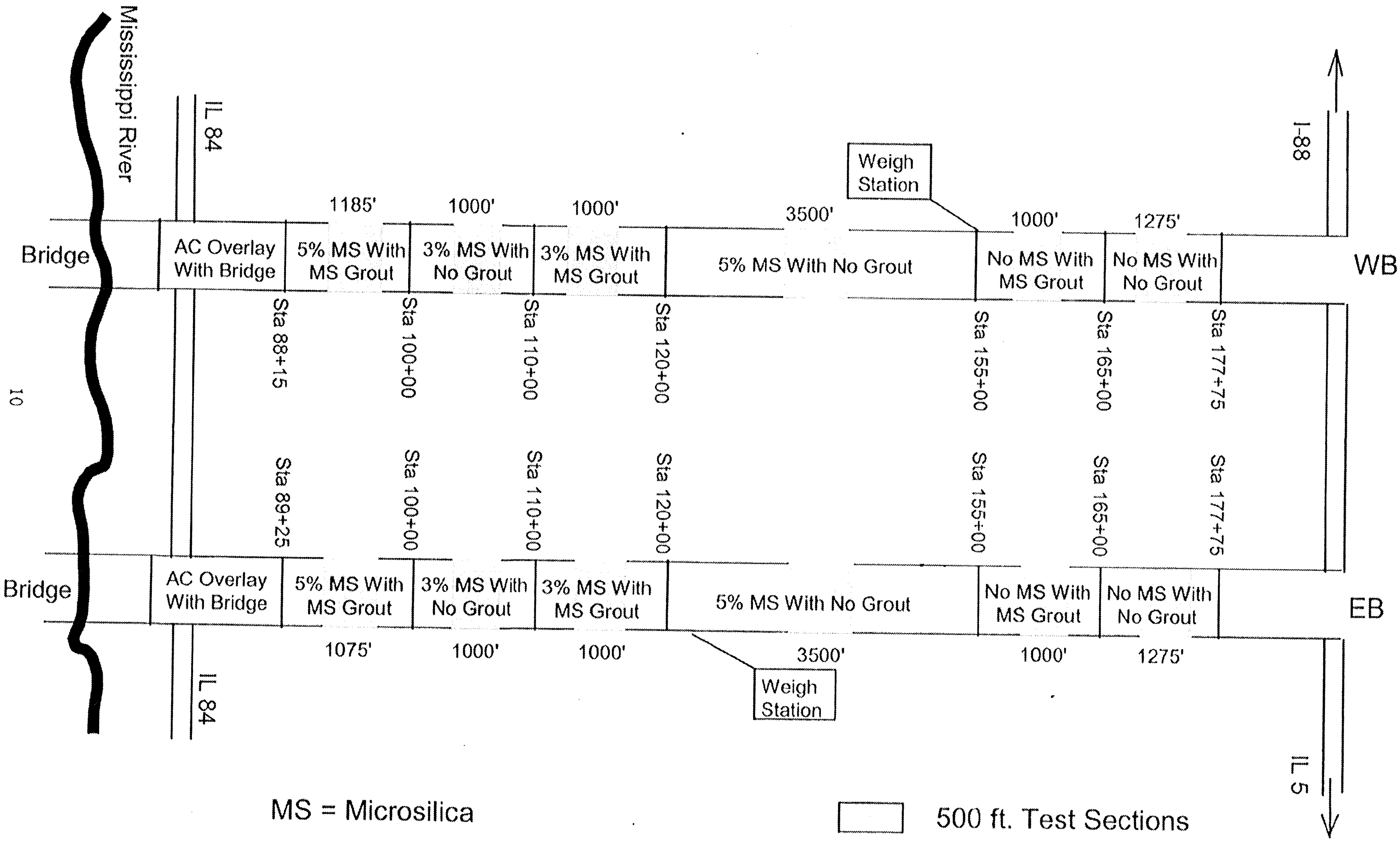

Figure 1

Interstate 88 Bonded Concrete Overlay Test Sections

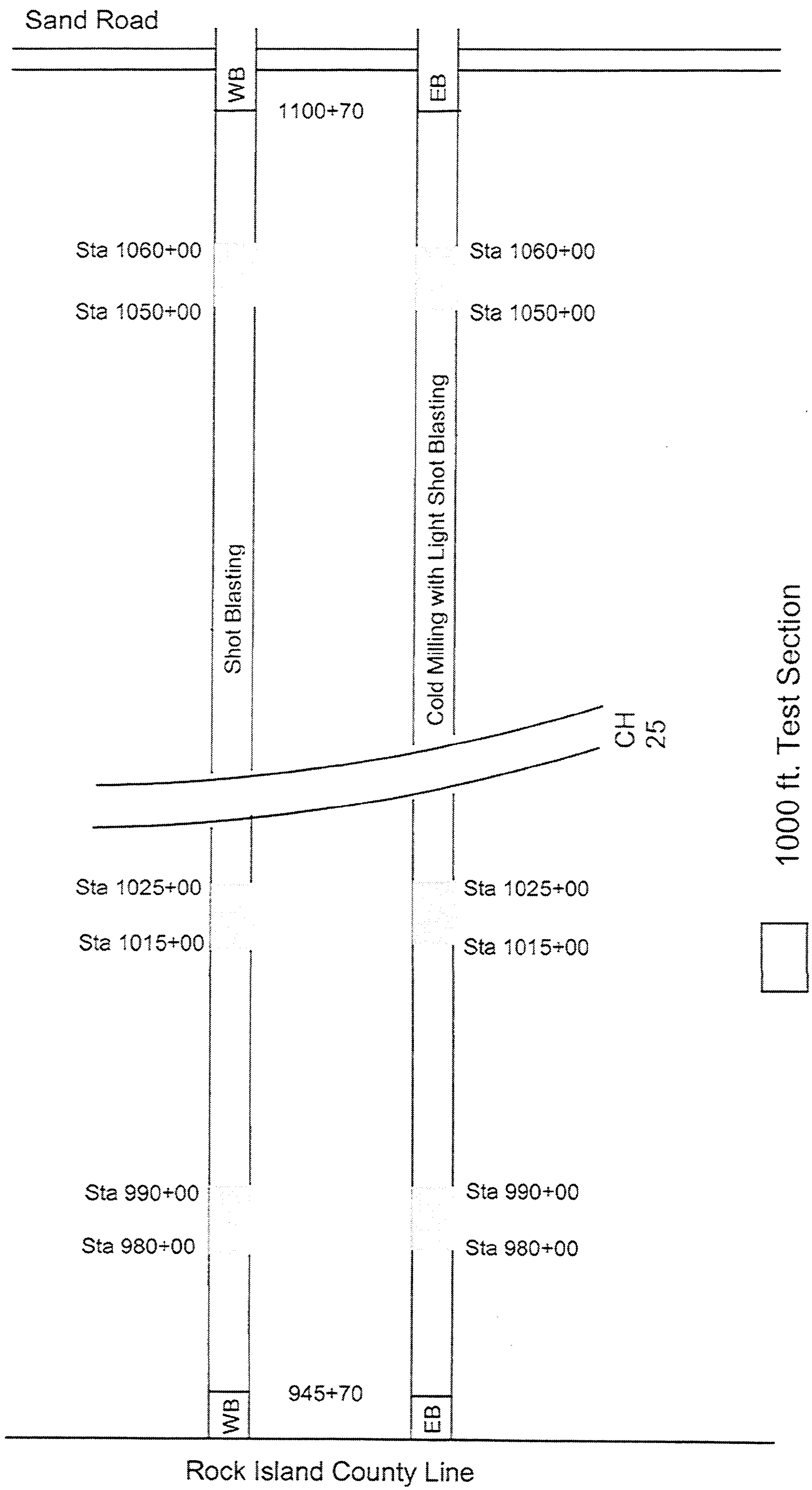

Figure 2

PRECONSTRUCTION CONDITIONS

INTERSTATE 80

The existing 8-inch CRC pavement on Interstate 80 was constructed in 1965. The shoulders were 12-inch bituminous concrete and there were no underdrains placed during original construction. The existing pavement displayed a frequent amount of medium severity, transverse cracking and a significant amount of centerline distress prior to the rehabilitation. Figure 3 illustrates a representative area of the Interstate 80 pavement before rehabilitation. Prior to placing the bonded concrete overlay, the existing pavement was patched with full-depth and partial depth patches. In addition, any bituminous patch material found on the surface was removed.

Figure 3
Interstate 80 Before Rehabilitation

Full-depth patches were placed at areas with medium to high severity distresses. Eleven patches were placed in the eastbound lanes and 28 were placed in the westbound lanes. These patches were "Class A" patches, which included full-depth pavement removal and CRCP replacement. The combined area of these patches was 1.23 percent of the total project roadway area.

One partial-depth patch was required in the eastbound direction and eight were required in the westbound direction. These patches were placed over severe longitudinal cracks. The existing surface was milled down to a depth of 2.5 inches by 36 inches wide. The crack was reinforced with #5 tie bars placed at 90 degree angles to the crack on 30-inch centers. These concrete patches were placed monolithically with the concrete overlay. Figure 4 illustrates the placement of the reinforcement bars within a partial depth patch area. The combined area of these patches was 0.28 percent of the total project roadway area.

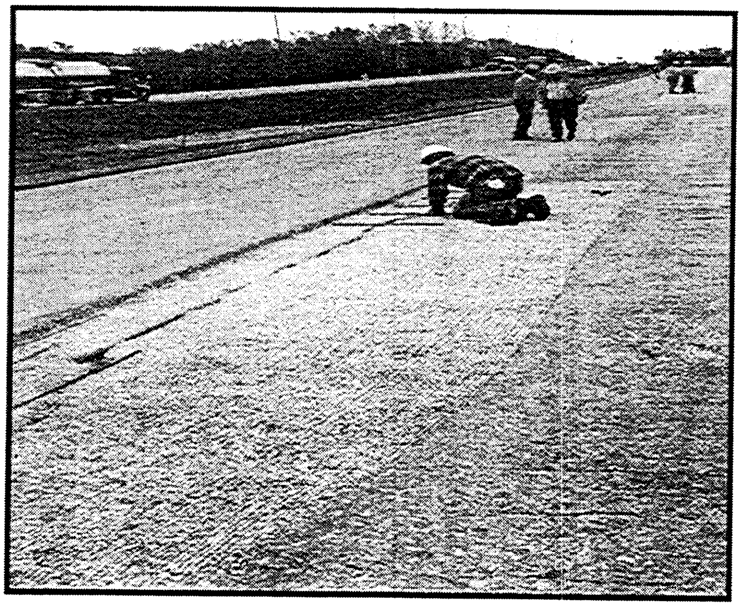

Figure 4
Partial-Depth Patch Reinforcement

Any bituminous patching material found on the pavement surface was removed prior to the overlay placement. Cold milling was used for any large areas, while jackhammers were used to remove cold patch material from areas of spalling. The loose and unsound concrete associated with these areas of distress was also removed. These areas were filled monolithically with the concrete overlay.

INTERSTATE 88

The existing 8-inch CRC pavement on Interstate 88 was constructed in 1975. The shoulders were 11-inch bituminous concrete and there were crushed stone french drains placed with the original construction. The pavement displayed minor distress prior to the overlay. Figure 5 is a typical view of this section prior to the overlay. Full-depth and partial-depth patches were placed in the existing pavement before the overlay was constructed.

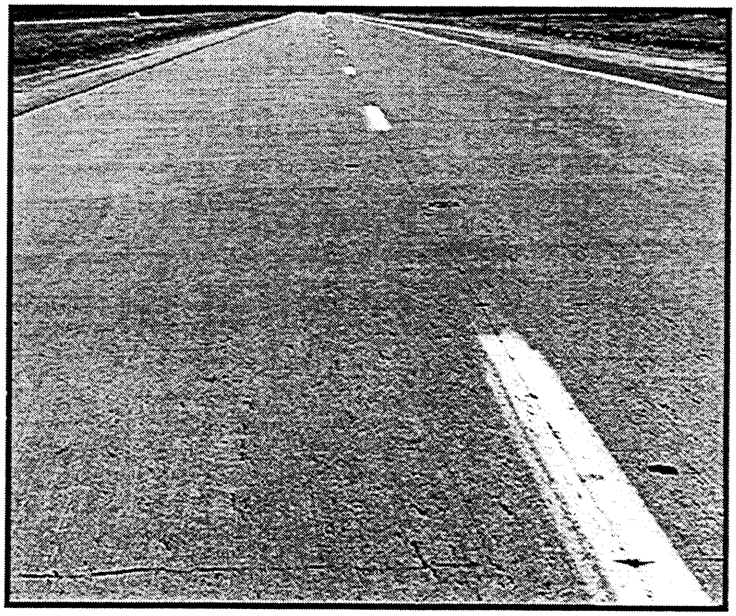

Figure 5
Interstate 88 Before Rehabilitation

Full-depth patches were placed at areas with medium to high severity distresses. Thirty patches were placed between the eastbound and westbound lanes. These patches were "Class A" patches, which included full-depth pavement removal and CRCP replacement. The combined area of these patches was 0.55 percent of the total project roadway area.

Eight partial-depth patches were required in the eastbound lanes and one was required in the westbound direction. These patches were placed over longitudinal cracks, in the same fashion as the partial-depth patches on the Interstate 80 project. The combined area of these patches was 0.10 percent of the total project roadway area.

OVERLAY CONSTRUCTION

INTERSTATE 80

The existing pavement surface of Interstate 80 was shot blasted prior to overlay placement. A 50/50 mix of S-390 and S-550 cast steel shot was used for this process. The shot blasting removed approximately 0.125 inches of the pavement surface. Sand blasting with wet bottom boiler slag was used in areas where the shot blaster could not operate, including areas of distress and the pavement edge. The pavement surface was thoroughly cleaned immediately before the overlay placement. Excess sand blasting dust, tire residue, and oil drips were cleaned up to minimize areas of debonding.

The grout mixture used as a bonding agent in the designated test areas consisted of Portland cement, microsilica (15 percent solids by mass of cement), and water. The grout was placed immediately in front of the paving machine, but behind the concrete delivery trucks. A pressure sprayer and squeegees were used to apply the grout and spread it uniformly over the pavement surface. Figure 6 illustrates the grout application procedure.

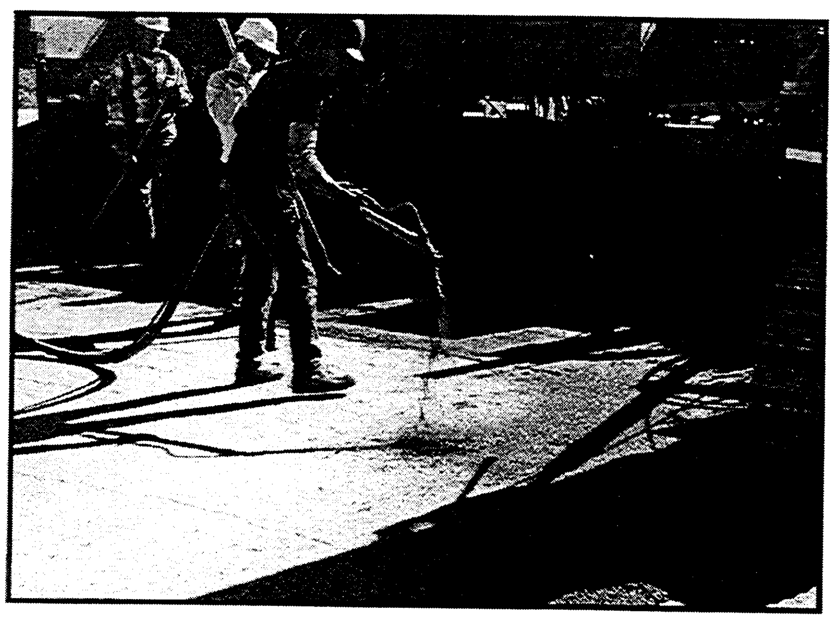

Figure 6
Microsilica Grout Application

The overlay was placed monolithically over both lanes with a slip-form paver guided by a string line. The concrete was placed on the existing pavement directly in front of the paving machine. The pavement was hand finished with bullfloats and trowels, followed by a burlap drag for longitudinal texture. The finished pavement was also transversely tined at a uniform spacing of 0.75 inch for additional texture. The final process was the application of two coats of a white pigmented curing compound. Each application was at the rate of 1.5 gallons per 250 square feet. This rate is slightly higher than for a standard pavement to ensure moisture retention in the thin overlay.

The centerline joint was sawed with an experimental lightweight saw. This experimental saw weighed less than 300 pounds, had an upward cutting diamond tip blade, and maintained 2500 RPM while in operation. The experimental saw may be seen in Figure 7. The intent was to saw this joint within two hours of the concrete placement; however, the cool weather and excess curing compound prevented this. In order to remedy this problem, the amount of curing compound was reduced to one application at the rate of 1.5 gallons per 250 square feet. In addition, the rate was also reduced at the centerline after the first day's paving.

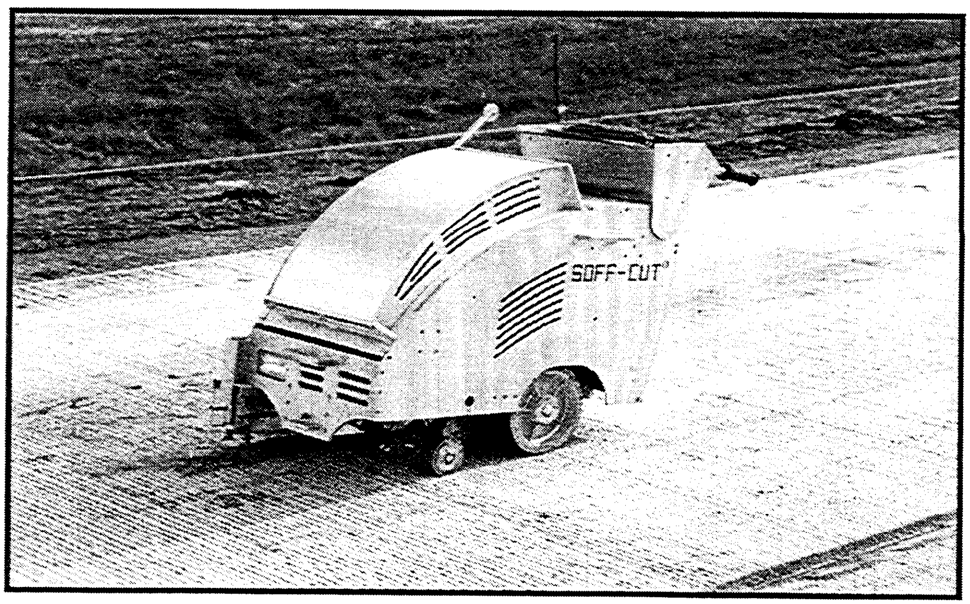

Figure 7
Experimental "Soff-Cut" Saw

INTERSTATE 88

The eastbound lanes of Interstate 88 were cold milled and shot blasted prior to the overlay placement. The cold milling operation involved removing the top 0.25 inch of the existing pavement. Once milling was completed, the surface was lightly shot blasted to remove any loose particles and foreign matter. Figures 8 and 9 illustrate the surface texture resulting from this procedure. The westbound lanes of this project were shot blasted only. The shot blasting was intended to expose the coarse aggregate and provide a rough surface texture to increase the bond of the overlay. The cold milling and shot blasting combination proved to be a better method of preparing the existing pavement than shot blasting alone. The milled pavement could easily be inspected for complete removal of the surface and the resulting texture was rougher, allowing more surface area for the overlay bond. The westbound lanes, with shot blasting alone, resulted in inspection problems and concerns over the complete removal of the existing surface.

Figure 8
Interstate 88 After Cold Milling And Shot Blasting

Figure 9
Interstate 88 After Cold Milling And Shot Blasting (Close-Up)

The concrete overlay was placed monolithically over both lanes using a slip-form paver with stringline guides. The concrete was fed to the paving machine by the use of a belt placer. Figure 10 illustrates the paving process. This process eliminated the contamination of the existing pavement, as the shoulder was used for a haul road. However, the belt placer tended to segregate the mix between lanes, placing more coarse material in the driving lane and fine material in the passing lane. The pavement was hand finished followed by a burlap drag for longitudinal texture. The finished pavement was transversely tined at a uniform tine spacing of 0.75 inch. The final process was the application of two coats of a white pigmented curing compound at the rate of 1.5 gallons per 250 square feet per application. The centerline joint was sawed with a standard concrete saw on this project, with the operation beginning 3 to 4 hours after the overlay was placed.

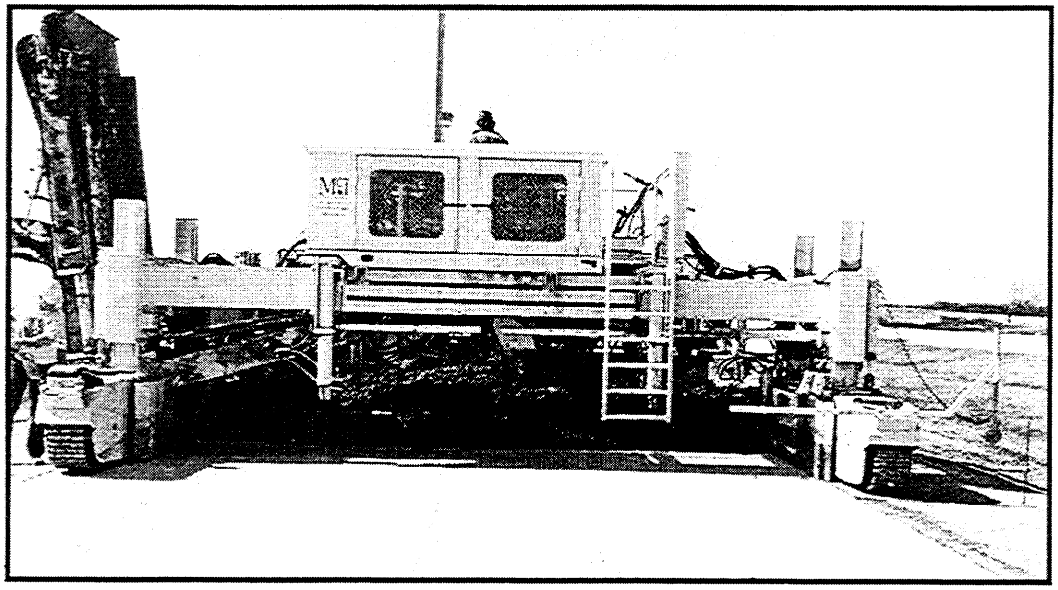

Figure 10
Interstate 88 Paving Process

PERFORMANCE

VISUAL DISTRESS SURVEYS

Research test sections for each of the various design criteria were identified for both the Interstate 80 and 88 projects. The project layout maps in the Planning and Design section of this report, on pages 10 and 11, show the locations for each test section. Visual surveys of these test sections were taken before construction and on an annual basis after construction. The most recent distress surveys (Spring 2001) may be found in Appendix B. The distresses that are noted in these surveys are only those which are considered medium to high in severity according to the "Distress Identification Manual for the Long-Term Pavement Performance Project [6]." This manual is used by the BMPR as a basis for evaluating the condition of research pavements.

The Interstate 80 BCO contains two test sections for each of the six different experimental areas. One test section was placed in each of the traveling directions, for a total of 12 test sections. Each test section is 500 feet long and is used for the visual distress survey. The Interstate 88 project contains three test sections within each of the two different experimental areas for a total of six test sections. Each test section is 1,000 feet long and was also used for the visual distress survey.

The pre-construction surveys of the Interstate 80 project indicated that the eastbound and westbound lanes were in the same condition prior to the overlay. The eastbound lanes exhibited a common occurrence of working transverse cracks in all sections. There was a significant amount of centerline popouts and spalling in all sections except the area of "no microsilica with no grout." The westbound lanes displayed a common occurrence of working transverse cracks throughout all the experimental sections. The westbound lanes also had a significant amount of the centerline spalling and popouts.

The post-construction distress surveys of the Interstate 80 project indicated that the eastbound lanes have deteriorated more rapidly than the westbound lanes. A large number of working, low severity, transverse cracks were found in the eastbound lanes within two years after construction. The three year survey indicated that many of these cracks had propagated into medium and high severity cracks. Examples of this type of distress may be found in Figures 11 and 12. Eventually, these cracks developed into areas of edge-of-pavement punch-outs and centerline spalling. An example of this may be found in Figure 13. The eastbound lanes continue to deteriorate at an increasing rate.

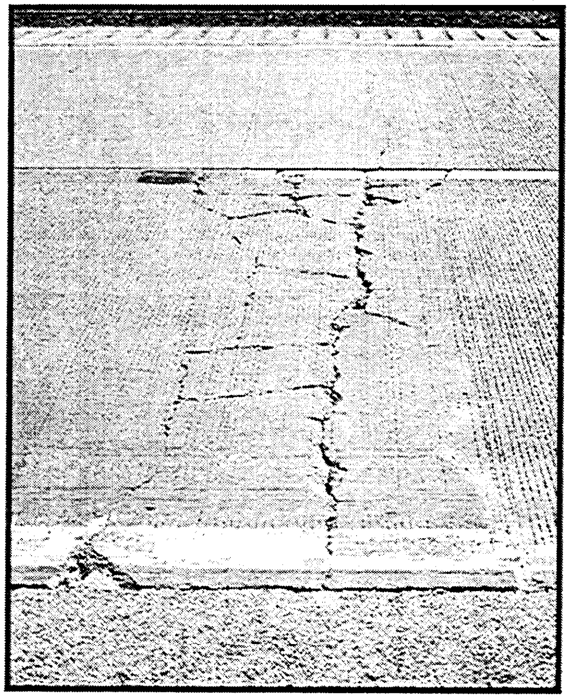

Figure 11
Interstate 80 High Severity Crack

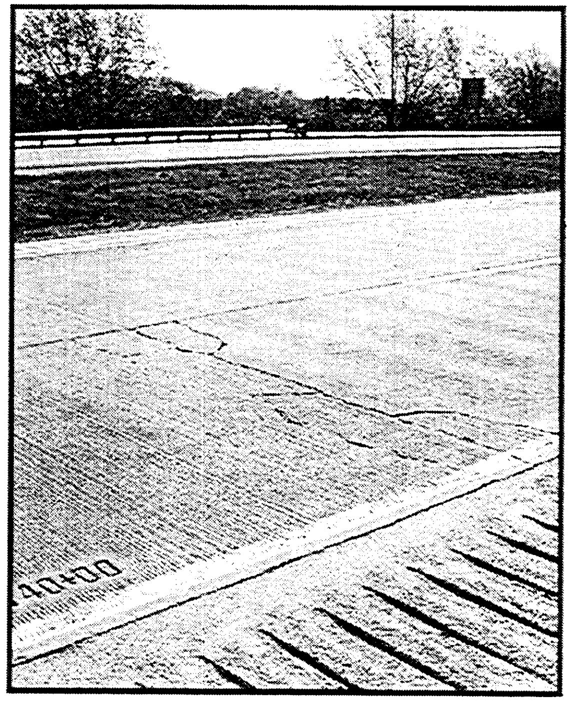

Figure 12
Interstate 80 High Severity Crack

Figure 13
Interstate 80 Edge-Of-Pavement Punch-Out

The westbound lanes initially deteriorated at a slower rate than the eastbound lanes. Working transverse cracks were noted within the first two years of the overlay's life. By 2000 and 2001, however, the number of distresses and working cracks had dramatically increased to match the performance of the eastbound lanes.

Patching was completed in both directions of Interstate 80 in 1998, 2000, and 2001, and is discussed in detail in the Maintenance / Patching section of this report.

The pre-construction surveys of the Interstate 88 project indicated that both directions were in very good condition prior to the overlay. Each direction contained a few low severity cracks and one to two small punchout areas. There was no centerline distress noted on this project, as compared to the Interstate 80 project.

The post-construction surveys for Interstate 88 have indicated little to no significant distress in either direction. The three test sections within the cold milling with light shot blasting area (eastbound lanes) have a few working cracks of low to medium severity. The three test sections within the shot blasting only area (westbound lanes) have only three to four working cracks per 1,000-foot test section. There have been no patches placed within this project to date. The overall visual performance of this project has been very good.

INTERNATIONAL ROUGHNESS INDEX

The International Roughness Index (IRI) is an indication of the deviation of a given pavement surface from an ideal smooth pavement [7]. This value is measured in inches per mile, with higher IRI values indicating increased pavement roughness. However, there is no rating system or scale used with the IRI data to indicate ranges for smooth or rough pavements. The statewide data are collected using video inspection vehicles and sorted into four equal groups from smoothest to roughest pavements. An average of all the data is found, and comparisons to this statewide average may be used. The graphs in Figures 14 and 15 indicate the average IRI values for both the Interstate 80 and 88 projects. The data have been separated for the eastbound and westbound directions, and the statewide average has been included for comparison.

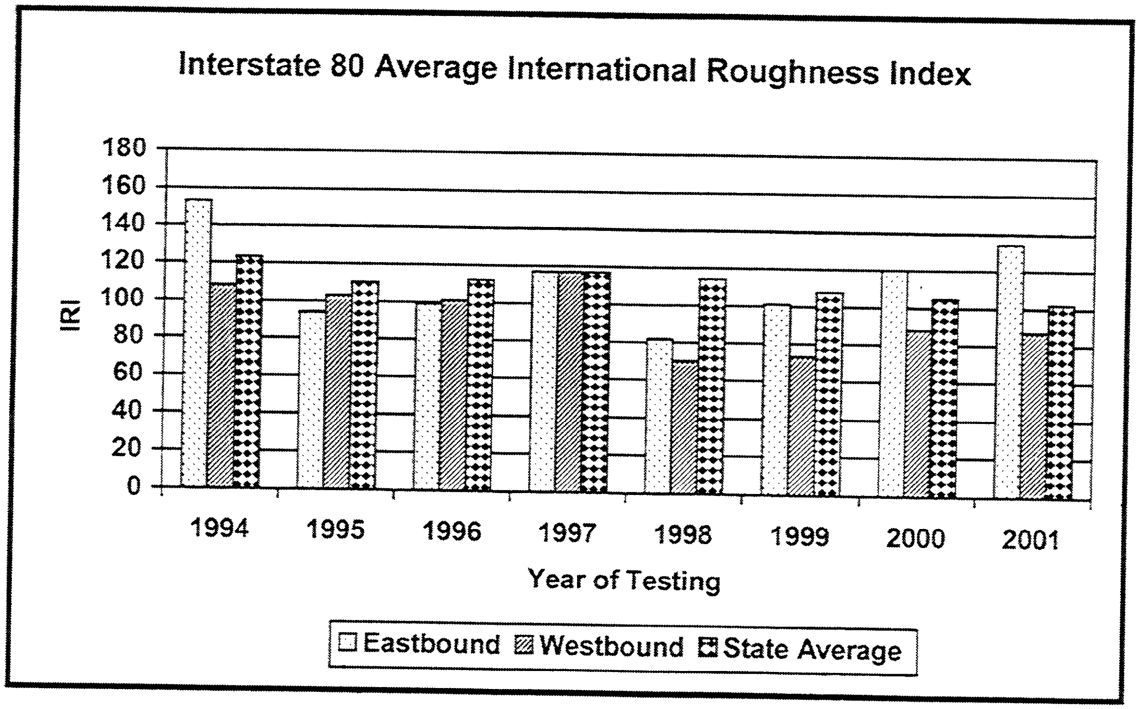

Figure 14
Interstate 80 Average International Roughness Index

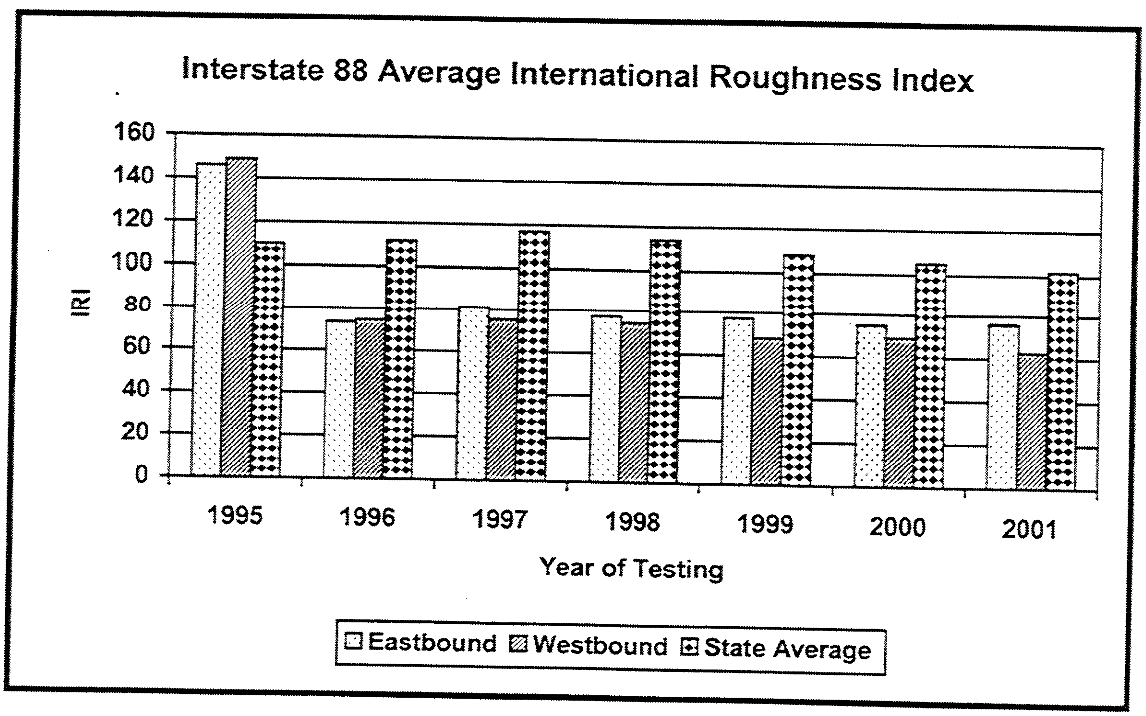

Figure 15
Interstate 88 Average International Roughness Index

The data for the Interstate 80 project indicate that the BCO dramatically improved the pavement smoothness in the eastbound direction, while only slightly improving the westbound direction. By 1997, both directions were rougher and comparable to the level of the statewide average. The patching completed in 1998 improved the pavement smoothness in both directions. The patching and maintenance that has been completed since 1998 has had little effect on the IRI in either direction. The IRI values for the eastbound lanes are increasing rapidly (from 82 to 134 over the last four years), while the westbound lanes have only increased from 70 to 87 over the same four years.

The IRI data for the Interstate 88 project indicates a much smoother pavement as a result of the bonded concrete overlay. The existing pavement prior to construction was much rougher than the statewide average. The IRI trend of this overlay has been very consistent since the time of construction, with nearly a constant value for both directions over the last six years.

CONDITION RATING SURVEYS

IDOT conducts a Condition Rating Survey (CRS) on interstate pavements on a biennial basis. The video inspection vehicles videotape the pavement surface and collect sensor data including IRI, rutting, and faulting. This video is viewed at a processing workstation to determine the predominant pavement distresses. A computerized mathematical model is then used to develop a CRS value based on the sensor data and the type, severity, and extent of the pavement distresses. The CRS values for the bonded concrete overlay projects may be found in Figures 16 and 17. The following scale is used to categorize the current condition of the pavement [8].

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

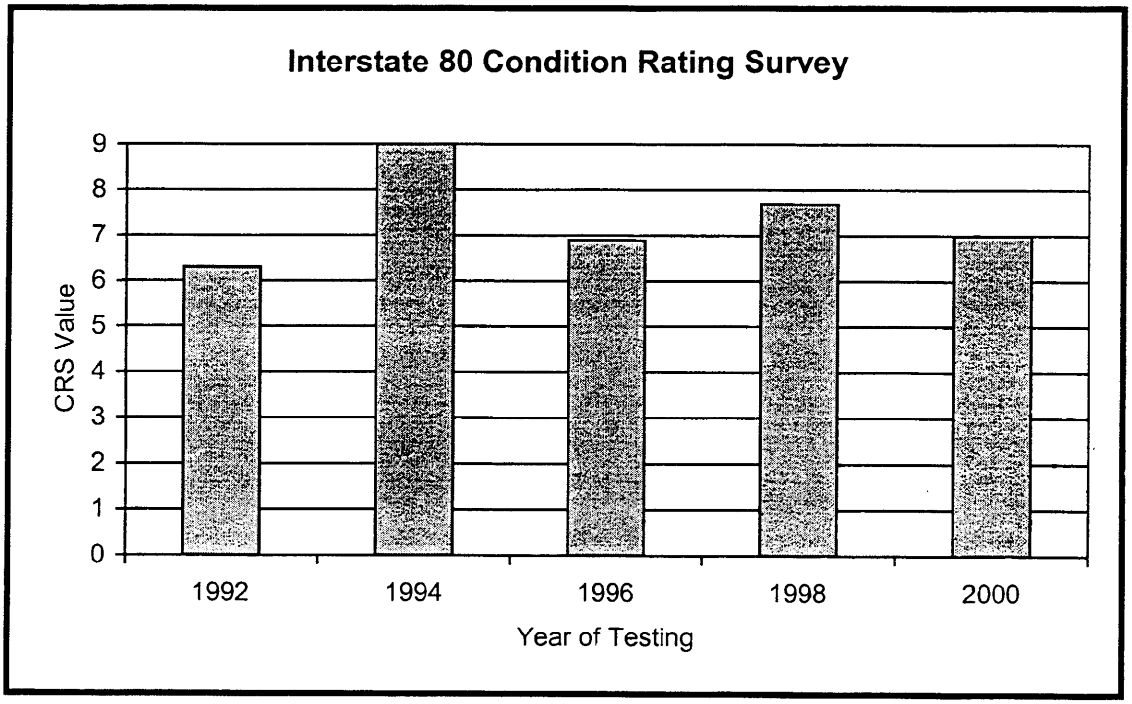

Figure 16
Interstate 80 Condition Rating Survey

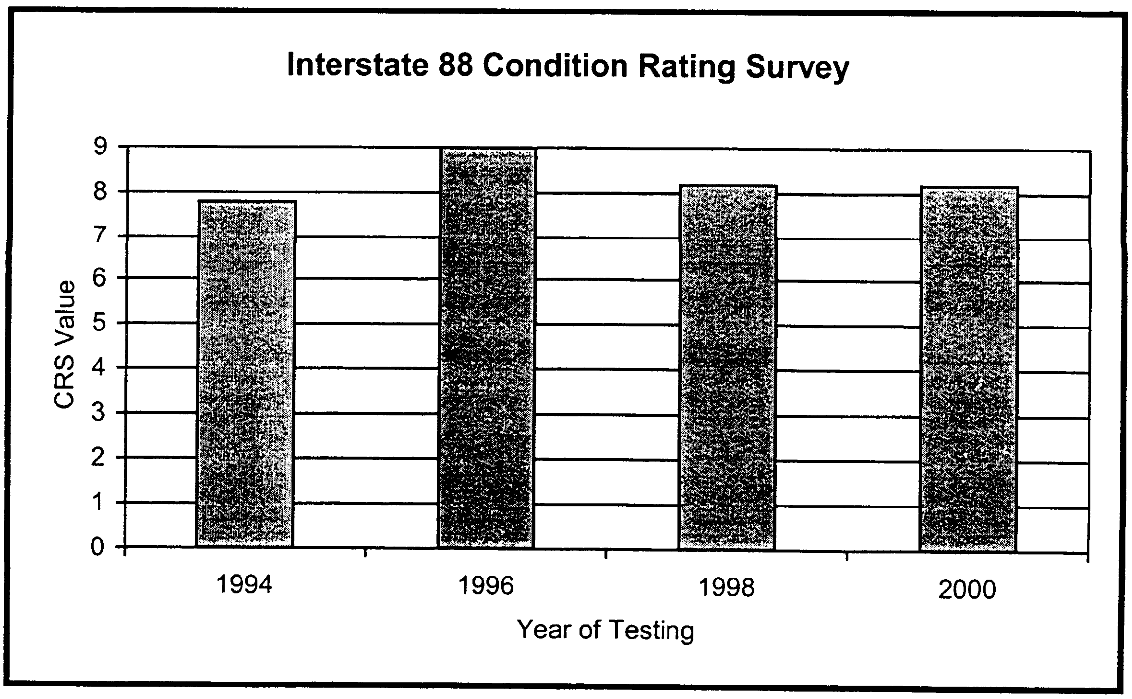

Figure 17
Interstate 88 Condition Rating Survey

The pre-overlay CRS value for Interstate 80 had fallen to a 6.3 value. This is still within the "good" category; however, a section of interstate that falls below a rating of 6.5 typically is scheduled for rehabilitation. Due to the construction of the overlay in 1994 and 1995, the 1994 CRS value was set at 9.0. The CRS value quickly fell back into the "good" category with a 6.9 by 1996 and only improved to a 7.7 with the patching contract in 1998. In spite of the patching contract in 2000, the CRS value was determined to be 7.0.

The Interstate 88 pre-overlay CRS value was determined to be 7.8, which falls within the "excellent" category. Construction of the overlay in 1995 improved the value to 9.0 for 1996. The CRS value fell to 8.2 in 1998 and has remained there through the 2000 rating. This value is still well within the "excellent" category, indicating minimal distresses and good sensor data from the video inspection vehicles.

MAINTENANCE / PATCHING

Three PCC patching contracts have been awarded for the Interstate 80 BCO since construction in 1994 and 1995. The amount, and cost, of patching has increased for each of the three contracts in 1998, 2000, and 2001. Table 2 below indicates the amount of full-depth and partial-depth patching that was completed in each direction for the three patching contracts. The values given in this table include the driving and passing lanes. In addition, the percentage of the total project area patched by direction has been included.

Table 2

Interstate 80 Patching Quantities by Year

Year/ Direction	Number of Full-Depth Patches	Area of Full-Depth Patches (yd^2)	Number of Partial-Depth Patches	Area of Partial-Depth Patches (yd^2)	Percent of Total Area Patched
1998					
Eastbound	33	915.9	3	182.8	4.7
Westbound	0	0.0	2	16.7	0.1
2000					
Eastbound	11	96.5	85	969.6	4.5
Westbound	8	71.2	50	417.5	2.0
2001					
Eastbound	2	16.4	151	1084.7	4.7
Westbound	2	26.6	44	321.7	1.5

The decision to use a full-depth or partial-depth patch was based on a visual survey and sounding of the pavement around a crack. Working cracks that developed into edge-of-pavement punchouts were rehabilitated with a full-depth patch. All moderate to severe transverse cracks were rehabilitated with a partial-depth patch. The size of the partial-depth patches was determined by sounding the pavement around the crack to determine the area of delamination. In some cases, a partial-depth patch was converted to a full-depth patch once the original pavement was exposed and the condition was rated.

A full-depth patch included replacement of the CRC pavement and the overlay as one monolithic patch. The CRC reinforcement was replaced in the original pavement; however, there was no reinforcement added to the concrete overlay. Partial-depth patches included replacement of the overlay only. The existing overlay was removed in these areas, and the original surface was cleaned and sand blasted for texture. Figures 18 and 19 illustrate a full-depth and partial-depth patch, respectively.

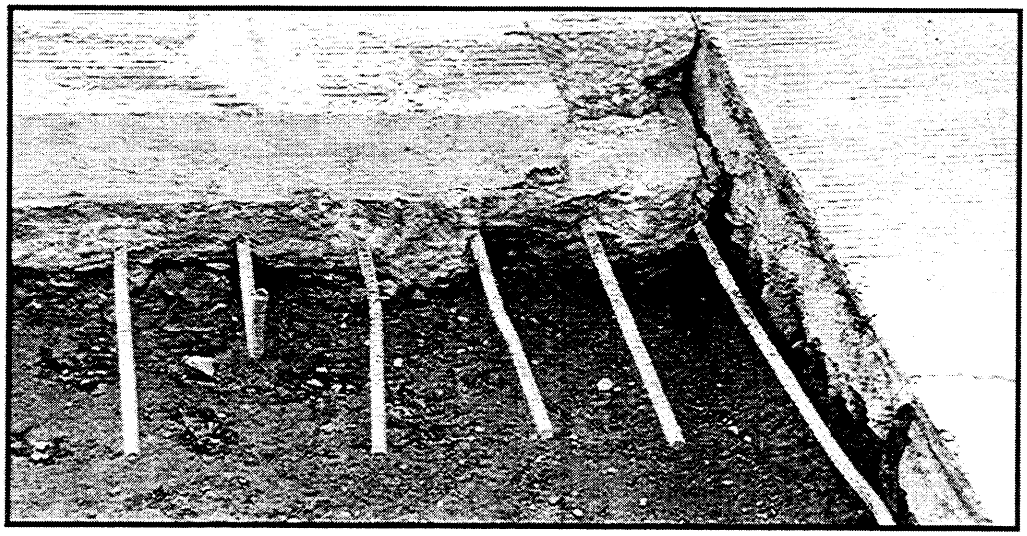

Figure 18
Full-Depth CRC Patch

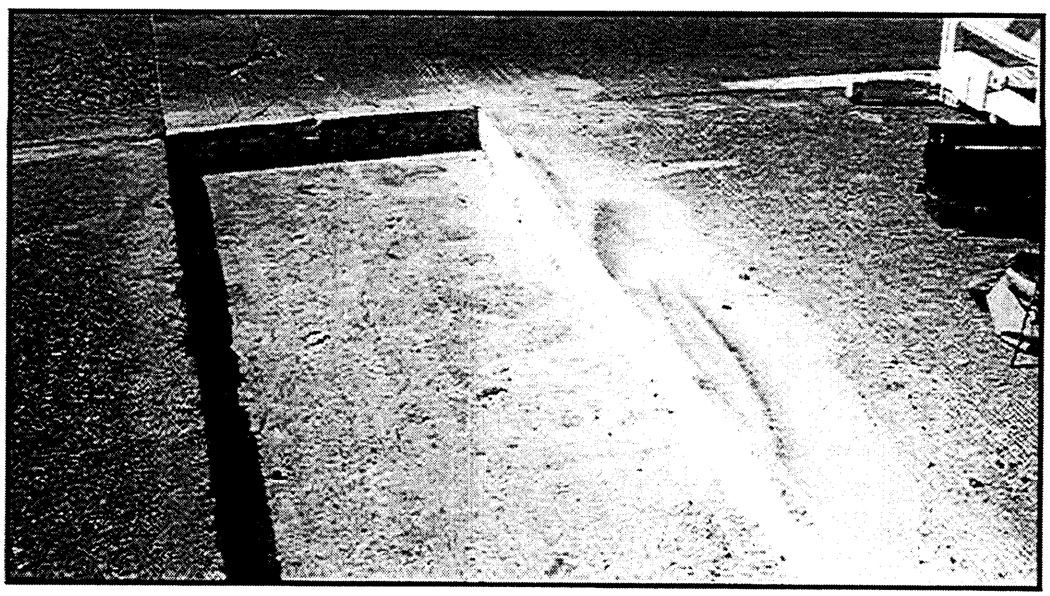

Figure 19
Partial-Depth Patch

Table 3 indicates the amount of patching that has been required for each of the test sections. The values given in Table 3 are a combination of all three patching contracts and a combination of the eastbound and westbound test sections. The values only indicate patches within the test sections and not the entire experimental section, so that all sections may be compared on an equal area basis. All patches that fell within the boundaries of a previous patch were counted separately and added to the total area patched.

Table 3

Interstate 80 Patching Quantities by Test Section

Test Section	Number of Full-Depth Patches	Area of Full-Depth Patches (yd^2)	Number of Partial-Depth Patches	Area of Partial-Depth Patches (yd^2)	Percent of Total Area Patched
0% MS no MSG	0	0.0	14	86.9	3.3
0% MS w/ MSG	2	25.0	9	52.5	2.9
3% MS no MSG	1	6.1	19	119.6	4.7
3% MS w/ MSG	4	32.7	14	122.9	5.8
5% MS no MSG	4	149.2	41	486.6	23.8
5% MS w/ MSG	4	37.5	16	88.6	4.7

Note: MS = Microsilica, and MSG = Microsilica grout

Evidence from Table 3 indicates that the test sections with no microsilica additive in the concrete mixture have performed better than those with the microsilica additive. It also appears that the use of microsilica grout was effective in two out of three cases when compared to those test sections without the microsilica grout.

PROJECT COSTS

The initial cost of constructing a bonded concrete overlay is much higher than a standard bituminous concrete overlay. However, based upon pre-construction estimates of the total life cycle cost over 20 years, the two are similar. The pre-construction expected life for both BCO projects was 20 years, whereas the average expected life for a bituminous overlay in Illinois is approximately 10 years. Tables 4 and 5 depict the construction costs for each of the BCOs constructed, as well as the costs that have been incurred since construction. Items included in these tables are only those that affect the traveling lanes.

Table 4

Interstate 80 Construction and Maintenance Costs

Pay Item	Units	Quantity	Total Cost
Patching (Existing Pavement)	Sq. Yd.	580	$65,130.00
Concrete Pavement Scarification	Sq. Yd.	51,801	$108,782.10
Bonded PCC Overlay 4 inches	Sq. Yd.	51,801	$732,984.15
Average Construction Cost Per Two-Lane Mile		**$266,891.19**	
Maintenance Patching 1998	Sq. Yd.	1,116	$103,705.30
Maintenance Patching 2000	Sq. Yd.	1,555	$133,272.15
Maintenance Patching 2001	Sq. Yd.	1,449	$767,888.95
Total Cost To Date		**$1,911,762.65**	

Table 5

Interstate 88 Construction and Maintenance Costs

Pay Item	Units	Quantity	Total Cost
Patching (Existing Pavement)	Sq. Yd.	561	$64,616.70
Concrete Pavement Scarification	Sq. Yd.	86,274	$258,822.00
Bonded PCC Overlay 3 inches	Sq. Yd.	86,274	$979,209.90
Average Construction Cost Per Two-Lane Mile		**$210,104.61**	
Total Cost To Date		**$1,302,648.60**	

The average cost of construction for these projects was $235,000 per two-lane mile. The average construction cost for a 3.25-inch bituminous concrete overlay during the same time period would have been $115,000 per two-lane mile (the same pre-overlay patching being completed). The additional expense for patching on Interstate 80 has made this project a very costly venture for the Department. At this time, it appears that the Interstate 80 project will not survive for 20 years without a major rehabilitation project. However, the Interstate 88 project has proven effective to date with regard to initial expense and maintenance requirements. This project may prove to be cost effective.

TRAFFIC FACTORS

The traffic conditions on Interstate 80 and Interstate 88 should be considered when comparing the performance of these two projects. Tables 6 and 7 below indicate the traffic conditions for each route, respectively. The percent trucks column includes both single unit and multiple unit truck types.

Table 6

Interstate 80 Traffic Conditions

Year	Average Annual Daily Traffic (AADT)	Percent Trucks	ESALs (million)	Cumulative Design Lane ESALs (million)
1995	19,200	28.4	1.44	1.44
1996	19,975	29.5	1.55	2.99
1997	21,300	30.5	1.73	4.71
1998	23,050	31.2	1.96	6.67
1999	25,400	31.5	2.25	8.92
2000	28,350	32.1	2.60	11.52
2001	31,800	32.2	3.01	14.53

Table 7

Interstate 88 Traffic Conditions

Year	Average Annual Daily Traffic (AADT)	Percent Trucks	ESALs (million)	Cumulative Design Lane ESALs (million)
1996	10,250	26.3	0.76	0.76
1997	10,800	26.4	0.81	1.57
1998	11,100	26.6	0.84	2.40
1999	11,300	27.0	0.86	3.27
2000	11,500	27.0	0.87	4.14
2001	11,650	26.9	0.89	5.03

The average annual daily traffic for Interstate 80 is twice that of Interstate 88. In addition, the traffic volume on Interstate 80 is increasing at a faster rate than the volume on Interstate 88. The percent of heavy truck traffic is also higher for Interstate 80. The higher traffic volume and percent heavy trucks on Interstate 80 have resulted in a higher ESAL count for Interstate 80 as well.

The actual traffic volumes are higher than the design projected traffic volumes for each of these interstates. The 2002 design projected traffic volume (AADT) for Interstate 80 is 21,100 vehicles, while the actual traffic volume for 2001 was 31,800 vehicles. The 2005 design projected traffic volume (AADT) for Interstate 88 is 11,700 vehicles, while the actual traffic volume for 2001 was already 11,650.

The actual percent trucks is much higher than the design projected percent trucks for both interstates. The 2002 design projected percent trucks for Interstate 80 is 17.5 percent, while the actual percent in 2001 was 32.2 percent. The 2005 design projected percent trucks for Interstate 88 is 20.9 percent, while the actual percent in 2001 was 26.9 percent.

CONCLUSIONS

Two bonded concrete overlay (BCO) projects were constructed in Illinois to investigate the potential of this type of rehabilitation for interstate pavements. These projects were located on Interstates 80 and 88 in the northwest section of the state, near the city of Moline. The Interstate 80 project (4-inch overlay) was constructed in the fall of 1994 and spring of 1995. The Interstate 88 project (3-inch overlay) was constructed during the summer of 1996. Both projects were built upon continuously reinforced concrete pavement that was in good to excellent condition.

Performance has been variable to date. Increased performance of the bonded concrete overlay may be insured through rehabilitation and maintenance before the pavement is severely distressed. This may occur several years before other rehabilitation options are considered. This should be considered when selecting a bonded concrete overlay as a rehabilitation technique.

INTERSTATE 80

The Interstate 80 project incorporated six different experimental sections. The purpose of these sections was to investigate the effects of adding various amounts of microsilica to the overlay concrete mixture. These sections were also used to investigate the effects of using grout to enhance the bond between the overlay and the existing pavement. All six sections were constructed in each direction so that each section would have a comparative section in the opposite direction.

Evidence from visual distress surveys and patching quantities indicate that the sections with no microsilica added to the concrete mixture have performed the best. In addition, the test sections with three percent microsilica added performed much better than those with five percent added. The addition of microsilica was shown to increase the amount of medium to high severity transverse cracking at an early age.

The application of grouts as a bonding agent proved to be very difficult and time consuming. Problems were encountered with applying a uniform layer of grout and with placing the concrete before the grout dried out and set-up. Visual surveys and pavement performance have shown that the areas with grout did not show a substantial improvement over the areas with no grout application.

The International Roughness Index values indicate that the overlay did improve the smoothness of this section. However, with the early distresses and cracking, the IRI values quickly increased. The patching contract in 1998 improved the IRI values considerably, but they quickly began to increase again. The patching contracts in 2000 and 2001 have had little effect on the IRI value.

The Condition Rating Survey value for this section was also improved, however it quickly decreased after the overlay placement. The patching contracts in 1998 and 2000 have only slightly improved the CRS rating for this section.

INTERSTATE 88

The cold milling and shot blasting techniques used on Interstate 88 were shown to perform very well based on visual surveys and maintenance requirements of the BCO. At this time, there is no clear evidence as to whether the eastbound lanes (cold milling with shot blasting) or westbound lanes (shot blasting only) are performing better. No patching or maintenance has been required on this bonded concrete overlay.

The International Roughness Index values indicate that the overlay has dramatically improved the smoothness of this section. The IRI values also indicate that this same level of smoothness has been maintained for the life of the overlay.

The Condition Rating Survey values also indicate that the overlay has improved the condition of this section based on pavement distresses. A high CRS value has been maintained for the life of this overlay.

RECOMMENDATIONS

1. It is recommended to place these overlays on pavements with very few major distresses or areas that require patching (CRS Rating of 7.0 or better).

2. Cold milling and shot blasting of the existing pavement surface for texture is recommended.

3. The addition of microsilica to the overlay concrete mixture is not recommended.

4. The use of grout as a bonding agent is not recommended.

5. Late season construction is not recommended.

6. If considering a bonded concrete overlay, pavement designers should understand that existing pavements qualifying for this rehabilitation should not require major repairs for several years. This should be considered in an economic analysis when comparing rehabilitation alternatives.

7. Following the above recommendations does not guarantee a successful project. Extreme caution is urged if considering a bonded concrete overlay.

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7. Illinois Department of Transportation, 2000 Interstate Surface Quality – An Analysis of International Roughness Index and Rut Depths on Illinois Interstate Pavements Including Tollways, Illinois Department of Transportation, Springfield, Illinois, March, 2001.

8. Illinois Department of Transportation, 1999 Illinois Condition Rating Survey, Illinois Department of Transportation, Springfield, Illinois.

Appendix

A

Mixture Designs

Interstate 80 Bonded Concrete Overlay
Mixture Designs(2)

0% Microsilica PCC Design Mixture[a]

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

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

3% Microsilica PCC Design Mixture[a,b]

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

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

5% Microsilica PCC Design Mixture[a,b]

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

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

Interstate 88 Bonded Concrete Overlay
Mixture Design[a]

Material	Type	Producer Name	Theoretical Weight, lbs (kg)
Cement	Type I	Dixon – Marquett	430 (195)
Fly Ash	Type C	American (Louisa)	135 (61)
Water			221 (100)
Sand	Natural	Moline Consumers (Cordova)	1,217 (552)
Stone	Crushed	Moline Consumers (Cleveland)	1,939 (880)
		Total Weight of Mix	3,942 (1,788)

Water / Cementitious Ratio = 0.39
Unit Weight of Mixture = 146.0 lb/ft^3 (2,338.7 kg/m^3)

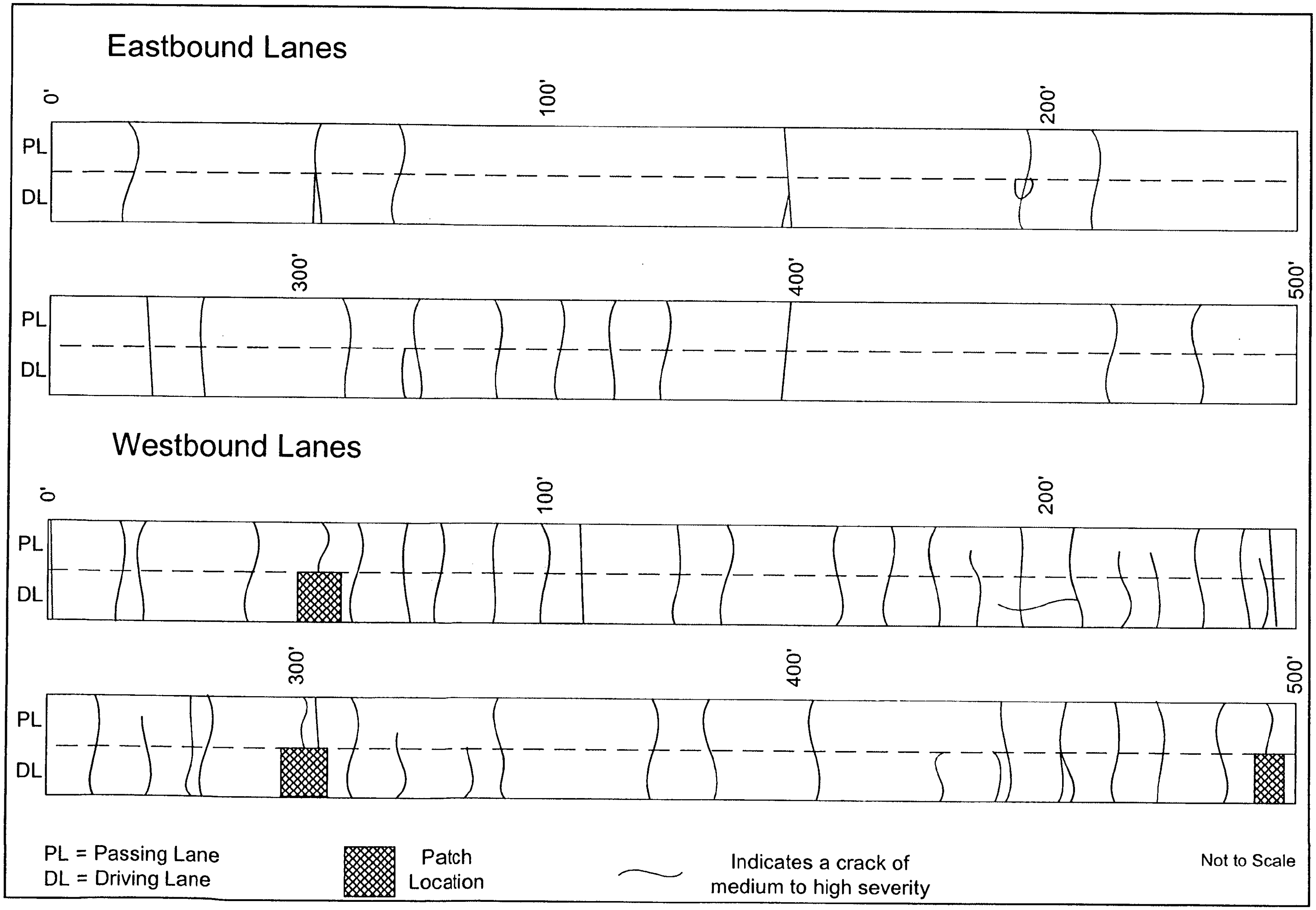
[a] All mixture designs used water reducing admixture and 6.5% air. Coarse aggregate had a top size of ¾ inch. All aggregates were assumed to be saturated surface dry.
[b] Mixture designs with microsilica also incorporated super plasticizer contained in the slurry.

Appendix

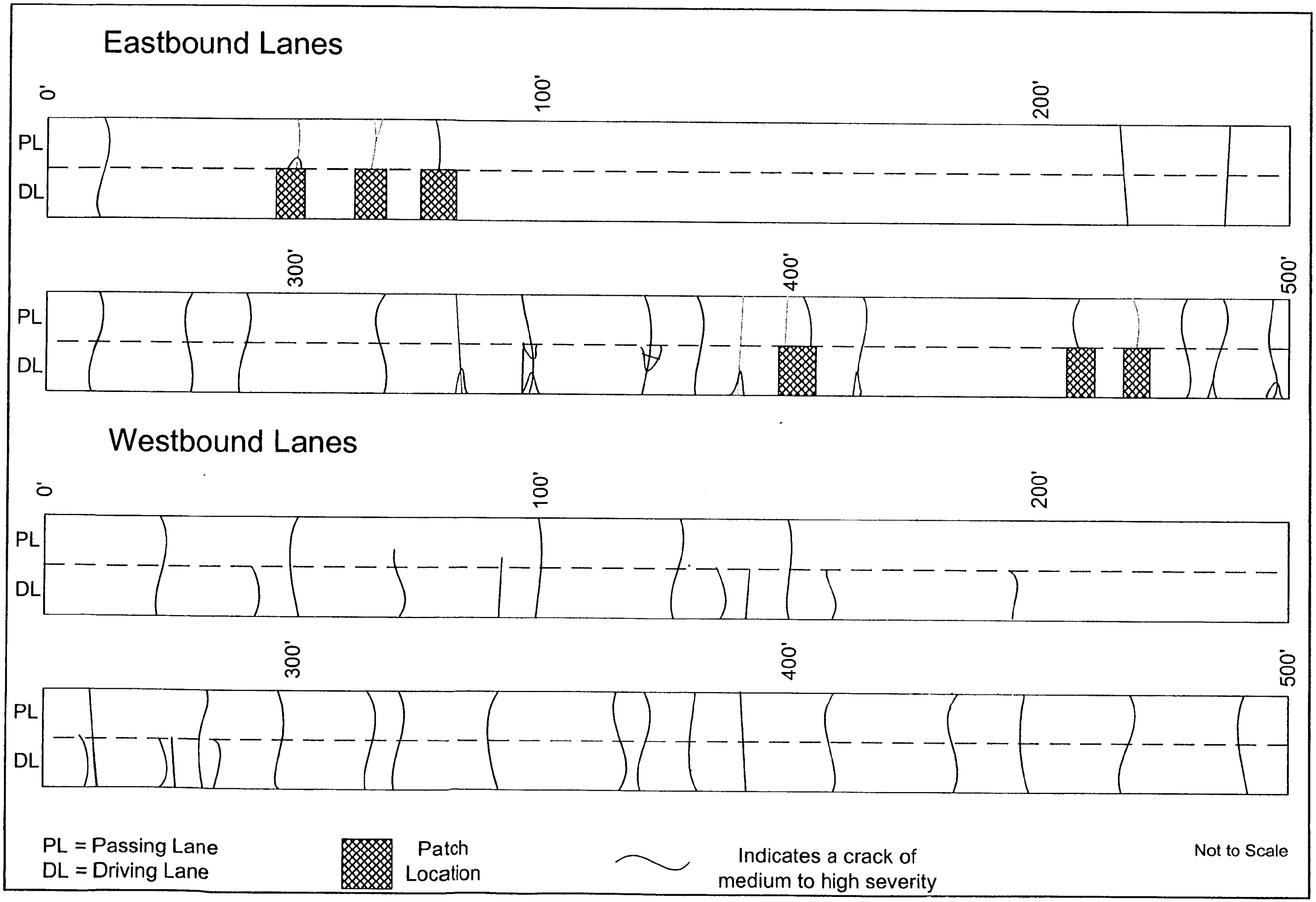
B

2001 Visual Distress Surveys

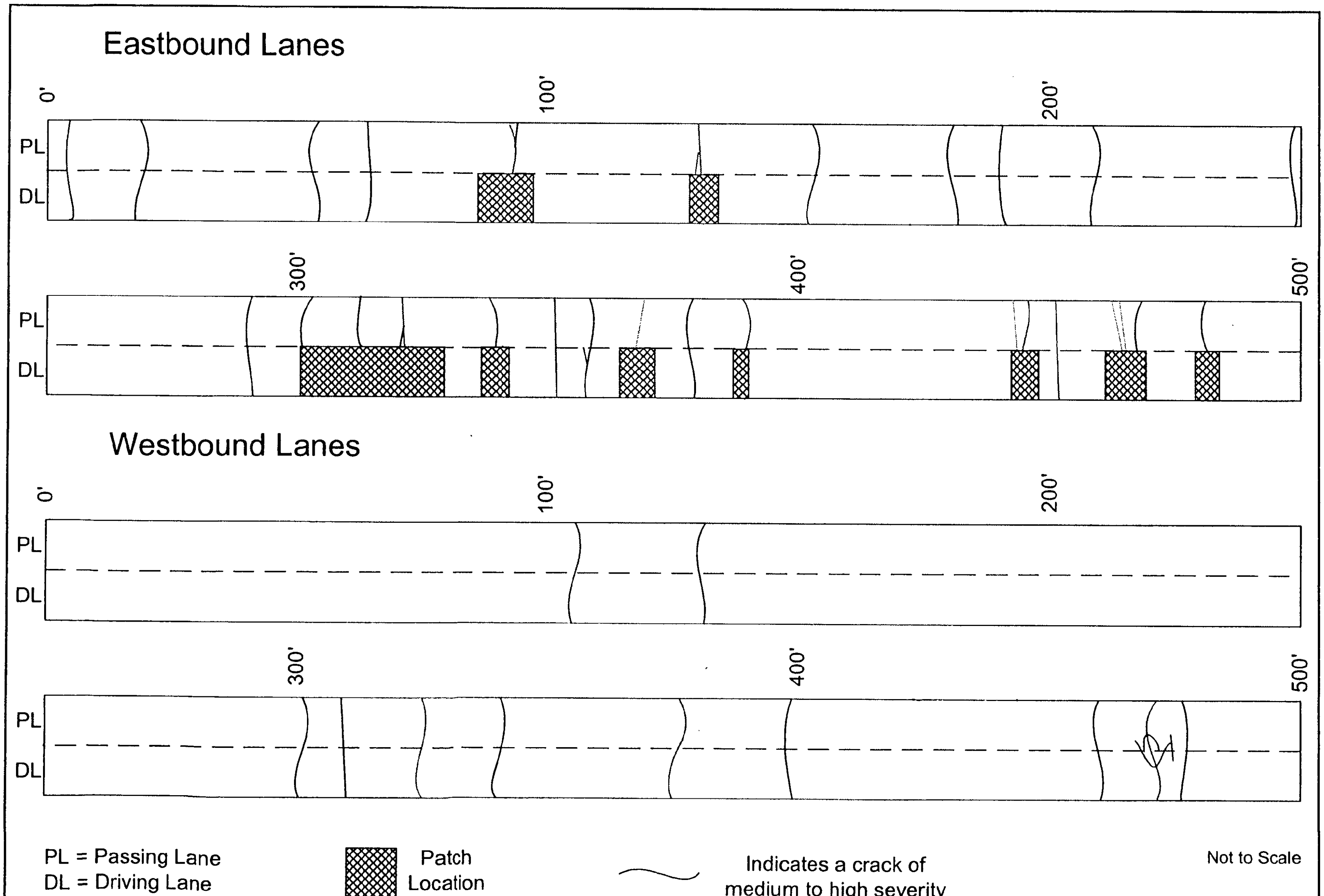
Interstate 80 Experimental Bonded Concrete Overlay
0% Microsilica With Microsilica Grout



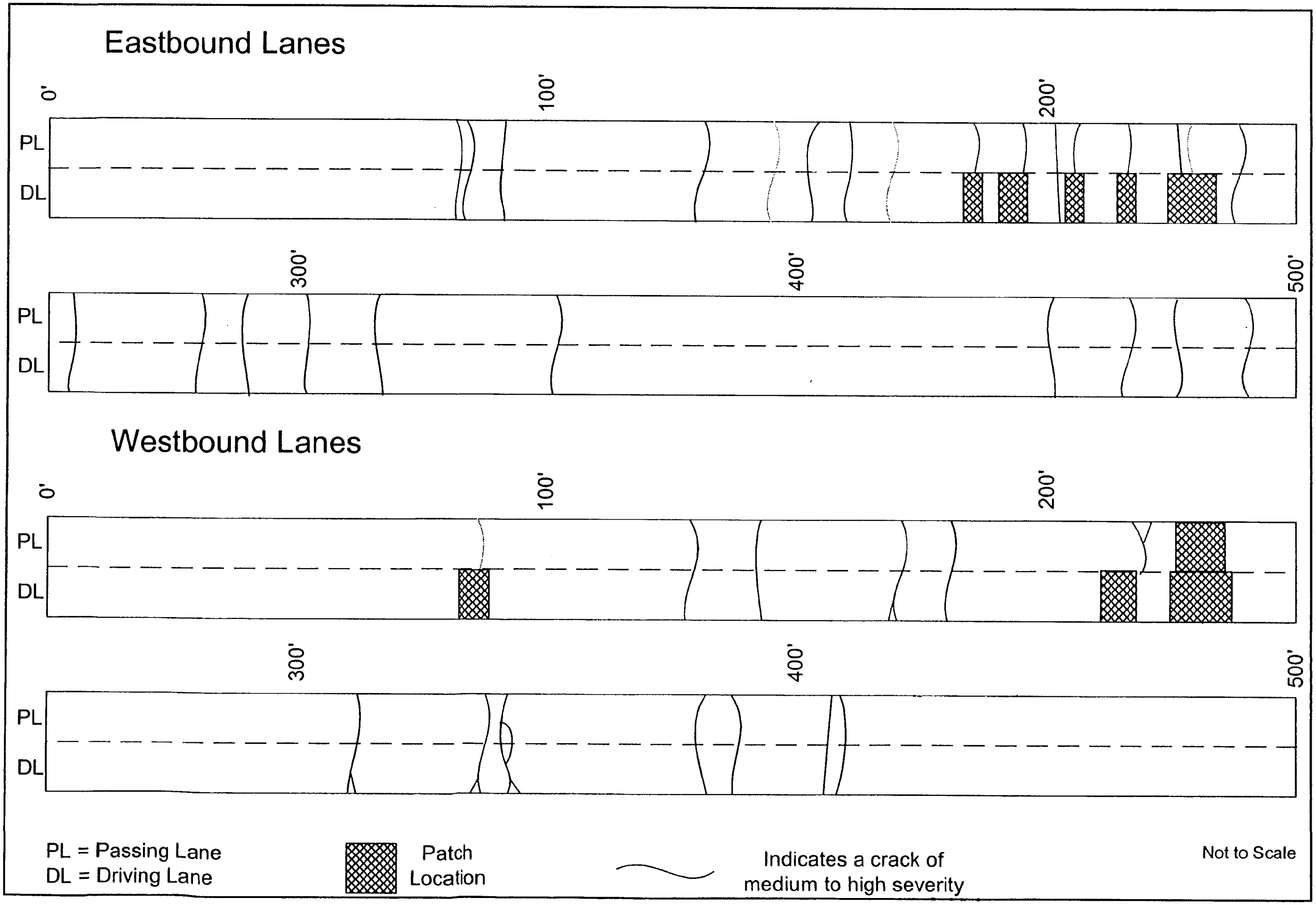
Interstate 80 Experimental Bonded Concrete Overlay
0% Microsilica With No Microsilica Grout



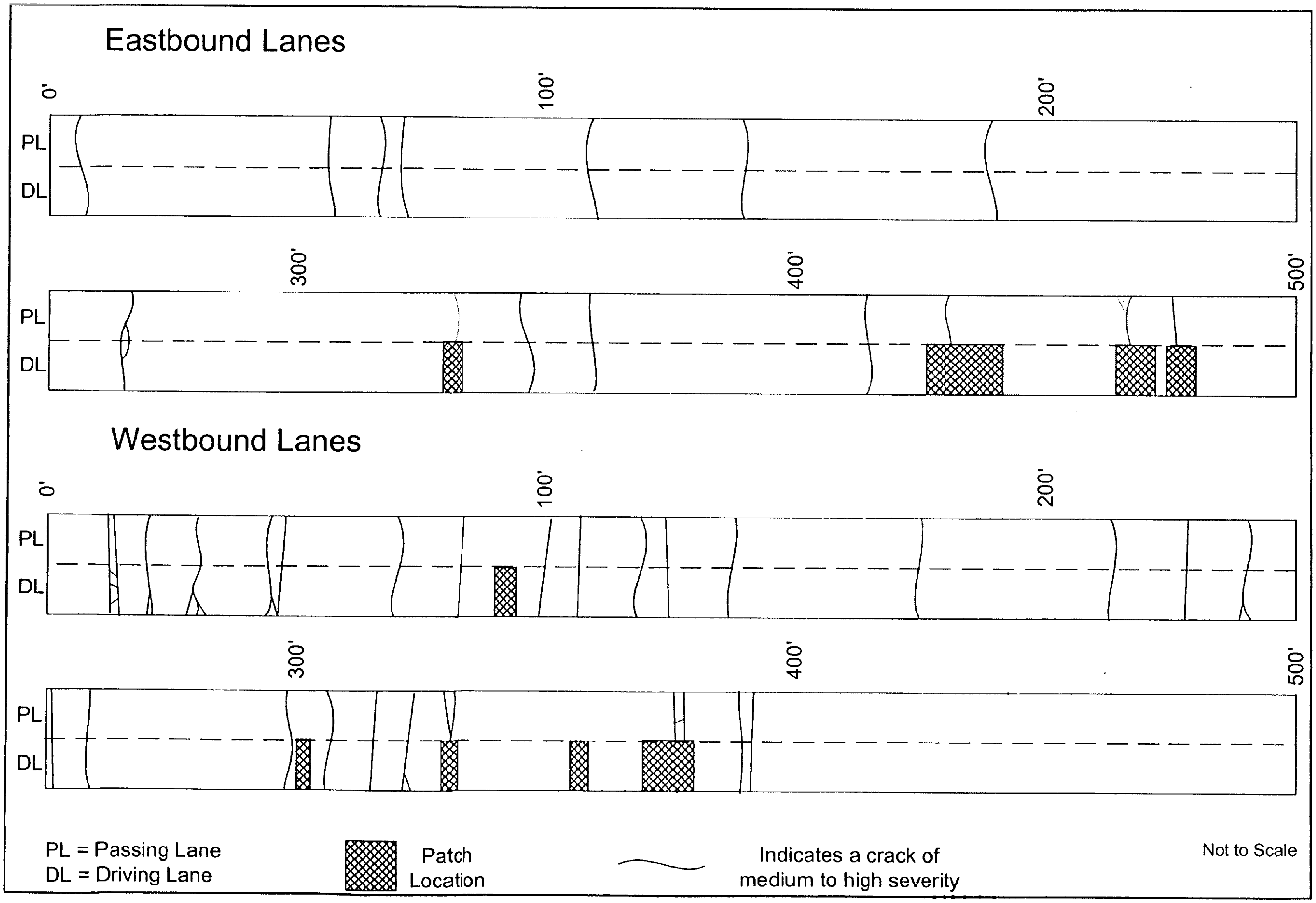
Interstate 80 Experimental Bonded Concrete Overlay
3% Microsilica With Microsilica Grout



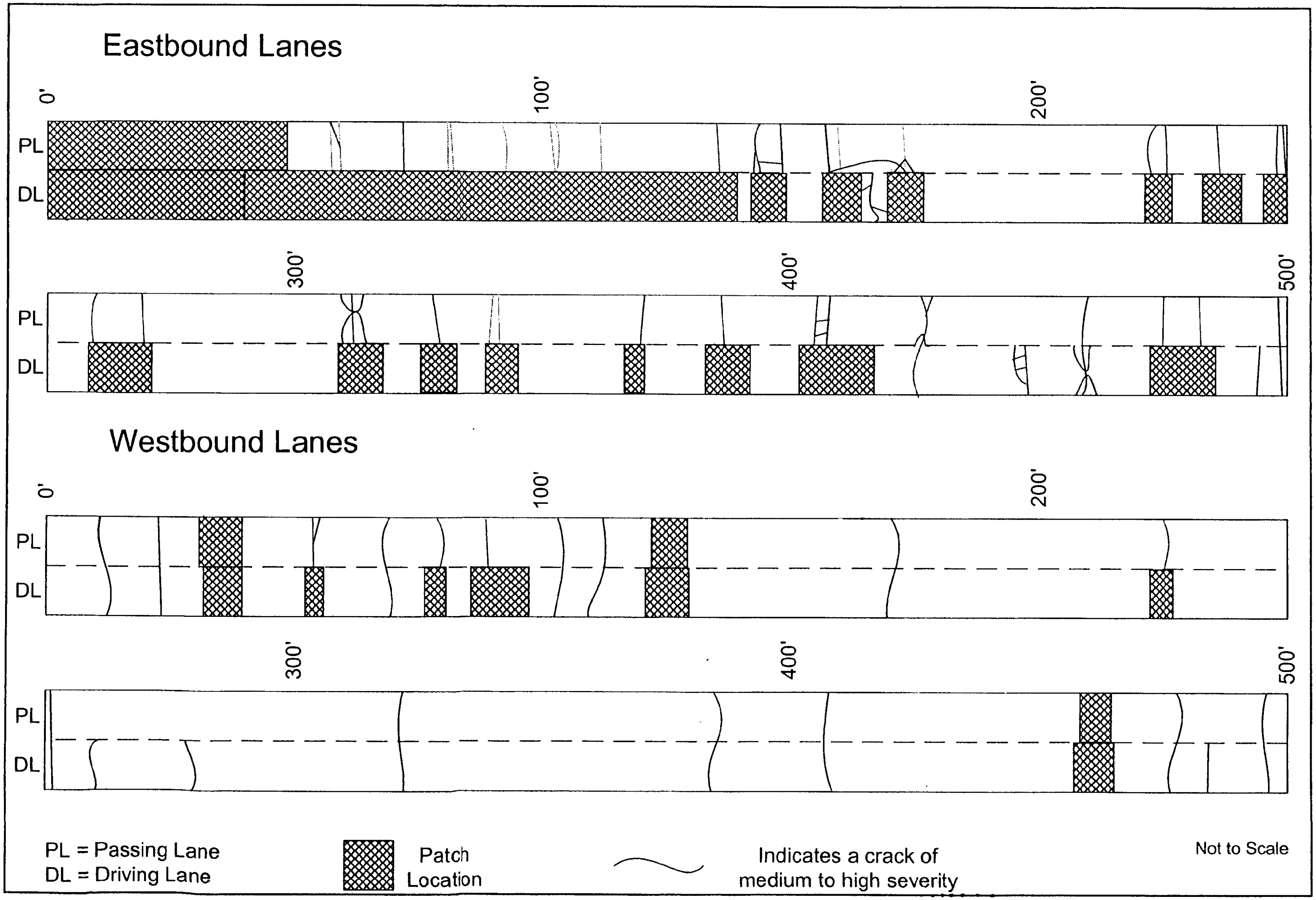
Interstate 80 Experimental Bonded Concrete Overlay
3% Microsilica With No Microsilica Grout



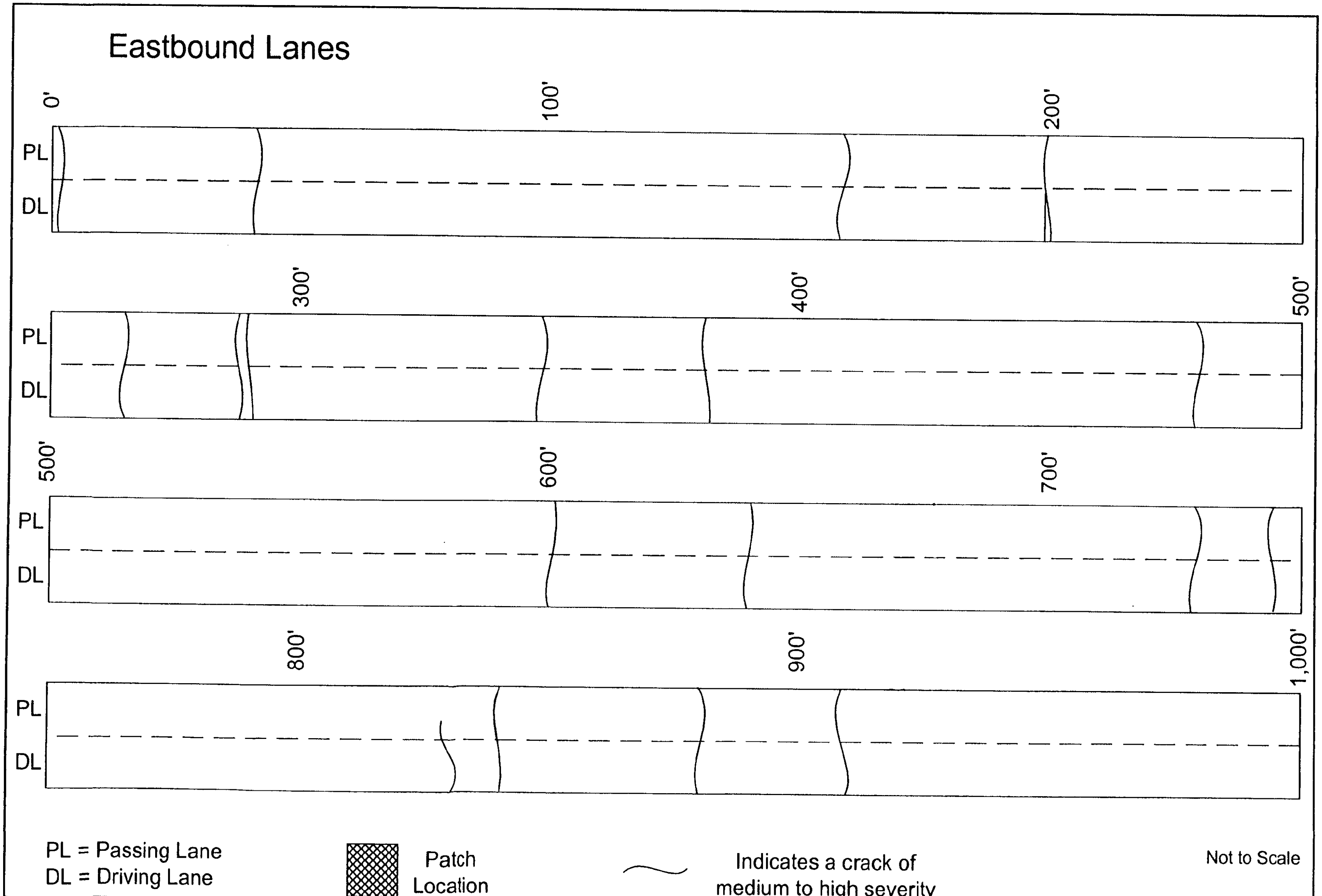
Interstate 80 Experimental Bonded Concrete Overlay
5% Microsilica With Microsilica Grout



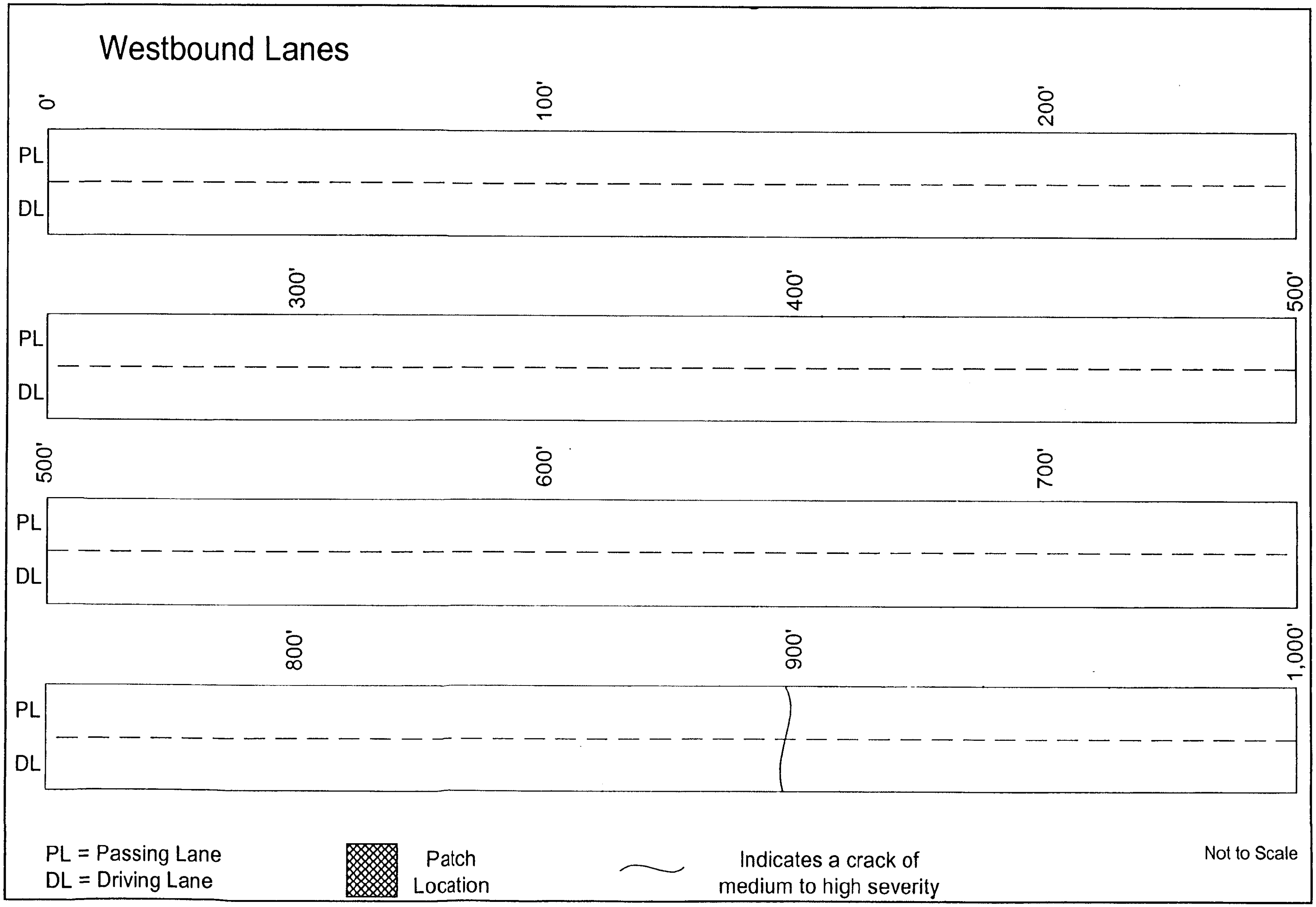
Interstate 80 Experimental Bonded Concrete Overlay
5% Microsilica With No Microsilica Grout



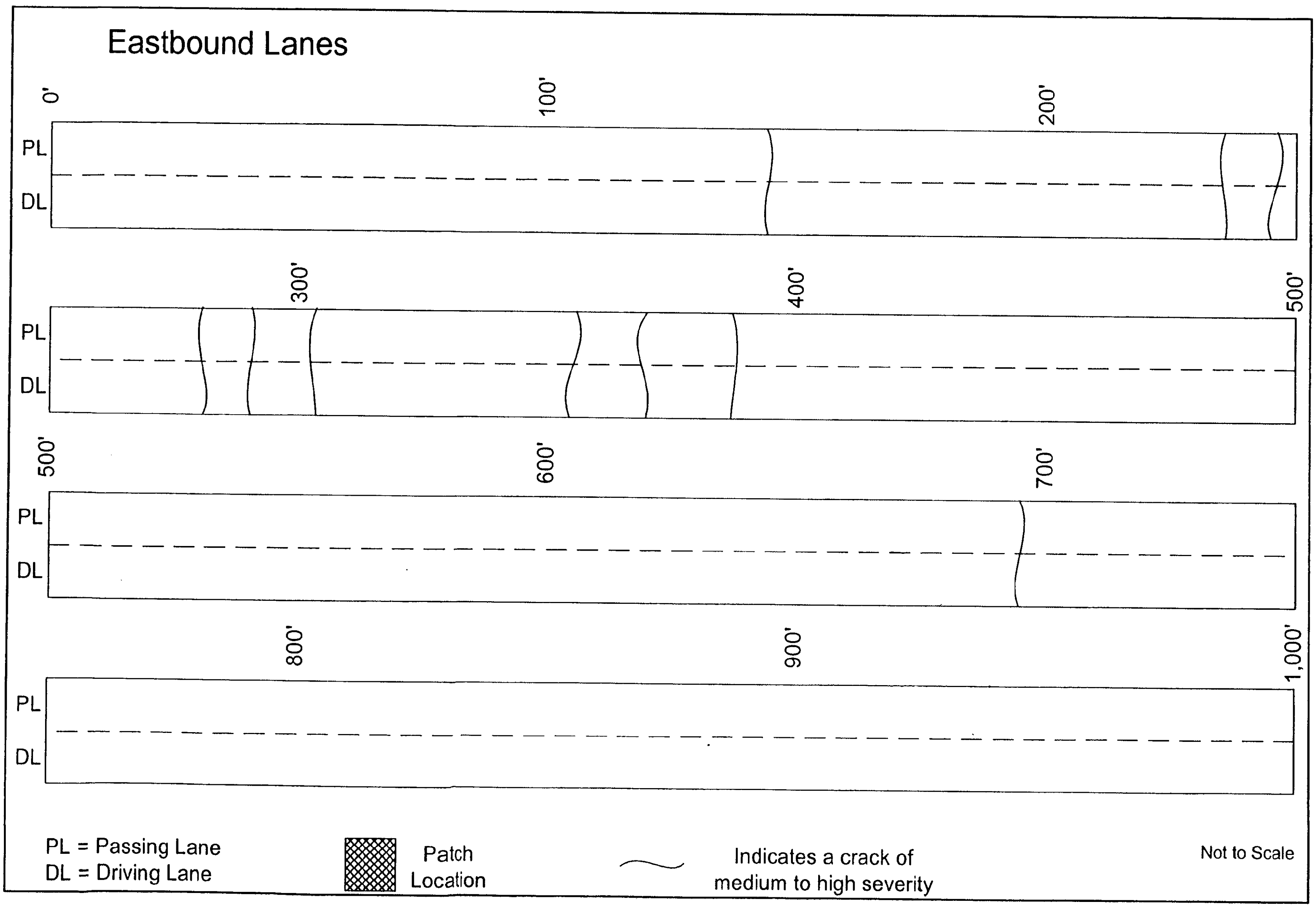
Interstate 88 Experimental Bonded Concrete Overlay
Cold Milling With Light Shot Blasting (Section 1)



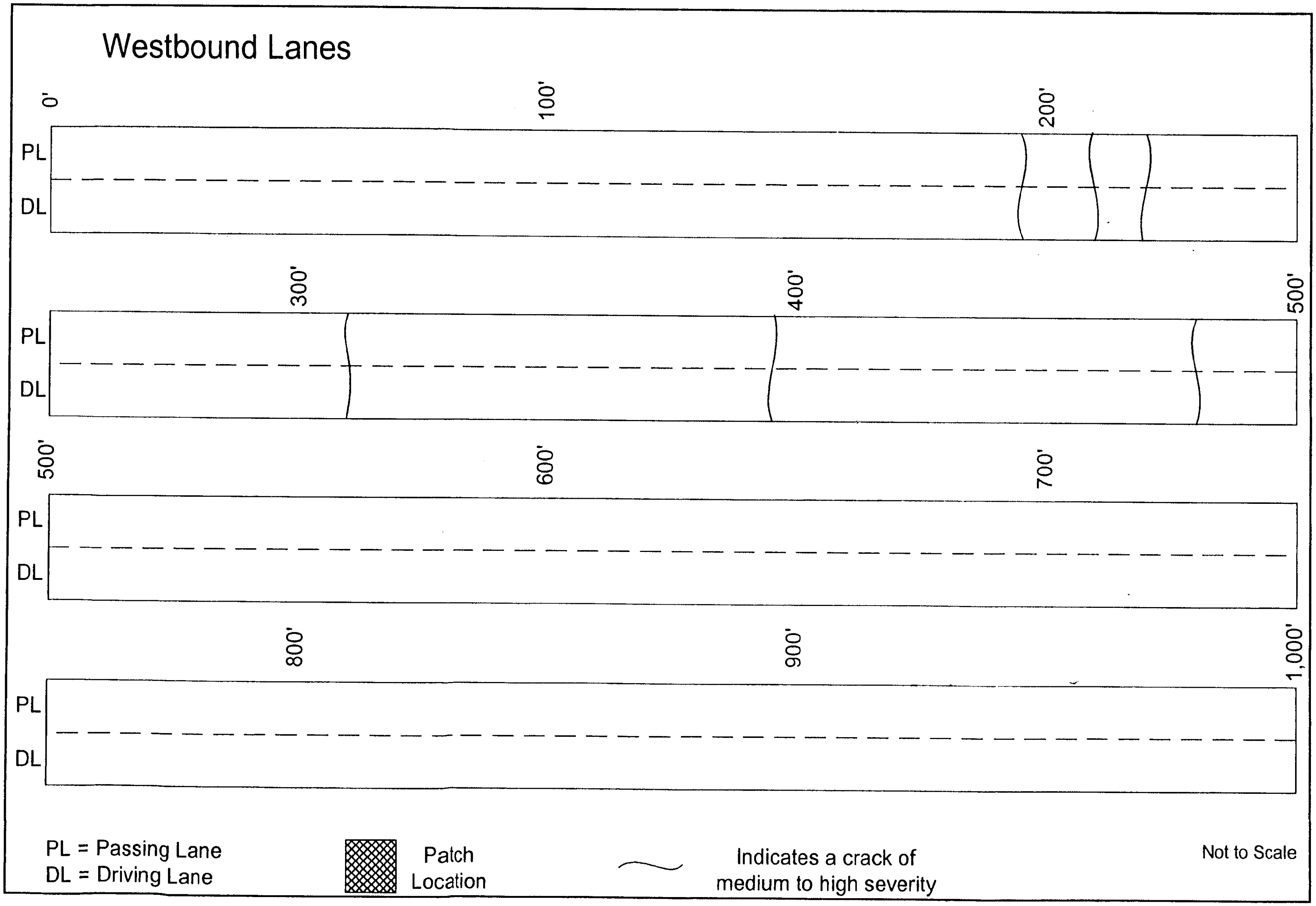
Interstate 88 Experimental Bonded Concrete Overlay
Shot Blasting (Section 1)



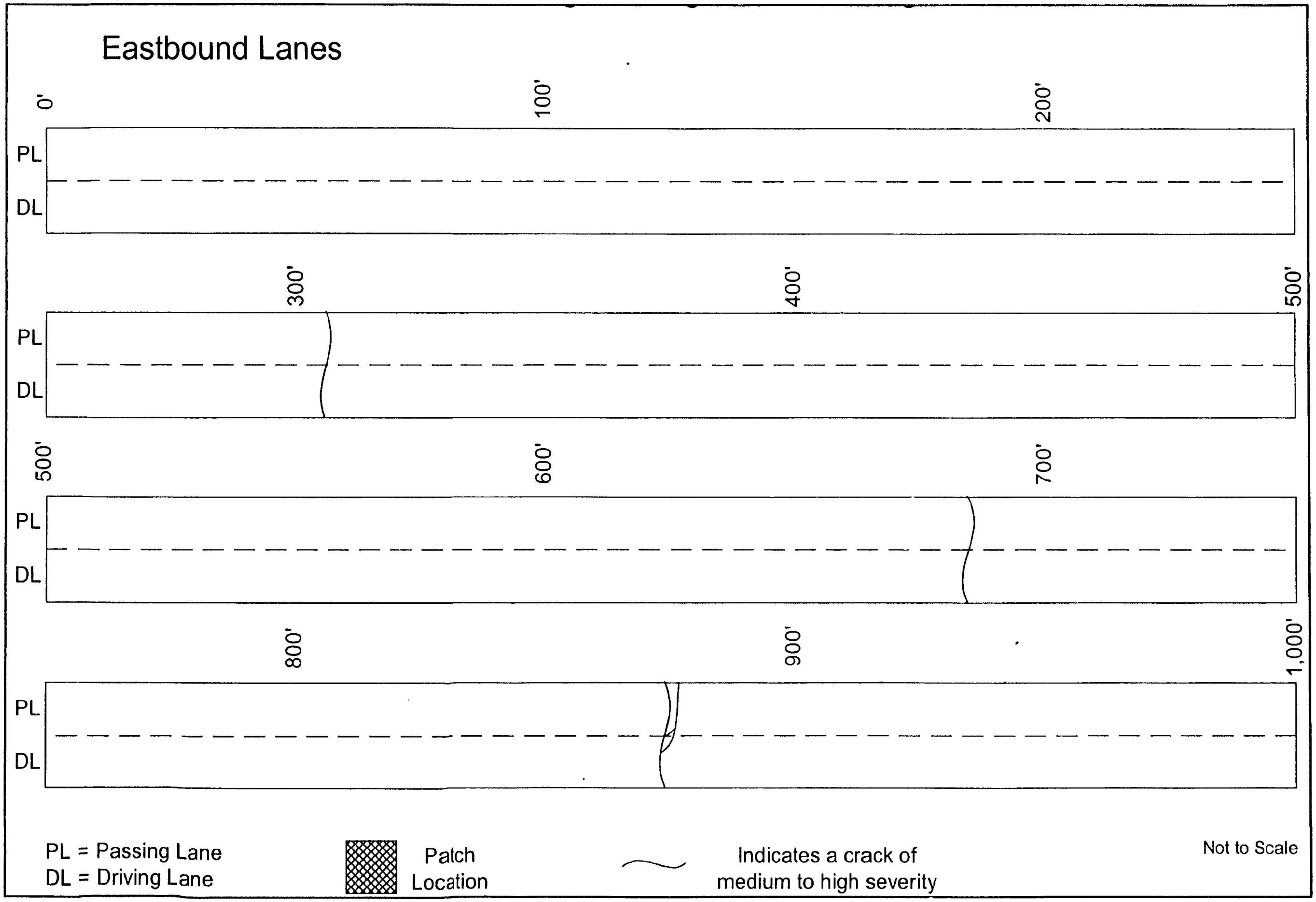
Interstate 88 Experimental Bonded Concrete Overlay
Cold Milling With Light Shot Blasting (Section 2)



Interstate 88 Experimental Bonded Concrete Overlay
Shot Blasting (Section 2)



Interstate 88 Experimental Bonded Concrete Overlay
Cold Milling With Light Shot Blasting (Section 3)



Interstate 88 Experimental Bonded Concrete Overlay
Shot Blasting (Section 3)