Transportation

Kentucky Transportation Center Research Report

University of Kentucky Year 1985

Latex-Concrete Overlays on Bridge Decks (I64, MP 150 to West Virginia Line)

James H. Havens* Theodore Hopwood II†

*University of Kentucky
†University of Kentucky, ted.hopwood@uky.edu
This paper is posted at UKnowledge.
https://uknowledge.uky.edu/ktc_researchreports/946
Research Report
UKTRP-85-22

LATEX-CONCRETE OVERLAYS ON BRIDGE DECKS

(I 64, MP 150 to West Virginia Line)

James H. Havens
Associate Director

and

Theodore Hopwood II
Transportation Research Engineer

Kentucky Transportation Research Program
University of Kentucky

in cooperation with the
Transportation Cabinet
Commonwealth of Kentucky

and the

Federal Highway Administration
U. S. Department of Transportation

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Kentucky, the Kentucky Transportation Cabinet, nor the Federal Highway Administration. This report does not constitute a standard, specification, or regulations.

September 1985
**Title and Subtitle:**
Latex-Concrete Overlays on Bridge Decks (I 64, MP 150 to West Virginia Line)

**Author(s):**
James H. Havens
Theodore Hopwood II

**Performing Organization Name and Address:**
Kentucky Transportation Research Program
College of Engineering
University of Kentucky
Lexington, Kentucky 40506-0043

**Sponsoring Agency Name and Address:**
Kentucky Transportation Cabinet
State Office Building
Frankfort, Kentucky 40622

**Abstract:**
Visual field inspections and soundings were performed on latex concrete overlays on 24 bridges on I 64 between Milepoint 150 and the West Virginia state line. The inspections were conducted in response to a request from the Kentucky Department of Highways to determine if cracking problems in the overlays were related to workmanship or materials.

The field inspections revealed that most of the overlay crack problems were related to 1) reflection cracking caused by pre-existing fractures in underlying concrete bridge decks and 2) "pull-in" cracks in the overlay, caused by belated taping of the bridge deck.

Field diaries, inspection reports, material test reports and the final construction inspection report were reviewed. Correlations were sought among latex brand, cement brand, date of pouring, rain during pouring, pouring temperature, percent entrained air, and slump to determine their effects on overlay cracks. No correlations were detected.

Pre-existing deck fractures are related to thermal stresses between the concrete and reinforcing steel, and to flexure of the bridge. Those cracking patterns and the extent of cracking have been found to be generally specific to the overall design of the structure.

A small number of construction-related bridge-deck flaws such as mudball holes and delaminations were detected. The extent of delaminations detected by the Kentucky Transportation Research Program was less than that identified by the Department of Highways. This was due to differences in sounding techniques and interpretations employed by the two parties.

It is recommended that the contractor be held liable only for patching or treating longitudinal "pull-in" cracks. The contractor also should be held accountable for mudball holes and delaminations. The contractor should not be held accountable for reflection cracks.

It is recommended that modifications be made to Kentucky Department of Highways Standard Specifications for Road and Bridge Construction, Section 617, entitled "Concrete Bridge Deck Overlays." Those changes should mandate 1) timely placing and texturing of the overlay and 2) qualification testing of overlay contractors.

**Key Words:**
Latex-Concrete Overlays
Bridge decks
Analyses of cracks

**Distribution Statement:**
Unlimited, with approval of Kentucky Transportation Cabinet

**Security Classification:**
Unclassified

**No. of Pages:**
Unclassified

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized
EXECUTIVE SUMMARY

Visual inspections were performed on 24 bridges located on I 64 between Milepoint 150 and the West Virginia state line. The inspections were conducted in response to a request from the Kentucky Department of Highways to determine if cracking in the overlays was related to problems in workmanship or materials.

The inspections revealed that overlay cracking was due to two primary causes. Short cracks, longitudinal to the bridge deck, are "pull-in" cracks created by tyning of the overlay. The second major cracking problem was associated with reflection of transverse pre-existing cracks in the underlying decks. Those cracks were created initially by temperature expansion and by flexure and contra-flexure. A small number of mudball holes and latex shrinkage-type cracks also were detected.

Additionally, all of the bridge decks were sounded using a different technique than that employed by the Kentucky Department of Highways. In most areas marked as delaminated by the Department of Highways, no signs of that problem were observed. Using the Transportation Research Program's sounding-rod technique, a few delaminations were detected, usually at the edges of joints or on the tops of abutment walls.

Construction documentation was reviewed to determine if any relationships existed among the overlay cracking and the cement, aggregate, latex, curing procedure, slump, air content, or atmospheric conditions. No relationships were discerned.
"Pull-in" cracking was due to belated tyning or other working of latex concretes that had partially stiffened. Working of the concrete caused cracks to form perpendicular to the stroke of the tyning tool. Temperature cracking is present in most reinforced concrete having more than 0.6 percent steel based on cross-sectional area. That cracking occurred due to differential thermal expansion between the steel and concrete. Flexure cracking is caused by live loading on simple-span bridges; contraflexure is due to live loading but in negative moment areas over piers of continuous-span bridges. Debonding is usually related to failure to clean the concrete substrate prior to overlayment. In some cases, it may be caused by severe overload by compacting rollers (at abutment tops).

The present Kentucky Department of Highways Standard Specifications for Road and Bridge Construction, Section 617 entitled "Concrete Bridge Deck Overlays," can be improved by requiring field performance tests by the contractor at the onset of work. It also is recommended that tyning and membrane placement be made in a more timely manner.

It is concluded that the Department of Highway's Final Construction Inspection Report is too punitive to the contractor. Many defects in the decks were unavoidable. Pull-in cracks as well as mudball holes and the few actual delaminations and latex shrinkage cracks were the responsibility of the contractor.

It is recommended that the "pull-in" cracks be treated (sealed) by the contractor. The temperature and flexure cracks also should be sealed, but as a pay item. The few areas having actual debonding and shrinkage cracking in the overlays should be cut out and replaced. The practice of tyning of overlays should be reconsidered. The top of abutments should be protected during placement of approaches. Section 617 should be revised. Also, inspectors should become more familiar with overlay operations.
INTRODUCTION

In 1983, twenty-four mainline bridges on I 64 were overlaid with latex concrete. They were reopened to traffic during the same year. Upon final inspection in May and April of 1984, defects were detected on the bridge decks, and the contractor was directed to make the repairs (Appendix A). The contractor, thereupon, disclaimed responsibility for the defects and refused to make the substantial repairs necessary to meet the KYDOH final inspection directive.

In August 1985, the Kentucky Transportation Research Program was asked to review construction records, reports, and diaries to hopefully determine a cause for the failures and to conduct field inspections of the overlays. The work was requested to determine if a pattern in the failures could be discerned and to ascertain the degree of the contractor's responsibility for the failures.

DOCUMENTATION REVIEW

The following documents were reviewed in an attempt to establish the cause(s) of failure:

1) District 9, Concrete Inspector's Report (Form No. TD64-308, Rev. 1/78);
2) District 9, Daily Inspectors Report (Form No. TD63-28, Rev. 7/78);
3) District 9, Aggregate Test Results (Form No. TC64-102 (715));
4) District 9, Sample Identification Form (Form No. TC64-2 (700));
5) District 9, Cement Test Report (Form No. TC64-300 (719));
6) District 9, Miscellaneous Materials Report (Form No. TC64-101 (717));
7) District 9, Concrete Cylinder Report (Form No. TC64-303 (726));
8) District 9, Water-Cement Ratio-Latex Concrete Overlay (Ex 63-8-53); and
9) District 9, Resident Engineer Diaries.
Data deemed relevant were tabulated and correlations were sought to pinpoint the cause(s) of the overlay cracking (Table 1). Problems were encountered as some of the report forms did not identify the latex or cement employed, but data in Table 1 are believed to be essentially correct. The Polysar latex was used until August 9, 1983. Thereafter, it was supplanted by Dow latex. The Kosmos cement was used until July 19, 1983, when it was replaced by Missouri Portland Cement.

The worst performing latex-cement combination was the Polysar-Kosmos; of nine original lanes placed, three had been previously removed and replaced with the Dow-Missouri combination. Of the remaining six, three were rated as requiring major repairs and three were rated as needing minor repairs in the Final Construction Inspection Report (Appendix A). Of the eight lanes using the Polysar-Missouri combination, two required major repairs, five required minor refurbishing, and one was satisfactory. Of the Dow-Missouri combination, 14 of the 34 lanes required major repairs, 9 required minor repairs, and 11 were satisfactory. A summary is shown in Table 2.

Review of the materials' records showed that all of the latexes were within the specified limits of the then-governing specification, Special Provision No. 21C (79), "Bridge Restoration and Waterproofing with Concrete Overlays," dated November 25, 1981. Slumps were all between 4-6 inches, entrained air was less than 7 percent, water-cement ratios were less than 0.40, and compressive strengths all exceeded 3,000 psi.

There were no clear or certain correlations among construction temperatures, material combinations, overlay slump, entrained air content, or the presence of rain during curing. A tendency towards delamination problems at construction temperatures less than 70° F was exhibited by the Dow-Missouri latex-cement combination (as noted by the Highway Department report). However, too little data existed to draw any firm conclusions on that issue. Some of the overlays had been wetted by rain during the required 72-hour dry-cure period. However, this did not appear to be the source of any cracking.
<table>
<thead>
<tr>
<th>BRIDGE M.P. AND LANE</th>
<th>CONSTRUCTION DATE</th>
<th>LATEX TYPE</th>
<th>GEMET TYPE</th>
<th>SLUMP (INCHES)</th>
<th>PERCENT AIR</th>
<th>CONSTRUCTION TEMP (°F)</th>
<th>COMMENT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>EB LT</td>
<td>06/23/83</td>
<td>Polyurea</td>
<td>Kansas</td>
<td>4 1/2</td>
<td>3.8</td>
<td>91-90</td>
<td>R(6/27-29/83), RRC</td>
</tr>
<tr>
<td>EB RT</td>
<td>06/12/83</td>
<td>Dow</td>
<td>Missouri(?)</td>
<td>5 1/2</td>
<td>3.6</td>
<td>91-92</td>
<td>R(6/27-29/83), RRC</td>
</tr>
<tr>
<td>EB LT</td>
<td>06/26/83</td>
<td>Dow</td>
<td>Missouri(?)</td>
<td>5 1/2</td>
<td>3.7</td>
<td>91-92</td>
<td>RRC, RRD, SMC</td>
</tr>
<tr>
<td>EB LT</td>
<td>06/22/83</td>
<td>Polyurea</td>
<td>Kansas</td>
<td>5</td>
<td>3.8</td>
<td>95-93</td>
<td>R(6/27-29/83), SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>07/18 &amp; 07/06/83</td>
<td>Polyurea</td>
<td>Kansas</td>
<td>6</td>
<td>3.4</td>
<td>79-93</td>
<td>SMC</td>
</tr>
<tr>
<td>EB LT</td>
<td>06/24/83</td>
<td>Polyurea</td>
<td>Kansas</td>
<td>5 1/2</td>
<td>3.7</td>
<td>92-91</td>
<td>RRC</td>
</tr>
<tr>
<td>EB RT</td>
<td>07/06/83</td>
<td>Polyurea</td>
<td>Kansas</td>
<td>6</td>
<td>3.9</td>
<td>77</td>
<td>RRC</td>
</tr>
<tr>
<td>EB LT</td>
<td>08/23/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>4</td>
<td>4.0</td>
<td>89</td>
<td>Rep(07/28/83), SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/10/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>4.1</td>
<td>86</td>
<td>R(08/11/83)</td>
</tr>
<tr>
<td>EB LT</td>
<td>07/27/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>5</td>
<td>5.4</td>
<td>80-89</td>
<td>RRC</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/09/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>R, Rep(04/06/84),</td>
</tr>
<tr>
<td>EB LT</td>
<td>07/28/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>5</td>
<td>4.5</td>
<td>91-95</td>
<td>SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/23/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>4.8</td>
<td>85-91</td>
<td>R(08/31/83)</td>
</tr>
<tr>
<td>EB LT</td>
<td>07/27/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>6</td>
<td>5.2</td>
<td>88-91</td>
<td>SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/09/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>5.0</td>
<td>93</td>
<td>R(08/11/83), RRC</td>
</tr>
<tr>
<td>EB LT</td>
<td>07/21/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>5.2</td>
<td>91-100</td>
<td>SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/24/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>NA</td>
<td>NA</td>
<td>91</td>
<td>—</td>
</tr>
<tr>
<td>EB LT</td>
<td>07/20/83</td>
<td>Polyurea</td>
<td>Kansas</td>
<td>5</td>
<td>4.7</td>
<td>86-96</td>
<td>RRD</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/25/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>NA</td>
<td>NA</td>
<td>93</td>
<td>R(08/31/83), SMC</td>
</tr>
<tr>
<td>EB LT</td>
<td>07/26/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>4</td>
<td>5.2</td>
<td>85-92</td>
<td>SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/08/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>5</td>
<td>4.9</td>
<td>86</td>
<td>SMC</td>
</tr>
<tr>
<td>EB LT</td>
<td>07/19/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>5.1</td>
<td>84</td>
<td>R(07/19/83), SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>08/08/83</td>
<td>Polyurea</td>
<td>Missouri</td>
<td>6</td>
<td>5.0</td>
<td>88</td>
<td>RRC</td>
</tr>
<tr>
<td>EB LT</td>
<td>09/12/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>6.2</td>
<td>88</td>
<td>R(09/13, 16/83)</td>
</tr>
<tr>
<td>EB RT</td>
<td>09/30/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>4.5</td>
<td>76</td>
<td>RRD</td>
</tr>
<tr>
<td>EB LT</td>
<td>09/12/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>4 1/2</td>
<td>6.8</td>
<td>89</td>
<td>R(09/13, 16/83)</td>
</tr>
<tr>
<td>EB RT</td>
<td>09/29/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>4.2</td>
<td>76</td>
<td>SMC</td>
</tr>
<tr>
<td>EB LT</td>
<td>09/13/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>5.7</td>
<td>88</td>
<td>R(09/13, 16/83)</td>
</tr>
<tr>
<td>EB RT</td>
<td>09/30/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>4.1</td>
<td>73</td>
<td>Unbond Repair</td>
</tr>
<tr>
<td>EB LT</td>
<td>09/15/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>4 1/2</td>
<td>2.5</td>
<td>79-86</td>
<td>R(09/16, 21/83)</td>
</tr>
<tr>
<td>EB RT</td>
<td>09/29/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>4.2</td>
<td>78</td>
<td>RRC</td>
</tr>
<tr>
<td>EB LT</td>
<td>09/13/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>5.8</td>
<td>80-86</td>
<td>R(09/16, 21/83)</td>
</tr>
<tr>
<td>EB RT</td>
<td>09/27/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>4.4</td>
<td>76-79</td>
<td>—</td>
</tr>
<tr>
<td>EB LT</td>
<td>09/14/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>6.0</td>
<td>79-86</td>
<td>R(09/16, 21/83), R</td>
</tr>
<tr>
<td>EB RT</td>
<td>09/28/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>4.0</td>
<td>76</td>
<td>RRC</td>
</tr>
<tr>
<td>EB LT</td>
<td>10/26/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>5.4</td>
<td>55</td>
<td>—</td>
</tr>
<tr>
<td>EB RT</td>
<td>11/19/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>—</td>
</tr>
<tr>
<td>EB LT</td>
<td>10/26/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>5.8</td>
<td>60</td>
<td>—</td>
</tr>
<tr>
<td>EB RT</td>
<td>11/18/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>—</td>
</tr>
<tr>
<td>EB LT</td>
<td>10/27/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>4.7</td>
<td>65</td>
<td>RRD, SMC</td>
</tr>
<tr>
<td>EB RT</td>
<td>11/19/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>4.3</td>
<td>61</td>
<td>RRD</td>
</tr>
<tr>
<td>EB LT</td>
<td>11/23/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>3.7</td>
<td>56</td>
<td>R(11/23, 27/83), R</td>
</tr>
<tr>
<td>EB RT</td>
<td>10/28/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5 1/2</td>
<td>4.6</td>
<td>59</td>
<td>Unbond Repair</td>
</tr>
<tr>
<td>MB LT</td>
<td>11/19/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>3.7</td>
<td>56</td>
<td>R(11/27/83), RRD</td>
</tr>
<tr>
<td>MB RT</td>
<td>11/27/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>4.5</td>
<td>64</td>
<td>RRD</td>
</tr>
<tr>
<td>MB LT</td>
<td>11/17/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>4 1/2</td>
<td>4.7</td>
<td>58</td>
<td>RRD</td>
</tr>
<tr>
<td>MB RT</td>
<td>10/29/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>5</td>
<td>4.7</td>
<td>58</td>
<td>Unbond Repair</td>
</tr>
<tr>
<td>MB RT</td>
<td>11/22/83</td>
<td>Dow</td>
<td>Missouri</td>
<td>6</td>
<td>3.7</td>
<td>56</td>
<td>R(11/23, 27/83), R</td>
</tr>
</tbody>
</table>

* - Polyurea last used 08-09-83. Kansas last used 07-19-83
EB - Eastbound; WB - Westbound; LT - Left Lane; RT - Right Lane
NA - Data Not Available
R (date) - Rain; Rep (date) - Replaced
RRC - Final Construction Inspection Recommendation - Remove and Replace Cracked Area
RBD - Final Construction Inspection Recommendation - Remove and Replace Delaminated Area
SMC - Final Construction Inspection Recommendation - Seal Minor Cracked Area
<table>
<thead>
<tr>
<th>LATEX-CEMENT COMBINATION</th>
<th>TOTAL LANES</th>
<th>MAJOR REPAIRS</th>
<th>MINOR REPAIRS</th>
<th>NO REPAIRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysar-Kosmos</td>
<td>6*</td>
<td>3 50</td>
<td>3 50</td>
<td>0 0</td>
</tr>
<tr>
<td>Polysar-Missouri</td>
<td>8</td>
<td>2 25</td>
<td>5 63</td>
<td>1 12</td>
</tr>
<tr>
<td>Dow-Missouri</td>
<td>34</td>
<td>14 41</td>
<td>9 27</td>
<td>11 32</td>
</tr>
</tbody>
</table>

* Three other lanes were removed and replaced with Dow-Missouri and are included in the Dow-Missouri compilation.
FIELD INSPECTIONS

Field inspections were conducted on all of the 24 bridges. The inspections consisted of close visual inspections of the overlays on the topside of bridges and occasional visual inspections on the bottom face of the decks looking for efflorescence.

Simple-span RCDG bridges (see Appendix B for definitions of codes) showed the least amount of visible cracking. Three-span continuous RCDG (haunched) bridges possessed a complex pattern of natural cracking and exhibited prominent flexural cracks.

Soundings were taken by tamping the deck with a 4-foot long, 1/2-inch diameter steel bar. Tamping was done over the entire deck of each bridge using an approximate spacing of one tamp per square yard. Where delaminations were marked from the previous Department of Highways inspections, closer tamp spacings were employed. Additionally, the tamping method was applied to I-64 mainline bridges over US 60 (which were not part of the subject overlayed bridges). Both the eastbound and westbound decks of those bridges had delaminations in the overlays. Those could be readily detected by the inspectors, and there was no disagreement between the three inspectors as to which areas were delaminated. This shows that good agreement is possible when the tamping technique is employed (i.e., it is not controversial).

Visual inspections disclosed both longitudinal and transverse cracks. Additionally, mud inclusions, footprints, and other minor surface blemishes were detected randomly on the decks, as indicated in the Final Construction Inspection Report. In several instances, a detailed effort was made to correlate the transverse overlay cracks with efflorescence underneath the bridge deck. This was successful in some instances. Also, some unpatched core holes in the decks were inspected, revealing cracking in the underlying bridge decks.

Very few delaminations were found in the bridge decks (Figure 1). Those were detected at or near joints and were mostly like D-cracks.
Most delaminations were present in the top of the abutment wall, adjacent to the deck. This may be due to bumping by a roller when compacting the asphaltic concrete on the approaches. Figures 1 through 10 show conditions observed. The delaminations marked by Department of Highways personnel were sounded using the steel rod method, but no delamination was detected.

BRIDGE DECK AND OVERLAY CRACKS

It is necessary to distinguish between those cracks in the bridge deck and those in the overlay. This may be achieved by determining the depth of cracking in the overlay (shallow or through) and by recognizing the cracking pattern (more specifically, cracking due to either temperature or flexure). Fortunately, structurally related cracks are never random; they occur systematically and may be analyzed.

Styles of bridges are illustrated in Figure 11 (see Appendix B for definitions of coding). Crack patterns are shown in Figure 12. Overlay cracks induced by raking and (or) tyning (texturing) are shown at the top in Figure 12 and in Figure 13. They are oriented parallel (longitudinal) to the axis of the bridge and perpendicular to the direction of pull on the rake or texturing tool. Some cracks may even be induced by a float or straightedge before texturing. Rough texturing is very near to the tearing threshold. The longitudinal orientation of these cracks is a tell-tale sign. They tend to be V-shaped. It is possible to pull cracks completely through the overlay and slide the overlay on the substrate -- that is, to widen a crack to a gap.

There is a time interval after overlay placement when no further screeding or raking may be done without great danger of pulling cracks into the surface. Prompt tyning will preclude this problem. Prevention of pull-cracks should be the responsibility of the contractor. Stickiness may be delayed or abated by a mist application of some glycols (and perhaps some water) (1-4).
Figure 1. Cracking (Lined with Paint) that Appears To Be Associated with Joint. Debonding would be suspected. Areas designated for repair may have been conservatively marked (I 64, MP 185.8; May 5, 1985).

Figure 2. Cracks beside Abutment Wall in Asphalitic Concrete Pavement. Pavement there tends to debond (I 64, MP 172.558; May 5, 1985).
Figure 3. Combination of Flexural Cracks and Pull Cracks in Skewed RCDG Bridge. Cracks have been lined for emphasis. Debonding is likely (I 64; MP 151.62, May 5, 1985).

Figure 4. Flexural Cracks in Skewed RCDG Bridge. Cracks have been lined for emphasis. Note skew of cracks to direction of grooving (I 64, MP 151.62; May 5, 1985).
Figure 5. Crack Orientation Shown by Paint on Deck. Arrows show boundary of area designated for removal and replacement (I 64, MP 151.620; May 5, 1985).

Figure 6. Scaling of Epoxy-Sand Coating in Gutter Area (I 64, MP 160.861; May 5, 1985).
Figure 7. Crack Orientation across the Direction of Pull of Rake.
Cracks were lined with paint.

Figure 8. Punch Out, I 64, over US 60; Older Overlay (I 64, MP 181.6;
May 5, 1985).
Figure 9. Crack Orientation, Shown by Paint on Deck (I 64, MP 150.118; May 5, 1985).

Figure 10. Broad-Stroke Designation of Area to be Removed and Replaced. (I 64, MP 150.118; May 5, 1985).
Figure 11. Styles of Bridges (Codes Are in Appendix B).

Figure 12. Topside Cracking Patterns.
Figure 13. I 471 over I 275, April 19, 1978; Pulled Cracks (perpendicular to stroke of rake). This portion of overlay was removed and replaced.
TEMPERATURE CRACKING

Reinforced concrete containing at least 0.6 percent steel cracks on an interval of about 30 inches (1-8). Those cracks may not be readily visible. However, some may become working cracks and appear prominently. Some of those cracks may merge with regularly occurring cracks located in the plinth and appear continuous across the bridge. Temperature cracks completely penetrate the bridge deck. If left uncovered, those cracks will eventually effloresce on the bottom of the deck (indicating seepage of water through the cracks and the subsequent deposition of lime along cracks after drying).

Temperature cracks are induced by steel reinforcement expanding at a greater rate than the concrete when the temperature rises. Such cracks are present in all reinforced concrete (except prestressed). They are naturally occurring and unavoidable. Those cracks located at points of flexure may become working cracks and may widen and show more efflorescence at the underneath surface than other cracks. Load cycling due to traffic eventually will widen all cracks a little.

Temperature cracking was not recognized or explained until it was observed in continuously reinforced concrete pavements (7, 8). The more unique crack pattern typical of RCDG bridges (especially those having haunched girders) was first observed about 1957 (1). Many interstate bridges are of that type. Deck panels in those bridges are constrained greatly by massive beams and bulkheads. Cracking patterns due to flexure and contraflexure is simple and easily recognizable. However, temperature cracking is complex. The pattern of temperature cracking is consistent from bridge to bridge, but the spacings vary slightly. There are no longitudinal cracks in the panels of RCDG bridges; there are only transverse cracks.

Reference is made to the term "slip modulus" as treated by Shrader (5); but, quite simply, the normal interval between cracks is about twice the length at which total bond strength at the surface of the
steel exceeds the total tensile strength of the concrete. Physically, the conditions that exist in a bridge deck are the reverse of the bond strength test by "pull out" as given by ASTM C 234. Of course, there is a rule-of-thumb that gives the necessary length of embedment of rebar steel in concrete as 30 diameters. The correctness of that rule may be shown in the nominal 30-inch spacing of temperature cracks observed on bridge decks.

FLEXURAL CRACKS

Flexure and contraflexure may induce cracking in unflawed bridge decks. Flexure cracks are due to bending or deflection along the axis of the bridge. These cracks are generally perpendicular to the axis of bending. A skewed bridge having skewed abutments and piers will develop skewed transverse cracks. Although maximum bending moment is presumed to be at midspan (simple spans), contraflexure occurs closer to the piers in continuous bridges.

Cracks subject to flexure and contraflexure will reflect easily through thin overlays. An overlay contractor should not be blamed for that type of cracking. If delamination spreads alongside that type of crack, the bond may weaken before the crack formed or while it was forming. This would not be through fault of the contractor unless the substrate were shown to have been unclean or otherwise contaminated.

Superimposing or combining temperature cracks with flexural cracks and with the more unique cracks in RCDG bridges, it is possible to define fairly well the natural crack patterns that will be detected upon inspection of mature bridges (Figures 14 and 15). Only those cracks due to drying shrinkage and punchouts, and those pulled into overlays while finishing, are unnatural.

SOME SIGNIFICANT CASES OF CRACKING IN DECKS AND(OR) OVERLAYS

I 264-1(43)3, over K and IT RR (3)

Camp Nelson, US 27
Figure 14. Example of Cracking in Deck on Steel Girders (I 24, Cumberland River, June 1981).
Figure 15. Early Cracking in RCDG Bridge; I 264-1(43)3, Shawnee Parkway over Railroad, Louisville, December 17, 1970 (3). This type of cracking was first recognized by Robert M. Gillian and first reported by Havens and Drake in 1963 (1).
US 25 Bridge over Ohio River
Cumberland River Bridge, I 24
I 275 over I 471, and others
I 24 over Tennessee River
Riverside Expressway, I 64, 6th to 18th Streets
US 421 over I 75, Georgetown
I 275 over 3-mile Road, Westbound
US 150, Danville Bypass

Tyning was questioned when it was instituted in 1974 (Figures 16 and 17). Tearing the surface is readily promoted by tyning in the form of "pull-in" cracking. The system proposed by Research employed a troweling process (grooves formed by parallel wires attached to a magnesium float) (Figures 18 and 19). This texturing is not as prone to pull-in cracks as tyning.

DEBONDING

Bond strength at the interface between the overlay and the existing concrete is not specified. However, it is well known that a good bond must be achieved. The overlay must not be loose or loosen from the existing deck concrete. Lack of bond may be readily detected by tapping the overlay surface with a hammer or rod.

Failure to clean the concrete substrate and (or) to wet it by scrubbing on the slurry bond coat will promote poor bonding. Loss of bond may occur after the overlay is spread if slippage is induced or if severe drying shrinkage is permitted during the curing period. Strong bonding occurs after wet curing and after the onset of drying.

Mud cracking (a pattern) together with hollowness indicates drying shrinkage. Lack of bond without cracking indicates poor cleaning of the substrate.

Unbonding or debonding (also delamination) may spread rapidly unless repairs are made somewhat expeditiously.
Figure 16. I 24, Tennessee River Bridge, May 26, 1976; Earliest Attempt to Groove Overlay. This portion was done with a "roller disc."
Figure 17. I 24, Cumberland River Bridge, October 4, 1979; Cracking in Early Texturing Project. The desired texture was not achieved. Results were controversial.
Figure 18. Preferred Grooving, Done with Ribbed Float (upper left, above; at center, below).
Figure 19. Preferred Grooving, Done with Ribbed Float (Laboratory Specimen, May 2, 1974). Note absence of tearing and smoothness of grooves. Surely, this type of surface would provide better drainage than one severely torn and roughened.
SPECIFICATION MODIFICATIONS

Several modifications that might reduce the number of problems with overlay contractors are envisioned:

1. Require a demonstration of contractor capability at the beginning of work. The contractor would be required to place the first 20 feet of the deck to show that no problems existed with pull-in cracking. Thereafter, if there were no defects, he would be allowed to continue unabated with the overlay process. If tears or pull-in cracks were detected, the contractor would have to remove the trial layer and adjust his placement procedures. A successful test would be required before the contractor could proceed.

2. Require that all tyning (if not discontinued) be done immediately after placement of the overlay. Also, require that the curing membrane be placed as soon as the tyning is completed.

3. Require that all cracks be filled with a grout or mastic material.

CONCLUSIONS

Inspections on the I-64 bridges (see Appendix A) were obviously thorough. Many cracks were not the fault of the contractor. Also, many areas identified as being delaminated were not so identified using the tamping test method described in this report. In short, the repairs mandated in the Department of Highways report were excessive. The problem is an abiding one, and the new context (1/4-inch crack depth) will not resolve the matter satisfactorily (9, 10). Not even a criterion that included crack depth and length per unit area would suffice altogether because the size of the crack area would be chosen arbitrarily. The best recourse, after the fact, may be in a peer committee review of the inspection report.

Many cracked areas in the overlays appear to be tightly bonded to the concrete. They do not show signs of breaking up or debonding.
Those cracks do not appear to adversely affect the durability of the overlays.

RECOMMENDATIONS

The short pull-in cracks identified by 1) being oriented perpendicularly to the pull or draw of finishing and texturing tools, 2) being V-shaped, and 3) being shallow and not associated with any unbonding should be exempted from repairs by removal and overlay replacement. They should be repaired by in-filling with latex slurry.

Transverse cracks that have the attributes of flexural cracks (more assuredly if they correspond to efflorescing cracks under the deck) should be routed and sealed with silicone-type caulking material. This could be done under a Stage 2 agreement with the contractor -- but somehow as a pay item.

A few areas on the bridge decks exhibit mudball holes, shrinkage cracks, and delaminations. The overlays in those areas should be removed and repaired by the contractor.

The following recommendations are made for future overlay work:

1. Severe texturing by tyning or raking should be discontinued. The wear and smoothing in the wheelpaths is far advanced on these decks that are a year old. A texture made by a ribbed float or troweling tool would suffice.

2. Existing core holes on the I-64 bridges should be filled immediately with latex mortar.

3. The top of the abutment wall should be protected. A roller compacting asphaltic concrete may loosen an overlay at the bridge abutment. It is too demanding of a narrow strip of overlay to withstand such service there.

4. The specification modifications previously enumerated should be adopted. Those would require 1) prequalification testing for overlay contractors, 2) prompt tyning and membrane covering after overlay placement, and 3) routine filling of subsequent cracks.
5. Inspectors and engineers should become more familiar with overlay procedures and potential problems.

SUPPLEMENTARY NOTES

Twin bridges at MP 181.6 (US 60, east of Grayson) had been overlaid at an earlier time. Smoother finish may have been made by a burlap drag. A small patch was noted on the westbound bridge. A punchout, about 3 feet by 3 feet, was observed in the westbound outer wheelpath. This should be repaired soon to prevent further deterioration.

The eastbound bridge at MP 191.2 had a tyned finish (texture) but appeared to be an older bridge. The westbound bridge appeared to have an overlay that predated the one on the companion bridge. It was a lightly broomed or burlap drag texture — smoothed somewhat by traffic.

REFERENCES


APPENDIX A

KENTUCKY DEPARTMENT OF HIGHWAYS
FINAL CONSTRUCTION INSPECTION REPORT -- I-64 BRIDGES
**Commonwealth of Kentucky**  
**Transportation Cabinet**  
**Department of Highways**

**FINAL CONSTRUCTION INSPECTION REPORT**  
CH No. 5643

**District** 9  
**County** Carter & Boyd

**Type of Construction** Bridge Deck Repair

**Roadway & Surface Width**  
**Road Name** Lexington - Catlettsburg Rd (I-64)

**Date of Inspection** 8/19/84  
**Inspection By** R. Hodges

**Contractor** Mid-State Paving  
**Date Completed** June 15, 1983

**Inspection Made In Company of** P. M. Shaffer

---

**THIS INSPECTION REPRESENTS:**

- ( ) 1. All Items in Contract
- ( ) 2. All Items Except Those Covered by Separate Report
- ( ) 3. Structures and Inclusive Items
- 4. Erosion Control
- 5. Painting
- 6. Others

**FMWA Report Applicable ( ) yes ( ) no**

- ( ) A Separate Report Will Be Issued For No. 3 ( ), No. 4 ( ), No. 5 ( ), No. 6 ( )

---

This report represents tentative acceptance only. The contractor will not be relieved of responsibility for the project until he has completed in a manner satisfactory to the Department of Highways any corrective or additional work outlined on final inspection reports and/or which may be designated by representatives of the FMWA resulting from their inspections. Date of formal acceptance will be established and indicated on a subsequent report issued after proper compliance as outlined herein.

**NOTE:** Final inspections were made at various times: April 18, 1984; April 19, 1984; May 22, 1984; and cores were drilled to investigate overlay cracks July 12, 1984.

The project requires deck rehabilitation and latex concrete overlay to 24 bridges on I-64, mile point 150 to mile point 192. All work inspected appeared to be in substantial conformity to plans and specifications except as noted. When noted "marked" the location in subject is circled by paint and a reference mark is painted on the adjacent plinth wall.

**Carter Co. FSP 22-64-150.118 East bound bridge insp. 5/22/84**

- Lt. Lane - remove and replace significantly cracked areas marked.
- Rt. Lane - remove mudding and patch. Remove delaminated area marked.

**Carter Co. FSP 22-64-150.118 West bound bridge insp. 5/22/84**

- Lt. Lane - remove and replace significantly cracked areas marked, seal other cracks.
- Rt. Lane - Remove and replace delaminated areas marked, remove significantly cracked areas marked, seal other cracks.

---

**Continued on Sheet 2 of 3.**

---

**DISTRIBUTION**

- 1 copy to Proj Eng J. A. Brox
- Copy to TMWA R. E. Johnson
- Contractor Mid-State Paving
- Div of Contract Mgmt J. Hawkins

---

**By**  
**Trans. Eng. Br. Wv**

---

**Project Engineer** B. R. Miller  
**Div of Accounts** J. Sykes  
**Div of Maintenance** G. Asbury  
**Div of Bridges** T. Lynam  
**Div of Design** L. Eillevang  
**Larry Jewell, C. Beesler**
Carter Co. FSP 22-64-151.620 East bound bridge insp. 5/22/84
Lt. and Rt. Lanes - seal cracks marked.
Carter Co. FSP 22-64-151.620 West bound bridge insp. 5/22/84
Lt. Lane - remove and replace significantly cracked areas marked (majority of lane) 6
Rt. Lane - remove and replace significantly cracked areas marked (majority of lane) 6
Remove mudball and patch.
Carter Co. FSP 22-64-158.107 East bound bridge insp 5/22/84
Lt. Lane - remove mudballs and patch locations marked. Seal cracks marked.
Rt. Lane - remove mudball and patch.
Carter Co. FSP 22-64-158.107 West bound bridge insp. 5/22/84
Lt. Lane - remove and replace substantially cracked areas
Rt. Lane - seal one crack marked. Clean latex splatters from handrail.
Carter Co. FSP 22-64-159.247 East bound bridge inspected 5/22/84
Lt. Lane - seal cracks marked. Remove and patch mudball
Rt. Lane - OK no additional work required
Carter Co. FSP 22-64-159.247 West bound bridge insp. 5/22/84
Lt. Lane - seal cracks marked
Rt. Lane - remove and replace substantially cracked areas marked 5
Carter Co. FSP 22-64-160.861 East bound bridge insp. 4/19/84
Lt. Lane - seal cracks marked. Remove and patch mudball and fill footprints with an approved epoxy.
Carter Co. FSP 22-64-160.861 West bound bridge inspected 4/19/84
Lt. Lane - remove and replace marked delaminated areas.
Both Lanes – clean out drains. Reseal centerline joint. Seal cracks marked. 10
Carter Co. FSP 22-64-161.453 East bound, insp. 4/19/84
Both Lanes - seal cracks marked. Seal centerline joint 11
Carter Co. FSP 22-64-161.453 West bound insp. 4/19/84
Both Lanes - seal cracks marked.
Rt. Lane - remove and replace substantially cracked area marked. 12
Carter Co. FSP 22-64-166.217 East bound insp. 4/18/84
Rt. Lane - remove delaminated area marked 13
Carter Co. FSP 22-64-166.217 West bound insp. 4/18/84
Rt. Lane - seal cracks marked. Grind area marked to straight edge tolerance 14
Carter Co. FSP 22-64-170.967 East bound insp. 4/18/84
Rt. Lane - grind marked area to straight edge tolerance 15
Carter Co. FSP 22-64-170.967 West bound insp. 4/18/84
Lt. Lane - remove and replace substantially cracked areas marked 16
Carter Co. FSP 22-64-172.585 East bound insp. 4/18/84
OK no additional work required 17
Carter Co. FSP 22-64-172.588 West bound, insp. 4/18/84
Lt. Lane - remove and replace two substantially cracked areas on west end, areas are marked: seal cracks marked
Rt. Lane - remove and replace one substantially cracked area marked 18
Boyd Co. FSP 10-64-181.985 East bound insp: 5/22/84
Rt. Lane - Grind hump to specification tolerance location marked 19
Boyd Co. FSP 10-64-181.985 West bound insp. 5/22/84 OK no additional work required 20
Boyd Co. FSP 10-64-185.179 East bound ins. 5/22/84 21
Lt. Lane - remove and replace delamination areas marked. Seal cracks marked
Rt. Lane - remove and replace marked delaminations. Remove and patch mudball marked.
Boyd Co. FSP 10-64-185.461 East bound insp. 5/22/84
Lt. Lane - Clean latex splatters from handrail
Rt. Lane - Remove and replace delaminated areas marked. Remove and patch mudball marked.
Boyd Co. FSP 10-64-185.461 West bound Ins. 5/22/84
Lt. Lane - contractor had patched a delamination at east pier exp. joint. The patch did not bond repatch. Location marked. 22
FINAL CONSTRUCTION INSPECTION REPORT
Carter & Boyd Cos. IR 64-7(30) and IR 64-8(50)
August 9, 1984
Sheet 3 of 3

Rt Lane - remove and replace delaminated areas marked.
Rt. Turn Lane - remove and replace delaminated areas marked.
Boyd Co. FSP 10-64-191.074 East bound insp. 5/22/84
Rt. Lane - East end of deck remove and replace delaminated area.

RWH: jp
APPENDIX B

CODES FOR TYPES OR STYLES OF BRIDGES
Reinforced Concrete

RCDG - Reinforced Concrete Deck Girder
RCBG - Reinforced Concrete Box Girder
RCRS - Reinforced Concrete Ribbed Slab
RCFS - Reinforced Concrete Flat Slab
PCDU - Prestressed Concrete Deck Unit
PCIB - Pretensioned Concrete I-beam
PCTB - Pretensioned Concrete T-beam
TCIB - Post-Tensioned Concrete I-beam
RCRF - Reinforced Concrete Rigid Frame
RCA1 - Reinforced Concrete Arch - 1 Hinge
RCA2 - Reinforced Concrete Arch - 2 Hinge
RCA3 - Reinforced Concrete Arch - 3 Hinge

Structural Steel

SSI - Structural Steel I-beam
SSW - Structural Steel WF beam
SSWC - Structural Steel WF, Composite
RSP - Riveted Steel Plate Girder
WSPC - Welded Steel Plate Girder, Composite
RST - Riveted Steel Truss
WST - Welded Steel Truss
WSA - Welded Steel Arch
WSRF - Welded Steel Rigid Frame
WSPA - Welded Steel-Plate Arch
WSTA - Welded Steel-Truss Arch