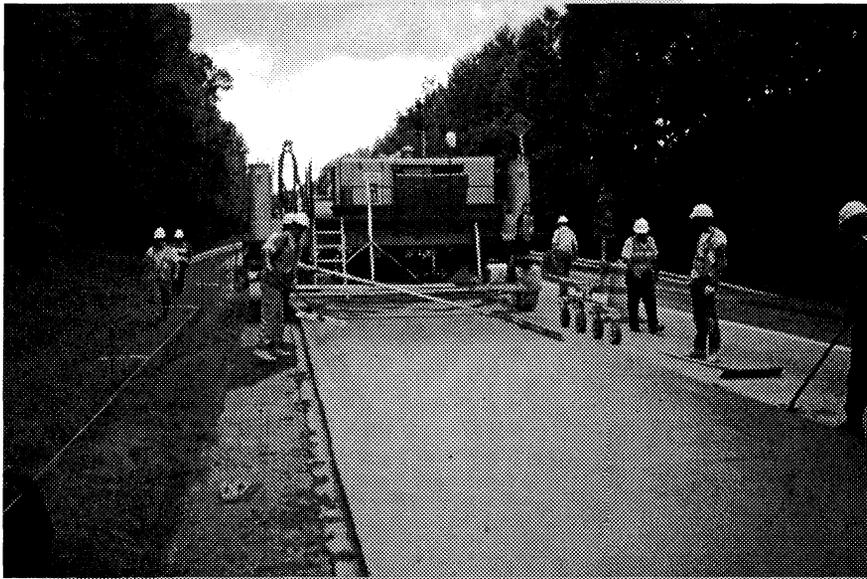


FINAL REPORT

EVALUATION OF A THIN-BONDED PORTLAND CEMENT CONCRETE PAVEMENT OVERLAY



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VIRGINIA TRANSPORTATION RESEARCH COUNCIL

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<p>Abstract</p> <p>This report discusses the performance of the Virginia Department of Transportation's first modern rehabilitation project involving a thin-bonded portland cement concrete overlay of an existing jointed concrete pavement. The performance of the rigid overlay, which was constructed in a fast-track mode to minimize lane closure time, was evaluated by detailed condition surveys conducted annually throughout a 6-year analysis period to identify, document, and monitor the occurrence of distress. The roughness of the overlay was also measured annually with an accelerometer-based inertial road profiler to permit an examination of the effects of surface deterioration on ride quality.</p> <p>After 6 full years of service, which included only minimal maintenance, the pavement overlay remained in good overall condition. Although the ride quality of the overlay remained virtually unchanged throughout the period, a significant increase in the occurrence of low-to-moderate-severity joint spalls, corner breaks, and to a lesser extent transverse cracks was noted during the fifth and sixth years. The extrusion of compression seals and the subsequent infiltration of water into the pavement structure probably contributed to the observed localized failure of the overlay/substrate bond in the vicinity of joints. This condition, in turn, weakened the pavement's structural capacity at panel edges and thereby resulted in the formation of corner breaks and cracks parallel with and near transverse joints.</p> <p>The consideration of thin-bonded concrete overlays constructed in a fast-track mode is recommended as a viable rehabilitation alternative for jointed concrete pavements that are not severely distressed. However, careful attention to joint installation and, in particular, joint maintenance is recommended for similar future rehabilitation projects.</p>				

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(The opinions, findings, and conclusions expressed in this
report are those of the author and not necessarily of
the sponsoring agency.)

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ABSTRACT

This report discusses the performance of the Virginia Department of Transportation's first modern rehabilitation project involving a thin-bonded portland cement concrete overlay of an existing jointed concrete pavement. The performance of the rigid overlay, which was constructed in a fast-track mode to minimize lane closure time, was evaluated by detailed condition surveys conducted annually throughout a 6-year analysis period to identify, document, and monitor the occurrence of distress. The roughness of the overlay was also measured annually with an accelerometer-based inertial road profiler to permit an examination of the effects of surface deterioration on ride quality.

After 6 full years of service, which included only minimal maintenance, the pavement overlay remained in good overall condition. Although the ride quality of the overlay remained virtually unchanged throughout the period, a significant increase in the occurrence of joint spalls, corner breaks, and, to a lesser extent, transverse cracks of low-to-moderate severity was noted during the fifth and sixth years. The extrusion of compression seals and the subsequent infiltration of water into the pavement structure probably contributed to the localized failure of the overlay/substrate bond in the vicinity of joints. This condition, in turn, weakened the pavement's structural capacity at panel edges and thereby resulted in the formation of corner breaks and cracks parallel with and near transverse joints.

The consideration of thin-bonded concrete overlays constructed in a fast-track mode is recommended as a viable rehabilitation alternative for jointed concrete pavements that are not severely distressed. However, careful attention to joint installation and, in particular, joint maintenance is recommended for similar future rehabilitation projects.

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INTRODUCTION

The transportation industry faces a growing challenge to reconstruct and rehabilitate an aging pavement infrastructure while minimizing disruption to increasing levels of traffic. The inconvenience and costs of delays to motorists, work zone safety concerns, and the high cost of traffic control have provided the impetus for finding new ways of reducing time requirements for pavement rehabilitation.

The placement of thin-bonded concrete overlays on old concrete pavement is not a new technology.¹ Such overlays have been used for a number of years to enhance jointed and continuously reinforced concrete pavements structurally in anticipation of increased traffic loads and volumes. The construction of such overlays using slipform pavers in a “fast-track” mode (rapid construction) is, however, a relatively new practice. One of the primary goals of this rehabilitation technique is to provide a durable, well-performing pavement capable of being constructed within a window (lane closure time) that is competitive with that of asphaltic concrete overlays.

In response to the economic importance of a competitive climate between the asphalt and concrete paving industries in Virginia, the Virginia Department of Transportation (VDOT) through the Virginia Transportation Research Council (VTRC) and in cooperation with the Federal Highway Administration (FHWA) initiated the construction of a thin-bonded overlay on a 1,500 m (4,900 ft) section of U.S. Route 13 in Northampton County, Virginia. The pavement chosen was an old, plain (unreinforced) jointed concrete structure that was in reasonably good condition and supported a moderate volume of traffic when the project was authorized in 1988. An installation report prepared by VTRC in 1992 documented the construction of the project and evaluated the feasibility of building the 90 mm (3.5 in) thick overlay of an existing concrete pavement in a fast-track mode so as to minimize lane closure time.² The report concluded that thin-bonded concrete overlays can be feasibly constructed in an accelerated mode as an alternative to the rehabilitation of jointed concrete pavements when those pavements are not seriously distressed but are in need of structural enhancement.

PURPOSE AND SCOPE

The purpose of this project was to evaluate the performance of the overlay during a 6-year period. This was accomplished by conducting detailed visual pavement condition surveys annually during the evaluation period to identify, document, and monitor the occurrence of distress. Additionally, the ride quality of the overlay was measured annually with an accelerometer-based inertial road profiler to permit an examination of pavement surface roughness trends. Unfortunately, the experimental nature of the project precluded a meaningful evaluation of costs that might apply to a similar nonexperimental project.

REVIEW OF OVERLAY INSTALLATION

The following presentation of relevant facts surrounding the construction of the overlay project is included to provide the reader with a basic understanding of the project's evolution. A summary of the history of the original concrete pavement precedes a discussion of findings included in the *Installation Report*.²

History of Original Pavement Construction

The original pavement, constructed in 1965, consisted of a 200 mm (8 in) thick unreinforced concrete surface supported by a native sand and gravel subgrade topped with a sand and gravel select material used as a subbase. Transverse joints, sealed with hot-poured rubberized asphalt, were undowelled and spaced at 6 m (20 ft). Traffic records indicate that the section had sustained approximately 2.2 million 18 kip equivalent single axle loads (ESAL) in the outside lane by 1988. Although project records did not indicate the design ESAL, traffic records indicate a rather modest growth of approximately 2.5 percent annually since 1980.

The major distresses reportedly manifested by the old pavement at the time the overlay was being considered were joint faulting and, to a lesser extent, joint spalling. Some concrete panels reportedly exhibited longitudinal cracking.

Construction of the Fast-Track Overlay

The development of specifications for construction of the overlay was a cooperative effort among VDOT, FHWA, and the American Concrete Pavement Association. The major elements of the project were (1) repair of the old pavement to restore any areas of structural failure, thereby providing a more uniform foundation, and (2) paving of the new overlay in a fast-track mode with a targeted maximum lane closure time of 48 hours, beginning with the initiation of concrete placement and ending with the removal of the curing blanket.

Concrete used in the overlay construction was VDOT Class A3 with the following specifications:

- *Minimum cement content:* 444.5 kg/m³ (750 lb/y³)
- *Maximum water-cement ratio:* 0.42
- *Minimum compressive strength at 24 hours:* 20.7 MPa (3,000 psi)
- *Coarse aggregate size:* No. 57 or No. 68.

The reader is referred to the *Installation Report* for more detailed information on material specifications and the results of trial concrete batching.²

Preparation of the existing pavement began in the spring of 1990 with the removal and replacement of damaged concrete. Concrete used in the patch repairs had a design strength of 20.7 MPa (3,000 psi) in 24 hours. Joints in the old pavement were cleaned and resealed with hot-poured joint sealing material conforming to AASHTO Specification M 173. Considerable attention was given to surface preparation to ensure full bonding of the overlay to the old pavement. Final surface preparation was accomplished through the use of shotblasting machines to achieve a surface texture whereby the coarse aggregate particles had a clean exposed face. Approximately one half of the surface to be paved was treated just ahead of the paver with a portland cement slurry grout to facilitate bonding of the overlay. The grout was omitted for approximately the second half of the project to enable a comparative evaluation of bond strength between layers with and without grout. Adequate bond strengths, as measured during laboratory shear tests on cores removed from the 7-day-old overlay, were consistently obtained from ungrouted and grouted sections.

Overlay paving operations began at 1 P.M. on June 14, 1990, with a Gomaco slipform paver. After the application of a fine texture with a burlap drag, the surface was tined transversely by a hand-held wire tine. Liquid membrane curing compound was then applied, followed by the placement of an insulated curing blanket to facilitate early strength development. As soon as the overlay had hardened sufficiently to support the equipment, 3 mm (1/8 in) wide cuts were sawed full depth through the overlay at locations previously marked to coincide with existing joints and cracks in the underlying old pavement. Transverse joints in the overlay were resawed for proper shape and sealed with preformed compression seals. Transverse joints over repaired joints containing expansion materials and longitudinal joints in the overlay were sealed with a rubberized, asphalt, hot-poured, joint sealing material.

The project was opened to traffic 58 hours after the first load of concrete appeared on the job. Although the actual construction duration exceeded the 48-hour target, project personnel were reportedly convinced that only a few logistical modifications in the transportation of concrete and in sawing operations would have permitted the target to have been met easily.²

PAVEMENT PERFORMANCE EVALUATION

An evaluation of the overlay's performance was made by visual examination of the pavement surface at close range on an annual basis throughout the 6-year period. Detailed records were made of all occurrences of visible distress during these surveys. In addition to the severity and extent of the observed distresses, their exact locations were documented and mapped to enable the propagation of the distresses to be monitored from year to year. The final condition survey included the full-depth removal of cores from areas representative of various surface conditions to support an evaluation of the observed deterioration. The core locations were selected to complement a concurrent assessment of bond failure between old and new pavement layers, which employed a sounding technique commonly used to identify zones of delaminated concrete on bridge decks.

The performance evaluation also included the annual measurement of pavement surface roughness with an accelerometer-based inertial road profiler to enable an examination of the effects of surface deterioration on ride quality.

Distress Surveys

The pavement surface in both lanes was visually examined once per year by a survey crew of two or three walking along the road (when traffic control was used) or roadway shoulder. The surveys were led by the same crew chief each year to minimize variation in the data collected between years due to human error. The distresses reported herein were identified and classified in general accordance with a distress dictionary developed by the Strategic Highway Research Program for engineers and organizations responsible for maintaining pavement infrastructure.³

Pre-Overlay Distress Survey

The first distress survey was conducted on June 1, 1990, just before construction of the overlay commenced but after completion of the preparatory pavement repairs. This survey was performed to document the location of existing distresses that could potentially reflect through the overlay later in the evaluation period. The pre-overlay survey also served to provide a record of the condition of the substrate just before rehabilitation.

Results of the survey demonstrated that both lanes of the entire experimental section were restored to an excellent condition before placement of the overlay. Only a few occurrences each of low-severity joint spalls, corner breaks, and longitudinal cracks were recorded as being untreated.

Post-Overlay Distress Surveys

June 1991

A single low-severity corner break was the only distress recorded during the first post-overlay visual survey, which was conducted in June 1991. The break, which intersected the centerline joint and a transverse joint in the outer lane, was located approximately 61 m (200 ft) from the north end of the project.

March 1992

The second visual survey revealed only slight evidence of additional deterioration. There were 8 new low-severity corner breaks and 2 low-severity transverse cracks. The cracks had developed within 0.75 m (2.5 ft) of and parallel with the nearest transverse joints.

October 1993

By October 1993, the occurrence of low-severity spalls along transverse joints and low-severity corner breaks had increased appreciably. A total of 22 and 35 previously unrecorded occurrences of these distresses, respectively, were observed. Additionally, the number of longitudinal and transverse cracks that had developed since March 1992 was 7 and 6, respectively. Similar to those recorded during previous surveys, transverse cracks were parallel with and generally located within 0.75 m (2.5 ft) of the nearest transverse joint. Approximately one fourth of the transverse joint seals exhibited low-to-moderate severity distress, which was evident by the partial extrusion of compression seals.

April 1994

Observations recorded during this survey included 34 new occurrences of low and moderate severity spalls along transverse joints. A total of 7 new corner breaks were also documented. Only 4 new transverse cracks, all of which were judged to be of low severity and similar in configuration to those previously discussed, were noted. New longitudinal cracks, which totaled 4, were judged to be of low severity. Several new instances of extruded compression seals were also observed.

November 1995

This survey, made during the overlay's fifth year of service, revealed that the pavement surface primarily manifested new transverse joint spalls and corner breaks, both of which had increased at approximately the same rate as during the previous 2 years. Likewise, transverse and longitudinal cracks continued to form at a rate of approximately 4 per year, which was similar to the previously recorded rates of development for those distresses. Although several new compression seal failures were observed during this survey, a number of previously noted

failures had been repaired by removing the extruded seals and replacing them with silicone joint sealant. Two full lane-width concrete panels, 6 m (20 ft) in length each, had also been replaced since the last survey.

August 1996

The final distress survey demonstrated that although the overall condition of the experimental pavement was still quite good, deterioration of the surface had accelerated somewhat. This was supported by the dramatic increase in new occurrences of transverse joint spalls and corner breaks. Visible discoloration in the immediate vicinity of joints exhibiting extruded seals was evident. Likewise, most of the length of the longitudinal centerline joint, which was generally judged to be slightly to moderately distressed, exhibited similar staining. Recorded occurrences of new longitudinal and transverse cracks were not significantly increased. Figure 1 illustrates the manifestation of corner breaks, joint spalls, and transverse and longitudinal cracks over the evaluation period.

The extent of bond failure between the overlay and the substrate was assessed during the final survey using a sounding technique. The procedure involved dragging four parallel metal chains, approximately 1.22 m (4 ft) in length each, over the pavement surface. This technique is commonly used on concrete bridge decks to identify zones of delamination within

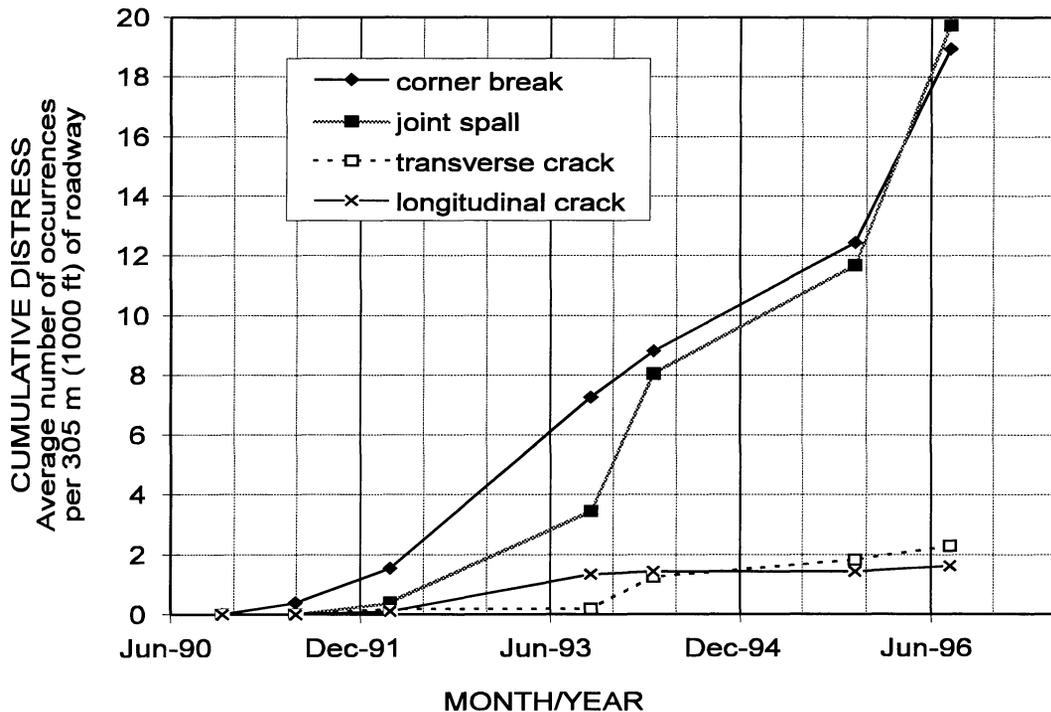


Figure 1. Occurrence of Distress Over Time

the paved surface. Generally, delaminated zones cause the chains to emit a dull or hollow sound as they are dragged over the deck; such a sound is easily distinguished from the higher pitched ring that results when the chain encounters a solid deck. The technique may successfully result in the identification of bond failure between concrete pavement layers, provided the layer interface is not too deep below the surface and the layer separation is distinct.

In this case, the chains were dragged across the overlay surface, and those areas that caused the chains to emit a hollow sound were noted and marked with paint. Interestingly, the vast majority of locations judged to be poorly bonded were within approximately 0.5 m (1.5 ft) of transverse or longitudinal joints. Those zones identified as being poorly bonded generally coincided with the surface stains surrounding distressed joints that were discussed previously.

The August 1996 distress survey also included the full-depth removal of seven 100 mm (4 in) diameter cores to enable the subsurface observation of distresses and provide information about the condition of the overlay bond. The three cores removed from areas exhibiting no distress and no evidence (by sounding) of delamination were consistently well bonded to the substrate. Another core, which was removed from a longitudinal crack that had developed during the overlay's third year of service, revealed that the crack extended full depth through the original concrete pavement. A review of the pre-overlay distress survey revealed that the crack did, in fact, exist in the original pavement but went unrepaired before construction of the overlay. This might suggest that the distress reflected upward through the overlay over a period of time. One core removed from a crack parallel with and near a transverse joint was located within a zone identified as being potentially delaminated. Interestingly, the overlay portion of this core was not bonded to the substrate, but the crack, which extended fully through the 90 mm (3.5 in) overlay, did not penetrate the substrate. The remaining two cores were taken from pavement surfaces near concrete panel corners that did not exhibit visible distress but were identified during sounding as being potentially delaminated. As suspected, neither core was bonded at the overlay/substrate interface.

Pavement Roughness Surveys

Measurements of overlay roughness were made annually with an accelerometer-based inertial road profiler. A K.J. Law Model 8300 Roughness Surveyor was used to measure the international roughness index (IRI) for the surveys conducted through 1994. Roughness measurements performed in 1995 and 1996 took advantage of VDOT's newly acquired South Dakota-type Road Profiler manufactured by the International Cybernetics Corporation to measure IRI for surveys conducted in those years.

Figures 2 and 3 summarize the results of the roughness surveys for the two lanes over time. When differences between the capacities of the two devices to measure are considered, the graphs demonstrate that the roughness of the overlay changed very little throughout the evaluation period. Results obtained with the K.J. Law Model 8300 device indicated that the

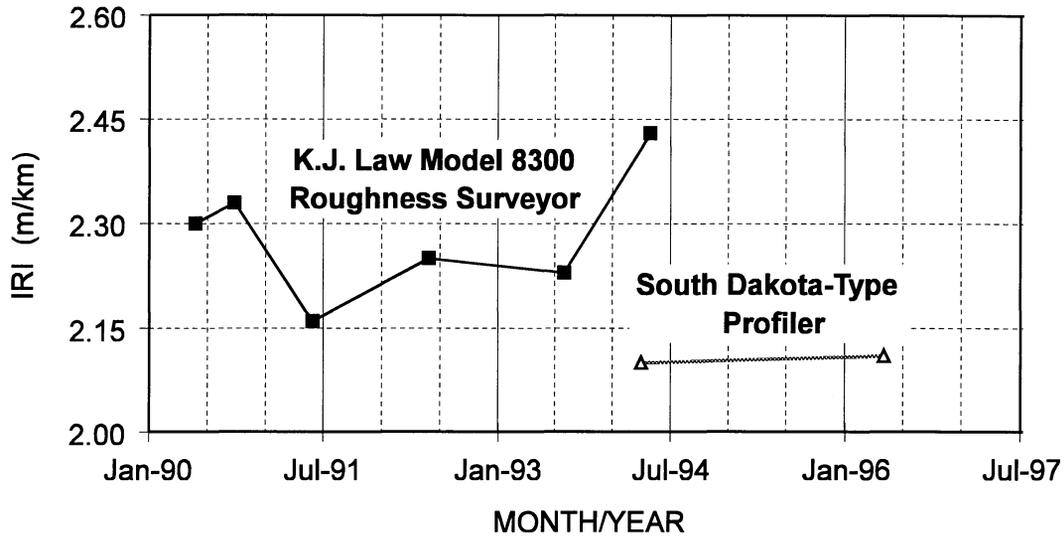


Figure 2. Pavement Roughness Over Time, Outer Lane

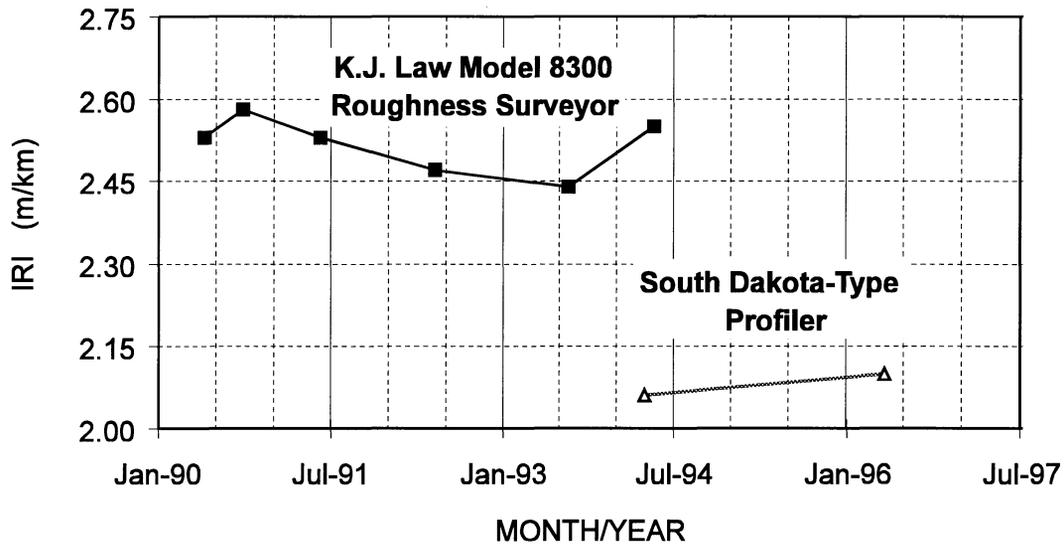


Figure 3. Pavement Roughness Over Time, Inner Lane

pavement was only moderately smooth, with IRI values ranging from approximately 2.21 to 2.37 m/km (140 to 150 in/mi) each year in the outside lane. The inside lane consistently yielded IRI values on the order of 2.52 m/km (160 in/mi) with the same device. Roughness surveys performed in 1995 and 1996 with the South Dakota Road Profiler consistently resulted in IRI measurements of 2.10 to 2.15 m/km (133 to 136 in/mi) in both lanes. Since it is unlikely that the ride quality of the overlay actually improved during the evaluation period, it is the author's

opinion that the differences in measurements made by the two devices reflect the inherent tendency of one to yield lower IRI measurements than the other.

CONCLUSIONS

Based on observations of the performance of the thin-bonded overlay made during the past 6 years, this pavement rehabilitation technique appears to be an effective means of enhancing the structural capacity, and thus extending the service life, of jointed concrete pavements when those pavements are not seriously distressed. The relatively good condition of this pavement at the end of the evaluation period in light of the small amount of maintenance performed during that time frame demonstrates that the pavement continues to perform well.

The observed joint seal failures and staining of the concrete surface in the vicinity of those failures suggest that the infiltration of water through open joints (hence, discoloration) probably contributed to the observed pavement deterioration. The apparent coincidence of overlay bond failure near poorly sealed joints supports the conclusion that the presence of water may have weakened the bond at the overlay/substrate interface. Likely exacerbating that condition, relatively large pavement deflections across the undowelled transverse and longitudinal joints (edge vs. interior loading conditions) contributed to flexural stresses at the layer interface in excess of the bond's bearing capacity. Such bond interruptions severely influenced the pavement's structural capacity; the effective pavement thickness under these conditions was reduced from the bonded monolithic section of 290 to 90 mm (11.5 to 3.5 in). This weakening of the section and corresponding increase in deflection were compounded by the induction of critical edge stresses under wheel loads near transverse and longitudinal joints. This, not surprisingly, resulted in the development of transverse cracks and corner breaks near those joints. Observations made during the examination of cores support this conclusion.

RECOMMENDATIONS

Thin-bonded concrete overlays constructed in a fast-track mode should be considered by VDOT to be a viable rehabilitation alternative for certain pavements.

It appears that the majority of distresses observed on this project to date may be directly or indirectly attributed to joint failures. Properly constructed and sealed joints would probably reduce the extent of overlay bond failure and, thus, delay the formation of corner breaks and cracks. As such, careful attention to the installation of joints, as well as an aggressive, continuous program of joint maintenance to minimize the infiltration of water into the pavement system, is recommended for future bonded concrete overlay projects.

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