Research Report
UKTRP-87-1

BRIDGE DECKS AND OVERLAYS

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Kentucky Transportation Research Program
College of Engineering
University of Kentucky

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Transportation Cabinet
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16. Abstract

The report presents a historical perspective of the Transportation Cabinet's bridge deck construction and maintenance efforts directed toward increasing bridge deck durability.

Bridge decks crack in specific patterns that primarily depend upon bridge designs. Normal deck cracking is due to load-induced and thermal effects. Each type of cracking has a distinct pattern.

One-hundred and nineteen experimental bridge deck overlays were inspected. Included were 9 membrane bridges, 87 latex concrete overlays and 23 low-slump overlays. The overlays had been placed originally on both new and existing bridge decks on various routes throughout the state. Most of the overlays were rated in good to excellent condition. None of the overlay methods was discernibly superior to the others.

Thirty-four integral abutment bridges were inspected. Nearly all of those bridges are in good to very good condition. Only one bridge had a problem caused by settlement.

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EXECUTIVE SUMMARY

A chronology of advances in bridge-deck construction and maintenance in Kentucky is presented. The I-64 bridges between Lexington and Frankfort each had differing experimental deck features. Bridges on US 119, Harlan-Cumberland, are experimental from the standpoint of overlayment on new bridges. Those and a large number of overlayed bridges were designated long-term experimental structures and were monitored during the course of this study. Research during the period from 1970-1980 focused on improvements in durability of bridge-deck concrete. Developmental work was conducted on latex concrete and concrete using super water reducers.

Initial protection efforts entailed preservation of deteriorated concrete decks using penetrants, seals, lacquers, epoxy resins, etc. All of those proved disappointing.

Kentucky was a pioneer in the development of latex overlays and first used latex mortar (1969-73) for deck rehabilitation. In 1973, the Transportation Cabinet switched to a concrete formula from the mortar-type mixture. The Transportation Cabinet also experimented with membrane overlays at the request of the Federal Highway Administration on nine bridges during the mid-1970's. Low-slump concrete became feasible and competitive, but was required to be placed at a slightly greater thickness than latex concrete due to its lower chloride impermeability. In the mid 1960's, Kentucky specifications required use of Class AA concrete and in the early 1970's increased concrete cover over the top mat of reinforcing steel. Benefits of those requirements were not widely recognized because epoxy-coated rebars were promoted by the Federal Highway Administration shortly thereafter. Milling machines and overlay pavers improved deck overlaying practices.

An attendant finding of this study, made during the survey of rigid concrete overlays, is the existence of specific deck crack patterns for each style of bridge and deck system. Those cracks are due to temperature and deck flexure effects. Natural deck cracks are caused by differences in thermal expansion between reinforcing steel and concrete. Load-induced cracks are specific and are recognized as working cracks.

Some bridge types (e.g., continuous steel I-beam type) appear to be more prone to deck cracking than other types (e.g., prestressed concrete I-beam type). That appears to be related to the stiffness of the superstructure and deck. On heavily traveled roads, load-induced cracking may be severe. The effect of cracking on deck durability has not been determined.

Deck texturing by tining has been associated with a number of problems including irregular grooving, rough decks, overlay pull cracking, and aggregate pull outs. One viable alternative for tining is to saw grooves into the completed deck or overlay.

Massive overlay debonding failures have occurred infrequently. Partial debonding is common. Often, that is associated with failure of the underlying deck.

Inspection of the membrane-treated bridges revealed eight of the nine bridges were in good condition. Visible surface distress including blisters and seam cracks did not appear to have affected their performance. Resistivity tests on two of those bridges indicated the membranes were gradually deteriorating.

Twenty-eight of the 38 Dow latex overlays were rated excellent, 5 were rated good, and 5 were judged poor. The poor overlays had delaminations and spalling. Most of the 49 Reichhold latex overlays were placed several years later than the Dow overlays. Forty-one Reichhold overlays were placed on in-service bridges. Twenty-eight of those were rated excellent, 15 were judged to be good, and 5 were rated fair to poor. Lower ratings for the Reichhold overlays are attributed to extensive use on decks that were more deteriorated than those on which Dow overlays were used. The 23 experimental low-slump overlays generally performed as well as the latex overlays. Nine of those were rated excellent and 14 were rated good. Low-slump overlays did not crack as extensively as latex overlays.

Thirty-six of the 46 existing integral abutment bridges in the state were inspected. Three of those bridges were of reinforced-concrete deck-girder type constructed in the 1970's. Four integral abutment bridges constructed in the mid to late 1970's used precast, prestressed I-beams. Of the 39 existing integral abutment bridges constructed in the 1980′s, 33 used precast, prestressed I-beam girders; five used precast, prestressed box-beam girders; and one used steel I-beams.

Bridge inspections and subsequent review of Division of Maintenance Structure Inventory and Appraisal Reports indicated that nearly all of the structures were in good to very good condition. The bridge decks contained very few cracks. The only problem detected was relative settlement of the abutments (and possibly piers) on one bridge that caused some deck cracking.

New deck concrete additives (micro-silica, super water reducers, and calcium nitrite) have been investigated and show promise for producing stronger and more durable concrete than the Class AA concrete presently used in bridge decks. Micro-silica additives enhance strength, wear resistance, and relative impermeability to chlorides. Super water reducers allow low water-cement ratios in concrete, which yields improved freeze-thaw resistance. Calcium nitrite is a corrosion inhibitor and may be used as an alternate to epoxy-coated reinforcing steel. Three trial bridge decks have been placed using those materials.

Overlays have been a major success. About 2,000 overlays have been placed on decks that often contain badly deteriorated concrete. Less than ten premature overlay failures have been experienced. Overlays have extended the service lives of all of those decks, and that has resulted in a significant maintenance savings for the Transportation Cabinet.

The virtual absence of problems with integral abutment bridges warrants their continued use.

Further development and investigations appear desirable related to bridge-deck cracking problems, deck texturing, and new concrete additives for decks and overlays.

INTRODUCTION

This report provides a brief review of bridge-deck and overlay advances, survey reports on overlays and integral abutment bridges, and analyses of bridge-deck cracking in Kentucky. A recent report presented the first preliminary analysis of bridge-deck crack patterns (1).

Over the years, the performance and durability of concrete bridge decks have been major concerns. The early performance of interstate concrete bridge decks proved disappointing and prompted changes. Earlier deck concrete was often too porous. In some cases, reinforcing steel was close to the surface (insufficient cover), prompting corrosion and concrete spalling. As a result of those and other problems, bridge-deck scaling was common. Increased use of deicing salts from the 1960's onward exacerbated the rate of deck deterioration. Beginning in the 1960's, a series of progressive technological improvements in concrete deck design, construction, materials, and maintenance were instituted (Table 1). Those changes were intended to increase the quality and endurance of bridge decks. While they addressed various factors related to deck durability and maintenance, those changes all had a positive effect in improving deck performance. Unfortunately, the fact that they were not instituted uniformly (due to the different ages of the Transportation Cabinet family of bridges) has made it difficult to properly quantify increases in deck quality and durability gained through individual changes.

DECK CONSTRUCTION

Before the use of full-width finishing machines, wooden templates on pipe rails were set to grade and the concrete was screeded manually by sawing a 2 by 6 board across the tops of the grade boards. Then, the template boards were removed and the concrete was floated to the final grade. Filling of voids remaining after removal of the boards (and pipes) was rarely adequate to prevent deterioration of the concrete.

Bridge-deck finishing machines were required for all new Kentucky bridges constructed after 1962. At one time, it was felt that use of a rotary steel-disk impacting finisher such as the Kelly compactor might

TABLE 1. CHRONOLOGY OF BRIDGE-DECK IMPROVEMENTS

YEAR	IMPROVEMENT
1956	Specified air-entrainment for deck concrete
1962	Specified full-width finishing machines
1962	Specified linseed oil protective coating
1964	Specified membrane curing
1964	Increased concrete cover over reinforcement to 2 inches
1965	Specified template clearance check for finishing machines
1966	Specified Class AA concrete (6.6 sacks of cement, maximum of 5 gallons of water per sack)
1967	Specified tie-down of reinforcing steel (8-foot centers)
1968	Dense concrete overlay, Clark Memorial Bridge, Louisville
1969	Specified temperature limitations for hot-weather concreting; nighttime concreting permitted
1975	Specified the use of epoxy-coated reinforcing bars in the upper mat

provide better concrete consolidation and that, coupled with the swirl finish provided by the compactor´s disk, would improve the concrete deck. The Kelly compactor was employed on only one bridge in 1968 and five in 1972. Thirteen bridges on I 64 contained experimental features, including use of the Kelly compactor on two bridges constructed in 1972. Those and other experimental features have been reported previously (2). The last inspections conducted on those bridges revealed that several of those bridges had varying amounts of deck cracks; but there were no indications of severe premature deck deterioration (i.e., spalling).

Bidwell developed the first full-width concrete finishing machine. It possessed a relatively light truss with an underslung, sawing screed float. Later, vibrators were added to the float. The Gomaco Company subsequently developed a pavement finishing machine with a spinning roller and auger (Figures 1 and 2). It was used for new decks and latex overlays. Later, the Bidwell Model OF-400 Overlay Finisher was developed to handle low-slump concrete (Figure 3). It was capable of single- or double-lane overlayments.

DECK MAINTENANCE

Until the late 1950´s, most major deck repairs consisted of filling potholes and depressions and resurfacing with asphaltic concrete. While that method provided a temporary patch, it also retained contaminants and moisture that attacked the underlying deck. The resulting deterioration progressed unseen. Perhaps some protection was achieved, but accelerated damage was suspected. During that time, underlayments of asphalt roofing were proposed. However, concerns about bleeding and slippage deterred their use. Conventional deck overlayment (blacktopping) was usually done in conjunction with roadway resurfacing. Sometimes second and third-generation asphalt overlayments were placed over bridge decks (usually after removing the previous asphalt overlayment). Even though that work was widespread, there was a strong reluctance to blacken bridge decks since it caused poor nighttime visibility.

Initially, new and existing bridges were treated with linseed oil, various varnishes, and penetrants to protect them from water and salt

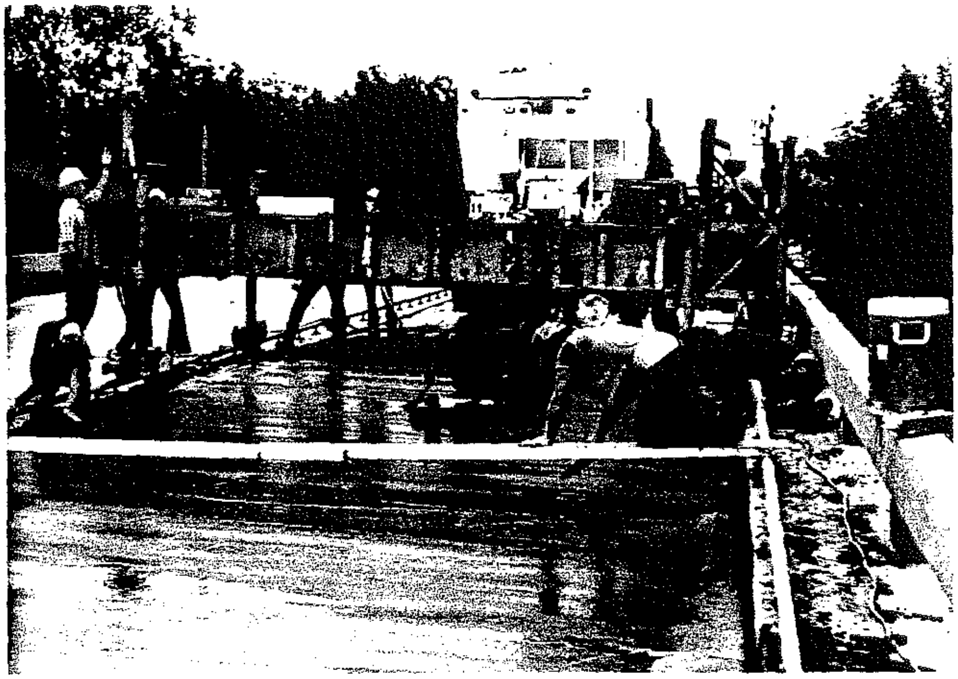


Figure 1. Spinning Drum Paving Machine (Bidwell) Commonly Used to Place New Bridge Decks and Latex Overlays.

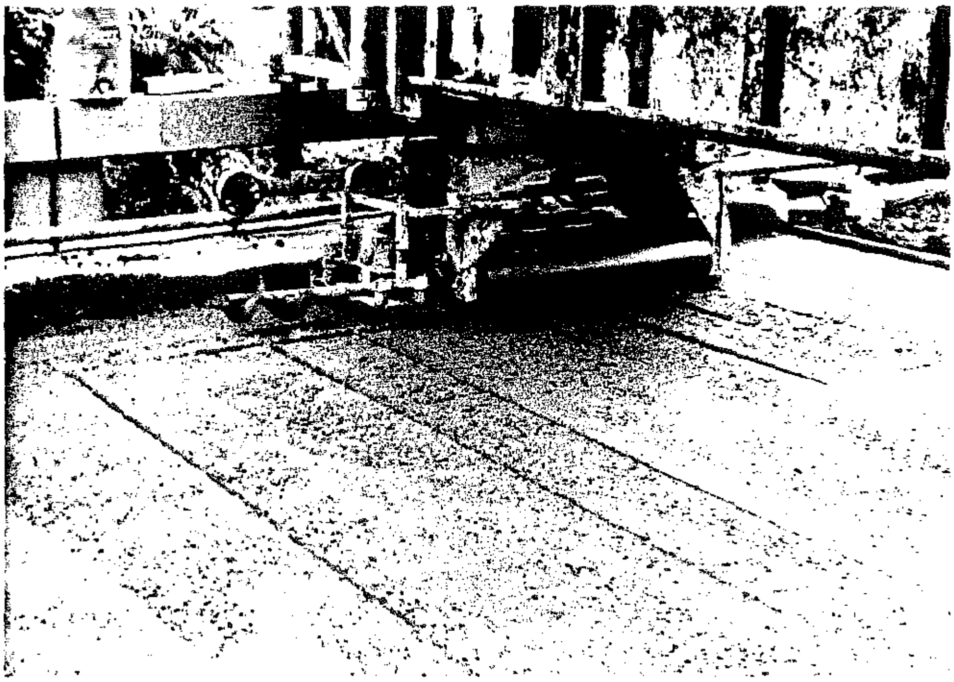


Figure 2. Spinning Drum and Auger on Paving Machine Shown in Figure 1.

(Figure 4). Often, solvents in those formulations evaporated and sufficient sealant thicknesses or penetrations were not achieved. Epoxy resin was investigated in the early 1970's. One of its primary appeals was that it consisted of two stable liquids that could be blended in the field. Subsequently, the compound hardened to great strength without significant loss of volume. Thus, concrete could be penetrated, sealed, and possibly strengthened. Unfortunately, the epoxy tended to separate from the concrete as it hardened. Due to that phenomenon, the epoxy-sand seal coats attempted on bridge decks debonded. The debonding mechanism was not widely understood at that time and no suitable remedies were formulated.

Concurrently, Kentucky proceeded with latex mortar and eventually with latex concrete overlays (3). For a short period in the mid-1970's, at the behest of the Federal Highway Administration, the Transportation Cabinet experimented with membrane overlays. The I-24 bridge over the Ohio River at Paducah was the first major membrane bridge constructed by the Transportation Cabinet. Subsequently, membranes were employed on eight other bridges. A third overlay option is dense (low-slump) concrete. An early version of this material was placed on the Clark Memorial Bridge in Louisville (1968). It had a reduced slump (1 to 2 inches) and used 6.6 bags of cement per cubic yard of concrete. The concrete was compacted with a Kelly rotary compactor. That deck has performed well. The need for an alternate overlay was necessitated by the high price of latex concrete in the mid-1970's. FHWA approved low-slump overlays but required a 1/2-inch thicker overlay than latex concrete due to its higher chloride permeability. In the interim, paving machines were improved, milling machines evolved, and deck restoration work became more routine and reliable.

Membrane overlays lapsed from use after a short period. However, the system was used for the KY-676 segmental bridge over the Kentucky River at Frankfort in 1979. Unfortunately, the membrane slipped in the westbound lane where traffic was required to brake before stopping at an intersection at the lower end of the bridge. The westbound bridge membrane was subsequently removed and replaced with a concrete overlay. The eastbound bridge membrane has been recently replaced.

Figure 3. Vibrating Screed Paving Machine (Bidwell) Commonly Used to Place Low-Slump Overlays.

Figure 4. Sealing of the I-24 Bridge over the Cumberland River with a Concrete Curing Compound (1980).

MEMBRANE OVERLAYS

Initially, it was thought that a well primed concrete deck surface overlaid with a dense sand-asphalt course 1/2 to 3/4 inch thick would provide protection to deck concrete, that it would enable easy leveling and patching, and that it could be overlaid or removed and renewed. Two trials, at the Ashland-Coal Grove Bridge and at the Clark Memorial Bridge in Louisville, proved disappointing.

Roofing-type overlays were first observed in other states. Those included the U.S. Steel system in Illinois, the Johns-Mannville system in Indiana, and the Royston system in Tennessee.

As previously noted, the first membrane used by the Transportation Cabinet was placed on the I-24 bridge over the Ohio River bridge near Paducah. The membrane was applied in June 1974 at a cost of $9.50 per square yard. The membrane was a slurry type consisting of 1) a concrete primer, 2) a layer of coal-tar emulsion slurry, 3) a coal-tar emulsion, 4) a layer of coal-tar emulsion and glass fabric, 5) a third layer of coal-tar emulsion and glass fabric, 6) a second layer of coal-tar emulsion slurry, 7) a 1/2-inch thick layer of rubberized sand asphalt, and 8) a 1-inch thick layer of bituminous concrete. The membrane was constructed to an Illinois Department of Transportation specification, since the bridge was owned jointly with the State of Illinois. That overlay was known as the "Illinois system".

During construction of that membrane, widespread blistering was detected. The blisters were subsequently punctured and rolled to reseal the affected areas.

The Transportation Cabinet prepared specifications for both liquid-applied and sheet-type membranes using simpler designs than employed by Illinois. The liquid-applied membrane specifications allowed the use of either Super Seal 4000 or NEA 4000. Only the Super Seal product was employed in Kentucky (Figure 5). Liquid membranes also were required to have a protective cover of asphalt roofing paper covered by 2 inches of a Class I, Type A modified surface asphaltic concrete mixture.

Sheet-type membranes permitted by the specifications were 1) W. R. Grace Heavy Duty Bituthene, 2) Royston Bridge Membrane No. 10, and 3) Protects Wrap M-400. Only W. R. Grace and Royston products were

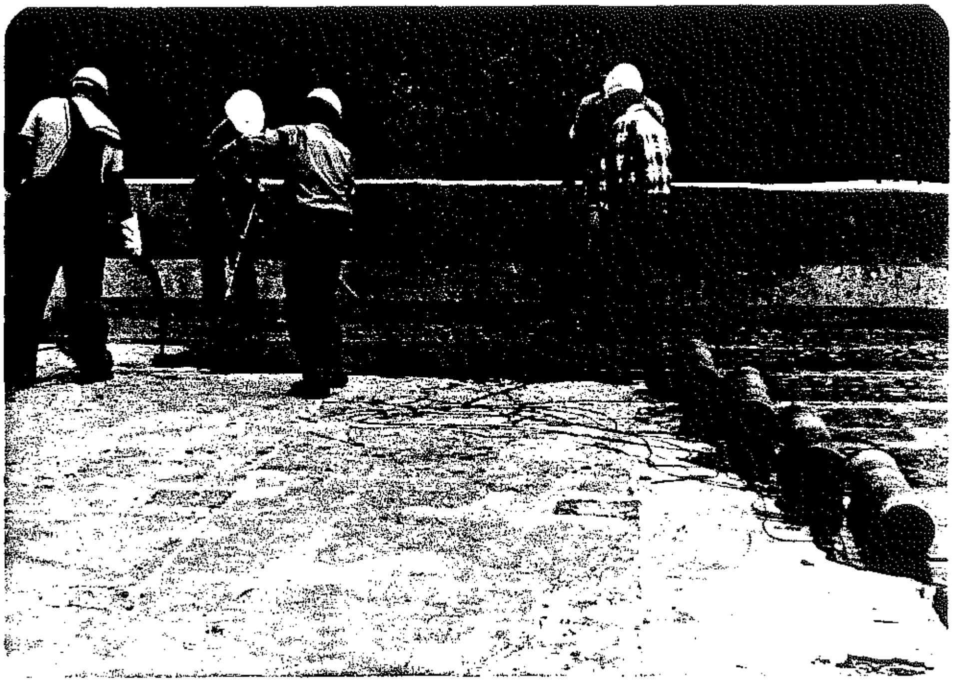


Figure 5. Placing a Liquid-Applied Membrane (Superior Products Super Seal 4000) on the KY-676 East-West Connector over the Kentucky River (1979).

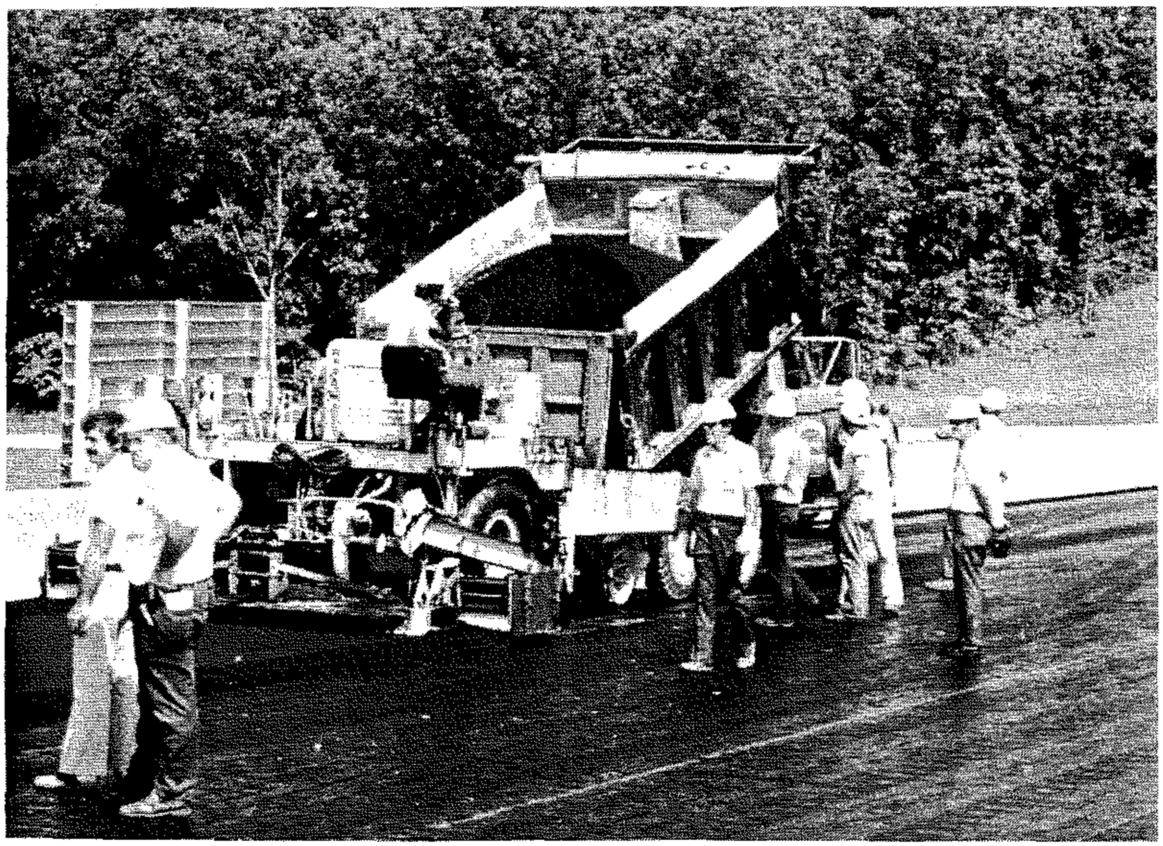


Figure 6. Placing a Sheet-Type Membrane (W. R. Grace & Co. Heavy-Duty Bituthene) on the Elizabethtown Bypass over the Western Kentucky Parkway (1974).

employed in Kentucky (Figure 6). The sheet-type membranes were covered with 1-1/2 inches of a Class I, Type A modified surface asphalt mixture.

Additionally, an unspecified membrane was placed by state forces on the US-460 bridge over Forks of Elkhorn in 1974. That consisted of a coal-tar slurry covered with a sand seal. The membrane was traffic compacted overnight and given a Class I asphaltic concrete riding surface.

Several membranes experienced blistering problems (most notably the I-24 bridge over US 62 in Marshall County). As with the I-24 bridge over the Ohio River, those were repaired by puncturing the blisters and resealing them (Figure 7). The Division of Maintenance also experienced problems in acquiring the small quantities of Class I asphaltic concrete required for most bridges. Those problems coupled with the success of rigid concrete overlays led to disuse of membranes by the Transportation Cabinet (except for the KY-676 bridges).

LATEX MORTAR AND LATEX CONCRETE OVERLAYS

A latex (Dow) mortar overlay was first used on the KY-90 bridge over Lake Cumberland at Burnside, Kentucky. Latex-mortar overlays were subsequently applied by state forces on a number of eastern Kentucky bridges beginning with the KY-114 bridge over Levisa Fork of the Big Sandy and the C&O Railroad at Prestonsburg in 1968. Mortar mixes experienced shrinking and cracking problems. Latex-concrete mixes were adopted by the Transportation Cabinet in 1973 and were accepted by FHWA in 1974. A greater thickness of concrete overlay could be used for less cost when compared to the mortar.

Dow latex concrete first qualified under FHWA guidelines for rigid overlays. Reichhold Chemical Company eventually became a competitor to Dow, and their product was first used on several I-275 bridges eastward from I 75. Some pull cracks were experienced early during construction of those bridges.

By 1978, the Federal Highway Administration had evaluated and approved a number of latex modifiers including 1) Dow Modifier A (SM-100), 2) Reichhold Thermoflex 8002, 3) Avco Dylex 1186, and 4) General Polymers Deco Rez 4776. The experimental bridges investigated

Figure 7. Resealed Blisters on the Membrane of the I-24 Eastbound Bridge over US 62 (1980).

under this study employed the Dow and Reichhold latex overlays. Some new bridges had 1-1/2 inches of latex. All maintenance projects funded with 100 percent state funds were only 1 inch thick (and included Bridges 32-34, 38-43, and 48-95). Latex overlays on federally funded projects in 1974, 1975, and 1976 were 1-1/4 inches thick. That was increased to 1-1/2 inches in 1976.

Cost figures were obtained for 25 experimental latex overlays placed on new bridge decks between 1974 and 1977. Deck areas varied from 826 to 25,108 square yards. Overlay costs (based on construction estimates) varied from $20.76 to $30.92 per square yard. Those cost figures did not show a relation between overlay cost and deck size. Costs also were obtained for nine experimental latex overlays used to rehabilitate aging bridge decks in 1977. Those bridges varied in deck area from 381 to 2,120 square yards. Unit costs for those projects ranged from $41.76 to $47.10.

LOW-SLUMP OVERLAYS

The first use of a low-slump (1 to 2 inches) overlay in Kentucky was on the main spans of the Clark Memorial Bridge at Louisville in 1968. Disintegrated concrete was chipped, some full-depth patching was performed, and the overlay was spread with a Bidwell, truss-mounted reciprocating screed. The concrete was consolidated with a Kelly compactor (4). That overlay performed well, but recommendations for its adoption as standard practice were withheld. It should be noted that the low-slump concrete employed on Clarke Memorial Bridge was not similar to that currently specified. CMI´s Bidwell, Model DF-400, Overlay Finisher was subsequently developed to place dense concrete. It became known as the "Kentucky machine." It also supplanted the need for the Kelly compactor. While awaiting more than a half-life cycle performance history on the Clark Memorial Bridge, Iowa´s performance reports on similar projects added impetus to its adoption. The Division of Materials actively promoted low-slump overlays as a means of circumventing the extremely high cost of latex concrete at that time. Eventually, dense concrete became an alternate to latex concrete. A drastic reduction in the cost of latex concrete resulted once an alternate was provided. Latex-concrete and low-slump concrete overlays were of equal thickness on decks placed in 1975 and 1976. Thereafter, an additional thickness of 1/2 inch was required for low-slump concrete because of its greater permeability to chlorides. To date, the pre-1977 and post-1976 low-slump concrete decks have both performed well. The effect of the additional 1/2 inch of thickness of overlay has not yet produced substantial differences in performance. Present Kentucky specifications require slumps of 1-1/2, 1-3/4, or 2 inches, depending on circumstances.

Cost figures were obtained for three low-slump overlays placed on new US 119 bridge decks in 1977. Deck areas for those bridges ranged from 1,203 to 1,584 square yards. Overlay unit costs (from construction estimates) ranged from $24.18 to $24.92 per square yard.

MATERIAL IMPROVEMENTS

A succession of experimental and other notable deck concrete projects was initiated. Class AA concrete, initially specified in 1966, was a reduced water-cement ratio concrete that was more durable than earlier deck concretes. Further efforts were aimed at improving the durability of concrete. Attempts were made to produce low-void concrete that would be immune (or more resistant) to freezing and thawing. One research study in the 1970's investigated the substitution of latexes and oil-water emulsions for normal mixing water. An emulsified epoxy-resin was field tested unsucessfully. However, several laboratory concrete mixes showed improvement over conventional deck concretes. All of that work was eventually surpassed by experimental laboratory concretes containing super water-reducers. Unfortunately, only nominal laboratory work was fully accepted into practice. The Transportation Cabinet also gave attention to problems with expansive limestone aggregates and shales in concrete pavements. Criteria and specifications were upgraded for their exclusion. Mechanisms of freezing and thawing were analyzed, and theories were evolved relating concrete properties and material performance during the period from 1970-1980.

Use of epoxy-coated reinforcing bars in conjunction with 2-1/2 to 3 inches of Class AA concrete cover has been the basis for the Transportation Cabinet´s efforts to construct durable bridge decks since 1976.

BRIDGE DECK CRACKING AND OVERLAY PROBLEMS

Characteristic cracking of haunched reinforced concrete deck girder (RCDG) bridges was first observed in Kentucky by Robert M. Gillim and first reported in 1963 (5). Actually, the very first occurrences date from the US-31E Buechel Bypass in Jefferson County in 1955 and KY 8 in Bracken County in 1957. This crack pattern is consistent from bridge to bridge, but the spacing varies along the length of the bridge. Constraints provided by massive girders and bulkheads influence the crack spacing. Otherwise, it would be more regular and uniform. Some cracks, especially at mid-spans and in negative moment areas over piers, are flexural (working cracks); others are natural (caused by peaking temperatures).

Fortunately, cracks in bridge decks that are due to structural causes are systematic and, therefore, may be analyzed. Recognition and comprehension of deck crack patterns and attendant causes are important. For example, it is necessary to distinguish between those cracks in the deck and those in overlays due to shrinkage. The performances of overlays should not be correlated with natural or flexural cracks in decks (Op. Cit. 1). Late in this study, it became possible to isolate performance factors to a significant degree.

An era of large-scale road-building in Kentucky began in 1924. Many large bridges of that era were steel through-trusses and simple-span formed-in-place reinforced concrete bridges with concrete handrails. After World War II, riveted and eventually welded steel plate girders (continuous, some haunched at the piers) and reinforced concrete deck-girder (continuous, haunched) bridges were used for three- or four-span bridges.

Steel I-beam bridges have been widely used since the 1940's. A more recent significant development has been the application of precast, prestressed concrete I-beams in simple or multispan bridges. Those and some steel-beam bridges (constructed during the last 20 years) were continuous over the piers (though the prestressed concrete I-beams were only continuous for live loads) and some were integral with the abutments (no joints). Prestressed bridges of all types have shown minimal deck cracking. Cracking on bridges employing prestressed I-beams usually has been longitudinal, occurring at the ends and at the middle or edges of deck panels.

The role of shear connectors (studs) in influencing cracking and crack patterns in steel girder bridges has not been determined.

The role of additional reinforcing steel in a deck was tested on one bridge, and the extra steel increased the number of cracks (i.e., shortened the interval between them). This is compatible with the temperature-induced cracking theory.

Concrete bridge-deck cracking has been deduced to be due to two effects: one thermal and the other structural.

TEMPERATURE CRACKING

Reinforced concrete containing at least 0.6 percent steel cracks on an interval of about 30 inches (5-10). Those cracks may not be readily visible. In bridge decks, some may become working cracks and appear prominently. Temperature cracks in bridge decks are often observed to merge with regularly occurring temperature cracks located in the plinth. Usually, those cracks completely penetrate the bridge deck. If left uncovered, efflorescence eventually appears on the bottom of the deck. That is due to seepage of water through the cracks and deposition of lime along the underlying crack face after drying (Figure 8).

Temperature cracks in bridge decks 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 the prestressed type). They are natural and unavoidable. If the cracks are located at points of flexure, they may become working cracks and widen. Those will exhibit more efflorescence at the bottom of the deck than other temperature cracks. Cyclic loading will eventually cause all cracks to widen somewhat.

Internal cracking due to thermal effects was not recognized or explained until it was observed in continuously reinforced concrete pavements (9, 10). The more unique crack pattern typical of RCDG bridges (especially those with haunched girders) was observed later. Cracking due to flexure and contraflexure is recognizable, but cracking due to above-normal temperatures is complex. The pattern is consistent from bridge to bridge, but spacings vary slightly. There tend to be very few longitudinal cracks in the panels of RCDG bridges compared to the great number of transverse cracks.

Reference is made to the term "slip modulus" as treated by Shrader (8); 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. Those conditions 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.

A likely explanation of early cracking over reinforcing steel is depicted in Figure 9. During placement, the fresh concrete subsides between and around the steel but is perched over the bars and is not perfectly settled. Bleed water may eventually exit upward around the bars or remain there long enough to create a void. As the concreting advances, the additional load may cause the steel in the concrete behind to rise and induce cracks. The cracks may result from workmen walking on and flexing steel adjacent to previously placed concrete.

Transverse cracks always may be observed in continuous deck-girder bridges. A higher incidence of those cracks occurs on the upper surface in negative moment areas. They have been observed on structures not opened to traffic. A seeming anomaly in crack frequency is observed in continuously reinforced concrete pavements; those having high percentages of steel also have more closely spaced cracks. However, crack widths decrease with increase in percent steel. Differences in the thermal coefficients of linear expansion of steel and concrete are

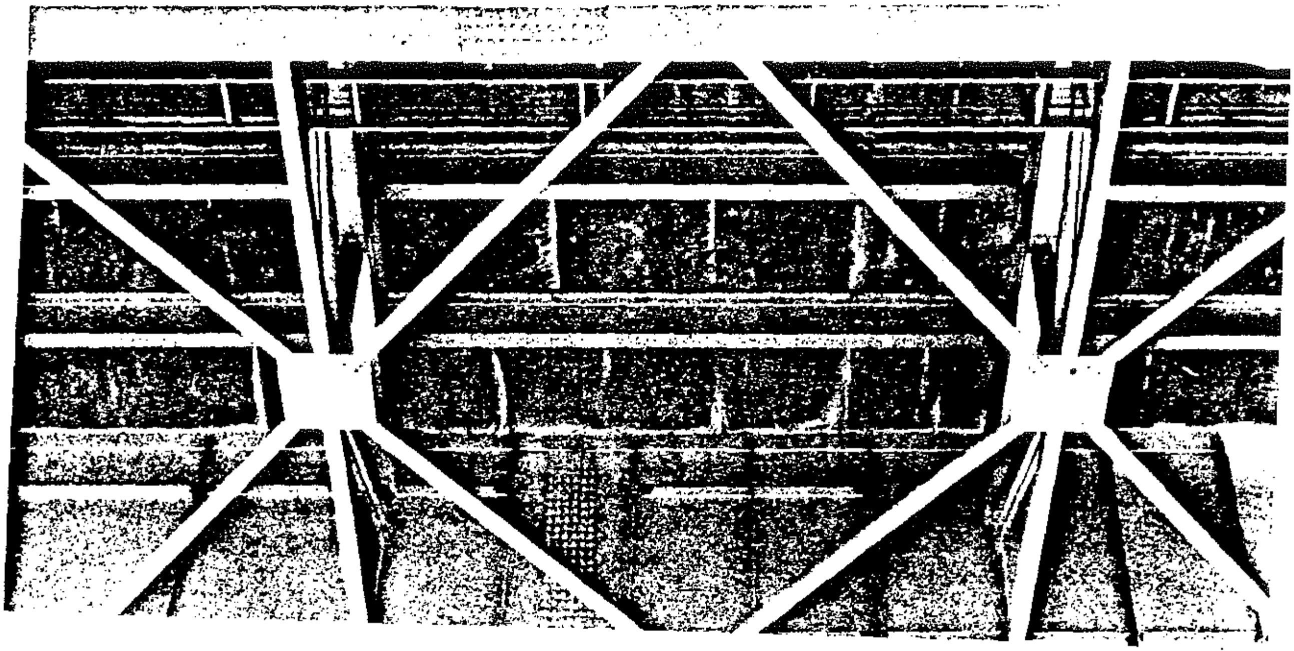


Figure 8. Example of Cracking in Deck on Steel Girders; Note Efflorescence Stain (I 24, Cumberland River) (June 1981).

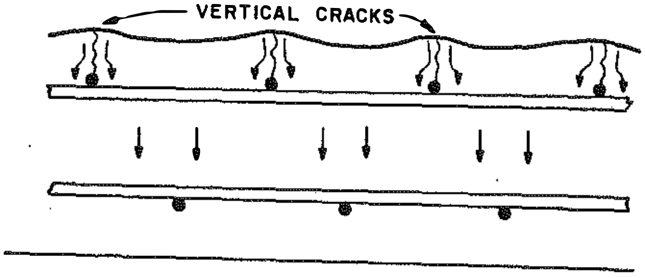


Figure 9. Possible Cause of Early Cracking in Steel Reinforced Concrete.

often neglected in structural designs. However, computed stresses become critical over a 100°F change. There appears to be a striking similarity between crack intervals in continuously reinforced pavements and certain decks. A hypothesized mathematical expression follows.

Respecting continuity of strain and letting e denote strain,

$$e_s = e_c$$

and

$$de_s = de_c.$$

Allowing free expansion and contraction (no external forces),

$$(de_s/dt)dt - \Delta\sigma_s/E_s = (de_c/dt)\ dt + \Delta\sigma_c s'c,$$

in which

$de_s/dt = C_s$ = coefficient of thermal expansion of steel ($6.5 \times 10^{-6}/{}^{\circ}F$),

$de_c/dt = C_c$ = coefficient of thermal expansion of concrete ($5.5 \times 10^{-6}/{}^{\circ}F$),

E_s = modulus of elasticity of steel = 30×10^6 psi,

E_c = modulus of elasticity of concrete = 5×10^6 psi,

$\Delta\sigma_s/E_s$ and $\Delta\sigma_c/E_c$ = counter strains arising from resisting stresses T_s and T_c,

$\Delta\sigma_s = \Delta\sigma_c/A_s$ (for balancing forces), and

A_s = decimal equivalent of percent steel.

Substituting and simplifying,

$$(C_s - C_c)(t_2 - t_1) = (6A_s\Delta\sigma_c + \Delta\sigma_c)/A_sE_s$$

and

$$\Delta\sigma_c = (C_s - C_c)\ (t_2 - t_1)A_sE_s/(6A_s + 1).$$

Therefore,

$$\Delta\sigma_c = 30(t_2 - t_1)A_s/(6A_s + 1)$$

and

$$\Delta\sigma_c = 30(t_2 - t_1)/(6A_s + 1).$$

$\Delta\sigma_c$ is the stress rise in the concrete per unit length. The stress rise in the steel is $\Delta\sigma_s$. Therefore,

$$\Delta\sigma_c/\Delta L = d\sigma_c/dL = 30(t_2 - t_1)A_s/(6A_s + 1).$$

Upon integrating,

$$\Delta\sigma_c = 30(t_2 - t_1)A_sL/(6A_s + 1) + C.$$

When L = 0, C = 0. Thus,

$$\sigma_c = 30(t_2 - t_1)A_sL/(6A_s + 1)$$

and

$\sigma_c = 30(t_2 - t_1)L/(6A_s + 1).$

When $\sigma_c(\max) = 600$ psi and $(t_2 - t_1) = 100^{\circ}F$,

$L = 0.2\,(6A_s + 1)/A_s.$ (1)

When $\sigma_s(\max) = 90{,}000$ psi and $(t_2 - t_1) = 100^{\circ}F$,

$L = 30(6A_s + 1).$ (2)

The derivation presented is verified in the equation for bond strength. Although bond strength is rational in a conservative sense, it has some emperical foundation. Simply stated,

$\sigma_s(\max) = u\Sigma_0 L/A_s$ (3)

in which u = bond strength (psi),

Σ_0 = perimeter of steel bar (in.),

L = length of embedment (in.), and

A_s = area of steel bar (in.^{2}).

From the foregoing, it may be noted that this particular type of cracking is induced by a rising temperature rather than a falling temperature. In all these equations, L may be assumed to represent the distance over which stress or virtual strain increases from zero to a critical value. Therein, L represents the half-length between cracks; therefore, 2L would represent the average cracking interval. Equation 1 applies in situations where maximum tensile strength of the concrete is the controlling factor, and Equation 2 would apply when the maximum steel stress controls. Others have derived somewhat similar relationships in terms of a "slip modulus". The "slip modulus" is the ratio of bond stress to differential strains in the steel and concrete.

Steel I-beam continuous multispan bridges are somewhat similar to prestressed concrete I-beam bridges that are continuous (with or without integral abutments). But, decks of steel bridges crack transversely on a regular spacing. Shear studs on top of the beams may possibly adversely effect deck crack spacing. Only the restraints of prestressing (in the prestressed I-beam bridges) appear to be capable of preventing temperature cracking. This suggests that allowance for slip, together with provisions for post-tensioning tendons (longitudinal) in the deck slabs, might prevent temperature cracking but would not (necessarily) prevent flexural cracking.

FLEXURAL CRACKING

Flexure and contraflexure will induce cracking in bridge decks. Flexure cracks are due to bending or deflection along the axis of the bridge (Figure 10). Those cracks are generally perpendicular to the axis of bending. A bridge having skewed abutments and piers will oftentimes develop skewed transverse cracks. While maximum bending moment is presumed to be at the midpoint of simple spans, contraflexure occurs closer to the pier in continuous bridges. Cracks tend to occur at those points on continuous bridges.

By superimposing or combining temperature cracks with flexural cracks, it is possible to define fairly well the natural crack patterns that will be detected upon inspection of mature bridges (Figures 11 and 12).

Of special interest in this regard are the experimental bridges on US 119 between Harlan and Cumberland. Seventeen bridges were constructed prior to completion of the roadway. Prior to their initial service, FHWA policy required they be overlayed. Dense concretes and latex concretes were placed on those bridges before the roadway was opened to traffic (Figures 13 and 14). That series of bridges were made experimental. Comparisons were intended between latex concrete and dense concrete. The bridge on US 421 at its junction with US 119 was added to the set, making 18 experimental bridges.

The earliest research inspections and reports prior to or at the onset of service indicated no serious problems with the decks. In a recent inspection, many deck cracks were visible (11). It was possible to associate upper deck surface cracking with underside cracking in a manner developed during the study of mainline bridges on I 64 between Morehead and the West Virginia line (Op. Cit. 1). Cracks (patterns of cracks) were then associated with styles of bridges and termed natural cracks (due to flexure and to temperature expansion). When natural (structural) cracks and those obviously attributable to workmanship were sorted and excluded from overlay performance, the defects remaining and attributable directly to overlay failures on the US-119 bridges became minimal.

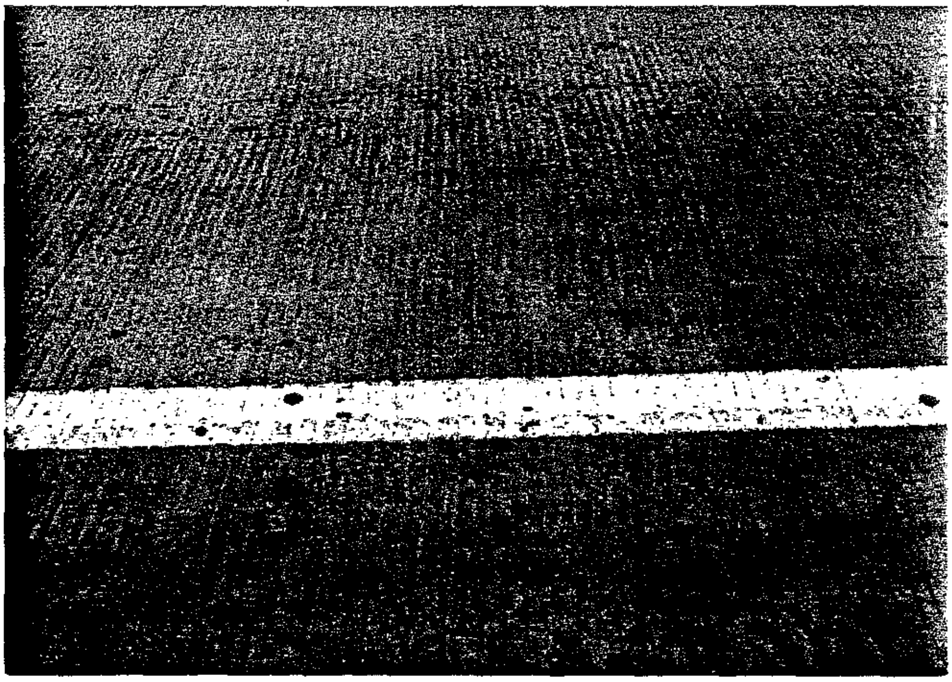
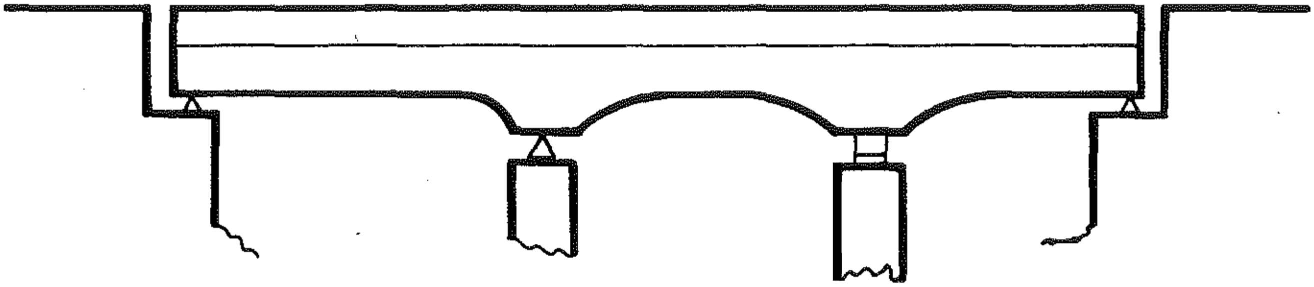
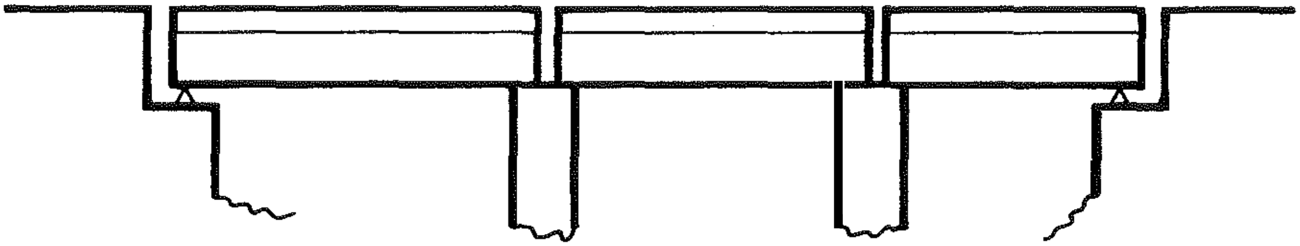


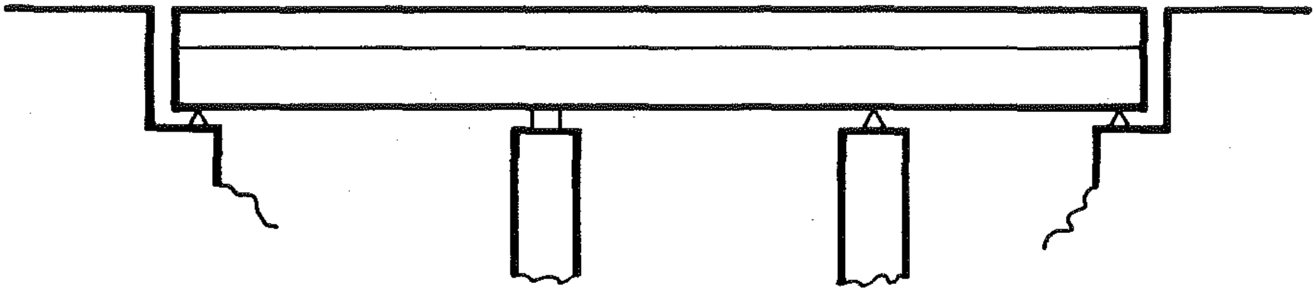
Figure 10. US-119 Bridge at MP 31.122 Showing Transverse Flexure Cracking.



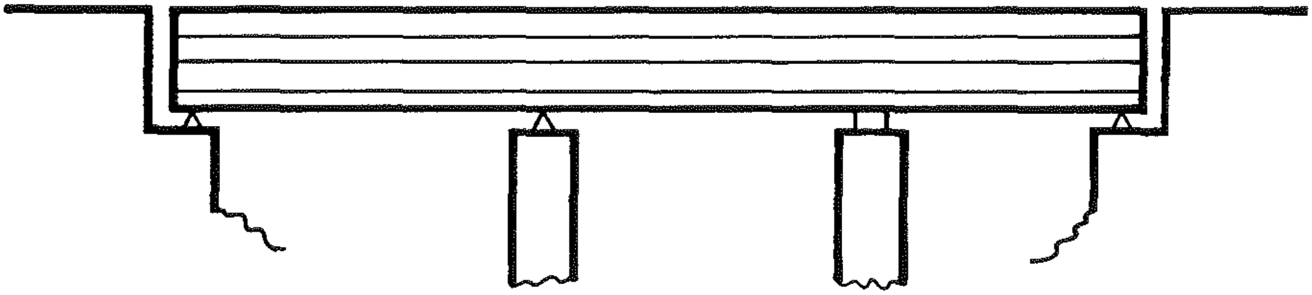
Three-Span, Continuous, RCDG, Haunched



Triple Simple-Span, RCDG

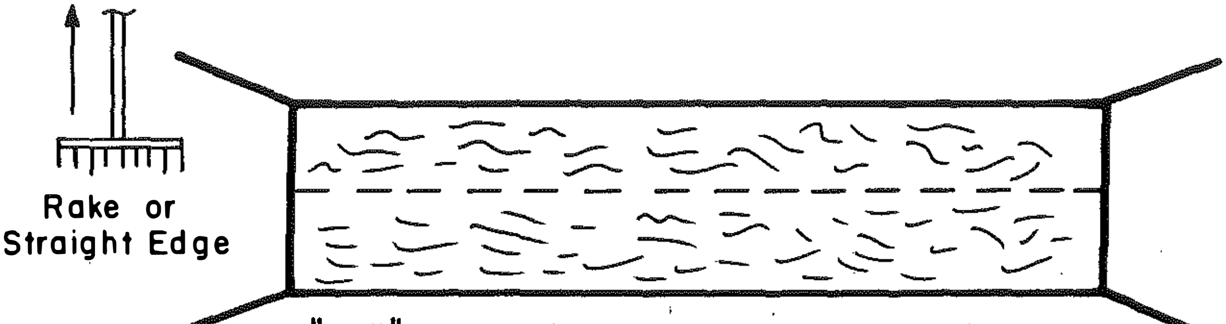


SSW, Continuous

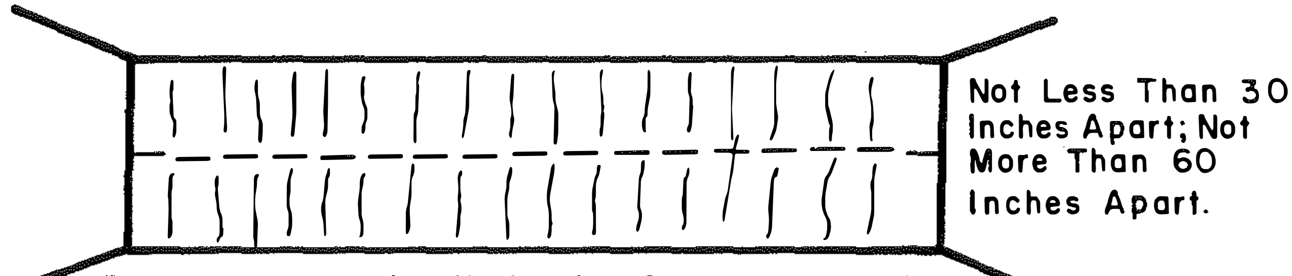


PCIB, Continuous Wihtout Integral Abutment

Figure 11. Styles of Bridges.

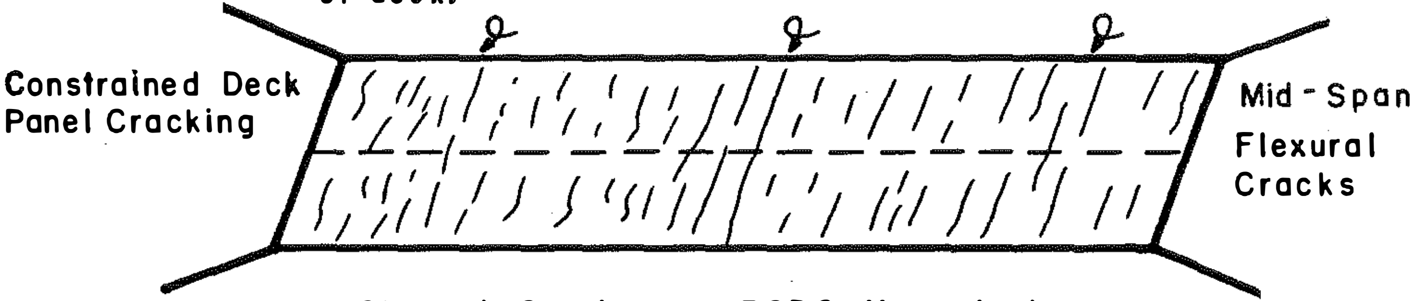


"Pull" Cracks in Latex-Concrete Overlays

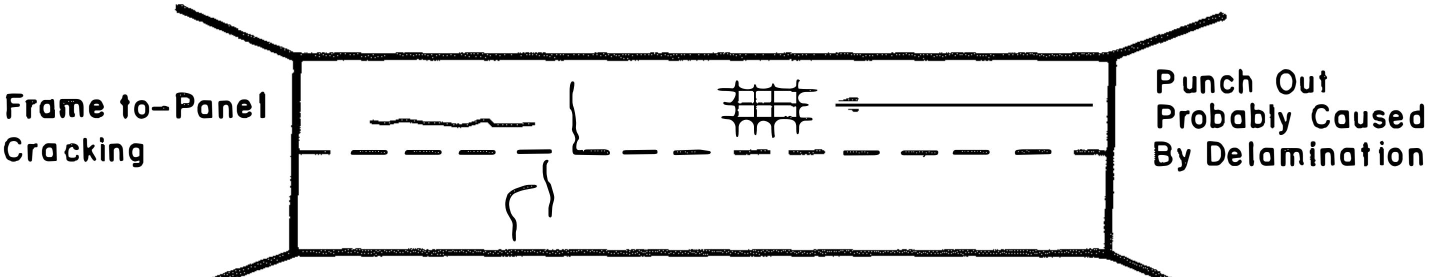


Temperature Cracking: Uniformly 30 inches Apart; In All Reinforced Concrete

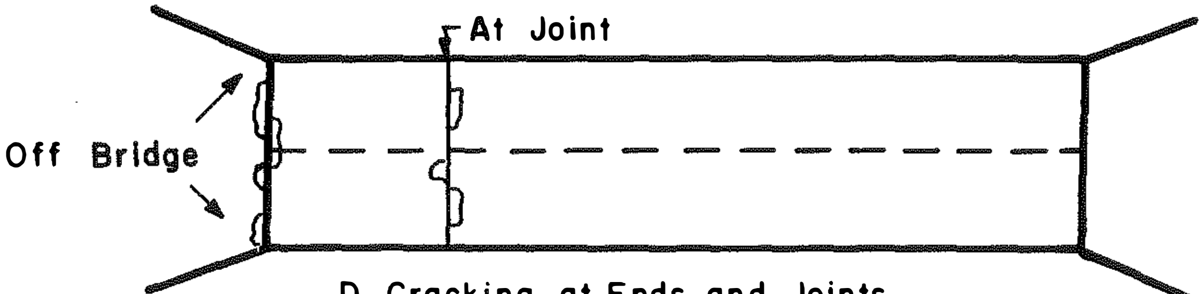
Some become working cracks and show efflorescence at Bottom side of deck.



Skewed, Continuous, RCDG, Haunched



Flexural



D-Cracking at Ends and Joints

Figure 12. Topside Deck Cracking Patterns.

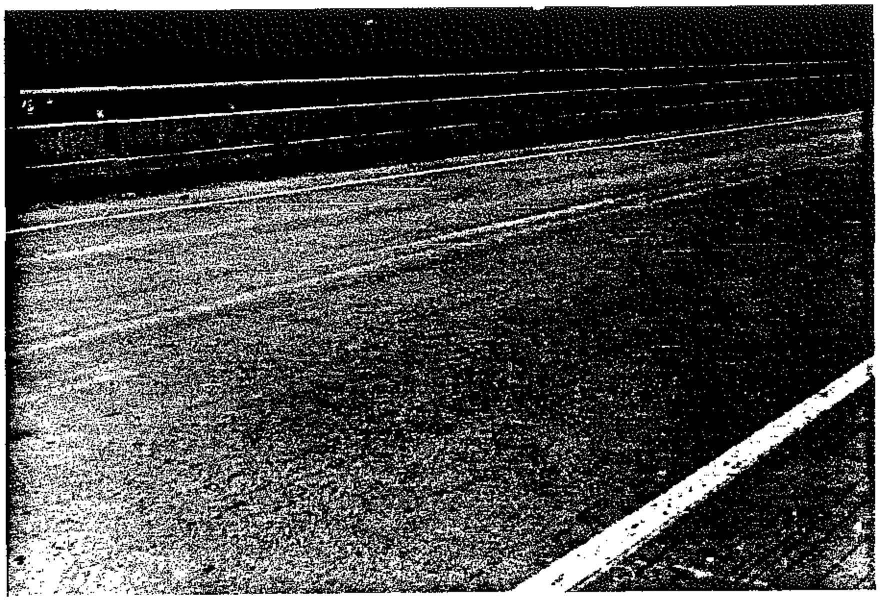


Figure 13. Latex Concrete Overlay, US 119 over Poor Fork (MP 27.626)(11/17/83).

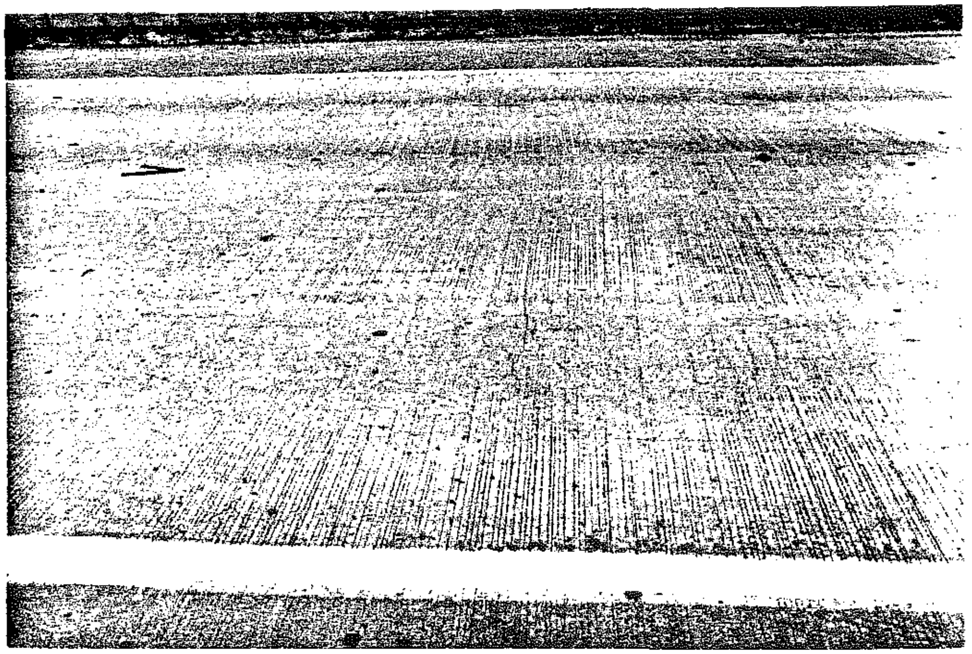


Figure 14. Low-Slump Concrete Overlay, US 119 (MP 18.214)(9/11/85).

Pattern cracking caused by flexure or temperature changes may not lead to an appreciable decrease in the life of the bridge deck (at least as observed to date). Cracking in the underlying deck will readily reflect through a thin rigid overlay. Additionally, some overlays (especially latex overlays) will exhibit shrinkage cracking. Cracking that reflects through the overlay from the underlying deck is probably less threatening to the overlay durability than shrinkage cracking (unless the underlying deck has been subject to block cracking). Many overlays, especially the earliest latex overlays, have been subject to shrinkage cracks. However, many of those have proven to be very durable despite the presence of many visible cracks.

The occurrence of concrete deck cracking is more widespread than is commonly realized. In many cases, such cracking is overlooked because it has negligible effect on deck durability. Some types of cracks that are closely spaced may lead to shattering of an overlay. That type of cracking is more typical of shrinkage cracking.

Cracking in reinforced concrete bridge decks is common. In terms of dehabilitation to the structural function, integrity, or durability, the effects of bridge cracking are inconsistent. A number of instances of significant concrete deck and overlay cracking have been encountered over the years (Table 2).

On routes frequented by heavy trucks, block cracking has been observed. This is very disabilitating and is a sign of rapid deck deterioration. An overlay on a bridge exhibiting that type of cracking is doomed to rapid failure. The only proper repair is to redeck the bridge. Stiffening the structure also may be necessary.

In a few of the decks on US 119, it appeared that trucks were too heavy for the deck panels and that "punch-outs" (block cracks) had formed. Deck overlays had cracked in checkerboard style over areas typically 2 feet wide by about 6 feet long. Those failures will probably enlarge. Also, if the decks flex and sag more, those overlays will eventually delaminate, loosen, and shatter. In such cases, the performance of the overlays reflects the inadequacy of the bridge and deck in supporting the imposed service loads. Such failures are not representative of normal service performance.

TABLE 2. SOME SIGNIFICANT CASES OF CRACKING IN DECKS AND(OR) OVERLAYS

ROUTE AND LOCATION
I 264-1(43)3, over K and IT RR (3)
Camp Nelson, US 27
US-25 bridge over Ohio River
I 275 over I 471, and others
I 24 over Tennessee River
Cumberland River Bridge, I 24
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
I 24 over Muddy Fork, 1978

BRIDGE-DECK TEXTURING PROBLEMS

Bridge-deck texturing (tining) may induce cracking in an overlay on a new deck. This was discussed in a 1978 interim report on latex overlays (12).

The 1936 Kentucky Specifications for concrete finishing required brooming (transverse) after belting. The 1956 Specifications required belting without brooming. The 1965 Specifications required a burlap drag finish after belting. Tining was instituted in 1974. The 1976 Specifications required the burlap drag followed by grooving.

Skid tests in the 1960′s and 1970′s indicated the tendency for decks to wear and polish. Generally, skid resistance was slightly higher than critical; but in a few cases, it was critical. A case in point was on I 71 where two short adjoining bridges were identified through accident records as being high-accident locations. Both the bridges and the pavement were involved. The bridges had been treated with linseed oil. Those decks were retreated with loose sand for deslicking purposes.

Several bridge decks were grooved in 1974. Grooving operations on the I-24 bridges over the Tennessee River were monitored in 1975. Grooving on that bridge was rather inconsistent and generally was not sufficiently deep. Although the present Specification states, "... the grooves shall be relatively smooth and uniform, shall be formed without tearing the surface or without bringing pieces of aggregate to the top of the surface...." However, it is generally acknowledged that texturing is detrimental to deck surfaces, and it is difficult to obtain a good textured surface.

Attempts to do deep texturing with coarse brooms (I-275 bridge over the Ohio River near Lawrenceburg, Indiana -- a latex overlay placed in 1973) together with tardiness of finishers resulted in pull cracks and some rejected work. Many of the original pull cracks remain in that deck.

Many overlay cracks detected during the recent study of the I-64 bridges were attributable to deep tining. Those cracks were probably due to tining when the overlay was in a plastic state, but beginning to set (Figure 15). Recommendations for the prevention of that type cracking have been provided (Op. Cit 1). However, tined grooves

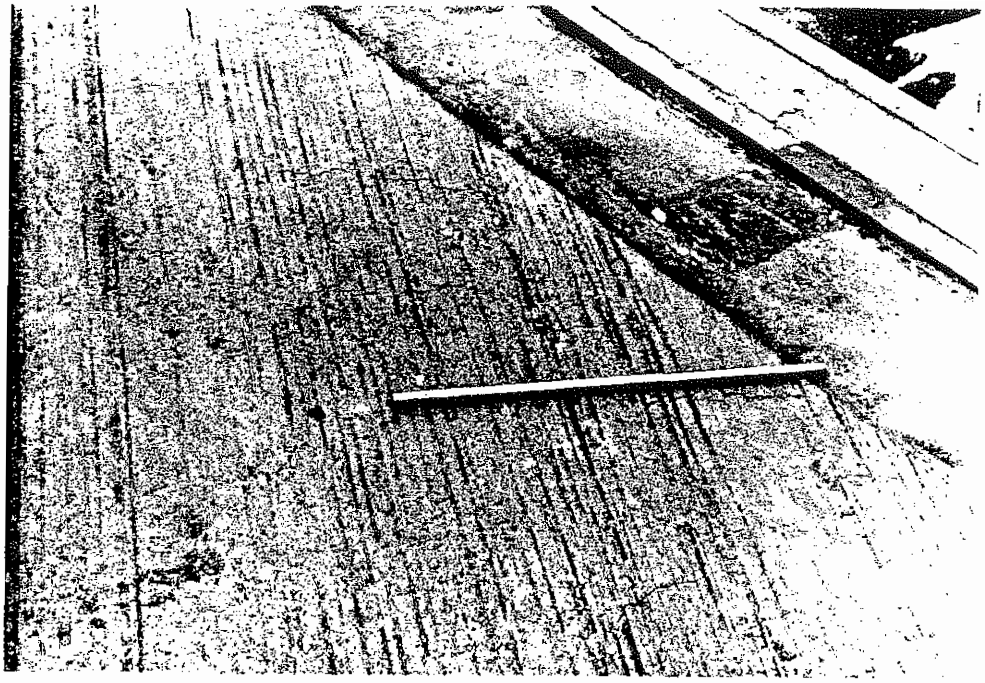


Figure 15. Pull-in Cracks Created by Overlay Tining (US-25 Bridge over the Ohio River at Covington).

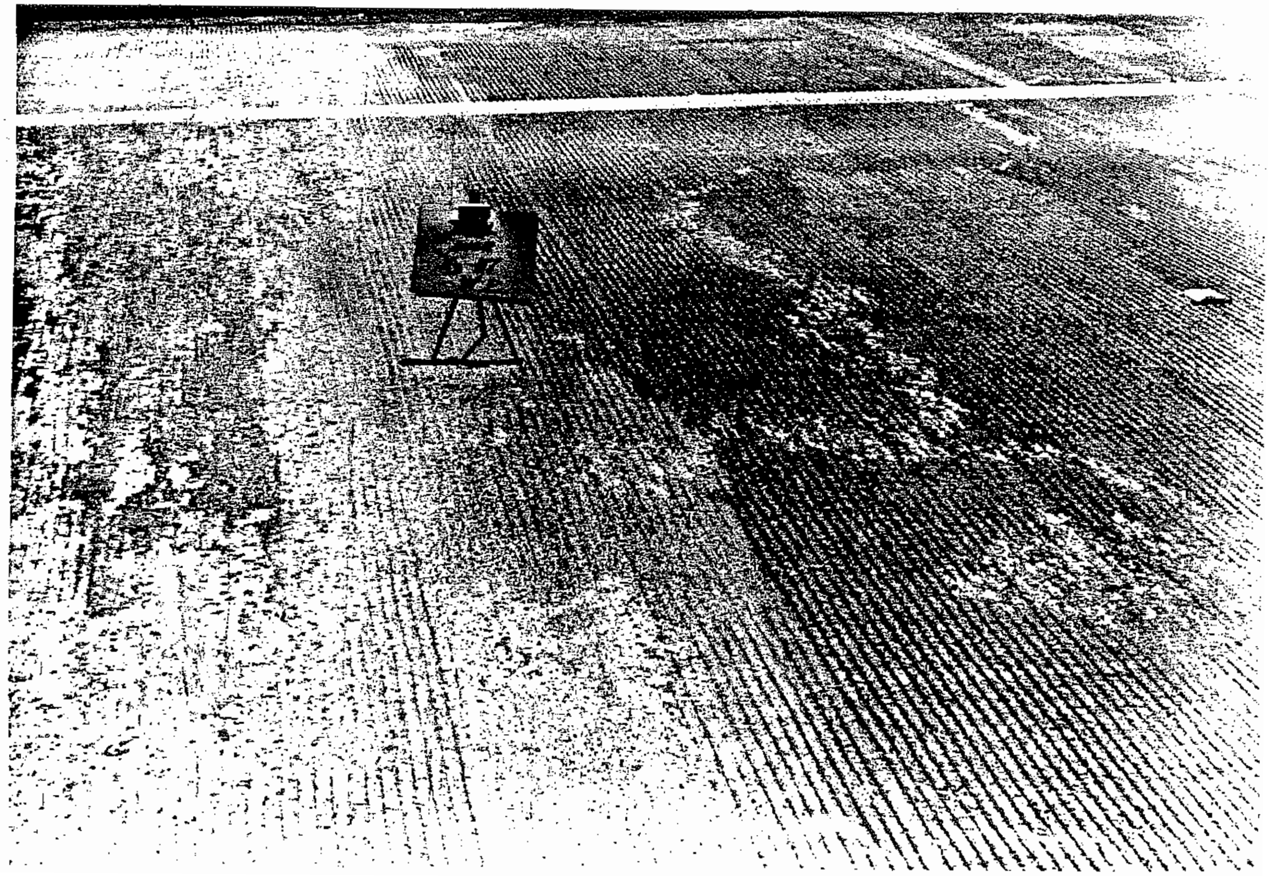


Figure 16. Irregular Pavement Grooves in a Tined Bridge Deck (I 24 over KY 117)(1980).

generally tend to be irregular (Figure 16). Even when properly performed, tining may pull aggregates and roughen deck surfaces (Figure 17). A recent report by the New Jersey Department of Transportation noted tining to be unsatisfactory and recommended that it be replaced with sawed grooves (13). Grooves were sawed on the Manchester Avenue approach to the Jefferson Street Viaduct in Lexington (Figure 18).

OVERLAY DEBONDING

Bond strength of overlays is not a specification requirement. There have been cases where good bond was not achieved. When detected, unbonded or delaminated materials have been removed and new overlays applied. Some replacements have been done at the contractors´ expense because defects appeared to be their fault. Some notable cases are listed in Table 3. Some overlays have exhibited partial debonding (Figure 19). Often, that problem is a sign of failure of the overlay to achieve proper bond with the deck; however, other times it is due to the mechanical failure of the underlying deck.

Controversies persist or recur regarding bond strength and delaminations. The roles of flexure and deck stiffness in delaminations remain obscure. Very heavy trucks appear to have a role in producing checkering and debonding of overlays, as observed on some US-119 bridges.

SURVEY OF EXPERIMENTAL OVERLAYS

During the course of this study, 119 deck overlays were examined. That total included 9 membrane overlays (placed between 1973 and 1980), 38 Dow Modified A Latex overlays (placed between 1971 and 1978), 48 Reichhold Thermoflex Latex overlays (placed between 1976 and 1978), and 24 low-slump overlays (placed between 1975 and 1979). Many of those were placed on new bridges (including seven of the membrane bridges). Ages of the older bridges ranged up to 56 years at the time of overlayment.

Figure 17. Rough Deck Surface Texturing Caused by Tining (KY 211 over KY 117)(1980).

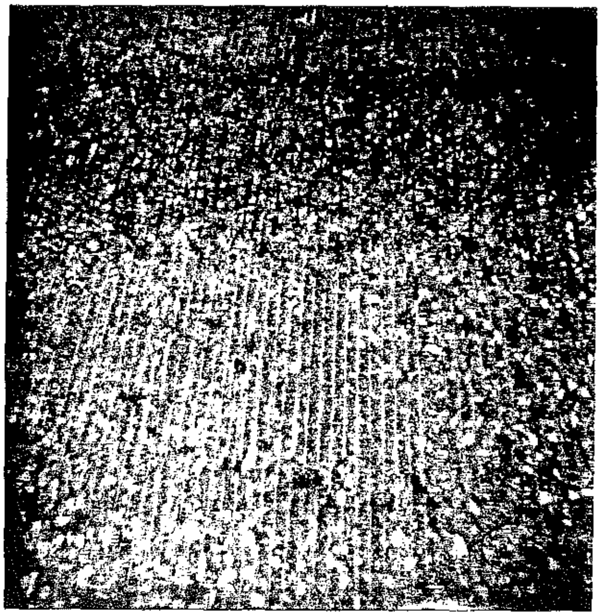


Figure 18. Sawcut Grooves in Pavement (Manchester Avenue Approach to Jefferson Street Viaduct in Lexington (1987).

TABLE 3. CASES OF OVERLAY DEBONDING PROBLEMS

ROUTE AND LOCATION
Clays Ferry Bridge, Northbound, I 75
US-150 Bridge over RR, Danville Bypass
I 64, Riverside Expressway, Louisville, from near 9th Street to 18th Street

Figure 19. Partially Debonded Dow Latex Overlay (KY 114 over Middle Creek)(1980).

MEMBRANE OVERLAYS

Inspections of the nine membrane bridges revealed that eight were in good condition (Figure 20 and Tables 4 and 5). Three of those bridges used liquid-applied membranes, four used sheet membranes, and two used slurry membranes. An experimental membrane applied to an existing bridge by state forces in 1980 (US 460 over Forks of Elkhorn) was judged to be in fair condition. The condition of that membrane may reflect the advanced deterioration of the bridge deck itself due to its age and service.

The main problems detected on membranes were blistering and cracks along laps or seams in the membranes or roofing paper that had reflected through the thin asphalt wearing surfaces (Figures 7 and 21). Many of those problems appeared early in the bridges′ service lives. A year after placing the membranes on the I-24 twin bridges over US 62, District 1 personnel recommended that badly blistered membranes (Royston) be removed and replaced with concrete overlays. Research personnel suggested that the membrane blisters should be punctured and sealed. That recommendation was followed and the subsequent performance of those membranes appears to have justified that course of action. As with the other membrane bridges, no visible efflorescence can be detected on the undersides of the I-24 twin bridges, indicating that large amounts of water have not penetrated through the membranes into the concrete decks. To date, surface blemishes have not severely affected performance of the membranes.

Remaining service lives of the membrane overlays is unknown. When the seven liquid-applied and sheet membranes were placed, resistance tests were conducted by laying a grid of thin cooper wire directly on the deck (and under the membrane). After the membrane overlays were completed, the decks were wetted and resistance readings were obtained on 10-foot by 10-foot intervals. Those readings measured conductivity between the top of the wetted asphalt wearing surface and the underlying wire in the grid. In each case, infinite resistances were obtained, signifying the membranes were impermeable to water. In 1985, follow-up resistivity tests were conducted on liquid-applied membrane bridges on US 68 in Christian County (over Muddy Fork Creek and Sinking Fork

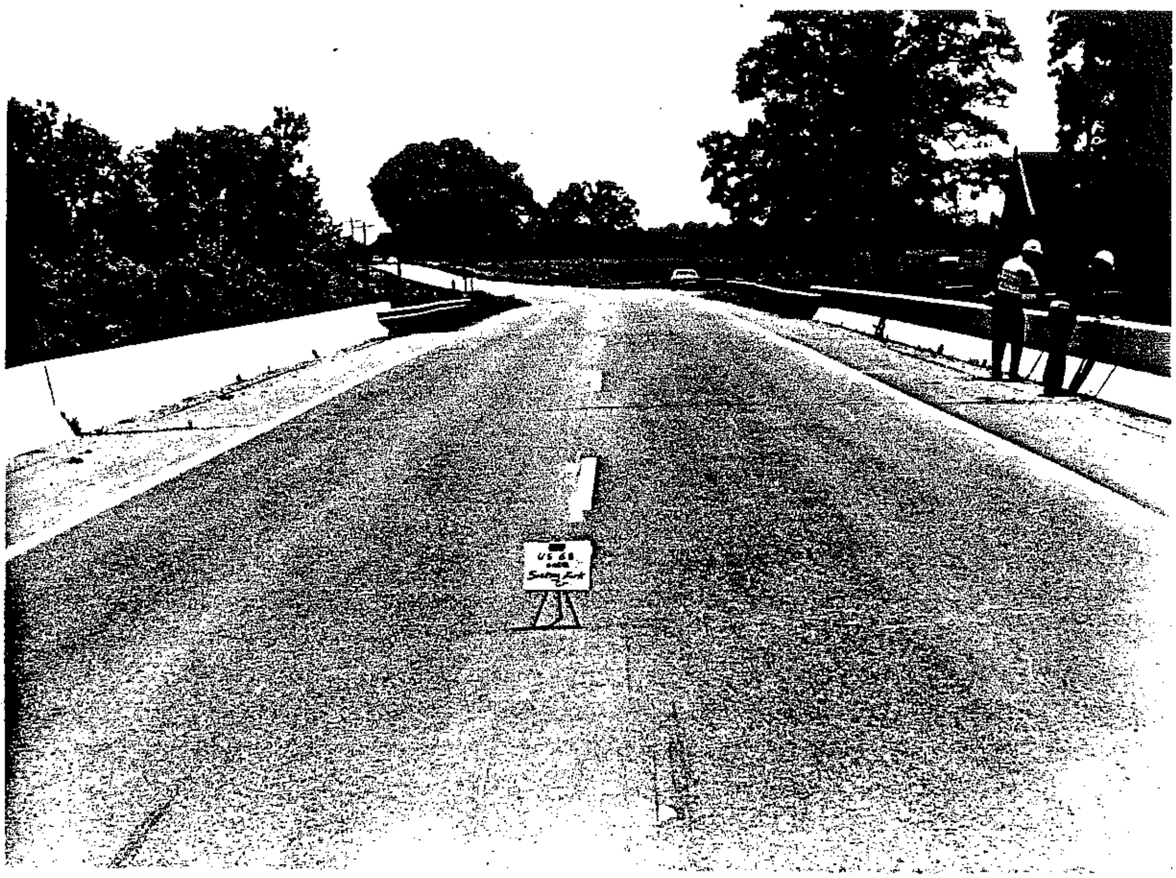


Figure 20. Liquid-Applied Membrane Overlay (US 68 over Sinking Fork Creek)(1980).

TABLE 4. BRIDGE DECK SUMMARY SHEET: ASPHALT WATERPROOFING MEMBRANES

BRIDGE NUMBER	LOCATION	COUNTY	MILEPOST	DATE CONSTRUCTED	DATE OVERLAYED	MEMBRANE TYPE	SUPPLIER AND TRADENAME	DATE OF INSPECTION(S)	CONDITION OF SURFACE
1	E-Town Bypass over WKP	Hardin	0.001	1974	1974	Sheet;Reinforced Asphalt/Resin	W. R. Grace & Co. Heavy Duty Bituthene	9-01-80 9-01-83	Good Good
2	E-Town Bypass over US 62 and L&N RR	Hardin	0.652	1974	1974	Sheet;Reinforced Asphalt/Resin	W. R. Grace & Co. Heavy Duty Bituthene	8-19-80	Good
3	US 23 over Tygarts Creek	Greenup	26.47	1973	1975	Sheet;Reinforced Resin	Royston Laboratories,Inc. Bridge Membrane No. 10	9-11-80 11-01-83	Good Good
4	US 460 over Forks of Elkhorn	Franklin	2.3	1934	1974	Slurry covered with a Sand Seal & Class I Surface	Slurry Seal of Ohio Slurry Seal	7-15-80 7-08-84	Good Fair
5	I 24 over Ohio River	McCracken	0.5	1974	1974	Coal Tar Emulsion Slurry with Glass Fiber	Illinois Spec.	6-13-80	Good
6	KY 676 East-West Connector over Kentucky River	Franklin	1.5	1979	1979	Liquid - Roofing Paper	Superior Products Super Seal 4000	8-21-80	Good
7	I 24 over US 62	Marshall	26.5	1976	1977	Sheet: Reinforced Resin	Royston Laboratories,Inc. Bridge Membrane No. 10	6-02-81	Good
8	US 68 over Muddy Fork	Christian	4.8	1976	1976	Liquid - Roofing Paper	Superior Products Super Seal 4000	6-01-81	Good
9	US 68 over Sinking Fork	Christian	3.6	1976	1976	Liquid - Roofing Paper	Superior Products Super Seal 4000	6-01-81	Good

TABLE 5. BRIDGE DECK COMMENTARY SHEET: ASPHALT WATERPROOFING MEMBRANES

BRIDGE NO.	LOCATION	REMARKS
1	E-Town Bypass over WKP	Few blisters and several cracks noted over entire deck and along the plane where the membrane overlapped. There was no leaching under the deck where water leaked through. Joints need reworking.
2	E-Town Bypass over US 62 and L&N RR	Some blisters, several cracks where the membrane was lapped, entire deck has cracks in all directions, joints need reworking, no leaching.
3	US 23 over Tygarts Creek	Several blisters noted in the north end of the deck, a few more noted along the gutter side of deck in the northbound lane, cracks observed over the entire deck, patches noted in both lanes. Wearing well.
4	US 460 over Forks of Elkhorn	Cracks were observed in the gutter area where membrane paper was lapped, large crack over joints, spalling around joints, large blister noted in the middle of the deck. Wearing well.
5	I 24 over Ohio River	Few blisters were observed and sealed, few cracks. Wearing well.
6	KY 676 over Kentucky River	Westbound lane had to be removed and replaced with latex concrete, large cracks were noted running about the full length of the eastbound lane, asphalt is pushing, asphalt is bleeding in some areas, deck is cracking where membrane was lapped, this is not one of the better jobs, no leaching.
7	I 24 over US 62	When membrane was placed on these decks, there were several air blisters noted under the asphalt. The blisters were opened to allow air to escape and then sealed with SS-1h emulsion and sand. A few cracks, joints need reworking, no leaching under deck. Wearing well.
8	US 68 over Muddy Fork	Cracking over membrane laps in the gutter area, cracking over piers, few cracks in main area. Deck performing very well. Joints need reworking.
9	US 68 over Sinking Fork	Cracking over membrane laps in gutter area, grass growing through them, cracking over piers, small amount of cracking in main area. Deck in good condition. Joints need reworking.

Figure 21. Cracking in Asphalt Wearing Surface Created by Laps in Underlying Roofing Paper (US 68 over Sinking Fork Creek) (1981).

Creek). Both bridges had finite resistance readings, indicating some deterioration of those membranes (Figures 22 and 23). Since the membranes possessed significant resistance (in the range of approximately one million ohms), they are still probably satisfactory. However, they probably will not be effective more than 5 to 10 years longer. That would result in membrane service lives of approximately 15 to 20 years. If those bridges could be overlayed again, they may provide 30 to 40 years of service without requiring re-decking. The US-460 bridge deck over the Forks of Elhorn should provide 5 to 10 years additional service.

LATEX OVERLAYS

Thirty-eight Dow Modified A (SM-100) Latex overlays (placed between 1971 and 1978) were considered experimental and were inspected. Seventeen of those were placed in 1975. Twenty-eight overlays were placed on new or bridges not opened to traffic (prior to the use of epoxy-coated reinforcing steel). The ten in-service bridges receiving those overlays were constructed between 1938-1977. Twenty-eight of the experimental Dow latex overlays inspected were rated excellent, five were rated good, and five were rated poor (Tables 6 and 7). The poor overlays exhibited widespread spalling and/or delaminations. Two of those overlays placed on the I-65 twin bridges over Nolin River in Hardin County in 1974 were rated poor and overlayed again in 1984.

The 49 experimental Reichhold Thermoflex 8002 latex overlays were placed several years later (between 1976 and 1979) than the experimental Dow latex overlays. The majority of those overlays (38) were placed in 1977. Only five of the Thermoflex overlays were used on new or unopened bridges. The Thermoflex latex overlays were placed on bridges constructed between 1922 to 1978.

Twenty-nine of those bridges were rated excellent, fifteen were rated good, and five were rated fair or fair to poor (Tables 8 and 9). Over a 6-year period, four of the overlays (on I 75 in Scott County) deteriorated from a rating of excellent (the overlay being three years old at the time of first inspection) to fair to poor (at an age of 9 years). Those bridges required patching and showed signs of

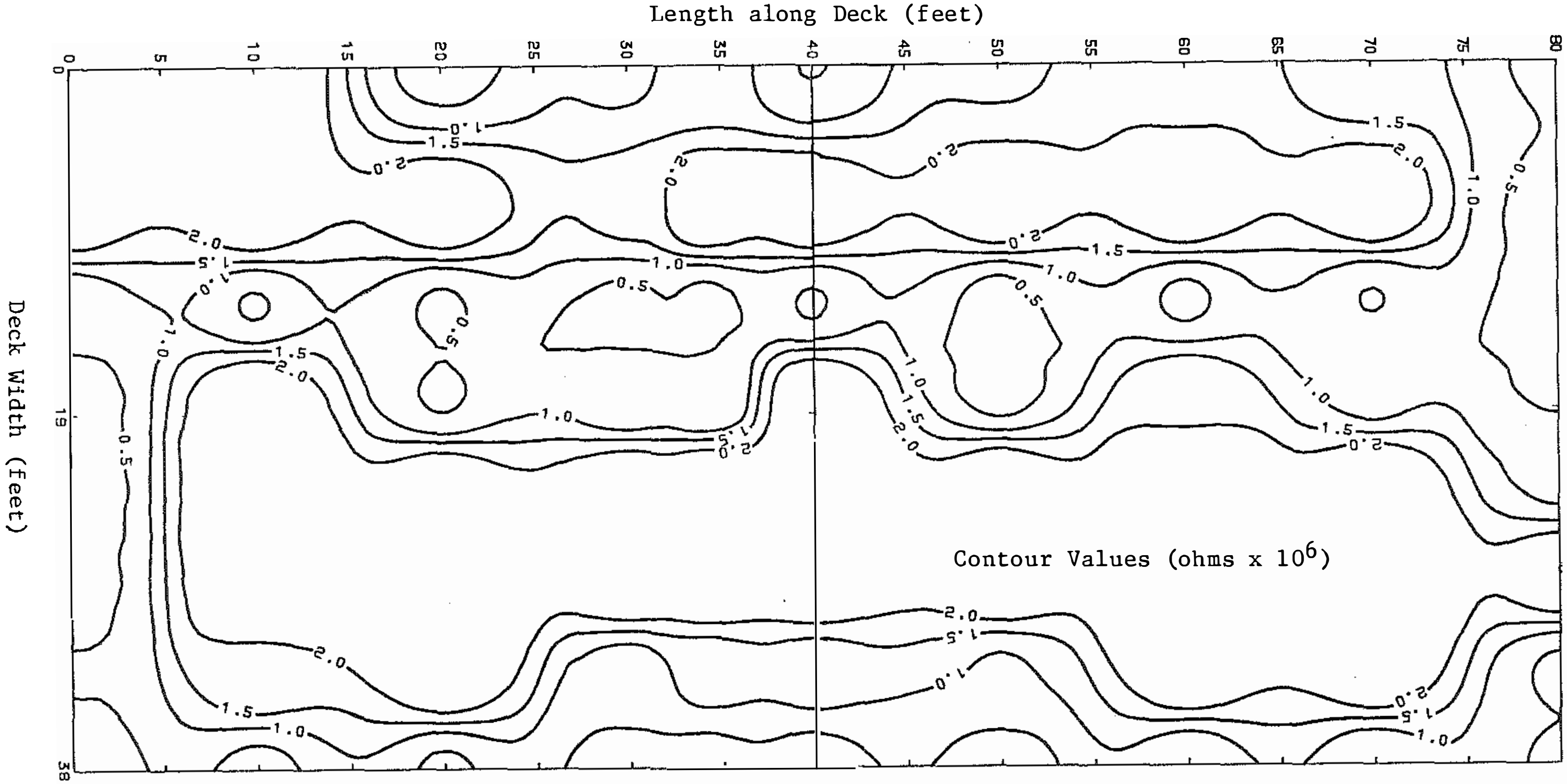


Figure 22. Resistivity Plot for Membrane Overlay (US 68 over Muddy Fork Creek)(1985).

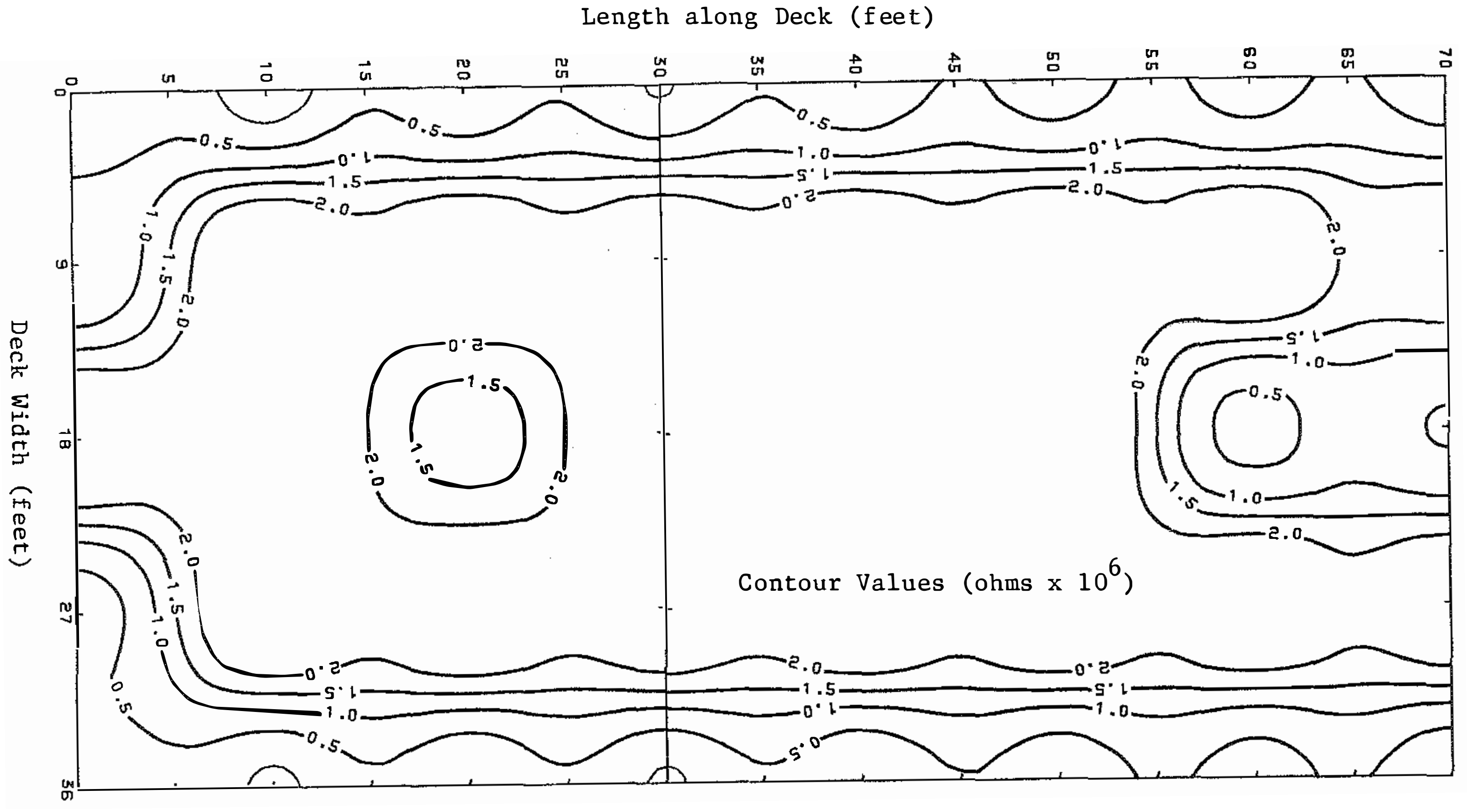


Figure 23. **Resistivity Plot for Membrane Overlay (US 68 over Sinking Fork Creek)(1985).**

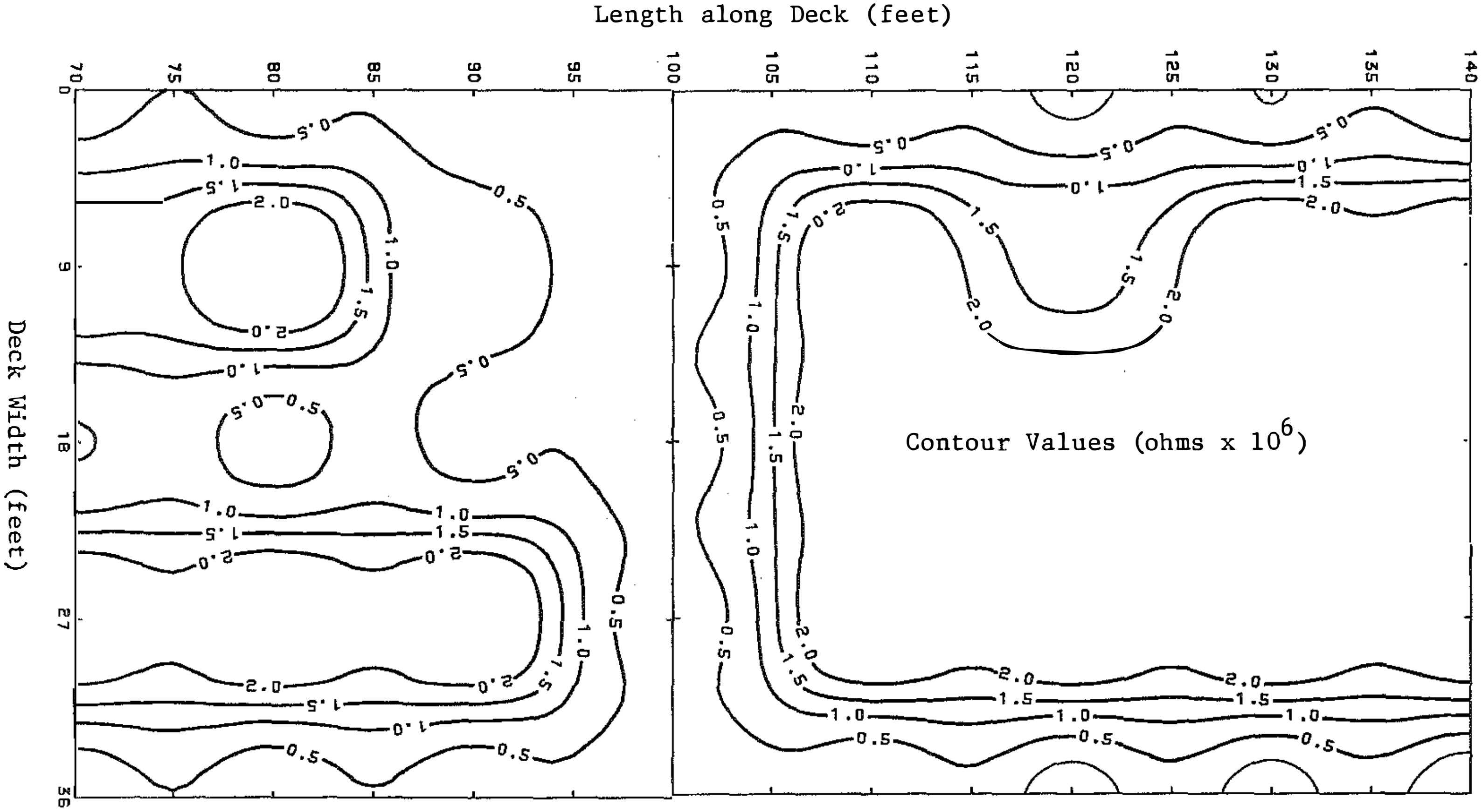


Figure 23. Resistivity Plot for Membrane Overlay (US 68 over Sinking Fork Creek)(1985).

TABLE 6. BRIDGE DECK SUMMARY SHEET: DOW LATEX OVERLAYS

BRIDGE NUMBER	LOCATION	COUNTY	MILEPOST	DATE CONSTRUCTED	DATE OVERLAYED	DATE OF INSPECTION	CONDITION OF SURFACE
10	I 24 over US 41-A WB	Christian	85.6	1974	1975	6-01-81	Excellent
11	I 24 over US 41-A EB	Christian	85.6	1974	1975	6-01-81	Excellent
12	I 24 over Sinking Fork WB	Christian	70.5	1973	1975	6-01-81	Excellent
13	I 24 over Sinking Fork EB	Christian	70.5	1973	1975	6-01-81	Excellent
14	I 24 over Little River WB	Christian	78.9	1973	1975	6-02-81	Excellent
15	I 24 over Little River EB	Christian	78.9	1973	1975	6-02-81	Excellent
16	I 24 over KY 117 WB	Christian	72.7	1973	1975	6-01-81	Excellent
17	I 24 over KY 117 EB	Christian	72.7	1973	1975	6-01-81	Excellent
18	I 24 over Cadiz RR WB	Trigg	66.5	1973	1975	6-01-81	Excellent
19	I 24 over Cadiz RR EB	Trigg	66.5	1973	1975	6-01-81	Excellent
20	I 24 over US 68 WB	Trigg	65.3	1974	1975	6-01-81	Excellent
21	I 24 over US 68 EB	Trigg	65.3	1974	1975	6-01-81	Excellent
22	I 24 over Muddy Fork WB	Trigg	60.276	1977	1978	6-01-81	Excellent
23	I 275 EB over I 471 SB	Campbell	74.985	1974	1978	8-25-80	Excellent
24	I 275 WB over I 471 SB and Ramp F	Campbell	74.984	1974	1977	8-05-80	Excellent
25	I 275 EB over I 471 NB and Ramp E	Campbell	74.818	1974	1977	8-25-80	Excellent
26	Ramp D over I 275 EB and Ramp E	Campbell	74.720	1974	1978	8-25-80	Excellent
27	Ramp B over I 275 WB and Ramp F	Campbell	74.990	1974	1977	8-25-80	Excellent
28	US 27 over I 275	Campbell	17.8	1974	1975	8-07-80	Excellent
29	KY 114 over Middle Creek	Floyd	3.6	1964	1977	9-16-80	Poor
30	KY 30 over Northfork of Kentucky River	Breathitt	14.7	1977	1977	9-23-80	Excellent
31	KY 211 over Salt Lick Creek	Bath	6.1	1975	1975	8-11-80	Excellent
32	Highland Ave over US 23 & C&O RR	Greenup	0.6	1938	1976	9-11-80	Excellent
33	US 62 over I 75	Scott	9.9	1962	1971	8-21-80	Poor
34	US 460 over I 75	Scott	8.9	1962	1971	8-21-80	Poor
35	US 25 over Ohio River	Kenton	13.6	1974	1975	10-22-80	Excellent
36	US 27 over Kentucky River NB	Garrard/ Jessamine Line	16.4	1974	1974	8-26-80	Excellent
37	US 27 over Kentucky River SB	Garrard/ Jessamine Line	16.4	1974	1974	8-26-80	Excellent
38	I 65 over Nolin River NB	Hardin	82.7	1958	1974/1984	8-30-83	Poor
39	I 65 over Nolin River SB	Hardin	82.7	1958	1974/1984	8-30-83	Poor
40	Bluegrass Pkwy over Chaplin River	Washington	42.1	1965	1976	8-06-80	Good
41	Bluegrass Pkwy over Chaplin River	Washington	42.1	1965	1976	8-06-80	Excellent
42	Kennedy Bridge and Indiana Approach over Ohio River, I 65 NB	Jefferson	13.7	1964	1975	3-26-86	Excellent
43	Kennedy Bridge and Indiana Approach over Ohio River, I 65 SB	Jefferson	13.7	1964	1975	3-26-86	Excellent
44	US 119 over Poor Fork of Cumberland River	Harlan	21.795	1974	1976	11-17-83	Good
45	US 119 over Poor Fork of Cumberland River	Harlan	21.795	1974	1976	11-17-83	Good
46	US 119 over Poor Fork of Cumberland River	Harlan	27.190	1974	1976	11-17-83	Good
47	US 119 over Poor Fork of Cumberland River	Harlan	27.626	1974	1976	11-17-83	Good

TABLE 7. BRIDGE DECK COMMENTARY SHEET: DOW LATEX CONCRETE

BRIDGE NO.	LOCATION	REMARKS
10	I 24 over US 41-A WB	Rough texture, high spots in gutter area, pull cracks in dry concrete, joints need reworking.
11	I 24 over US 41-A EB	Rough texture, high spots in gutter area, pull cracks in dry concrete, joints need reworking.
12	I 24 over Sinking Fork WB	Water standing in gutter, large soil popout in middle of deck, latex showing on deck surface, joints need reworking, deck is in excellent condition.
13	I 24 over Sinking Fork EB	Water standing in gutter, poor joint performance, latex bleeding to surface.
14	I 24 over Little River WB	Joints need reworking.
15	I 24 over Little River EB	Joints need reworking.
16	I 24 over KY 117 WB	Exposed aggregate, pull cracks, standing water in gutter, joints depressed 2 in., full of debris.
17	I 24 over KY 117 EB	Exposed aggregate, pull cracks, standing water in gutter, joints depressed 2 in., full of debris.
18	I 24 over Cadiz Railroad WB	Pull cracks in surface, latex bleeding on surface, joints in poor condition.
19	I 24 over Cadiz Railroad EB	Pull cracks in surface, latex bleeding on surface, joints in poor condition, large wet area.
20	I 24 over US 68 WB	Pull cracks in dry concrete, standing water in gutter, latex bleeding on surface, debris in joints.
21	I 24 over US 68 EB	Pull cracks in dry concrete, standing water in gutter, latex bleeding on surface, debris in joints.
22	I 24 over Muddy Fork WB	Before this deck was overlayed, there were shrinkage cracks over the entire deck. Those cracks were filled with epoxy, then overlayed. As of 1984, no cracks reflected through.
23	I 275 EB over I 471 SB	Several long pull cracks in deck on both sides, deck is in very good condition.
24	I 275 WB over I 471 SB and Ramp F	Deck is rough, several pull cracks in deck, poor drainage, deck is in excellent condition.
25	I 275 EB over I 471 NB and Ramp E	Overall deck finish is rough, pull crack on right-hand side.
26	Ramp D over I 275 EB	Few pull cracks found in deck.
27	Ramp B over I 275 WB and Ramp F	Excessive bleeding of latex on surface, two different types of finishing used on this deck, broom finish appears best.
28	US 27 over I 275	Surface is pitted due to air bubbles in concrete, cracking over piers, pull crack noted, transverse crack in deck.

TABLE 7. BRIDGE DECK COMMENTARY SHEET: DOW LATEX CONCRETE

BRIDGE NO.	LOCATION	REMARKS
29	KY 114 over Middle Creek	Delamination failure over 1/3 of deck, joints need reworking. This overlay is a complete failure. Deck is in poor condition.
30	KY 30 over North Fork of Kentucky River	Few pull cracks, wearing in wheel tracks.
31	KY 221 over Salt Lick Creek	Rough surface, no cracks observed.
32	Highland Ave over US 23 C&O Railroad	Rough surface due to deep striations, overlays mixed too dry in some areas.
33	US 62 over I 75	Large alligator cracking over entire deck, spalling at curbs, 16 patches.
34	US 460 over I 75	Large alligator cracking over entire deck, spalling at curbs, 3 patches.
35	US 25 over Ohio River	Pull cracks on north end of bridge, drains are too high in some areas, wearing in wheel tracks.
36	US 27 over Kentucky River NB	Normal transverse cracking, few pull-crack areas, joint closed on north end.
37	US 27 over Kentucky River SB	Very long longitudinal cracks in the driving lane, some pull cracks, one joint leaking.
38	I 65 over Nolin River NB	This deck was replaced in 1984, "Problem Bridge."
39	I 65 over Nolin River SB	This deck was replaced in 1984, "Problem Bridge."
40	Blue Grass Pkwy WB over Chaplin River	Surface pitted, transverse cracking every 4 to 5 ft, joints need reworking, condition of deck not good overall.
41	Blue Grass Pkwy EB over Chaplin River	Surface pitted, transverse cracking every 4 to 5 ft, joints need reworking. Overall condition of deck not good.
42	I 65, Kennedy Bridge and Indiana approach over Ohio River, I 65 NB	Deck has a few pull-crack areas around Finger Dams, three small spalls.
43	I 65, Kennedy Bridge and Indiana approach over Ohio River, I 65 SB	Spall area, small pull cracks.
44	US 119 over Poor Fork MP 21.795	Deeply grooved, epoxy skin patches, dirt in gutters.
45	US 119 over Poor Fork, MP 22.382	Bird baths in gutters, seal crumpled.
46	US 119 over Poor Fork, MP 27.19	Cracking about 1/3 from north end, looked like a dip in deck, dirt in gutters.
47	US 119 over Poor Fork, MP 27.626	Cracking about 1/3 from north end, looked like a dip in deck, dirt in gutters.

TABLE 8. BRIDGE DECK SUMMARY SHEET: REICHHOLD LATEX OVERLAYS

BRIDGE NUMBER	LOCATION	COUNTY	MILEPOST	DATE CONSTRUCTED	DATE OVERLAYED	DATE OF INSPECTION	CONDITION OF SURFACE
48	WKP over Rhodes Creek WB	Hardin	130.9	1962	1977	8-19-80	Excellent
49	WKP over Rhodes Creek EB	Hardin	130.9	1962	1977	8-19-80	Excellent
50	WKP over Valley Creek WB	Hardin	132.4	1962	1977	8-19-80	Excellent
51	WKP over Valley Creek EB	Hardin	132.4	1962	1977	8-19-80	Excellent
52	WKP over L & N RR WB	Hardin	132.6	1962	1977	8-19-80	Excellent
53	WKP over L & N RR EB	Hardin	132.6	1962	1977	8-19-80	Excellent
54	US 31-W over Valley Creek	Hardin	16.47	1936	1977	8-30-83	Excellent
55	US 31-W, 2nd bridge south of West Point	Hardin	36.28	1942	1977	8-30-83	Excellent
56	KY 84 over I 65	Hardin	25.37	1959	1977	8-30-83	Excellent
57	KY 61 over Pitman Creek	Green	11.624	1940	1977	10-10-80	Excellent
58	I 75 over Rogers Gap Road NB	Scott	130.98	1962	1977	3-10-80 5-28-86	Excellent Fair to Poor
59	I 75 over Rogers Gap Road SB	Scott	130.98	1962	1977	3-10-80 5-28-86	Excellent Fair to Poor
60	I 75 over Burton Road NB and Little Eagle Creek	Scott	135.11	1961	1977	3-10-80 5-28-86	Excellent Fair to Poor
61	I 75 over Burton Road SB and Little Eagle Creek	Scott	135.11	1961	1977	3-10-80 5-28-86	Excellent Fair to Poor
62	US 62 over IC RR	Muhlenburg	24.71	1940	1977	6-05-80	Good
63	Ky 66 600 ft North of US 421	Clay	18.63	1958	1977	2-05-80	Excellent
64	US 25 over Little Laurel River	Laurel	8.435	1942	1977	9-04-80	Good
65	US 25 over Robinson Creek	Laurel	3.275	1940	1977	9-04-80	Good
66	KY 229 over Little Laurel Creek	Laurel	10.63	1935	1977	9-04-80	Good
67	KY 229 over Laurel River and Sallie Branch	Laurel	6.85	1935	1977	9-04-80	Excellent
68	US 25 over Lynn Camp Creek	Whitley	33.73	1948	1977	9-04-80	Excellent
69	KY 229 over Big Richland Creek	Knox	3.94	1950	1977	9-04-80	Excellent
70	US 25-E over Richland Creek	Knox	14.92	1960	1977	9-04-80	Excellent
71	US 25-E at KY 92 over Greasy Creek (3.82 mi North of Pineville)	Bell	18.1	1940	1977	11-17-83	Excellent

TABLE 8. BRIDGE DECK SUMMARY SHEET: REICHHOLD LATEX OVERLAYS

BRIDGE NUMBER	LOCATION	COUNTY	MILEPOST	DATE CONSTRUCTED	DATE OVERLAYED	DATE OF INSPECTION	CONDITION OF SURFACE
72	US 119 over Cumberland River	Bell	0.02	1950	1977	2-05-80	Good
73	KY 91 over Muddy Fork	Christian	11.26	1939	1977	6-01-81	Good
74	US 41-A over Craborchard Creek	Hopkins	0.82	1955	1977	6-01-81	Good
75	US 23 over Paint Lick Creek	Johnson	0.12	1936	1977	12-18-83	Good
76	US 23 Bypass Road over Paint Lick Creek (1 mi north of Paintsville)	Johnson	8.675	1959	1979	12-18-83	Good
77	US 27 over Cumberland River (Burnside)	Pulaski	9.19	1950	1977	1-06-80	Excellent
78	KY 32 over Licking River	Nicholas	15.58	1933	1977	1-15-80	Excellent
79	KY 30 over Hunting Creek	Breathitt	30.04	1932	1977	9-23-80	Excellent
80	KY 1959 over Everman Creek	Carter	1.15	1957	1977	9-11-80	Excellent
81	KY 1947 over Barretts Creek	Carter	2.71	1922	1978	9-11-80	Excellent
82	KY 555 over Beech Fork River	Washington	3.4	1976	1976	8-04-80	Good
83	KY 1091 over Beaver Creek	Knott	0.01	1952	1976	10-10-83	Good
84	I 275 over relocated Three Mile Road EB	Campbell	75.386	1974	1977	8-05-80 9-06-83	Excellent
85	I 275 over relocated Three Mile Road WB	Campbell	75.386	1974	1977	8-25-80 9-06-83	Good
86	I 275 EB over I 471 SB	Campbell	74.817	1974	1978	8-25-80	Good
87	I 275 at I 471 and Ramp B	Campbell	75.0	—	—	9-06-83	Good
88	I 275 WB over I 471 NB	Campbell	73.3	—	—	9-06-83	Excellent
89	Newburg Road over I 264	Jefferson	2.26	1955	1977	10-05-83	Excellent
90	I 264 over Beargrass Creek WB	Jefferson	19.50	1960	1977	10-05-83	Excellent
91	I 264 over Beargrass Creek EB	Jefferson	19.50	1960	1977	10-05-83	Excellent
92	I 264 over US 60 WB	Jefferson	19.91	1961	1977	10-05-83	Excellent
93	I 264 over US 60 EB	Jefferson	19.91	1961	1977	10-05-83	Excellent
94	KY 1426 over Levisa Fork of Island Creek	Pike	0.1	—	—	1983	Good
95	US 31-E over Scaggs Creek Fork of Barren Resevoir	Barren	6.67	1963	1976	10-10-83	Fair
96	KY 225 over Cumberland River	Knox	11.2	1978	1978	11-17-83	Excellent

TABLE 9. BRIDGE DECK COMMENTARY SHEET: REICHHOLD LATEX CONCRETE

BRIDGE NO.	LOCATION	REMARKS
48	WKP over Rhodes Creek WB	Few pull cracks in deck surface.
49	WKP over Rhodes Creek EB	Few pull cracks in deck surface.
50	WKP over Valley Creek WB	Few pull cracks in surface.
51	WKP over Valley Creek EB	Few pull cracks in surface.
52	WKP over L&N RR WB	Few pull cracks in surface. Machine finish.
53	WKP over L&N RR EB	Few pull cracks in surface. Broom finish.
54	US 31-W over Valley Creek	No faults.
55	US 31-W, 2nd bridge south of West Point	One of the best surfaces in state.
56	KY 84 over I 65	Small transverse cracking over entire deck, patch 3 ft x 8 ft on centerline joint, joints need reworking.
57	KY 61 over Pitman Creek	Transverse cracking over entire deck, more in the southbound than in northbound.
58	I 75 over Rogers Gap Road NB	Several patches around all joints, delamination failure in areas, severe cracking in deck, joints need reworking, leaking badly, should be redecked.
59	I 75 over Rogers Gap Road SB	Several patches around all joints, delamination failure in areas, severe cracking in deck, joints need reworking, leaking badly, should be redecked.
60	I 75 over Burton Road NB and Little Eagle Creek	Severe cracking over entire deck, delamination failure, several patches around joints along centerline, neoprene joints not working, gutters need repairing, some piers have reinforcing steel showing. Bridge is in poor condition.
61	I 75 over Burton Road SB and Little Eagle Creek	Severe cracking over entire deck, delamination failure, several patches around joints along centerline, neoprane joints not working, gutters need repairing, some piers have reinforcing steel showing. Bridge is in poor condition.
62	US 62 over IC RR	Delamination failure around joints, large cracks in all directions.
63	KY 66, 600 ft north of US 421	Good deck.
64	US 25 over Little Laurel River	Wheel paths are worn, pitting, spalling around joints, few cracks.
65	US 25 over Robinson Creek	Deck polishing, bad pitting.
66	KY 229 over Little Laurel Creek	Deck polishing, pitting, joint failure on south end.
67	KY 229 over Laurel River and Sallie Branch	Deck is pitted, good condition.
68	US 25 over Lynn Camp Creek	Spalling at joint on south end of deck, pitting. Joints need reworking.
69	Ky 229 over Big Richland Creek	Some longitudinal cracking at joints.
70	US 25-E over Richland Cr.	Some cracking at joints, pitting.

TABLE 9. BRIDGE DECK COMMENTARY SHEET: REICHHOLD LATEX CONCRETE

BRIDGE NO.	LOCATION	REMARKS
71	US 25-E at Ky 92 over Greasy Creek	No cracking or other defects. Joints need reworking.
72	US 119 over Cumberland River	Few cracks, good deck.
73	KY 91 over Muddy Fork	Water standing in SB gutters, transverse cracking.
74	US 41-A over Craborchard Creek	Deck pitted, alligator cracking in SB lane, water standing in gutters.
75	US 23 over Paint Lick Creek	Delamination failure around joint 1.5 ft x 15 ft.
76	US 23 Bypass over Paint Lick Creek (1 mi north of Paintsville)	Core holes need filling, very few cracks.
77	US 27 over Cumberland River	Good deck.
78	KY 32 over Licking River	Good deck.
79	KY 30 over Hunting Creek	Good deck.
80	KY 1959 over Everman Creek	Good deck.
81	KY 1947 over Barretts Creek	Good deck.
82	KY 555 over Beech Fork River	Gutters in poor condition, deck good.
83	KY 1091 over Beaver Creek	Large patches on east end of deck, cracks extended from patches.
84	I 275 over relocated Three Mile Road EB	Several pull cracks in inside lane, few cracks in outer lane.
85	I 275 over relocated Three Mile Road WB	Random cracking, some pull cracks.
86	I 275 EB over I 471 SB Bridge 5	Several pulled cracks in eastbound lane, large pulled places in crack, poor drainage in gutters.
87	I 275 at I 471 and Ramp B	Little wear in outer lane, excellent condition.
88	I 275 WB over I 471 NB	Finish is fair, several pull-crack areas in deck.
89	Newburg Road over I 264	Surface cracking over entire deck, seems to be sound.
90	I 264 over Beargrass Creek WB	Polishing in wheel paths, a few small pull cracks.
91	I 264 over Beargrass Creek EB	Polishing in wheel paths, a few small pull cracks.
92	I 264 over US 60 WB	Extreme cracking over entire deck.
93	I 264 over US 60 EB	Extreme cracking over entire deck, cracks around the joints.
94	KY 1426 over Levisa Fork of Island Creek	Good deck.
95	US 31-E over Scagg Creek, Fork of Barren Reservoir	Two large patches on ends of deck, cracks running from each patch, cracks in the middle of deck.
96	KY 225 over Cumberland River	Wear in wheel paths, few popouts, core holes need filling, dirt in gutters.

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delamination (Figure 24). The decks on those bridges were 24 to 25 years old at the time of the last inspection. What would or could be superficially viewed as overlay deterioration on those bridges is probably more a sign of deterioration of the underlying decks. One difficulty of this survey was to distinguish between the performances of the overlays and the underlying decks. In any event, those bridges are subjected to severe service and the 9 years of service of those overlays reflects well upon their performance.

LOW-SLUMP OVERLAYS

Twenty-three low-slump overlays were considered experimental under this study (Tables 10 and 11). Eighteen of those were placed on new or unopened bridges. The low-slump overlays were constructed between 1975 and 1979. Bridges receiving those overlays were constructed between 1940 to 1979.

Nine low-slump overlays were rated excellent and 14 were rated good. Some overlays rated good had numerous patches, which were believed to be construction-related. The low-slump overlays were not as extensively cracked as the latex overlays. However, most decks overlayed with low-slump concrete were newer and in better condition at the time of placement than many of the decks overlaid with latex (especially those employing the Thermoflex latex).

SURVEY OF INTEGRAL ABUTMENT BRIDGES

Kentucky's integral abutment bridges have no hinges at the base of the abutment stem. Kentucky bridges accommodate expansion and contraction by bending the piles below ground. It is probable that only minimal expansion occurs at those points. Some rotation of the abutments may occur when significant expansion and contraction occurs. In those instances, there should be evidence of a gap or closure of the ends abutting the pavement. That kind of movement has not been detected. If it occurs, it may be confused with settlement and/or wedging.

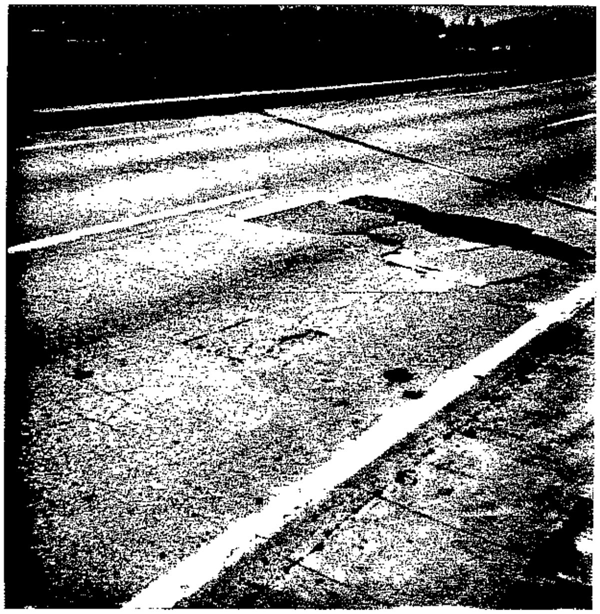

Figure 24. Patches on Areas of Overlay Debonding Thermoflex Latex (I 75 over Rhodes Creek in Scott County)(1987).

TABLE 10. BRIDGE DECK SUMMARY SHEET: LOW SLUMP CONCRETE OVERLAYS

BRIDGE NUMBER	LOCATION	COUNTY	MILEPOST	DATE CONSTRUCTED	DATE OVERLAYED	DATE OF INSPECTION	CONDITION OF SURFACE
97	KY 52 over Kentucky River	Estill	7.4	1940	1977	9-18-80	Excellent
98	US 421 over Clover Fork and L&N RR	Harlan	17.7	1974	1978	1-21-80	Excellent
99	US 421 over Clover Fork	Harlan	18.1	1976	1978	1-21-80	Excellent
100	US 421 over KY 840 and L&N RR, Clover Fork	Harlan	17.2	1974	1978	1-21-80	Excellent
101	US 421 over Cumberland River	Harlan	19.05	1976	1978	11-17-83	Good
102	I 275 over Ohio River SB	Campbell	74.6	1979	1979	8-18-80	Excellent
103	I 275 over Ohio River NB	Campbell	74.6	1979	1979	8-18-80	Excellent
104	I 24 over Tennessee River EB	Marshall	29.5	1974	1975	6-02-81	Excellent
105	I 24 over Tennessee River WB	Marshall	29.5	1974	1975	6-02-81	Excellent
106	I 24 over Muddy Fork EB	Trigg	60.276	1977	1978	6-01-81	Excellent
107	US 119 over Poor Fork of Cumberland River	Harlan	18.814	1975	1978	11-17-83	Good
108	US 119 over Poor Fork of Cumberland River	Harlan	23.466	1973	1976	11-17-83	Good
109	US 119 over Poor Fork of Cumberland River	Harlan	17.237	1975	1978	11-17-83	Good
110	US 119 over Poor Fork of Cumberland River	Harlan	23.680	1973	1976	11-17-83	Good
111	US 119 over Poor Fork of Cumberland River	Harlan	25.282	1973	1976	11-17-83	Good
112	US 119 over Poor Fork of Cumberland River	Harlan	25.459	1973	1976	11-17-83	Good
113	US 119 over Poor Fork of Cumberland River	Harlan	28.374	1974	1977	11-17-83	Good
114	US 119 over Poor Fork of Cumberland River	Harlan	28.743	1975	1977	11-17-83	Good
115	US 119 over Poor Fork of Cumberland River	Harlan	29.837	1975	1977	11-17-83	Good
116	US 119 over Poor Fork of Cumberland River	Harlan	31.122	1975	1978	11-17-83	Good
117	US 119 over Poor Fork of Cumberland River	Harlan	31.879	1975	1977	11-17-83	Good
118	US 119 over Poor Fork of Cumberland River	Harlan	33.317	1975	1977	11-17-83	Good
119	US 119 over Poor Fork of Cumberland River	Harlan	35.568	1978	1978	11-17-83	Good

TABLE 11. BRIDGE DECK COMMENTARY SHEET: LOW SLUMP CONCRETE OVERLAYS

BRIDGE NO.	LOCATION	REMARKS
97	KY 52 over Kentucky River	Surface is polishing in wheel tracks.
98	US 421 over Clover Fork and L&N Railroad	New deck when surveyed.
99	US 421 over Clover Fork	New deck when surveyed.
100	US 421 over KY 840 and L&N RR, Clover Fork	New deck when surveyed.
101	US 421 over Cumberland River	Longitudinal crack in west end, wear in wheelpaths, few dimples.
102	I 275 over Ohio River SB	Few pull cracks in deck, gutter drains too high in some places.
103	I 275 over Ohio River NB	Few pull cracks in deck, gutter drains too high in some places.
104	I 24 over Tennessee River EB	Deck is in excellent condition.
105	I 24 over Tennessee River WB	Deck is in excellent condition.
106	I 24 over Muddy Fork EB	Few cracks located on each end of deck, wearing good.
107	US 119 over Poor Fork, MP 18.814	Cracking in southbound lane, near south end, core hole filled with water, soft wear in wheel paths, skin patches near south end.
108	US 119 over Poor Fork, MP 23.466	Several rectangular patches, bird baths in gutters, compression seals at each end looked good.
109	US 119 over Poor Fork, MP 17.237	One core hole void, patch loose in another, several skin patches (may be epoxy), some soft wear in wheelpaths. It is not apparent whether patches were done for construction acceptance or for maintenance.
110	US 119 over Poor Fork, MP 23.680	Several, some large, rectangular patches (some are not good) — one has broken out at corner.
111	US 119 over Poor Fork, MP 25.282	Some large rectangular patches; otherwise, appearance is good; seals were good.
112	US 119 over Poor Fork, MP 25.459	Long centerline patch at south end, patches and cracking near north end, crazing (may be a pothole there). There was a dropoff (settlement) at the shoulder and abutment.
113	US 119 over Poor Fork, MP 28.374	Seal at south end was good, no seal at north end, two cracks, dog tracks at south end of southbound lane — otherwise looked good.
114	US 119 over Poor Fork, MP 28.743	Compression seal at south end was good, no seal at north end, one transverse crack was very noticeable, otherwise OK.
115	US 119 over Poor Fork, MP 29.832	Good overlay, no seal at south end, compression seal at north end was OK except for two ridges.
116	US 119 over Poor Fork, MP 31.122	Compression seal at south end was in fair condition, there was no seal at the north end, cracking in northbound lane 2/3-point (flexural) — 2 or 3 yards square, some beyond. Bridge bounced considerably when coal truck entered onto south span.
117	US 119 over Poor Fork, MP 31.879	Overlay looked good, no seal at south end, compression seal at north end was in fair condition, there was dirt and debris in the joint and in the gutters.
118	US 119 over Poor Fork, MP 33.317	Deck was in good condition, compression seal at south end was in fair condition, there was no seal at the north end.
119	US 119 over Poor Fork, MP 35.568	Looking southward to US 119 bridge in curve and RR bridge over US 119 beyond. Good condition. Joints need reworking.

Of the 48 experimental integral abutment bridges, 11 were under construction and several were only a few months old at the time of inspections in 1984 (Tables 12-14). The oldest bridge, originally constructed in 1955, had been built as an integral abutment bridge in 1971. Seven experimental integral abutment bridges were constructed between 1970 and 1978. Twenty-seven bridges constructed and in service between 1980 and 1984 were inspected.

Three of the seven integral abutment bridges constructed (or reconstructed) in the 1970's were T-beam, reinforced-concrete, continuous, multi-span structures having three or four spans (Figures 25 and 26). The other four bridges used precast, prestressed I-beams (PCIB). The span length of the RCDG structures varied from 28 to 50 feet. Span lengths of the PCIB bridges ranged from 37 to 80 feet. Bridge lengths ranged from 86 to 259 feet and deck widths were from 24 to 48 feet. Deck areas ranged from 2,568 to 12,303 square feet.

All structures were in good to very good condition. The Division of Maintenance Structure Inventory and Appraisal Reports revealed that three decks were rated at 8 (i.e., good, no repairs necessary) and two were rated 7 (i.e., generally good contition -- possibly requiring minor maintenance such as cleaning the deck). All superstructures had ratings of 8. One substructure was given a rating of 7. The remaining had ratings of 8.

Of the 39 integral abutments constructed in the 1980's (two were still under construction at the time of this report); 33 were PCIB bridges; five were precast, prestressed box-beam bridges (PCBB); and one was a steel rolled-beam bridge (Figures 27-29). Three of the PCIB bridges were single, simple-span structures. The remainder had multiple spans and were continuous for live loads. The PCBB bridges were all simple-span structures. The steel rolled-beam bridge was a multiple-span continuous bridge.

The longest PCIB bridge span was 103 feet. The longest PCBB bridge span was 81 feet. The longest span of the steel rolled-beam bridge was 131 feet. Span lengths for bridges constructed in the 1980's ranged from 27.3 feet to 131 feet. Structure lengths varied from 53 to 342 feet. Deck widths ranged from 8 feet (for a pedestrian bridge, the US

TABLE 12. SUMMARY SHEET: INTEGRAL ABUTMENT BRIDGES

BRIDGE DRAWING NO.	LOCATION	COUNTY	MILEPOST	DATE OF CONSTRUCTION	DATE OF INSPECTION
17987	KY 989-Charters-Burtonville Road over Salt Lick Creek	Lewis	12.69	1970	1984
18310	KY 10-Maysville-Vanceburg Road over Ben Willen Branch	Lewis	13.501	1971	1984
18335	KY 1348-Crofton-Macedonia Road over Tradewater River	Christian	4.49	1975	1984
18631	KY 227-Worthville Road over White Run over Long Creek	Carroll	3.70	1972	1984
18972	KY 279 over Panther Creek	Daviess	4.10	1974	1984
19265	CR 1381-Curdsville-Delaware Road over Panther Creek	Daviess	County Road	1976	1984
19602	US 60 over Indian Creek	Hancock	14.23	1978	1984
19869	KY 726-McKendree Church Road	McCracken	4.23	Under construction	1984
19899	KY 218 over Blue Springs Creek	Hart	13.59	1980	1984
19976	KY 339-Melber Road over Mayfield Creek	McCracken	0.74	Under construction	1984
20048	KY 11-Beattyville-Booneville Road over Buck Creek	Owsley	12.06	1984	1984
20102	US 460-Pedestrian overpass over Maysville Street	Montgomery	8.93	1981	1984
20103	US 60 at Shelbyville over Clear Creek	Shelby	11.16	1980	1984
20196	KY 70-Smithland-Dycusburg Road over Ferguson Creek	Livingston	2.41	1982	1984
20253	KY 58-Mayfield-Benton Road over Mayfield Creek	Graves	6.68	1982	1984
20259	KY 61-Elizabethtown-Hodgenville over Middle Creek	Hardin	0.01	Under construction	
20260	KY 61-Elizabethtown-Hodgenville over Middle Creek	Hardin	0.01	Under construction	
20262	US 60-Henderson-Owensboro Road over Race Creek	Henderson	0.01	1981	1984
20278	KY 61-Elizabethtown-Hodgenville over Middle Creek Relief Twin	Hardin	0.24	Under construction	
20279	KY 61-Elizabethtown-Hodgenville	Hardin	0.24	Under construction	
20282	KY 365-Sturgis-Hood Road over Tradewater River	Crittenden-Union Co. Line	8.53	1982	1984
20285	KY 348-Benton-Symsonia Road over Middle Fork Creek	Marshall	4.71	1983	1984
20291	KY 70 Smithland-Dycusburg Road over McCormick Creek	Livingston	0.93	1982	1984
20294	US 51-Clinton-Fulton Road over Bayou DeChien	Hickman	3.72	1982	1984
20349	KY 270-Clay Hardin-Sturgis Road over Caney Creek	Webster	2.39	1981	1984
20356	KY 1346-Dexter-Faxon Road over East Fork of Clarks River	Calloway	1.36	1982	1984
20357	KY 1346-Dexter, Faxon Road over East Fork of Clarks River Overflow	Calloway	1.41	1982	1984
20390	CR 8548 Black Joe Bridge Access over Clover Fork of Cumberland River	Harlan	County Road	1983	–
20423	KY 40-Paintsville-Oil Springs over Mudlick Creek	Johnson	7.235	1983	–
20429	KY 464-Almo-Shiloh over Jonathan Creek	Calloway	7.9	1982	1984
20437	KY 703-Clinton-New Cypress over Bugg Creek	Hickman	7.435	1982	1984
20446	KY 703-Clinton-New Cypress over Bugg Creek	Hickman	7.332	1982	1984
20449	KY 703-Clinton-New Cypress over Little Cypress Creek	Hickman	7.965	1982	1984
20472	KY 583-Lyons Station-Youngers Creek Road over Youngers Creek	Hardin	1.50	1982	1984
20477	CR-1422-Greasy Creek Road over Levisa Fork River	Pike	County Road	1982	1984
20521	US 421-Hyden-Manchester Road over Goose Creek	Clay	15.52	1983	–
20535	KY 5-Princess-Fairview Road over East Fork of Little Sandy River	Boyd	3.81	1982	1984
20538	US 31E-Hodgenville-Bardstown Road over Thompson Creek	Larue	18.28	1982	1984
20553	US 231-Bowling Green-Beaver Dam Road over Gasper River	Warren	22.609	1983	1984
20570	US 62-Washington-Murphysville Road over North Fork of Licking River	Mason	County Road	Under construction	1984
20592	KY 132-Dixon-Sebree Road over Knoblick Creek	Webster	24.59	1983	1984
20650	CR 5118 Harpers Ferry-Lockport Road over Six-Mile Creek	Henry	County Road	1982	1984-1986
20662	KY 329-Prospect-Crestwood Road over Harrods Creek	Oldham	1.47	Under construction	1984
20666	KY 49-Lebanon-Bradfordsville Road over Rolling Fork River	Marion	10.48	Under construction	1984
20672	KY 1187-Union-Silver City Road over Muddy Creek	Butler	4.85	1984	1984
20682	KY 623 Waterford-Fairfield Road over Salt River	Spencer	5.03	1983	1984
20683	US 45-Mayfield-Fulton Road over Brush Creek	Graves	6.09	Under construction	1984
20695	KY 139-Cadiz-Princeton Road over Goose Creek	Caldwell	9.24	Under construction	1984

TABLE 13. DATA SHEET: INTEGRAL ABUTMENT BRIDGES

BRIDGE DRAWING NO.	LOCATION	TYPE OF STRUCTURE	TYPE OF GIRDERS	NUMBER OF SPANS	LENGTH OF SPANS(ft.)	LENGTH OF STRUCTURE(ft.)	WIDTH OF DECK(ft.)	DEGREE OF SKEW	AREA OF DECK(ft.)
17987	KY 989-Charters-Burtonville Road over Salt Lick Creek	RCDG Cont	T-Beam	3	(2)33;37	107	24.0	0	2568
18310	KY 10-Maysville-Vanceburg Road over Ben Willen Branch	RCDG Cont	T-Beam	3	(3)28	86	44.0	0	3784
18335	KY 1348-Crofton-Macedonia Road over Tradewater River	RCDG Cont	T-Beam	3	(2)37.5;50	128	28.0	0	3584
18631	KY 227-Worthville Road over White Run over Long Creek	PCIB Cont	I-Beam	4	(4)64	259	47.5	0	12303
18972	KY 279 over Panther Creek	PCIB Cont	I-Beam	3	(3)60	184	26.0	0	4784
19265	CR 1381-Curdsville-Delaware Road over Panther Creek	PCIB Cont	I-Beam	3	(2)76.4;80	233	27.8	0	6477
19602	US 60 over Indian Creek	PCIB Cont	I-Beam	3	(2)37;57	144	47.5	0	6840
19869	KY 726-McKendree Church Road (bridge under construction)								
19899	KY 218 over Blue Springs Creek	PCIB Cont	I-Beam	3	(2)30;40	102	43.1	0	4396
19976	KY 339-Melber Road over (bridge under construction) Mayfield Creek								
20048	KY 11-Beattyville-Booneville Road over Buck Creek	PCIB Cont	I-Beam	3	(3)85	258	33.3	0	8591
20102	US 460-Pedestrian overpass over Maysville Street in Mt. Sterling	PCIB Cont	I-Beam	5	(2)60;52.5;83;64.5	321	8.0	0	2568
20103	US 60 at Shelbyville over Clear Creek	PCIB Cont	I-Beam	3	(2)40;65	148	44.0	15	6512
20196	KY 70-Smithland-Dycusburg Road over Ferguson Creek	PCBB Simp	Box Beam	1	81	83	31.2	0	2590
20253	KY 58-Mayfield-Benton Road over Mayfield Creek	PCIB Cont	I-Beam	3	43.7;68;43	159	43.3	0	6884
20259	KY 61-Elizabethtown-Hodgenville over Middle Creek	PCIB Cont	I-Beam	3	(3)75	228	47.3	30	10784
20260	KY 61-Elizabethtown-Hodgenville over Middle Creek	PCIB Cont	I-Beam	3	(3)75	228	47.3	30	10784
20262	US 60-Henderson-Owensboro Road over Race Creek	PCIB Simp	I-Beam	1	48	53	44.0	30	2332
20278	KY 61-Elizabethtown-Hodgenville over Middle Creek Relief Twin	PCIB Simp	I-Beam	1	80	83	41.9	0	3478
20279	KY 61-Elizabethtown-Hodgenville	PCIB Simp	I-Beam	1	80	83	41.9	0	3478
20282	KY 365-Sturgis-Hood Road over Tradewater River	PCIB Cont	I-Beam	3	(3)94	285	31.3	0	8921
20285	KY 348-Benton-Symsonia Road over Middle Fork Creek	PCIB Cont	I-Beam	3	(3)38	114	43.3	15	4936
20291	KY 70-Smithland-Dycusburg Road over McCormick Creek	PCIB Cont	I-Beam	3	(2)35;50	123	31.2	0	3838
20294	US 51-Clinton-Fulton Road over Bayou DeChien	PCIB Cont	I-Beam	3	(2)36;53	126	43.3	20	5456
20349	KY 270-Clay Hardin-Sturgis Road over Caney Creek	PCIB Cont	I-Beam	3	(3)34	111	31.5	15	3497
20356	KY 1346-Dexter-Faxon Road over East Fork of Clarks River	PCIB Cont	I-Beam	3	(2)50;70	173	31.3	0	5415

TABLE 13. DATA SHEET: INTEGRAL ABUTMENT BRIDGES

BRIDGE DRAWING NO.	LOCATION	TYPE OF STRUCTURE	TYPE OF GIRDERS	NUMBER OF SPANS	LENGTH OF SPANS(ft.)	LENGTH OF STRUCTURE(ft.)	WIDTH OF DECK(ft.)	DEGREE OF SKEW	AREA OF DECK(ft.)
20357	KY 1346-Dexter-Faxon Road over East Fork of Clark River Overflow	PCIB Cont	I-Beam	3	(2)50;70	173	31.3	0	5415
20390	CR 8548 Black Joe Bridge Access over Clover Fork of Cumberland Riv.	PCBB Simp	Box Beam	4	(2)58;20;40	176	27.0	0	4752
20423	KY 40-Paintsville-Oil Springs over Mudlick Creek	PCIB Cont	I-Beam	3	(2)45;44	134	35.0	45	4690
20429	KY 464-Almo-Shiloh over Jonathan Creek	PCBB Simp	Box Beam	3	(2)32;46	110	27.0	0	2970
20437	KY 703-Clinton-New Cypress over Bugg Creek	PCBB Simp	Box Beam	1	59	62	31.3	30	1941
20446	KY 703-Clinton-New Cypress over Bugg Creek	PCBB Simp	Box Beam	1	59	62	31.7	30	1965
20449	KY 703-Clinton-New Cypres over Little Cypress Creek	PCIB Cont	I-Beam	3	(3)30	93	31.3	15	8911
20472	KY 583-Lyons Station-Youngers Creek Road over Youngers Creek	PCIB Cont	I-Beam	3	(2)40;60	142	31.3	0	4 45
20477	CR 1422-Greasy Creek Road over Levisa Fork River	Stl Cont	I-Beam	3	86;131;76	293	33.5	0	9816
20521	US 421-Hyden-Manchester Road over Goose Creek	PCIB Cont	I-Beam	3	(2)65;100	233	33.3	30	7 59
20535	KY 5-Princess-Fairview Road over East Fork of Little Sandy River	PCIB Cont	I-Beam	3	(3)55	167	33.3	0	5561
20538	US31E-Hodgenville-Bardstown Road over Thompson Creek	PCIB Cont	I-Beam	3	89;103;84	276	33.5	15	9246
20553	US 231-Bowling Green-Beaver Dam Road over Gasper River	PCIB Cont	I-Beam	3	(2)50;60	163	43.0	15	7 42
20570	US 62-Washington-Murphysville Road over North Fork of Licking River	PCIB Cont	I-Beam	3	(2)76;98	258	33.3	0	8 91
20592	KY 132-Dixon-Sebree Road over Knoblick Creek	PCBB Simp	Box Beam	3	(3)34	101	35.6	15	3595
20650	CR 5118-Harpers Ferry-Lockport Road over Six-Mile Creek	PCIB Cont	I-Beam	3	45;100;55	203	25.3	15	5136
20662	KY 329-Prospect-Crestwood Road over Harrods Creek	PCIB Cont	I-Beam	3	(2)72;100	247	31.3	15	7 31
20666	KY 49-Lebanon-Bradfordsville Road over Rolling Fork River	PCIB Cont	I-Beam	4	(2)58;(2)90	298	31.2	15	9298
20672	KY 1187-Union-Silver City Road over Muddy Creek	PCBB Simp	Box Beam	3	(2)32;63	127	24.0	15	3048
20682	KY 623-Waterford-Fairfield Road over Salt River	PCIB Cont	I-Beam	4	(2)75;(2)95	342	31.3	0	10705
20683	US 45-Mayfield-Fulton Road over Brush Creek	PCIB Cont	I-Beam	3	(2)32;40	106	33.3	0	3530
20695	KY 139-Cadiz-Princeton Road over Goose Creek	PCIB Cont	I-Beam	3	(2)27.3	102	33.8	0	3448

Cont = Continuous Span
Simp = Simple Span
Legend (Length of Spans) = example (2)33;37 means two-33 ft spans and one-37 ft span.

TABLE 14. COMMENTARY SHEET: INTEGRAL ABUTMENT BRIDGES

BRIDGE NO.	LOCATION	DECK* RATING	SUPERSTRUCT.* RATING	SUBSTRUCT.* RATING	REMARKS
17987	KY 989-Charters-Burtonville Road over Salt Lick Creek	7	8	8	No cracking, good condition.
18310	KY 10-Maysville-Vanceburg Road over Ben Willen Branch	7	8	8	Concrete is deteriorating under the deck where the drain pipe is located.
18335	KY 1348-Crofton-Macedonia Road over Tradewater River	8	8	7	Spilling water on the piers, few cracks, rest of deck is in good condition.
18631	KY 227-Worthville Road over White Run	8	8	8	Like-new condition.
18972	KY 279 over Panther Creek	8	8	8	Some transverse cracking in the middle span.
19265	CR 1381-Curdsville-Delaware Road over Panther Creek	8	8	8	Nine spalled areas where a fire occurred on the deck. Few transverse cracks.
19602	US 60 over Indian Creek	8	8	8	Few longitudinal cracks in deck.
19869	KY 726-McKendree Church Road				Under construction at time of survey.
19899	KY 218 over Blue Springs Creek	8	8	8	Small longitudinal cracking in each end of deck.
19976	KY 339-Melber Road over Mayfield Creek				Under construction at time of survey.
20048	KY 11-Beattyville-Booneville Road over Buck Creek	9	9	9	Like-new condition.
20102	US 460-Pedestrian overpass over Maysville Street in Mt. Sterling	8	8	8	Cracks on north end of bridge where precast beams were connected to the end bent on both east and west side. Some leaching was visible under the deck.
20103	US 60 at Shelbyville over Clear Creek	7	8	8	Several cracks over the entire deck, more cracks on each end than the middle, walkways cracked about every 5 ft.
20196	KY 70-Smithland-Dycusburg Road over Ferguson Creek	8	8	8	One small crack close to drain, several cracks in the plinth.
20253	KY 58-Mayfield-Benton Road over Mayfield Creek	8	8	8	Like-new condition.
20259	KY 61-Elizabethtown-Hodgenville over Middle Creek	8	8	8	Under construction at time of survey.
20260	KY 61-Elizabethtown-Hodgenville over Middle Creek	8	8	8	Under construction at time of survey.
20262	US 60-Henderson-Owensboro Road over Race Creek	8	8	8	Some diagonal cracking on each end of deck, few small cracks in the middle of the deck.
20278	KY 61-Elizabethtown-Hodgenville over Middle Creek Relief Twin	9	9	9	Under construction at time of survey.
20279	KY 61-Elizabethtown-Hodgenville	9	9	9	Under construction at time of survey.
20282	KY 365-Sturgis-Hood Road over Tradewater River	7	8	8	Some diagonal cracking on one end of deck, few cracks about 2 ft long in the middle of the deck.
20285	KY 348-Benton-Symsonia Road over Middle Fork Creek	8	8	8	Like-new condition.
20291	KY 70-Smithland-Dycusburg Road over McCormick Creek	8	8	8	Like-new condition.
20294	US 51-Clinton-Fulton Road over Bayou DeChien	8	8	8	Like-new condition.
20349	KY 270-Clay Hardin-Sturgis Road over Caney Creek	8	8	8	Like-new condition.
20356	KY 1346-Dexter-Faxon Road over East Fork of Clarks River	7	8	8	Like-new condition.

TABLE 14. COMMENTARY SHEET: INTEGRAL ABUTMENT BRIDGES

BRIDGE NO.	LOCATION	DECK* RATING	SUPERSTRUCT.* RATING	SUBSTRUCT.* RATING	REMARKS
20357	KY 1346-Dexter, Faxon Road over East Fork of Clarks River Overflow	7	8	8	Like-new condition.
20390	CR 8548 Black Joe Bridge Access over Clover Fork of Cumberland Riv.	8	8	8	Did not survey.
20423	KY 40-Paintsville-Oil Springs over Mudlick Creek	8	8	8	Did not survey.
20429	KY 464-Almo-Shiloh over Jonathan Creek	7	8	8	Like-new condition.
20437	KY 703-Clinton-New Cypress over Bugg Creek	8	8	8	Like-new condition.
20446	KY 703-Clinton-New Cypress over Bugg Creek	7	8	8	Like-new condition.
20449	KY 703-Clinton-New Cypress over Little Cypress Creek	8	8	8	Like-new condition.
20472	KY 583-Lyons Station-Youngers Creek Road over Youngers Creek	8	8	8	Cracks in plenth wall, no cracks in deck.
20477	CR 1422-Greasy Creek Road over Levisa Fork River	8	8	8	Very few small cracks (steel structure).
20521	US 421-Hyden-Manchester Road over Goose Creek	7	8	8	Did not survey.
20535	KY 5-Princess-Fairview Road over East Fork of Little Sandy River	7	8	8	Like-new condition.
20538	US 31E-Hodgenville-Bardstown Road over Thompson Creek	8	8	8	Like-new condition.
20553	US 231-Bowling Green-Beaver Dam Road over Gasper River	8	8	8	Like-new condition.
20570	US 62-Washington-Murphysville Road over North Fork of Licking River	8	8	8	Under construction at time of survey.
20592	KY 132-Dixon-Sebree Road over Knoblick Creek	8	8	8	Some longitudinal cracking.
20650	CR 5118-Harpers Ferry-Lockport Road over Six-Mile Creek	8	8	8	Some diagonal cracking on west end of deck, very small.
20662	KY 329-Prospect-Crestwood Road over Harrods Creek	8	8	8	Under construction at time of survey.
20666	KY 49-Lebanon-Bradfordsville Road over Rolling Fork River	8	8	8	Under construction at time of survey.
20672	KY 1187-Union-Silver City Road over Muddy Creek	8	8	8	Like-new condition.
20682	KY 623-Waterford-Fairfield Road over Salt River	7	8	8	Like-new condition.
20683	US 45-Mayfield-Fulton Road over Brush Creek	8	8	8	Under construction at time of survey.
20695	KY 139-Cadiz-Princeton Road over Goose Creek	9	9	9	Under construction at time of survey.

*Ratings from Division of Maintenance Structure Inventory and Appraisal Reports (1987).

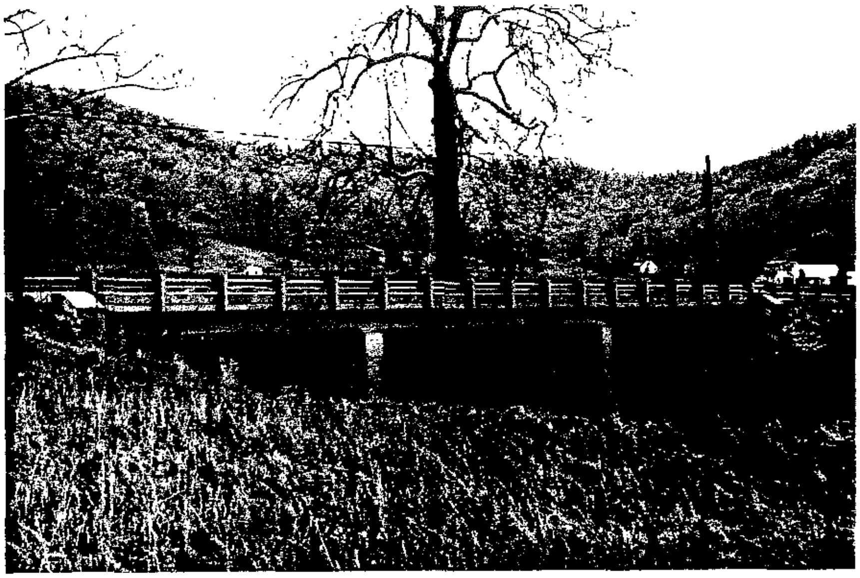

Figure 25. Three-Span RCDG Integral Abutment Bridge (KY 989 over Salt Lick Creek)(1984).

Figure 26. Integral Abutment Detail of RCDG Bridge (KY 989 over Salt Lick Creek)(1984).

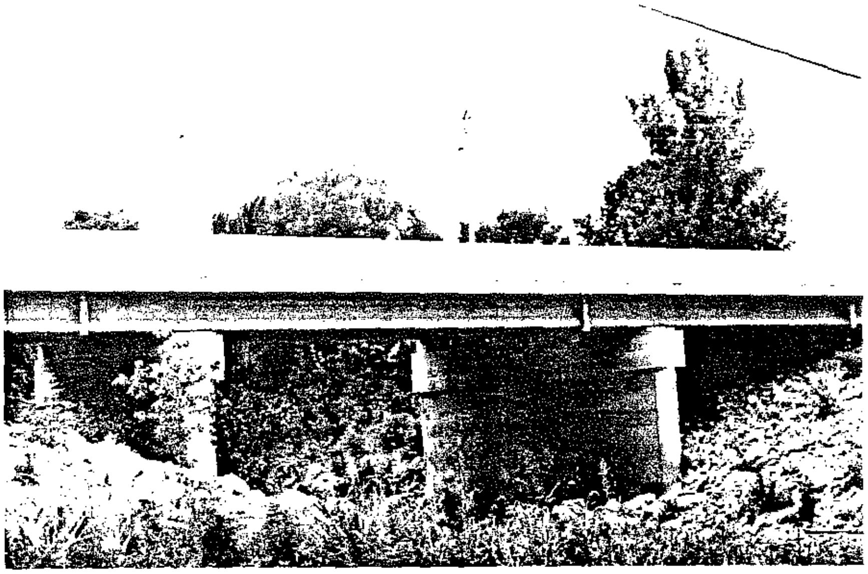

Figure 27. Integral Abutment Bridge Using PCIB Girders (KY 218 over Blue Springs Creek)(1984).

Figure 28. Integral Abutment Bridge Using PCBB Girders (KY 464 over Jonathan Creek)(1984).

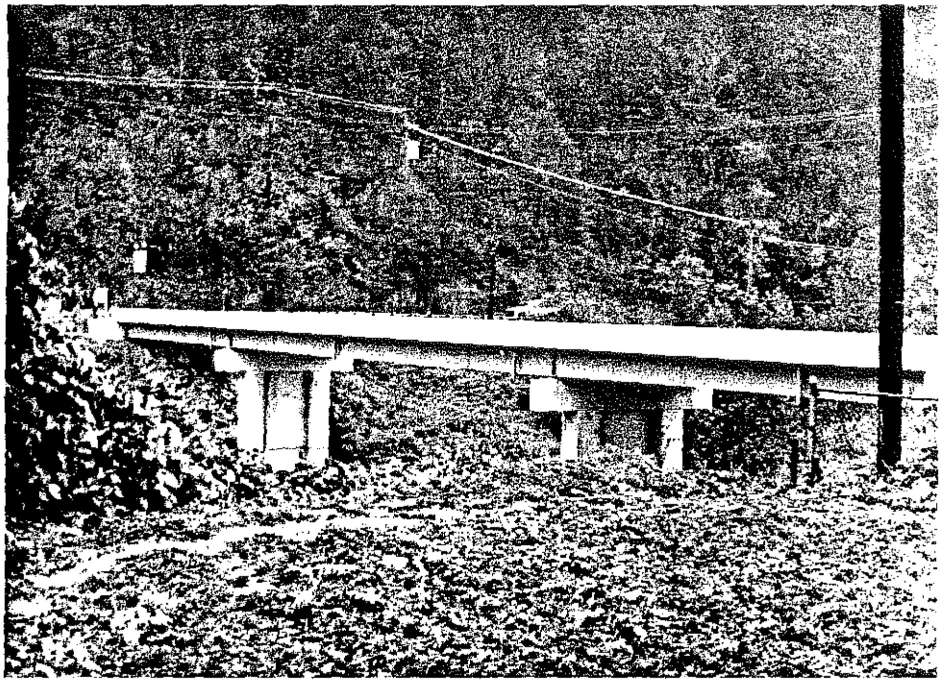

Figure 29. Integral Abutment Bridge Using Steel I-Beams (CR 1422-Greasy Creek Road over Levisa Fork River) (1985).

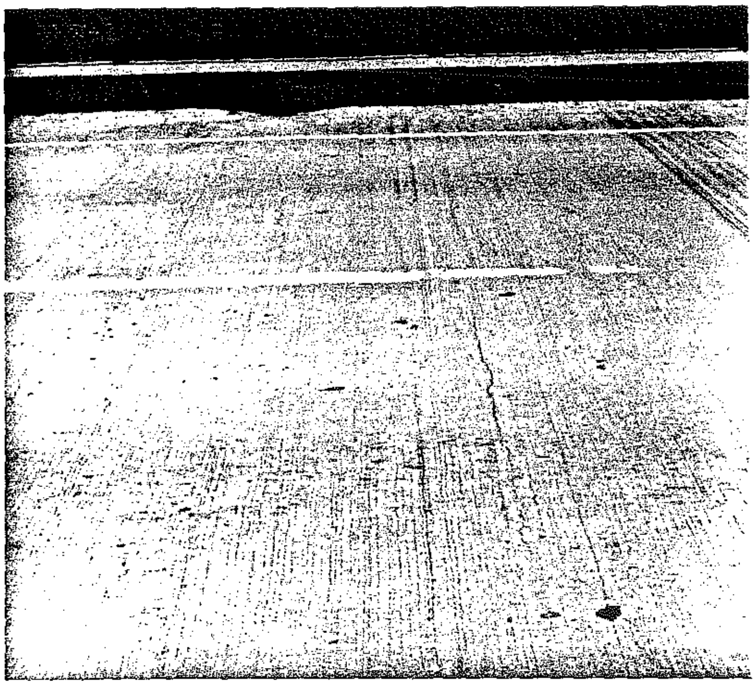

Figure 30. Cracking in the Deck of the US-60 Bridge over Clear Creek in Shelby County due to Differential Settlement (1984).

460 Overpass in Mt. Sterling) to 47.3 feet. Deck areas varied from 1,941 to 10,705 square feet.

Nine decks on those bridges were rated 7 on the Structure Inventory and Appraisal Report. Twenty-eight decks were rated 8 and four bridge decks were rated 9 (i.e., like new). It should be noted that the upper flanges of th PCBB bridges acted as the deck for those structures. Only one of the five PCBB bridges had a deck rated 7. The remaining were rated 8. None of the superstructures was rated 7. Four were rated 9 and the remaining 37 were rated 8. Four of the substructures were rated 9 and the remaining were rated 8.

The US-60 bridge at Shelbyville over Clear Creek appeared to have a settlement problem on the west end. The west bridge approach had been mud-jacked. The deck was also badly cracked (Figure 30). That was the only structure exhibiting a settlement problem.

NEW DECK MATERIALS AND OVERLAYS

New deck treatments and overlays have been developed since this study was initiated. Several have been used in Kentucky on experimental bases. Even though some problems were experienced in those trials, they warrant further research.

In May 1985, a micro-silica (Elkem Chemicals, Emsac) overlay was applied on the access road to the Big Rivers Steam Plant (KY 1097 over East Fork of Graves Creek near Sebree). Some problems were encountered in placing and finishing the micro-silica overlay with a latex-type (spinning-drum) finishing machine. Better results were obtained using a low-slump (vibrating-screed) finisher. The micro-silica additive is intended to provide a dense concrete that acts as an impermeable barrier to chlorides. Some cracks were noted in the completed deck (14).

Calcium-nitrite corrosion inhibitor is an inorganic compound that acts to prevent the electrochemical corrosion reaction caused by chloride attack on reinforcing steel. It also acts as a Type C admixture. Calcium nitrate (W. R. Crace, DCI) has been used experimentally in Class AA concrete on two small bridges (KY 152 over

Beech Fork in Washington County and Gose Road over Clarks Run in Boyle County). A super water reducer also was employed on the Gose Road Bridge. Both bridges were completed in 1986. Evaluation is ongoing.

In addition to the use of calcium-nitrite inhibited concrete on new decks, it may be combined effectively with micro-silica additives and water-blast demolition for overlaying. Other states have used water-blast demolition to economically strip old concrete from around a corroded top reinforcing mat. Typically, 3 to 4 inches of deteriorated concrete can be removed using the water-blast method. Then, an equal thickness of overlay could be placed using calcium-nitrite/micro-silica concrete. That repair option could be used on decks too severely deteriorated to be overlayed by conventional methods.

Other overlays showing promise are the thin-layered epoxies, blended polymers, and epoxy asphalts. All of those might be considered where lightweight bridge decks are being employed. Some experimental decks using those overlays have been used in other states, and it would be desirable to examine their performance before adopting them.

SUMMARY AND CONCLUSIONS

The progression of improvements in the design, materials, and construction and maintenance practices used on Kentucky's concrete decks has reached a plateau. Many decks that pre-date the Class AA concrete/epoxy-coated reinforcing steel combination have been overlayed and are presently providing continued useful service. Most decks employing Class AA concrete and epoxy-coated reinforcing steel are still performing satisfactorily and have not required overlayment. That probably holds true for bridges overlayed when new or before they were opened to traffic (with the exception of the membrane overlays on the KY 676 East-West Connector in Frankfort). Latex and low-slump concretes are presently meeting the Transportation Cabinet's service requirements satisfactorily.

In the next 5 to 10 years, the accumulated wear and tear on existing decks will necessitate new maintenance strategies and methods to maximize benefits of expenditures for constructing new decks and for extending the life of older decks. The older decks overlayed after years of service may eventually need to be redecked. Newer decks may require their first overlay and decks overlayed prior to opening may need their second overlays. If a deck is to be widened in a few years, the Transportation Cabinet may elect to extend the life of the deck by patching until it is deteriorated.

This study revealed that reinforced-concrete bridge decks crack in specific patterns. The degree of cracking depends upon a number of factors -- bridge design, construction, and service. Deck cracking is caused primarily by live loads and differences in thermal expansion gradients between the reinforcing steel and concrete. Cracking of rigid concrete overlays may be attributed to shrinkage cracking that occurs during setting (latexes) and pull cracking created during deck finishing and texturing (tining).

The effects of deck (and overlay) cracks upon durability was not assessed during this study. Many decks have remained in service for years after the occurrence of prominent and extensive flexure and temperature cracking. Shrinkage and pull overlay cracks are often closely spaced and may lead to debonding. Several overlayed bridge decks containing such cracks have provided extensive service. That is not to imply that all signs of deck cracking are harmless. Usually, overlay block cracking is a sign of badly deteriorated concrete in the underlying deck (Figures 31 and 32). Block cracking also may signify the onset of overlay delaminations and punch outs in the bridge deck.

On some heavy-haul and interstate routes, decks of continuous steel-girder bridges contain extensive block cracking. Apparently, those bridges are not sufficiently stiff. Conversely, bridges employing precast, prestressed concrete I-beams, especially the integral abutment bridges, contain very few cracks. Most of those cracks are longitudinal and may indicate the need for more transverse reinforcement. Deck cracking may probably be eliminated by prestressing the slab. Previous efforts to seal cracks have not proven satisfactory. Further investigations are needed relative to that issue.

Figure 31. Patch in Concrete Deck Adjacent to Area Showing Block Cracking (US 460 over I 75 in Scott County)(1987).

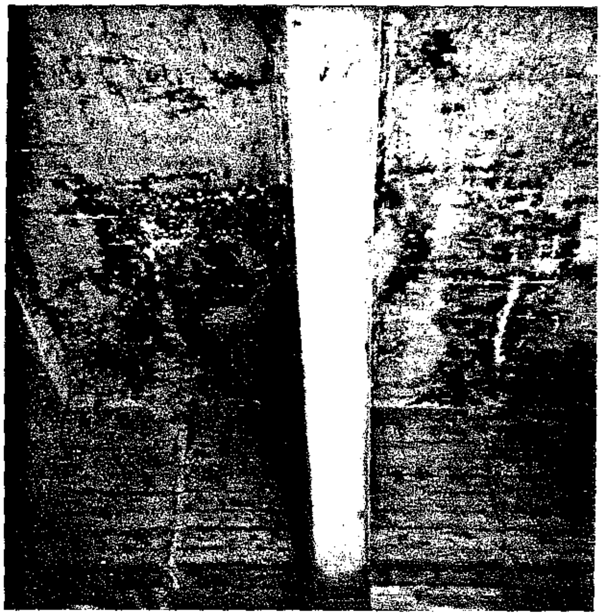

Figure 32. Underside of Bridge Deck below Patched and Cracked Area Shown in Figure 30.

Debonding may be the only clear, discernable sign of overlay failure. A few overlays have experienced massive debonding failures; however, such problems have been rarely encountered in recent years. Where localized overlay debonding has occurred, it is usually effectively repaired by patching.

Deck texturing has been a controversial topic since its inception. Broomed finishes on the I-64 experimental bridges between Frankfort and Lexington were observed to have worn considerably in the wheelpaths after a few years of service. The same results could be expected from shallow tining. In the last few years, the number of pull-in crack problems due to tining has apparently decreased. In part, that is probably due to timely texturing operations on the part of experienced contractors. Still, tining produces a relatively rough riding surface. Also, aggregates often are pulled from the latex concretes and the tining tends to be uneven. Those problems could be alleviated by sawing grooves into the completed deck. An obvious comparison would be the smooth riding freeways in the Los Angeles, California, area, which have sawed grooves, compared to the I-275 Bypass around Covington and Newport, which has tined grooves.

Despite their poor surface appearance, most membrane bridges have performed very well, with the exception of those on the KY-676 twin bridges. The KY-676 membranes may have been placed on grades too steep for their intended application. Several states still use membranes successfully. Their surfaces are not afflicted with seam cracks or blisters. Superficial blistering and seam cracking in the wearing surfaces on the Kentucky bridges have not resulted in significant distress in the membranes. Inspections below the membrane bridge decks revealed no signs of efflorescence, indicating the membranes are still acting as effective impermeable barriers. Performances of all types of membranes (sheet, liquid-applied, and slurry) match those of rigid overlays. They may be advantageous for certain applications.

The performance of rigid concrete overlays has been very good. About 2,000 overlays have been placed throughout the state with less than ten known premature failures. Many initial overlays, including some that were experimental, are approaching 15 years service. It appears that many of those initial overlays may exceed 20 years service.

The Dow experimental latex overlays were rated slightly better overall than those using Reichhold latex. However, more Reichhold experimental overlays were placed on older decks, which probably accounts for that difference. The experimental low-slump overlays have performed well. They appear to be a suitable alternate to latex overlays. Also, they are probably a little more crack resistant than latex overlays.

All rigid overlays were observed to be amenable to spot repairs by patching. That allows for extension of the overlay (and deck) life.

The extent of chloride penetration into overlayed decks was not investigated during this study. This issue was considered by New York in a comprehensive study of 77 older bridges containing black steel reinforcement in the decks (15). Correlation revealed that chloride penetration was contributory to deck deterioration, but was not a major factor. Further attention to that issue may be warranted.

Inspections indicated that some bridges are too flexible (at least for their present level of service), causing their decks to crack excessively. Those bridges should be identified and stiffened. They would not provide sufficiently stable deck support for overlays. Also, they should not be redecked as initially constructed without either stiffening the longitudinal beams or the deck. Bridges may be stiffened either by adding additional beams, by prestressing existing members, or by providing composite action (shear connectors). If deck stiffening is considered, it may be possible to employ a prestressed slab to add stiffness to the structure. It would be desirable to survey a significant number of bridges of different designs, on routes with different levels of service, to determine crack patterns caused by service loads. That information would be useful in the design of new bridges and in design of replacement decks for existing bridges.

Performance of overlays is closely tied to the quality of the underlying decks. Based upon previous inspections, the most crack-free decks were usually observed on PCIB bridges. That is probably because the PCIB bridges are stiffer than other bridge types. Presently, some steel fabricators and designers are promoting competitive bridges having wider girder and floor-beam spacings. Those bridges may be initially economical, but may later prove prone to live-load induced deck cracking (especially if employed on heavy-service routes). The relationship between bridge stiffness and deck cracking needs to be investigated further. It might be desirable to strain gage some existing bridges of different designs to determine why some decks crack more extensively.

The Transportation Cabinet may soon need to redeck a large number of bridges. Besides the issue of sufficient bridge/deck stiffness and strength, the development of improved deck concrete needs to be addressed. Use of super water-reducer admixtures combined with micro-silica additives may provide concrete superior to the current Class AA concrete in freeze-thaw durability, chloride impermeability, strength, and wear resistance. Those improvements would yield decks having superior performance and durability than those constructed to current specifications. Improvements would lead to reduced maintenance costs for the Transportation Cabinet.

It would require a series of progressive laboratory and field tests to develop a successor to the Class AA concrete. However, if such a program were instituted, desired new concrete mixture and placement specifications might be perfected within 3 to 5 years. Concrete could probably be placed suitably by a spinning-drum paving machine; however, some modifications to existing paving procedures are anticipated. Sawed grooving of cured concrete could also decrease the potential for placement problems using super water-reducer/micro-silica concrete.

Integral abutment bridges appear to have provided good service, however significant service histories (10 years or more) have been obtained on only a very few of those bridges. They offer the advantages of eliminating such components as bearings, deck expansion joints, and seals normally used in conventional bridges and that sometimes prove troublesome in service.

Problems involving differential settlement between abutments and/or piers where anticipated; however, only one bridge, the US-60 bridge over Clear Creek in Shelby County, exhibited that problem.

It was anticipated decks might be prone to cracking if relative settlement of the substructure elements occurred. That was only encountered on the aforementioned bridge. The bridges exhibited no signs of deck distress due to lateral movement or rocking of the piers. Most integral abutment bridge decks were relatively free of cracks. In part, that was attributed to the use of prestressed concrete girders in most structures. The Structure Inventory and Appraisal Reports for those bridges (related to structural components) indicated no ratings lower than 7 (generally good condition) for the major bridge components: decks, superstructures, and substructures.

Performance of integral abutment bridges revealed no inherent defects that would inhibit their further use. In fact, the virtual absence of major problems indicates that further use of that type of bridge might be desirable.

Decks are expensive to maintain. The Division of Maintenance has exercised good engineering practice and administration in managing the bridge-deck inventory. Technological advancements related to bridge decks are possible. Those improvements would greatly benefit Transportation Cabinet in maintaining and perhaps even improving bridge-deck quality while controlling deck-maintenance costs.

REFERENCES

1. "Latex-Concrete Overlays on Bridge Decks (I 64, MP 150 to West Virginia Line)," J. H. Havens and T. Hopwood, Research Report UKTRP-85-22, Kentucky Transportation Research Program, September 1985.

2. "Bridge Decks Constructed for Increased Durability," A. S. Rahal, Research Report 402, Division of Research, Kentucky Department of Transportation, October 1974.

3. "Kentucky Bridge Decks Repaired with Latex Mortar Overlays," W. A. Crace, Better Roads, May 1969, pp 19-21.

4. "Construction, Protection and Maintenance of Concrete Bridge Decks," R. D. Hughes and J. H. Havens, Research Report 335, Division of Research, Kentucky Department of Highways, August 1972.

5. "Concrete Bridge Decks: Deterioration Coatings and Repairs," J. H. Havens and W. B. Drake, Research Report 200, Division of Research, Kentucky Department of Highways, February 1963.

6. "Concrete Bridge Decks: "Deterioration and Repairs, Protective Coatings, and Admixtures," R. D. Hughes and J. W. Scott, Research Report 235, Division of Research, Kentucky Department of Highways, June 1966.

7. Memo Report to C. S. Layson (attn, Robt. Hodges) from J. H. Havens, December 1970, Re: Inspection of Cracking; Twin Bridges; Shawnee Parkway, I 264-1(43)3, Jefferson County, over K and IT RR Tracks, November 5, 1970, Division of Research, Kentucky Department of Highways.

8. "Distribution of Negative Moment Reinforcement in Reinforced Concrete T and Box Girder Bridge Deck Slabs," W. D. Shrader, Ph.D. Dissertation, College of Engineering, University of Kentucky, 1972.

9. "Cracking in Continuously Reinforced Concrete Pavements," J. H. Havens, R. C. Deen, A. S. Rahal, and W. V. Azevedo, Research Report 480, Division of Research, Kentucky Department of Transportation, October 1977.

10. "Cracking in Concrete Pavements," R. C. Deen, J. H. Havens, A. S. Rahal, and W. V. Azevedo, Research Report 529, Kentucky Department of Transportation, October 1979; also Journal of Transportation Engineering, American Society of Civil Engineers, 1980.

11. Memorandum by J. H. Havens dated November 17, 1983, Kentucky Transportation Research Program.

12. "Performance Survey; Thermoflex 8002; Latex-Modified Overlays," A. S. Rahal, KYP-74-62; HPR-PL-1(13), Part III-B, April 1978.

13. "Texturing Bridge Decks -- A Final Report," J. J. Quinn, K. Diringer, New Jersey Department of Transportation, Trenton, New Jersey, Report No. FHWA/NJ-86-009-7703, April 1986.

14. Memorandum by D. Hunsucker to T. Hopwood dated February 10, 1985, Kentucky Transportation Research Program.

15. "Long-Term Evaluation of Unprotected Concrete Bridge Decks," W. P. Chamberlin, New York State Department of Transportation, Albany, New York, Research Report 128, November 1985.