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COST EFFECTIVE BRIDGE DECK RECONSTRUCTION IN KANSAS USING HIGH-DENSITY CONCRETE OVERLAYS AND ASPHALT MEMBRANE OVERLAYS

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August 2009

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16 Abstract

In 1976 the Federal Highway Administration (FHWA) approved federal aid funding for experimental installations of corrosion protection for reinforcing steel in existing concrete bridge decks. Sixteen of the sixty-nine Kansas bridges with Cost Effective Overlays built between 1976 and 1987 were selected for ongoing monitoring of delaminations, cracking and corrosion potential in the reinforcing bars. Fourteen bridges with low water-cement ratio concrete overlays and two bridges with asphalt membrane protective systems were monitored annually for the life of the overlays. Eight of the low water-cement ratio overlays were constructed with high-cement-content Iowa System Overlays and six with lower-cement-content Kansas System Overlays. The two asphalt membrane overlays were constructed with a non-woven polypropylene fabric membrane laid onto asphalt cement and overlaid with hot-mix asphalt as a wearing surface. A comparison of service life with initial cost of each type of overlay shows that correctly-installed asphalt membrane overlays may have been the most cost effective, followed by the Kansas System concrete overlays.

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Final Report

Prepared by

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August 2009

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ABSTRACT

In 1976 the Federal Highway Administration (FHWA) approved federal aid funding for experimental installations of corrosion protection for reinforcing steel in existing concrete bridge decks. Sixteen of the sixty-nine Kansas bridges with Cost Effective Overlays built between 1976 and 1987 were selected for ongoing monitoring of delaminations, cracking and corrosion potential in the reinforcing bars. Fourteen bridges with low water-cement ratio concrete overlays and two bridges with asphalt membrane protective systems were monitored annually for the life of the overlays. Eight of the low water-cement ratio overlays were constructed with high-cement-content Iowa System Overlays and six with lower-cement-content Kansas System Overlays. The two asphalt membrane overlays were constructed with a non-woven polypropylene fabric membrane laid onto asphalt cement and overlaid with hot-mix asphalt as a wearing surface. A comparison of service life with initial cost of each type of overlay shows that correctly-installed asphalt membrane overlays may have been the most cost effective, followed by the Kansas System concrete overlays.

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CHAPTER 1 - INTRODUCTION

Extending the service life of concrete bridge decks has been a concern for the Kansas Department of Transportation (KDOT) since the mid twentieth century. In 1959 KDOT launched a large-scale study of bridge deck deterioration to determine the extent and causes of bridge deck deterioration and also to develop preventative and maintenance treatments for the deterioration, with a final report published in 1973. This study found that corrosion of reinforcing steel in the deck was the primary cause of deterioration. Inadequate concrete cover over the steel, a high water-cement ratio, high permeability, and the use of deicing salts all contributed to the accelerated deterioration of the bridge decks. Several treatment and repair options were identified, including surface patching, injection of bonding agents into hollow planes, covering the deck with membrane and bituminous overlays, installing thin bonded concrete overlays or replacement of the entire deck if warranted (Bukovatz et al., 1973).

By the early 1970s, bridge deck deterioration had also been identified as a significant threat to the serviceability of the national highway system. In 1976 the FHWA approved federal aid participation for several methods of protecting reinforcing steel in existing concrete bridge decks from the corrosive effects of deicing chemicals. Until that time, all work done on bridge decks after the initial construction was the financial responsibility of the states. The 1976 Federal Aid program reimbursed the states for “reconstruction”, which encompassed overlays and other techniques that completely replaced the existing bridge deck surface. Repairs such as patching and rebonding of hollow planes that did not replace the entire wearing surface of the bridge were still not reimbursable.

Several protective systems were approved for federal reimbursement for reconstruction of existing bridge decks that were likely to be subjected to deicing chemicals. Low water-cement ratio dense concrete overlays and latex polymer-modified concrete overlays were recommended. Asphalt overlays over a waterproof membrane and cathodic protection systems were not among the recommended alternative protection systems but were accepted for federal reimbursement under the program.

Two categories of bridge deck restoration were made available to the states in the 1976 Federal Aid highway program, “permanent” and “cost-effective experimental reconstruction”. For a heavily deteriorated bridge deck, permanent restoration meant completely removing and replacing the original deck. Cost Effective Experimental Reconstruction offered the option of removing only deteriorated concrete, then using any of the types of overlays and/or cathodic protection to replace the wearing surface and protect the reinforcing steel from corrosion. This application was designed to extend the life of the bridge deck by ten to fifteen years, not “permanently”, thus the name “Experimental Cost Effective Bridge Deck Reconstruction”. On a light to moderately deteriorated bridge deck, permanent restoration encompassed the removal of all salt-contaminated, delaminated and deteriorated concrete, as well as all corroded reinforcing steel from the deck of the bridge, then applying a protective system. Applying the protective systems without the removal of all salt-contaminated concrete was also approved on an experimental basis.

As part of an experimental program, the first three installations of any of the Cost Effective applications as well as ten percent of any following installations were declared to be test bridges and were monitored intensely. The FHWA program required complete surveys of the test bridges before and immediately after overlay construction, and every two to three years thereafter. The surveys were to include measurements of corrosion potentials and delaminations on concrete overlays and resistivity readings on asphalt membrane overlays.

Sixty-nine Kansas bridges were selected for Cost Effective Overlay installations between 1976 and 1987. Sixteen test bridges were selected for complete surveys, including fourteen with low water-cement ratio concrete overlays and two with asphalt membrane protective systems. One of the bridges with a low water-cement ratio concrete overlay also had epoxy-coated reinforcing steel installed before the overlay was constructed. KDOT staff conducted preconstruction surveys of the bridge decks to measure percent of the total area delaminated, corrosion potentials and salt contents at three depths. After construction the Concrete Research Section conducted annual surveys of cracking, delamination and corrosion potential or resistivity as appropriate. The annual surveys continued until the overlays were removed, overlaid or the bridges were replaced. As of January 2009, the only overlay still in service of the original sixty-nine was a low water-cement ratio overlay on a county bridge near Quenemo, Kansas.

The remainder of this report is divided into two sections. The first addresses the installation and performance of the concrete overlays. The second section covers the decks with the asphalt membrane protective systems.

CHAPTER 2 - CONCRETE OVERLAYS

The bridge deck overlays in this project were built under four separate Special Provisions, which is the term KDOT uses for revisions and additions to the KDOT Standard Specifications for Road and Bridge Construction. Standard Special Provisions are denoted by the version of the Standard Specifications that they modify and then the order of issue. For example, Special Provision 73P-87 R is the 87th modification to the 1973 Standard Specifications. Special Provisions to be used on a limited number of projects are given numbers outside of the normal sequence, as in 73P-1210. The following descriptions of specification requirements do not indicate the requirements of the most recent specifications but rather the requirements of the specifications used for the bridges in this study. The mix designs and construction requirements for each Special Provision are summarized in Table 2.1. The complete text of all Special Provisions is included in Appendix A.

Table 2.1: Concrete mixes and preparation used in Kansas experimental bridge deck overlays.

Special Provision	Cement, lbs/cy (min)	w/c (max)	Air,%	Slump	Preparation
1976 Kansas System (73P-87 R)	602	0.44*	6 ± 2%	½” max	24 hr soak
1977 Iowa System (73P-1210)	825	0.36	6.5 ± 1%	¾” max	24 hr soak
1979 Iowa System (73P-281 R)	825	0.36	6.5 ± 1%	¾” max	No soak
1981 Kansas System (80P-129 R3)	625	0.40	6 ± 2%	¾” max	No soak

*Limited to 0.39 in practice

At the time of the FHWA recommendation of low water-cement ratio overlays in 1976, Kansas had already used bonded concrete overlays constructed under KDOT Special Provision 73P-87 R and earlier Special Provisions with a minimum cement factor of 602 lbs/cy and a maximum water-cement ratio of 0.44 on over 100 bridge decks. The Federal-Aid Highway Program Manual recommended using a much higher minimum cement factor of 825 lbs/cy and a maximum water-cement ratio of 0.36 for the Low Water Cement Ratio, Dense Concrete ("Iowa System") protective overlays. KDOT immediately submitted an Experimental Feature Work Plan for reconstruction of four bridges on Interstate 70 using the existing KDOT Special Provision 73P-87 R (1976 Kansas System). The Concrete Research team was assigned the task of monitoring construction and subsequent surveys for the evaluation of the overlay performance. The FHWA accepted the research proposal and the four overlays were completed by November 1976. In 1979 the Research Section requested approval for further use of Kansas System overlays on Federal Aid bridge projects. The FHWA refused the request, citing concerns about the lower cement content and higher allowable maximum water cement ratio. A study of existing Kansas System overlays was requested as a prerequisite for the reconsideration of the appeal. No action was taken by KDOT to further the use of Kansas System overlays until late 1981.

In the meantime, sixty-seven Iowa System overlays were installed on Kansas bridges between 1978 and 1981. Six Iowa System overlays built under Special Provision 73P-1210 (1977 Iowa System) were selected for complete evaluation. The Iowa System special provision was revised and made a Standard Special Provision in 1979 as 73P-281 R (1979 Iowa System). Two bridges constructed in 1979 under 73P-

281 R were added to the experimental program. Kansas System overlays were not reconsidered until October 1981, when the Research Steering Committee discussed the relative performance of the two systems. The Kansas System was believed to cost less, perform better and crack less than the Iowa System. A task force was formed to prepare a report answering the FHWA's concerns, and Kansas System bridge deck overlays were approved for federal participation in 1982. The Special Provision was revised at this time, and two Kansas system bridge deck overlays constructed under Special Provision 80P-129 R3 (1981 Kansas System) were added to the experimental program in 1986 and 1987. Table 2.2 lists all of the bridges surveyed for this project.

Table 2.2: Kansas bridges with experimental concrete deck overlays.

Overlay Type	Experimental Number	Bridge Name and Number	Bridge Type	Age at time of overlay
1977 Iowa System	1977 IA no. 1	Industrial Ave over I-35 35-56-11.58 (008)	Continuous concrete box girder	11
	1977 IA no. 2	I-470 EB over Shunganunga Creek - 470-89-2.87(057)	Continuous haunched reinforced concrete deck T-girder	19
	1977 IA no. 3	I-470 WB over Shunganunga Creek - 470-89-2.87(056)	Continuous haunched reinforced concrete deck T-girder	19
	1977 IA no. 6	Milford Lake Road (FAS 270) over I-70 - 70-31-1.03 (002)	Continuous concrete box girder	20
	1977 IA no. 34	I-470 EB over Huntoon Street 470-89-1.04 (050)	Continuous concrete box girder	21
	1977 IA no. 35	I-470 EB over Wanamaker Street - 470-89-1.20 (052)	Continuous concrete voided slab	20
1979 Iowa System	1979 IA no. 14†	I-70 EB over K-4 (Auburn Road) - 70-89-7.08 (013)	Continuous concrete voided slab	22
	1979 IA no. 24	I-470 EB over 10th Street 470-89-0.36 (048)	Continuous concrete box girder	21
1976 Kansas System	1976 KS no. 1	I-70 EB over Mulberry Creek 70-85-17.46 (063)	Continuous composite weathering steel box girder	15
	1976 KS no. 2	I-70 EB over Solomon River 70-85-28.8 (077)	Circular haunched composite steel welded plate girder	15
	1976 KS no. 3	I-70 EB over Saline River 70-85-18.64 (066)	Continuous composite haunched steel welded plate girder	15
	1976 KS no. 4	I-70 WB over Saline River 70-85-18.65 (065)	Continuous composite haunched steel welded plate girder	15
1981 Kansas System	1981 KS no. 5	K-18 over South Solomon River - 18-33-0.69 (44)	Continuous prestressed concrete beam	21
	1981 KS no. 6	FAS 511, Osage Co. 000000000700090	Continuous steel beam	17

†This bridge also had epoxy-coated reinforcing bar installed at the time of overlay construction.

2.1 Materials and Construction Methods

All of the concrete mix designs used in these overlays called for low-slump concrete with 50% sand and 50% coarse aggregate. The coarse aggregate gradation requirements were all as given in Table 2.3.

Table 2.3: Coarse aggregate gradation requirements for Kansas experimental bridge deck overlays.

Sieve size	percentage retained
¾"	0
½"	0-10
⅜"	30-50
#8	90-100

Fine aggregate gradation requirements varied among the Special Provisions. The 1976 Kansas System allowed the most fines, requiring that 5% to 15% of the aggregate pass the #100 sieve. Later Special Provisions added gradation requirements for the #8 and #30 sieves, and reduced the fines to 2% to 10% passing the #100 sieve. See Table 2.4 for more detail on the fine aggregate gradation requirements.

Table 2.4: Fine aggregate gradation requirements, in percent retained per sieve, for Kansas experimental bridge deck overlays.

Special Provision	⅜"	#4	#8	#16	#30	#50	#100
1976 Kansas System (73P-87 R)	0	0-5	-	20-40	-	75-85	85-95
1977 Iowa System (73P-1210) and 1979 Iowa System (73P-281 R)	0	0-5	0-20	15-50	40-75	70-90	90-98
1981 Kansas System (80P-129 R3)	0	0-5	0-24	15-50	40-75	70-90	90-98

The most notable differences between the Iowa System concrete mix designs and the Kansas System mix designs are the cement content and the water-cement ratio. As previously mentioned, the Iowa System mix designs used a minimum of 825 pounds of cement per cubic yard of concrete, an increase of 37% over the minimum of

602 pounds of cement per cubic yard of concrete called for in the 1976 Kansas System Special Provision. The Iowa System Special Provisions also calls for a maximum water-cement ratio of 0.36, while the 1976 Kansas System Special Provision allowed a water-cement ratio of as high as 0.44. However, in practice the requirement that the slump not exceed ½" kept the water cement ratio at 0.39 on the 1976 Kansas System overlays. The 1981 Kansas System Special Provision reduced the maximum allowable water-cement ratio to 0.40. This Special Provision also increased the minimum cement content to 625 pounds of cement per cubic yard.

All of the bridge deck overlays built in this program shared the same basic construction sequence. First, all of the unsound concrete, dirt and asphalt patching materials were removed from the existing deck surface using scarification, cutting, or scabbling. One quarter inch of concrete was also removed from the remainder of the deck, according to the 1976 Kansas System and the 1977 Iowa System Special Provisions. Deck preparation requirements were separated from the 1979 Iowa System and 1981 Kansas System Special Provisions to form a whole new specification and the depth of concrete removal was specified on the plans.

After the removal of the concrete, the surface of the bridge deck was cleaned to remove dirt, scale and laitance. The 1977 Iowa and 1976 Kansas systems called for dry sandblasting for this purpose and also to remove rust and heavy scale from the top mat of reinforcing steel. The 1979 Iowa System Special Provision calls for a high pressure (minimum 3,500 psi) water jet to achieve this purpose, and the 1981 Kansas System Special Provision permits dry sandblasting only to remove unsound concrete, dirt, scale and laitance. Cleaning of the reinforcing steel was not required in either the 1979 Iowa System or the 1981 Kansas System.

One construction requirement differs significantly between the early and later versions of the Iowa and Kansas Systems. The 1976 Kansas System and the 1977 Iowa System Special Provisions call for saturating the deck with water for 24 hours between the removal of the old concrete and before the placement of the new concrete. The water was to be blown off the deck leaving the deck moist but with no standing water at the time of the application of grout. The water was often not adequately removed, leaving puddles that diluted the grout, which was suspected as a cause of delaminations in the new overlays. Also, application of grout to a dry deck was believed to provide better adhesion through capillary action drawing grout into microcracks in the old concrete (Wojakowski, 2009). Pre-saturation of the bridge decks was eliminated in the 1979 Iowa System and the 1981 Kansas System Special Provisions. Wetting the deck surface for two hours prior to overlay placement without the use of grout was instated as a requirement in 1998.

Next, grout was brushed onto all of the surfaces that were to be overlaid, including the adjacent vertical surfaces. The grout consisted of a mixture of equal amounts of fine aggregate and Portland cement, with enough water added to reach the consistency of “heavy cream”. The consistency of the grout slurry was to be such that it could be applied with a stiff brush or broom to the previously placed concrete in a thin, even coating that would not run or puddle in low spots. The use of grout was discontinued in 1998 as debonding of bridge deck overlays was a common problem. Although specifications required the removal of all dried grout from the deck before placing the overlay concrete, cores of delaminated bridge decks showed that this procedure was not commonly followed and a layer of dried, unhydrated grout was frequently found to be the cause of delamination (Meggers, 2009).

Immediately following the application of the grout, two inches of concrete was placed in a single continuous operation, vibrated into place and screeded. Differences in the concrete placement requirements among the Special Provisions mostly reflect the rapid evolution of concrete bridge deck construction during the late 1970's and early 1980's. For example, the earliest Special Provision calls for placing the concrete with shovels and tamping the concrete with hand-held tamping rods. By 1981, all placement, consolidation and screeding of the concrete were automated.

Finishing by brooming or tining was followed by a 72 hour wet cure. Curing requirements did not vary greatly among the four Special Provisions. All called for 72 hours of wet curing with burlap or polyethylene. The 1977 Iowa and 1976 Kansas systems also allowed the use of two inches of wet sand.

2.2 Test Methods

KDOT staff conducted preconstruction surveys of the bridge decks to measure percent of the total area delaminated, corrosion potentials and salt contents at three depths. Beginning immediately after construction, the Concrete Research Section conducted annual surveys of delamination, corrosion potential and cracking. A chain drag was used to identify delaminated areas on the deck, which were then plotted on a map. The total delaminated area was measured from the map and reported as a percentage of the deck area. Cracking was measured on the deck and plotted on crack maps for each bridge deck. Cracking data was normalized by dividing the total length of cracks by the total area of the bridge deck. *ASTM C 876 Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete* was used to measure the corrosion potential. Results were reported as a percentage of the total half cell potentials that were more negative than -0.35 V. Areas with potentials more negative than -0.35 V are considered active corrosion areas, as they have a 90% chance that corrosion is occurring at the time of measurement (ASTM C 876).

2.3 Results and Comments

A summary of the results of monitoring the 14 concrete bridge deck overlays in this program are presented in Tables 2.5 and 2.6. A ten-year term was selected for reporting total delamination and total active corrosion area to reflect the stated intention of the program to extend the life of the bridge by ten to fifteen years. Complete data are presented in Appendix B. Significant performance differences were seen among the four types of bridge deck overlays in the extent of delamination, measured corrosion rates and in cracking.

Table 2.5: Delamination and corrosion results of complete surveys of Kansas concrete bridge deck overlays.

Experimental Number	Annual delamination area increase	Total delamination at 10 years	Annual active corrosion area increase	Total active corrosion area at 10 years
1977 IA no. 1	1.8%	21%	0.4%	3%
1977 IA no. 2	1.9%	21%	1.8%	15%
1977 IA no. 3	4.2%	49%	1.3%	11%
1977 IA no. 6	1.7%	14%	1.0%	6%
1977 IA no. 34	2.6%	29%	0.9%	11%
1977 IA no. 35	0.4%	4%	1.1%	11%
1979 IA no. 14†	0.1%	0%	1.1%	8%
1979 IA no. 24	1.4%	25%	1.3%	10%
1976 KS no. 1	3.5%	35%*	3.8%	38%*
1976 KS no. 2	0.5%	5%*	3.7%	37%*
1976 KS no. 3	0.6%	6%*	2.4%	24%*
1976 KS no. 4	0.3%	3%*	2.3%	23%*
1981 KS no. 5	1.3%	13%	0.7%	7%
1981 KS no. 6	0.5%	5%	0.0%	0%

*Projected ten-year total based on projections from 8 years of data.

†This bridge also had epoxy-coated reinforcing bar installed at the time of overlay construction.

Delamination: 1976 and 1981 Kansas system overlays had less total delamination on average at the end of ten years and also had lower average annual rates of delamination than the Iowa system bridges. 1977 and 1979 Iowa System overlays delaminated four times faster than Kansas System overlays. One Kansas system bridge deck (1976 KS no. 1) had an anomalously high rate of delamination, which is believed to be due to extreme events before, during and after overlay construction, including a vehicle fire on the deck before overlay construction, rapid deterioration of the half of the deck carrying traffic during construction and bearing excess traffic loads after construction (Bukovatz, 1985).

Corrosion rates: 1977 and 1979 Iowa System overlays outperformed 1976 and 1981 Kansas system overlays in corrosion prevention, with only one-third as much active corrosion area.

Table 2.6: Results of crack surveys of Kansas concrete bridge deck overlays.

Experimental Number	Annual cracking rate ($ft/ft^2/yr$)		
	longitudinal	transverse	total
1977 IA no. 1	0.065	0.101	0.166
1977 IA no. 2	0.299	0.246	0.545
1977 IA no. 3	0.059	0.080	0.139
1977 IA no. 6	0.164	0.164	0.328
1977 IA no. 34	0.196	0.155	0.351
1977 IA no. 35	0.080	0.170	0.250
1979 IA no. 14†	0.390	0.096	0.486
1979 IA no. 24	0.221	0.151	0.372
1976 KS no. 1	0.081	0.275	0.356
1976 KS no. 2	0.074	0.405	0.479
1976 KS no. 3	0.077	0.436	0.513
1976 KS no. 4	0.071	0.255	0.326
1981 KS no. 5	0.094	0.097	0.191
1981 KS no. 6	0.014	0.004	0.018

†This bridge also had epoxy-coated reinforcing bar installed at the time of overlay construction.

Cracking: The 1979 Iowa System overlays cracked fastest at an average of 0.43 ft/ft^2 of total cracking per year. 1976 Kansas System overlays had an average of 0.42 ft/ft^2 per year of total cracking, and 1977 Iowa System overlays had 0.30 ft/ft^2 per year of total cracking. 1981 Kansas System overlays performed best with less than 0.20 ft/ft^2 of total cracking per year.

2.4 Discussion

The chloride content of the existing bridge decks were measured for all but one of the bridges in this study (Table 2.7). At the depth of 1.5” below the surface of the bridge deck, approximately the depth of the top of the reinforcing steel, the results ranged from 0.5 to 8.7 lbs/yd^3 and averaged 3.73 lbs/yd^3. All but one of the chloride contents measured on the existing bridge decks prior to overlay construction exceeded the 1 lb/yd^3 threshold amount of chloride necessary for salt-induced corrosion. No correlation was found between the corrosion rate of the steel measured in this study and the pre-overlay chloride content.

Table 2.7: Additional data on Kansas bridges with experimental concrete deck overlays.

Experimental Number	Maximum AADT	Pre-overlay chloride (lbs/yd^3) 1.5" depth	Structure Type*	Annual total cracking (ft/ft^2/yr)
1977 IA no. 1	5997	3.1	Continuous concrete box girder	0.17
1977 IA no. 2	9800	2.5	HRCDTG	0.54
1977 IA no. 3	9800	8.7	HRCDTG	0.14
1977 IA no. 6	390	5.8	Continuous concrete box girder	0.33
1977 IA no. 34	3205	6.9	Continuous concrete box girder	0.35
1977 IA no. 35	6070	1.5	Continuous concrete voided slab	0.25
1979 IA no. 14†	11845	1.7	Continuous concrete voided slab	0.49
1979 IA no. 24	3205	3.6	Continuous concrete box girder	0.37
1976 KS no. 1	8250	8.3	Continuous composite weathering steel box girder	0.36
1976 KS no. 2	7180	2.2	composite haunched steel welded plate girder	0.48
1976 KS no. 3	7650	2.4	composite haunched steel welded plate girder	0.51
1976 KS no. 4	7650	NA	composite haunched steel welded plate girder	0.33
1981 KS no. 5	1140	0.5	Continuous prestressed concrete beam	0.19
1981 KS no. 6	NA	1.27	Continuous steel beam	0.02

† - This bridge also had epoxy-coated reinforcing bar installed at the time of overlay construction.
+ - Overlay still in service as of January 2009.
NA - Data not available.

The efficiency of cleaning the old deck and reinforcing steel varied among the four Special Provisions. The 1976 Kansas System and the 1977 Iowa System Special Provisions required that all rust be removed from any reinforcing bar exposed in the process of removing unsound concrete from the bridge decks. Although this procedure might be expected to reduce the corrosion rate of the reinforcing steel, no correlation was found.

The decks with the highest chloride contents before the installation of the overlays had the highest overlay delamination rates and the largest total debonded areas (See Figure 2.1). The correlation between pre-overlay chloride content and total delamination was observed for all types of overlays and all types of bridge structures. This correlation was the strongest of any observed in this study.

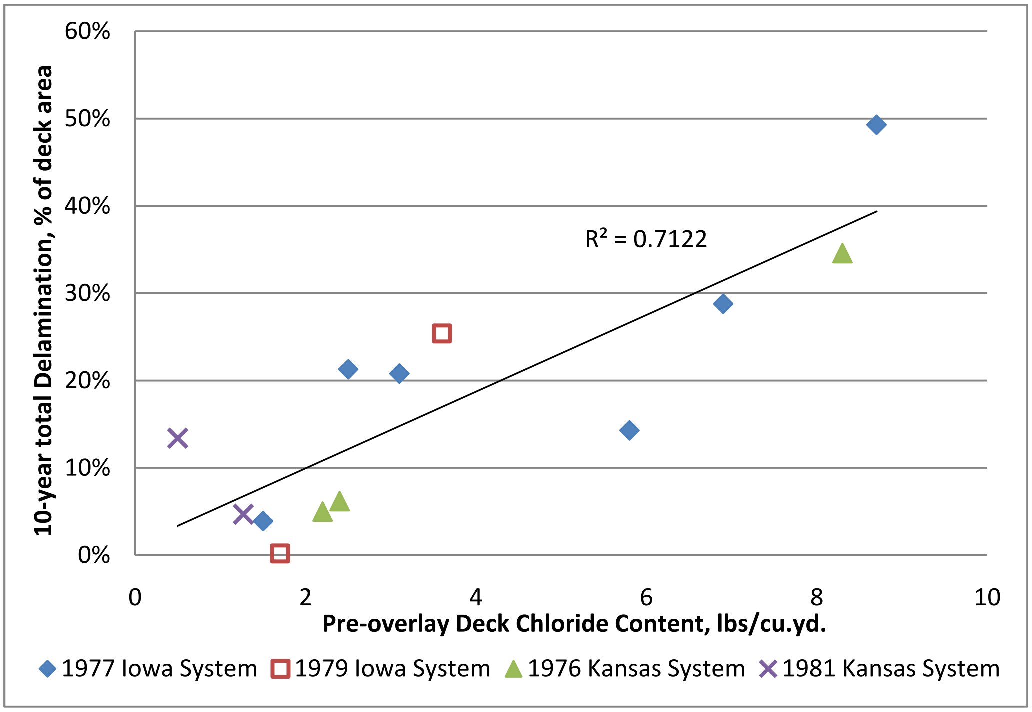

Figure 2.1: Correlation of deck chloride content and 10-year total delamination on Kansas bridges with experimental concrete deck overlays.

Bridge deck condition surveys conducted by the KDOT Geology Section on four 1979 Iowa System overlays offer some insight into the correlation between pre-overlay deck chloride content and post-overlay delamination. Cores taken as part of the surveys showed a consistent relationship between the depth of the overlay, the top mat of reinforcing steel and the level of delaminations. On average, the overlays were 2.75 inches thick and were well-bonded to the underlying deck concrete. The delaminations were found predominantly at the level of the reinforcing steel 4.5 inches below the surface, embedded an average of 1.75 inches in the existing chloride-contaminated deck concrete. None of the 40 cores showed evidence of the removal of the deck concrete to the level of the reinforcing steel or the cleaning of rust from the steel at the time of the overlay. The addition of the overlays may have prevented additional moisture from reaching the reinforcing bar but did not otherwise alter the immediate environment of the reinforcing bar. Delaminations that were developing in the bridge deck were slowed but not halted by the addition of the overlays.

The decks with the highest chloride contents before the installation of the overlays also had the highest total cracking rates (See Figure 2.2). The correlation between pre-overlay chloride content and total cracking rate was observed for all types of overlays and all types of bridge structures. The higher salt concentrations may have accelerated corrosion in these bridges, leading to increased cracking. Even though little correlation was observed between the chloride content of the concrete and the corrosion potentials measured, corrosion potential is not a measurement of the occurrence or rate of corrosion, just the potential for corrosion. Alternately, the chlorides themselves may have weakened the concrete, leading to cracking. Finally, the cracking and high chloride contents may both be related to some other attribute of the bridge deck concrete such as strength or permeability that was not recorded in the course of this study.

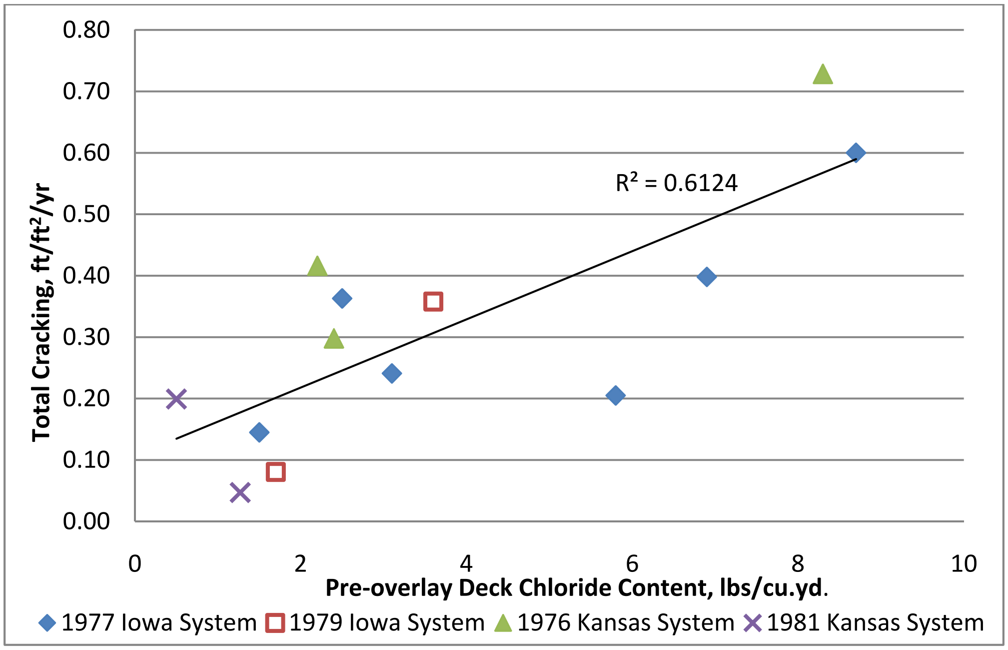

Figure 2.2: Correlation of deck chloride content and total cracking rate on Kansas bridges with experimental concrete deck overlays.

The correlation between the maximum traffic levels as measured in AADT (average annual daily traffic) and the rate of cracking overall was weak, but noticeable (see Figure 2.3). No consistent correlation was found between the maximum AADT and the longitudinal or the transverse cracking rates, or the rate of delamination.

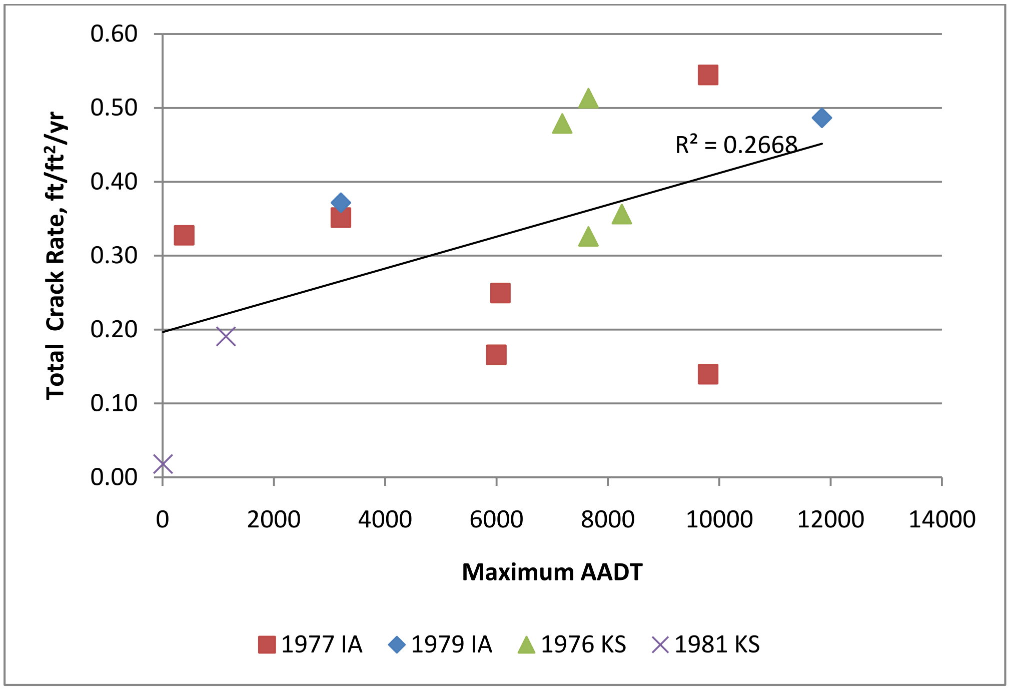

Figure 2.3: Correlation of maximum traffic In AADT and total cracking rate on Kansas bridges with experimental concrete deck overlays.

Structure type plays an important role in the type and extent of cracking on bridge decks. Steel girder bridges undergo more thermal stresses due to higher temperature variations and a higher coefficient of thermal expansion than concrete girder bridges, which contributes to more transverse deck cracking (Miller and Darwin, 2000). All of the 1976 Kansas System overlays and one of the 1981 Kansas System overlays (1981 KS no. 6) in this study were on steel girder bridges; all others were concrete structures of various types. The 1976 Kansas System overlays on steel girder bridges had a much higher ratio of transverse to longitudinal cracking than the Iowa System overlays that were constructed on concrete bridges with comparable traffic levels (See Figure 2.4). 1981 KS no. 6 atypically showed very little cracking for an overlay on a steel girder bridge. This may be due to the extremely low traffic levels and possibly lower use of deicing chemicals that this bridge sees in its remote rural location.

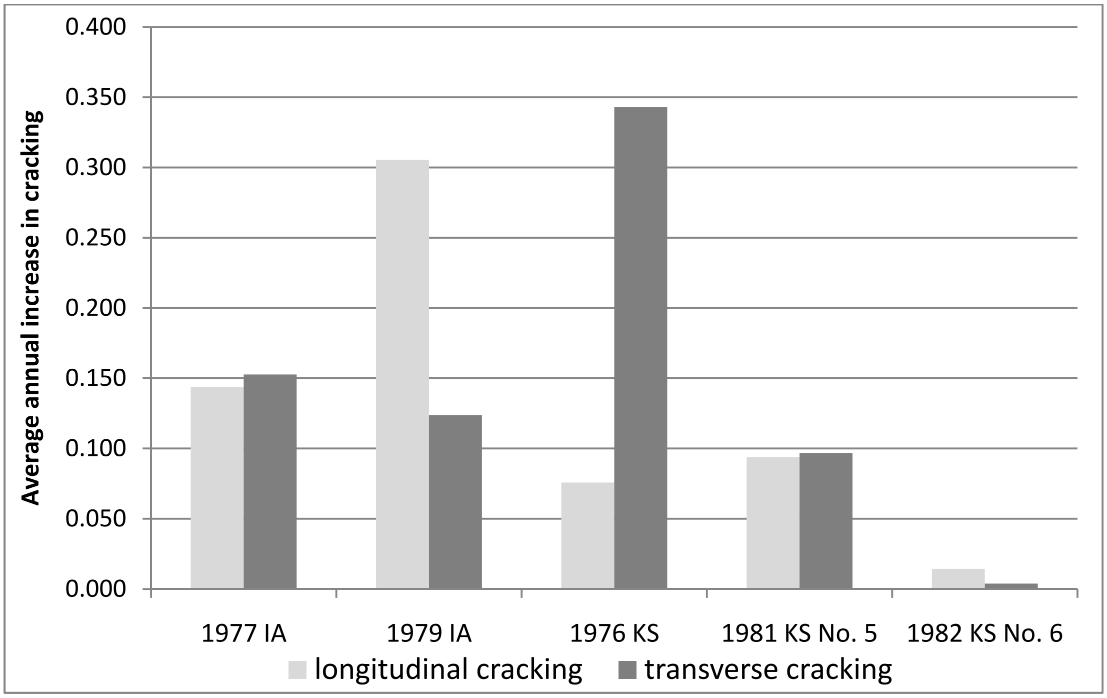

Figure 2.4: Annual average cracking rates on Kansas bridges with experimental concrete deck overlays.

Longitudinal cracking intensity does not typically show any correlation to bridge structure type (Freyermuth et al., 1970). Therefore, an examination of longitudinal cracking intensity can give some insight into cracking caused by materials, construction practices and environmental conditions. The 1976 and the 1981 Kansas System overlays had about half the longitudinal cracking of the 1977 IA System overlays. The 1979 IA System overlays showed twice the longitudinal cracking of the 1977 IA System overlays.

The higher cement content of the Iowa System Overlays may have made them more susceptible to longitudinal cracking due to curing and weather conditions at the time of construction. An increase in the temperature at the surface of the concrete can increase the evaporation rate leading to a lower ultimate concrete strength and enhanced susceptibility to cracking. Variations in construction practices such as the exact type and timeliness of curing application on individual bridges can also affect the likeliness of cracking. Construction records were not preserved for these overlays, so the exact weather conditions at the time of construction and curing techniques are not known. The KDOT has since incorporated monitoring of evaporation rate into bridge deck construction and requires that measures be taken to reduce the evaporation rate if it exceeds 0.2 pounds per square foot per hour.

The difference in cement content between the Kansas and Iowa Systems may also account for differences in corrosion performance. Well-consolidated concrete with a high cement content and a low water-cement ratio has been observed to provide effective corrosion protection on bridge decks (Kepler et al., 2000). In this study, the high cement content Iowa System overlays did show lower corrosion potentials than the Kansas System overlays.

CHAPTER 3 - ASPHALT OVERLAYS WITH INTERLAYER MEMBRANES

Two bridge decks in Wichita, Kansas were restored in 1985 using a Petromat interlayer membrane installed over a tack coat of AC-5 asphalt cement and then topped with a two-inch wearing course of BM-2 hot mix asphalt. Annual surveys on these bridges consisted of visual inspection on structures, chaining to check for delamination, resistivity readings and crack measurements. Both overlays were milled off and replaced in 2000. Table 3.1 lists two bridges surveyed for this project.

Table 3.1: Kansas bridges with experimental asphalt membrane bridge deck overlays.

Experimental Number	Bridge Name and Number	Bridge Type	Age at time of overlay	Overlay service life
Membrane 1	I-235 SB over Zoo Blvd 235-87-10.07(094)	Continuous concrete voided slab	14	15
Membrane 2	I-235 SB over Flood Canal 235-87-12.39(099)	Continuous haunched reinforced concrete deck T-girder	15	15

3.1 Materials and Construction Methods

Petromat is a non-woven polypropylene fabric with a textured side and a smooth side. In preparation for the overlays, all unsound concrete was removed from the bridge deck and concrete patches applied to those areas. The surface of the deck and the face of the curbs was cleaned using dry methods such as air jets, sweeping or sandblasting to remove all dirt, grease, salt deposits, loose material and any sharp protrusions from the surface. Next, an asphalt cement binder of type AC-5 was applied to the deck as a sealant. AC-5 was an asphalt cement with a penetration resistance of 85 to 100 at 77° F (KDOT, 1980). A calibrated distributor was used to ensure a uniform application of between 0.35 gallons per square yard residual asphalt and 0.40 gallons per square yard residual asphalt, depending on the depth of the texture of the bridge surface. After the sealant was in place, a machine was used to place the Petromat fabric onto the deck with the textured side facing down. Brooming then removed small air bubbles and ensured good contact between the fabric and the road surface. Larger wrinkles were slit and laid flat, then compacted. The fabric was lapped four to six inches at the edges and extra sealant was applied to ensure adhesion. At the curbs the fabric was turned up and applied to the curb to the height of the intended overlay. Paving followed as soon as the membrane cured. A two-inch wearing surface of BM-2 gradation hot-mix asphalt was placed over the membrane (KDOT, 1980). The complete construction specification is included in Appendix A.

3.2 Test Methods

The Concrete Research Section conducted annual surveys of delamination, electrical resistivity and cracking. A chain drag was used to identify delaminated areas on the deck, which were then plotted on a map. The total delaminated area was measured from the map and reported as a percentage of the deck area. Cracking was measured on the deck and plotted on crack maps for each bridge deck. Cracking data was normalized by dividing the total length of cracks by the total area of the bridge deck. *ASTM C 3633 Standard Test Method for Electrical Resistivity of Membrane-Pavement Systems* was used to measure the level of electrical connection between the surface of the bridge and the top mat of reinforcing steel. The level of resistivity can be used as an estimate of the efficacy of the membrane, as an electrical connection between the surface and the reinforcing steel cannot be made through an impermeable water-proofing membrane (ASTM C 3633). This method gives only an indirect indication of the possibility of corrosion in the reinforcing steel, not a measurement of the actual electrical activity in the steel itself. The measured level of resistivity is also an indication of the integrity of the membrane and the asphalt mat.

3.3 Results

A summary of the results of monitoring the two asphalt membrane bridge deck overlays in this program are presented in Table 3.2. A ten-year term was selected for reporting total delamination and total active corrosion area to reflect the stated intention of the program to extend the life of the bridge by ten to fifteen years. Complete data are presented in Appendix B.

Table 3.2: Results of complete surveys of Kansas asphalt membrane bridge deck overlays.

Experimental number	Annual delamination area increase	Total delamination at 10 years	Area above 100,000 ohms at 10 years	Annual longitudinal cracking ($ft/ft^2/yr$)	Annual transverse cracking ($ft/ft^2/yr$)
Membrane 1	0.27%	2.5%	74%	0.0012	0.0065
Membrane 2	0.21%	2.1%	91%	0.0747	0.0587

3.4 Discussion

The two Wichita bridges with the interlayer membranes saw the highest average annual traffic counts of any of the bridges in this study, and the deck surfaces performed admirably under these conditions. Fourteen years after installation, both decks received ratings of “Good” from KDOT Bridge Management Inspectors. The overlays successfully extended the life of the bridges by fifteen years.

These results are consistent with the findings of an earlier report that looked at the condition of six bridge decks that had asphalt interlayer membrane overlays installed between 1967 and 1971 after 20 to 25 years in service (Wojakowski and

Hossain, 1995). Three different types of membranes were considered in that study, including a preformed coal tar and polypropylene sheeting, a polyurethane elastomer membrane covered with an asphalt roofing sheet, and a non-woven polypropylene fabric. All three types of membranes were overlaid with hot-mix asphalt. The study found that the system most similar to Petromat using non-woven polypropylene membranes overlaid with hot-mix asphalt was the most effective.

Despite the outstanding performance of these overlays, Kansas has not used asphalt membrane overlays on a regular basis since 1977. Although asphalt membrane overlays were heavily promoted and their use was encouraged by the FHWA in the early 1970's, Kansas was reluctant to adopt the technology. In October 1976 a heavy-duty Bituthene interlayer membrane and asphalt overlay was installed on a bridge on US 281 in Barton County as part of the 1976 Federal-Aid Program for bridge deck corrosion prevention that also sponsored the installation of the concrete bridge deck overlays in the first section of this report . Interlayer membranes were believed to be the best system for protecting bridge decks from water and chloride infiltration at the time that the US 281 bridge was placed under contract (Hemphill, 1977). Between letting the contract and construction of the overlay numerous reports of membrane overlay problems and failures came in from other states. On the Barton County bridge, numerous blisters and air bubbles were trapped under the membrane, which caused the asphalt overlay to crack and spall off the deck almost immediately. The membrane manufacturer inspected the bridge deck and questioned the integrity and waterproofing capability of the membrane.

In February of 1977, six key KDOT personnel and two representatives of the FHWA met to discuss the Barton County bridge deck overlay failure (Hemphill, 1977). In the light of the evidence of the Barton County bridge and the reports of failures in other states, the consensus of those present was overwhelmingly against installation of any more interlayer membranes with asphalt overlays. They would “go with systems offering higher confidence factors for satisfactory protection of bridge decks”, especially Kansas System concrete overlays and Dow latex-modified concrete overlays (Hemphill, 1977). As a result, all contracts that called for asphalt membrane overlays were changed to concrete overlays and a concrete overlay was placed on the US 281 bridge.

Eight years would pass before another experimental installation of asphalt membrane overlays would be attempted. In the meantime, almost all of Kansas bridges with bare steel bars would either go out of service or would receive concrete overlays. Epoxy-coated reinforcement became the protective system of choice on new bridges. Currently, Kansas uses asphalt membrane overlays only as a rehabilitation measure on existing bridges with decks in very bad condition to extend the service life by three to five years (Whisler, 2009 and Hobson, 2009). The performance of Petromat membrane overlays is highly dependent on correct installation. When installed correctly, these overlays commonly exceed the three to five year service life expectation. However, asphalt membrane overlays deteriorate rapidly in Kansas’ harsh freeze-thaw conditions if moisture is allowed to penetrate beneath the membrane to the concrete below (Whisler, 2009). The KDOT also uses asphalt membrane overlays to reduce the added dead load when deck rehabilitation is needed on bridges with total load limitations (Meggers, 2009).

CHAPTER 4 - OVERALL COST EFFECTIVENESS

Cost data was available for only seven of the fourteen bridges constructed for this program (See Table 4.1). Three Iowa System overlays constructed in 1979 cost an average of $4.94 per square foot for overlay construction. Two Kansas System overlays (1976 KS no. 2 and 1976 KS no. 4) cost $3.44 per square foot in 1979 dollars. According to Cady (1981), asphalt membrane overlays cost $2.11 per square foot in 1979. Data from two other Shawnee County bridges very similar to the bridges evaluated in this research project is also included in Table 10. These two concrete hollow tube slab bridges were originally constructed in 1959 and 1960, then retrofitted in 1979 with epoxy-coated reinforcement and overlaid with 2.5" concrete cover over the top bars.

Table 4.1: Additional data on Kansas bridges with experimental concrete deck overlays.

Experimental Number	Maximum AADT	Overlay service life	Average deck condition rating	Initial Cost per square foot
1977 IA no. 2	9800	11	7.4	$ 4.26
1977 IA no. 3	9800	11	7.3	$ 4.26
1977 IA no. 6	390	29	6.5	$ 6.31
1976 KS no. 2	7180	23	6.5	$ 3.44
1976 KS no. 4	7650	28	6.8	$ 3.44
Membrane 1	16405	15	7.1	$ 2.11
Membrane 2	13390	15	7.0	$ 2.11
Retrofit Epoxy Steel Bar 1	17320	26	7.4	$ 27.66
Retrofit Epoxy Steel Bar 2	17320	26	7.4	$ 27.66

Bridge condition history was gathered from the bi-annual structural inventory compiled by the KDOT Bridge Management office. All Kansas bridges are inspected every two years and the data is compiled into a report that includes geometry, condition of deck, superstructure, substructure, channel, approach roadway and waterway (if applicable). The deck is rated on a scale of 1 (worst) to 9 (brand new), based on the percent of deck area observed to be deteriorated. Deck area deterioration includes spalls that expose reinforcing bars and delaminations (Wojakowski and Hossain, 1995). See Table 4.2 for details of the deck condition ratings.

Table 4.2: Bridge deck rating system used by the KDOT.

1	Closed
2	Critical Condition, should be closed
3	Unsafe, needs to be replaced
4	20-40% deck area deterioration
5	10-20% deck area deterioration
6	5-10% deck area deterioration
7	Less than 5% deck area deteriorated
8	Good condition, no repairs needed
9	New, not yet open to traffic

The Kansas System overlays were in fair condition after 23 years of service and in satisfactory condition after 28 years of service, respectively. Two of the three Iowa System overlays (1977 IA no. 2 and 1977 IA no. 3) were replaced after 11 years while still in good condition. The third overlay (1977 IA no. 6) was in fair condition after 29 years of service at very low traffic levels. The average service life of the Iowa System concrete overlays in this project was 15 years (See Table 4.3). The Kansas System overlays had a total average service life of 22 years. The two membrane overlays in this project had 15 year service lives. Using Cady's (1981) estimate of the installation cost of membrane overlays and the average service life of each of the three types of overlays discussed in this paper, an average cost per year can be calculated as a rough estimate of the cost-effectiveness. All cost data were converted to 1979 values by applying factors based on the Federal-Aid Composite Bid Price Index (Cady, 1981).

Table 4.3: Estimation of relative annual cost of bridge deck overlays used in Kansas.

	Average Initial Cost per ft^2	Average Service Life, yrs.	Average deck condition rating	Cost per Year/ft^2
Retrofit Epoxy-Steel Bars	$27.66	26	7.4	$ 1.06
Iowa System Overlays	$ 4.94	15	7.4	$ 0.32
Kansas System Overlays	$ 3.44	22	6.6	$ 0.16
Membrane Overlays	$ 2.11*	15	7.1	$ 0.12

*Average cost from five states reported in Cady, 1981

As can be seen from Table 4.3, the most cost effective rehabilitation technique may have been the membrane overlays, with an average annual cost of $0.12 per square foot per year of service life. Kansas System overlays were a close second, at $0.16 per square foot per year of service life. Iowa System overlays were twice as expensive as the Kansas System overlays per year of service life per square foot. Retrofitting epoxy-covered steel bars was the least cost-effective alternative at the time with an annual cost over three times that of the Iowa overlays.

CHAPTER 5 - CONCLUSIONS

These overlays were state-of-the-art solutions to the problems of bridge deck deterioration at the time they were introduced in the 1970's and 1980's. Since that time the need for wide-spread bridge deck reconstruction has been largely eliminated through the use of thicker concrete cover over the top mat of reinforcing steel, epoxy-coated reinforcing bars and low-permeability silica fume overlays in new construction.

1. All four types of thin-bonded concrete overlays performed very well and met the program goals of extending the life of the bridge surface by ten to fifteen years. Fully one-half of these overlays were in service for over twenty years.

2. The correlation of high chloride contents in the old deck concrete with high rates of overlay delamination suggests that efficient cleaning and removal of heavily salt-contaminated concrete from old bridge decks may enhance the performance of thin-bonded concrete overlays. The removal of all salt-contaminated concrete was not required as part of this experimental program. Although the overlays did meet the program goals for extending the life of the structures, thorough removal of all heavily salt-contaminated concrete prior to overlay construction may extend the life of the overlay even further.

3. Cracking performance did not correlate to either cement content or to the practice of soaking the deck for 24 hours before the placement of the overlay.

4. Both asphalt membrane bridge deck overlays surveyed for this project performed very well, showing little distress even after fifteen years of service on a heavily travelled route.

5. Membrane overlays were the most cost effective alternative explored in this program. Kansas System bonded concrete bridge deck overlays were a close second in terms of cost-effectiveness. Kansas System overlays were estimated to be twice as cost effective per year of service life as the Iowa System overlays.

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APPENDIX A - KDOT SPECIAL PROVISIONS FOR BRIDGE DECK RECONSTRUCTION

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
TO THE
STANDARD SPECIFICATIONS
EDITION OF 1973

Note: Whenever this Special Provision conflicts with the Plans, Supplemental Specifications or Standard Specification, this Special Provision shall govern.

73P 87R: THIN BONDED CONCRETE OVERLAY—MACHINE PREPARATION

DESCRIPTION:

This work shall consist of furnishing all labor, materials and equipment including an approved grinding device; and performing all work necessary to remove all bituminous seal and bituminous patches and all unsound concrete, as well as the surface from sound areas, from the roadway surface of the entire bridge to the depth specified, and by bonding by means of Portland cement grout, new Portland cement concrete as required to bring the surfaces of the concrete to the lines and grade shown on the plans.

Bid Items:
THIN BONDED CONCRETE OVERLAY-MACHINE PREPARATION
AREA PREPARED FOR PATCHING

1) MATERIALS:

Portland cement. Standard Specifications, Edition of 1973.

a) Course Aggregate. Standard Specifications, Edition of 1973, article 1001.02 (a), except grading, which shall be as follows:

Sieve Size	Percentage Retained
¾”	0
1/2"	0-10
3/8"	30-50
#8	90-100

b) Fine Aggregate. Standard Specifications, Edition of 1973, article 1001.02 (c), type FA-A, except grading, which shall be as follows:

Sieve size	percentage retained
3/8"	0
#4	0-5
#16	20-40
#50	75-85
#100	85-95

1. Fine Aggregate for grout. Standard Specifications, Edition of 1973, article 1001.02 (e), type FA-M.
2. Water. Standard Specifications, Edition of 1973, subsection 1014.01.
3. Curing Materials. Standard Specifications, Edition of 1973, section 1004.
4. Admixtures. Standard Specifications, Edition of 1973, section 1004.
5. Precure Material. This material shall be an approved material such as master builders "Confilm" or equal, capable of producing a monomolecular film over freshly placed concrete and grout.

2) CONSTRUCTION REQUIREMENTS:

a) Work sequence. Traffic shall be provided for as shown on the plans or as directed by the engineer.
b) Removal of Old Concrete. Unsound concrete and bituminous patching, as shown on the plans and/or delineated by the engineer, shall be removed to what ever depth is necessary to reach sound concrete and rust free reinforcing steel. The materials removed shall be disposed of on sites approved by the engineer. This unsound concrete, to the extent practicable and concrete to a depth of 1/4" over the remaining area of the deck shall be removed by means of a machine capable of scarifying, cutting, scabbling, or otherwise removing the required concrete, without injury to the sound concrete. Air driven chipping tools not exceeding 30 lbs. In weight may be used to complete cut out of unsound concrete.
c) Cleaning of Concrete Surface and Reinforcing Steel. All scale and heavy rust shall be removed from steel bars by sand blasting. Wet sand blasting will not be permitted. T he bottom 3" of hubguard shall also be sand blasted to clean sound concrete. If delays caused by weather or other reasons occur the engineer may require that sand blasting be repeated. Final cleanup shall be accomplished with a high pressure water jet with a minimum pressure of 3,500 psi.
d) Preparation of Surface for Grout. For a period of not less than twenty-four (24) hours before grout is applied all surfaces to be covered shall be kept wet. A double layer of burlap and sprinklers shall be used. Before grout is applied, however, all free water shall be blown out, and off, and this procedure shall be continued until the surface appears dry, or just barely damp.
e) Application of Portland Cement Grout. A slurry of Portland cement grout shall be brushed and scrubbed into all portions of the concrete to be overlaid, including

those areas under reinforcing steel if it has been found necessary to remove concrete to that depth. The grout shall consist of a one to one (1:1) by weight mixture of Portland cement and fine aggregate with sufficient water added to produce a "heavy cream" consistency. The grout shall not be allowed to show signs of drying before the resurfacing concrete is applied. If grout is allowed to dry out, a header shall be placed, and no further concreting shall be done until the old grout has been removed and the surface again sand blasted. Special care shall be exercised to avoid thick grout near hubguards and headers.

f) Composition and Consistency of Concrete. Concrete shall be class AAA (AE) in all respects and the proportions of fine and coarse aggregate shall be equal by weight. The slump shall not exceed one-half (1/2) inch. It will be required that mixers of the paddle or pugmill type or other approved be used. Each batch shall be mixed two (2) minutes.

g) Placing and Consolidating Concrete. Concrete shall be carefully placed by shoveling to prevent all segregation. This is particularly important where new concrete meets old at the hubguard or at centerline or other construction joints. The concrete shall be tamped into place using hand tamps with not more than thirty-six (36) square inches of face. Tamping shall be preceded by passes with a spud vibrator which shall be moved along touching the old concrete underneath. A vibrating screed may be used for strike off.

h) Finishing. Finishing shall be accomplished by means of a Kelly vibrator compactor or other approved, and circular power floats. If satisfactory finish can be obtained with the Kelly compactor alone the circular power floats will not be required. These tools shall be operated in a direction parallel to centerline insofar as possible. When finishing along edges against existing concrete care shall be exercised that the trailing edge of the float is moving towards the old concrete. Other equipment and/or methods, approved by the engineer, may be used in lieu of these floats provided satisfactory results are obtained. Surface variations exceeding one-eighth (1/8) inch in ten (10) feet shall be corrected. A light brooming shall be used for final finish.

i) Curing. Immediately after completion of finishing the concrete surface shall be cured by one of the following methods: wet burlap cure, polyethylene sheets covered with wet burlap or a minimum of two (2) inches of wet sand. The curing material shall be kept in place on the surface of the concrete and continuously wet for the entire curing period. This period shall be not less than (72) hours.

j) Concreting in Hot Weather. Standard specifications concerning hot weather concreting shall apply and in addition monomolecular film shall be used to prevent rapid evaporation of water rising to the surface of both grout and concrete. Use of this film in no way alters the requirements for curing as provided in (I), it is used to prevent rapid evaporation between the initial strike off and brooming prior to covering with polyethylene sheeting. One or more light applications of this material may be required depending on the weather and sequence of consolidating and finishing operations. Hot weather shall be defined as weather with temperatures over 70°F, or when combinations of temperature, low humidity, and wind create conditions which, in the judgment of the Engineer, require hot weather procedure.

k) Concreting in Cold Weather. Except by specific written authorization concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 45° F, nor shall operations be started or resumed until an ascending air temperature reaches 40° F., nor shall operations be carried on when night time temperatures are expected to fall below 35° F.

l) Placement of Centerline Form and Headers. If these forms cannot be held in place in a manner preventing movement during consolidating and finishing the following procedure shall be required before new concrete is placed against hardened concrete from previous placements the older concrete shall be sawed back six (6) inches and chipped away before new concrete is placed.

m) Correction of Unbounded Areas. If, during construction of the project newly overlain areas are discovered by tapping to be unbonded, concrete from such areas shall be outlined by sawing, removed with small air tools and replaced by the contractor at no additional compensation.

3) METHOD OF MEASUREMENT:

The "Area Prepared for Patching", shall be determined by State Forces by tapping the bridge deck after any asphaltic concrete overlay and the top one quarter (1/4) inch of Portland cement concrete surface has been removed. The “Area Prepared for Patching ", shall be measured by the square yard to the nearest one tenth (1/10) square yard. "Thin Bonded Concrete Overlay-Machine Preparation", shall be measured by the square yard to the nearest one tenth (1/10) square yard.

4) BASIS OF PAYMENT:

The amount of completed and accepted work, measured as provided above, shall be paid for at the contract unit price bid, per square yard for " Area Prepared for Patching", and upon approval of the Engineer, areas to be patched which require forming of the underside shall be paid for at a rate of 1 1/2 times the contract unit price bid, per square yard for " Area Prepared for Patching,", which shall include grinding and chipping out unsound concrete and bituminous patches, per square yard for " Thin Bonded Concrete Overlay-Machine Preparation ", which shall include grinding the sound areas, sand blasting steel where needed and the bottom 3" of the hubguards and median, preparing the entire area of the deck for overlay, and grout and concrete overlay, which prices shall be full compensation for furnishing and placing all materials, and for all labor, equipment, tools and incidentals necessary to complete the work.

5-24-76

KANSAS DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION TO THE STANDARD PROVISIONS EDITION OF 1973

NOTE: Whenever this Special Provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

73P-1210: BRIDGE DECK OVERLAY

1.0 DESCRIPTION: The work shall consist of furnishing all labor, materials and equipment including an approved grinding device; and performing all work necessary to remove all Bituminous Seal and Bituminous Patches and all unsound concrete, as well as the surface from the sound areas, from the roadway surface of the entire bridge to the depth specified, and by bonding by means of Portland Cement Grout, New Portland Cement Concrete overlay as required to bring the surfaces of the concrete to the lines and grade shown on the Plans.

Bid Items:
Bridge Deck Overlay
Area Prepared for Patching

2.0 MATERIALS:

(A) Portland Cement, Type II, Standard Specifications, Edition of 1973.

(B) Coarse Aggregate. Standard Specifications, Edition of 1973, Article 1001.02 (A). Except grading, which shall be as follows:

Sieve Size	Percentage Retained
¾”	0
½”	0-10
3/8”	30-50
#8	90-100

(C) Fine Aggregate. Standard Specifications, Edition of 1973, Article 1001.02 (C), Type FA-A.

(D) Fine Aggregate for Grout. Standard Specifications, Edition of 1973, Article 1001.02 (E), Type FA-M.

(E) Water. Standard Specifications, Edition of 1973, Subsection 1014.01.

(F) Curing Materials. Standard Specifications, Edition of 1973, Section 1004.

(G) Admixtures.

(1) Air Entraining Admixture. Standard Specifications, Edition of 1973, Section 1004.

(2) Water Reducing Admixture. ASTM C 494, Type A. Basis of acceptance shall be by Type D Certification.

(H) Precure Material. This material shall be an approved material capable of producing a monomolecular film over freshly placed concrete.

3.0 EQUIPMENT: Equipment used shall be subject to approval of the Engineer and shall comply with the following:

(A) Surface preparation equipment shall meet the following requirements:

(1) Sand-blasting equipment shall be capable of removing rust, oil and laitance from the existing surface of the bridge deck. Wet sand blasting shall not be permitted.

(2) Power-driven hand tools will be permitted with the following restrictions:

(a) Air driven chipping tools not exceeding 30 lbs. in weight (unless shown otherwise on the Plans) may be used to complete cut out of unsound concrete. Chipping tools shall not be operated at an angle in excess of 45 degrees measured from the surface of the roadway.

(B) Proportioning and Mixing Equipment. This equipment shall meet the requirements of Section 401 of the Standard Specifications with the following exceptions:

A construction skip type mixer, stationary concrete mixer of the rotating-paddle type, or a continuous mixer used in conjunction with volumetric proportioning, will be required. For batch mixers, a two (2) minute minimum mix time is required, Sufficient mixing capacity or mixers shall be provided to permit the intended pour to be placed without interruption.

If a continuous mixer using volumetric proportioning is used it shall meet the following:

(1) The mixer shall be self-propelled and shall be capable of carrying sufficient unmixed, dry, bulk cement, sand, coarse aggregate, admixtures and water to produce on the site not less than 6 cubic yards of concrete.

(2) The mixer shall be capable of positive measurement of cement being introduced into the mix. A recording meter visible at all times shall indicate this quantity.

(3) The mixer shall provide positive control of the flow of water and admixture into the mixing chamber. Water flow shall be indicated by a flow control valve and shall be readily adjustable to provide for minor variations in aggregate moisture.

(4) The mixer shall be capable of being calibrated to automatically proportion and blend all components of indicated composition on a continuous or intermittent basis as required, The calibration shall be performed in accordance with the manufacturer’s recommendations.

(5) A water flow meter that will indicate to the nearest 0.10 gallon the number of gallons used shall be provided on the mixer.

(6) Permission to continue operation of the mixer may be rescinded upon failure to maintain acceptable production within the limits of the specifications.

(C) Placing and Finishing Equipment. This equipment shall include adequate hand tools for placement of stiff plastic concrete and for working down to approximately the correct level for striking-off with the finishing screed. A finishing machine complying with the following requirements shall be used. The finishing machine shall be inspected and approved by the Engineer before work is started on each project.

The finishing machine shall consist of a mechanical strife-off capable of providing a uniform thickness of concrete slightly above finish grade in front of an oscillating screed or screeds.

At least one oscillating screed shall be designated to consolidate the concrete by vibration to 100 percent of the unit weight, determined with KT-20 modified, by vibration.* A sufficient number of identical vibrators shall be effectively installed such that at least one vibrator is provided for each 5 feet of screed length. The bottom face of this screed shall be at least 5 inches (12.7 centimeters) wide with a turned up or rounded leading edge to minimize tearing of the surface of the plastic concrete. Each screed shall have an effective weight of at least seventy-five pounds for each square foot of bottom face area. Each screed shall be provided with positive control of the vertical position, the angle of tilt, and the shape of the crown. Design of the finishing machine together with the appurtenant equipment shall be such that positive machine screeding of the plastic concrete will be obtained as close as practical to the face of the existing curb line. The length of the screed shall be sufficient to extend at least 6 inches (15.2 centimeters) beyond a line where a joint is intended to form the edge of a subsequent placement section, and shall overlap the sawn edge of a previously placed course at least 6 inches (15.2 centimeters). The finishing machine shall be capable of forward and reverse motion under positive control. Supporting rails upon which the finishing machine travels will be required on all projects. The support rails shall be sufficiently rigid that they do not deflect under the weight of the machine. Anchorage for supporting rails shall provide horizontal and vertical stability. When placing concrete in a lane abutting a previously completed lane, the side of the finishing machine adjacent to the completed lane shall be equipped to travel on the completed lane.

*See attached KT-20 Modified Test Procedure.

4.0 CONSTRUCTIONS REQUIREMENTS: Traffic shall be provided for as shown on the Plans or as directed by the Engineer.

(A) Preparation of Surface-Existing Deck.

(1) Removal of old concrete, unsound concrete and bituminous patching, as shown on the Plans and/or delineated by the Engineer, shall be removed to whatever depth is necessary to reach sound concrete and rust free reinforcing steel. The materials removed shall be disposed of on sites approved by the Engineer.

This unsound concrete, to the extent practicable, and concrete to a depth of ¼" over the remaining area of the deck shall be removed by means of a machine capable of scarifying, cutting, scabbling or otherwise removing the required concrete, without injury to the sound concrete. Air driven chipping tools not exceeding 30 lbs. in weight may be used to complete cut out of unsound concrete.

(2) Cleaning of concrete surface and reinforcing steel. All scale and heavy rust shall be removed from steel bars by sand blasting. Wet sand blasting will not be permitted. The bottom 3” of hubguard shall also be sand blasted to clean sound concrete. If delays caused by weather or other reasons occur the Engineer may require that sand blasting be repeated. Final cleanup shall be accomplished with a high pressure water jet with a minimum pressure of 3,500 psi.

(B) Preparation of Surface-New Concrete Deck

(1) Preparation of Surface. All lose, disintegrated or unsound concrete shall be removed from the bridge floor as designated by the engineer.

(2) Prior to applying grout in preparation for placement of new concrete overlay, the surface shall be sand blasted followed by an air blast. The sand blast shall be of such an extent as to remove all dirt, oil and other foreign material, as well as any unsound concrete or laitance from the surface and edges against which new concrete is to be placed. Metal floor drains and areas of the curb or railing above the proposed surface shall be protected from the sand blast. The bottom 3” of hubguard shall be sand blasted to clean sound concrete. It is desired that the surface be roughened by the sand blast to provide satisfactory bond with the surfacing concrete.

(C) Portland Cement Grout. Grout shall consist of a one-to-one (1:1) by weight mixture of portland cement and fine aggregate (FA-M) with sufficient water added to produce a “heavy cream” consistency.

The consistency of the grout slurry shall be such that it can be applied with a stiff brush or broom to the previously placed concrete in a thin, even coating that will not run or puddle in low spots.

For sealing vertical joints between adjacent lanes and at the curbs, this grout may be thinned to paint consistency.

Preparation of Surface for Grout. For a period of not less than twenty-four (24) hours before grout is applied all surfaces to be covered shall be kept wet. A double layer of burlap and sprinklers shall be used. Before grout is applied, however, all free water shall be blown out, and off, and this procedure shall be continued until the surface appears reasonably dry.

Application of Portland Cement Grout. A slurry of Portland cement grout shall be brushed and scrubbed into all portions of the concrete to be overlaid, including those areas under reinforcing steel if it has been found necessary to remove concrete to that depth. The grout shall not be allowed to show signs of drying before the resurfacing concrete is applied. If grout is allowed to dry out, a header shall be placed, and no further concreting shall be done until the old grout has been removed and the surface again sand blasted. Special care shall be exercised to avoid thick grout near hubguards and headers.

(D) Proportioning and Mixing of Concrete Overlay Materials. The applicable provisions of Section 402 of the Standard Specifications shall apply with the following exceptions and additional provisions:

(1) Concrete shall be mixed at the project site. Ready-mixed concrete will not be approved. Continuous mixers, if used, shall be charged at the site.

(2) Water-reducing admixture for improved workability, if used, shall be mixed and incorporated in the concrete mixture in accordance with the manufacturer's recommendations and the Engineer's instructions.

Proportioning. Concrete for bridge deck overlay shall comply with the following requirements:

Lbs. of Cement Per Cu. Yd., Min.	Gallons of Water Per sack, Max.	Percent of Air By Volume
825 lbs.	4.0	6.5 ± 1.0 **

**As determined by KT-19 only (Rollometer)

A water-reducing admixture for improving workability may be required. Use of such admixture shall be approved by the Engineer.

The slump shall not exceed ¾ inch.

The commencement of tests shall be delayed from 4 to 4½ minutes after the sample has been taken from a continuous mixer. If a batch type mixer is used the tests shall commence immediately.

Aggregates shall be combined such that the proportions of coarse and fine aggregate shall be equal be weight.

(E) Placing and Finishing Concrete. A finishing machine meeting the requirements stipulated in Section 3.0 (C) will be required. Screed rails shall be placed and fastened in position to insure finishing the concrete to the required profile. The supporting rails upon which the finishing machine travels shall be placed outside the area to be concreted. A hold-down device shot into concrete will not be permitted unless the concrete is to be subsequently surfaced. Hold-down devices of other types leaving holes in exposed areas will be approved provided the holes remaining are grouted full. Methods for anchoring and supporting the rails and the concrete placing procedure shall be approved by the Engineer.

The thickness of all new concrete overlay above the prepared surface shall be as specified on the Plans. The clearance shall be checked in the following manner before concrete is placed.

A filler block having thickness ¼ inch less than the designated surface thickness shall be attached to the bottom of the screed; with the screed guides in place, the screed shall be passed over the area to be concreted. As an alternate to the passage of the finishing machine, an approved template, supported by the screed guides, may be passed over the area to be concreted. If the filler block does not clear the area to be concreted, the profile of the new surface shall be adjusted as approved by the Engineer.

Longitudinal joints will be located in accordance with details shown on the Plans or as approved by the Engineer. The joints shall be kept clear of wheel paths as much as practical.

The concrete shall be produced and placed within the specified limits in as continuous and uniform of an operation as practical. After the surface has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the prepared surface. Care shall be exercised to insure that all parts receive a thorough, even costing and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete overlay. If the grout is allowed to dry out, a header shall be placed and no further concreting shall be done until the old grout has been removed and the surface again sand blasted. The new concrete overlay shall be manipulated, mechanically struck off and mechanically consolidated to within a minimum of 98% of the rodded unit weight and screeded to final grade. Hand tamping is encouraged to assist in consolidation and bonding of the concrete. The Engineer may use an approved Nuclear Density Measuring device to monitor in-place density. Hand floating operations may be required to produce a tight, uniform surface. The contractor shall take every reasonable precaution to secure a smooth riding bridge deck. Surface variations exceeding 1/8 inch (0.3 centimeter) in 10 feet (3.05 meters) shall be corrected.

When a tight, uniform surface has been achieved, the surface shall be given a suitable texture by transverse grooving with a wire broom or comb having a single row of times. The grooving may vary from 1/8” (0.32 centimeter) width at ½-inch (1.25 centimeter) centers to 3/16-inch (1/2 centimeter) centers, and the groove depth should be approximately 1/8 inch to 3/16 inch. This operation shall be done at such time and in such manner that the desired texture will be achieved while minimizing displacement of the larder aggregate particles. The transverse grooving should terminate approximately 2 feet in from the gutter line at the base of the curbs. Finishing has been completed, all vertical joints with adjacent concrete shall be sealed by painting with thinned grout.

(F) Curing. Immediately after completion of finishing operations, the concrete surface shall be cured by one of the following methods: Wet burlap cure, polyethylene sheets, or a minimum of two (2) inches of wet sand. The curing material shall be kept in place on the surface of the concrete and continuously wet for a period of 72 hours.

The curing material shall be applied as soon as possible after the finishing operation without marring the surface as directed by the Engineer. Damage created by a failure to apply curing materials at the proper time may be cause for rejecting the work so affected. Surface concrete in the rejected area shall be removed at no additional cost to the contracting authority.

(G) Concreting in Hot Weather. Standard specifications concerning hot weather concreting shall apply and in addition monomolecular film may be used only to prevent rapid evaporation of water rising to the surface of the concrete, it should not be used to work up grout as an aid to finishing operations. Use of this film in no way alters the requirements for curing as provided. It is used only to prevent rapid evaporation between the initial strike off and brooming prior to covering with the curing media. One or more light applications of this material may be allowed depending on the weather and sequence of consolidating and finishing operations. Monomolecular film may be used at temperatures over 70 °F (21 °C), or when combinations of temperature, low humidity, and wind create conditions which, in the judgment of the engineer, require hot weather procedure.

(H) Concreting in Cold Weather. Except by specific written authorization concreting operations shall not be continued when a descending air temperature in the shade and away from art1f1cal heat falls below 45°F (7°C), nor shall operations be started or resumed until an ascending air temperature reaches 40°F (4°C), nor shall operations be carried on when night time temperatures are expected to fall below 35°F (2°C).

(I) Limitations of Operations. Work on the surface shall not be commenced until the lower course meets the time and/or strength requirements of Section 701 of the Standard Specifications unless specified otherwise on the Plans.

Concrete shall not be placed adjacent to a surface overlay course less than 36 hours old; however, this restriction does not apply to a continuation of placement in a lane or strip beyond a transverse joint in the same lane or strip.

In areas where there is no traffic, preparation of the area may be started in a lane or strip adjacent to newly placed surface the day following its placement. If this work is started before the end of the 72-hour curing period, the work will be restricted as follows:

Sawing or other operations shall interfere with the curing process for the minimum practical time only, and in the immediate work area only, and the curing shall be resumed promptly upon completion of the work. The exposed area shall be kept damp until such time as the curing media is replaced. No power-driven tools heavier than a 15-pound chipping hammer shall be used.

No traffic shall be permitted on a finished surface course until 72 hours after placement. At temperatures below 55 degrees F, the Engineer may require a longer waiting time.

(J) Placement of Centerline Form and Headers. If these forms cannot be held in place in a manner preventing movement during consolidating and finishing the following procedure shall be required. Before new concrete is placed against hardened concrete from previous placements the older concrete shall be sawed back six (6) inches and chipped away before new concrete is placed.

(K) Correction of Unbounded Areas. If, during construction of the project newly overlain areas are discovered by tapping to be unbonded, concrete from such areas shall be outlined by sawing, removed with small air tools and replaced by the Contractor at no additional compensation.

4.0 METHOD OF MEASUREMENT: The "Area Prepared for Patching", shall be determined by state forces by tapping the bridge deck after any asphaltic concrete overlay and the top one quarter (1/4) inch of Portland Cement Concrete Surface has been removed. The "Area Prepared for Patching", shall be measured by the square yard to the nearest one tenth (1/10) square yard. "Bridge Deck Overlay", shall be measured by the square yard to the nearest one tenth (1/10) square yard.

5.0 BASIS OF PAYMENT: The amount of completed and accepted work, measured as provided above, shall be paid for at the contract unit price bid, per square yard for "Area Prepared for Patching ", and upon approval of the engineer, areas to be patched which require forming of the underside shall be paid for at a rate of 1 1/2 times the contract unit price bid, per square yard for "Area Prepared for Patching ", which shall include grinding and chipping out unsound concrete and bituminous patches, per square yard for " Bridge Deck Overlay", which shall include grinding the sound areas, sand blasting all areas as required, preparing the entire area of the deck for overlay, and grout and concrete overlay, which prices shall be full compensation for furnishing and placing all materials, and for all labor, equipment, tools and incidentals necessary to complete the work.

The quantities for Bridge Deck Overlay for which payment will be made shall be the quantities shown on the Plans provided the project is constructed essentially to the lines and grades shown on the Plans.

When the Plans have been altered or when disagreement exists between the Contractor and the Engineer as to the accuracy of the plan quantities, either party shall have the right to request and cause the quantities involved to be measured in accordance with measured quantities.

Water reducing admixture, if used, will be paid for in accordance with Section 402.09 of the Standard Specifications.

KT-20 MODIFIED TEST PROCDURE ATTACHMENT

5.16.20 Weight per Cubic Foot, Yield, and Air Content (Gravimetric) Of Fresh Concrete (Kansas Test Method (KT-20-75)

(A) SCOPE - This method of test covers the procedure for determining the weight per cubic foot) of freshly mixed concrete and gives formulae for calculating the following values:

(1) The volume of concrete produced from a mixture of known quantities of variable materials.

(2) The yield, which is the volume of concrete per unit volume of cement.

(3) The actual cement factor.

(4) The air content of the concrete.

NOTE: This method of calculating air content is of value when equipment is not available for making the test in accordance with more convenient methods such as KT-18 and KT-19. This gravimetric method is not applicable for concrete or mortar made with highly porous aggregates.

(B) APPARATUS

(1) Balance readable to within 0.01 lb. and sensitive to within 0.05 lbs.

(2) Tamping rod shall be a straight steel rod 5/8 in in diameter, approximately 24 in long and rounded to a hemispherical tip on the tamping end.

(3) Cylindrical measure fabricated of steel or cast aluminum having a nominal inside diameter of 10 in. and a nominal inside height of 11 in. and capacity of approximately ½ cu. Ft. The wall thickness shall be sufficient to insure adequate rigidity during testing procedures. It is recommended that the measure be equipped with a handle to facilitate lifting and carrying.

(4) Heavy glass cover plate somewhat larger than the top of the measure for accurately striking off and leveling the surface of the concrete.

(5) Hand Scoop.

(6) Large Trowel.

(7) Mallet with rubber or rawhide head weighing approximately ½ lb.

(8) Internal vibrator

A. Internal vibrators may have rigid or flexible shafts, preferably powered by an electric motor. The diameter of the vibrating element shall be not less than 0.75 in. or more than

1.50 in. and the length of the shaft should be 24 in. or more. The frequency of vibration shall be 7,000 VPM or greater. A tachometer should be used to check the frequency of vibration while in use.

(C) CALIBRATION OF MEASURE, AND CALIBRATION FACTOR

(1) Determine the weight of the empty measure (coated with grease on the top rim if necessary) and cover plate to the nearest 0.1 lb) and record.

(2) Fill the measure with water, using the cover plate to insure that it is exactly full.

(3) Weigh and record the weight of the measure, water, and cover plate.

(4) Calculations:

$$V = \frac{B-C}{62.4}$$

Where:

V = Volume of the measure in cu. ft.

B = Weight of measure filled with water plus glass cover plate.

C = Weight of measure and glass cover plate.

$$F = \frac{62.4}{B-C}$$

Where:

F = Calibration Factor.

(D) TEST PROCEDURE

(1) Obtain a sample of fresh concrete in accordance with Test Method KT-17.

(2) Methods of Consolidation: Concretes at different slump levels require different methods of consolidation to prepare satisfactory test specimens. The methods listed below should be used as a guide in determining the type of consolidation to use:

Slump of Concrete	Type of Consolidation
More than 3”	Rodding
1”to 3”	Rodding or Vibration
less than 1”	Vibration

(3) Rodding Procedure.

a. Place concrete in the measure in three equal layers.

b. Rod each layer 25 times. When rodding the first layer, avoid striking the bottom of the container. When rodding successive layers, use only enough force to penetrate the surface of the underlying layer.

c. After each layer is rodded, spade around the sides to the depth of each layer.

d. After each layer is rodded and spaded, tap the exterior surface of the base with the mallet a sufficient number of times to eliminate the voids left by rodding and spading. Discontinue tapping when mortar begins to appear on the surface of the layer

e. Strike off the top surface of the concrete and finish it smooth with the cover plate using great care to leave the measure just level full.

f. Clean all excess concrete from the exterior of the filled measure and the cover plate. With the cover plate in place weigh the measure, concrete and cover plate to the nearest 0.1 lb. and record the weight.

(4) Vibration Procedure.

a. Fill the measure approximately 1/2 full of concrete. Place all the concrete required for the layer in the measure before starting vibration.

b. Vibrate until the layer is properly consolidated. The duration of vibration will depend on the effectiveness of the vibrator and the consistency of the concrete, but usually sufficient vibration has been applied when the surface of the concrete becomes relatively smooth in appearance.

c. Fill the measure to an elevation somewhat above the top rim and vibrate this second layer.

A small quantity of concrete may be added to correct a deficiency. If the measure contains a great excess of concrete at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately and before the measure is struck-off.

d. Strike off the top surface of the concrete and finish it smooth with the cover plate using great care to leave the measure just level full.

e. Clean all excess concrete from the exterior of the filled measure and the cover plate. With the cover plate in place weigh the measure, concrete and cover plate to the nearest 0.1 lb. and record the weight.

f. Special Precautions:

1. Insert vibrator into concrete at three different points when vibrating each layer.

2. Do not allow vibrator to rest on the bottom or touch the sides of the measure when vibrating the bottom layer.

3. When vibrating the top layer, penetrate the layer and approximately the top inch of the bottom layer.

4. Withdraw the vibrator in such a manner that no air pockets are left in the specimen.

(E) CALCULATIONS

(1) Mass per cubic foot of fresh concrete.

$W = (D-C) \times F$

Where:

W = Weight of concrete in lbs. per cu. ft.

D = Weight of measure filled with concrete plus glass cover plate.

C = Weight of measure and glass cover plate

F = Calibration Factor.

(2) Volume of Concrete Produced per Batch:

$$S=\frac{(N\times 94)+W_F+W_C+W_W}{W}$$

Where:

S = Volume of concrete produced per batch, in cubic feet.

N = Number of bags of cement in the batch

94 = Net weight of bag of cement, in pounds.

W_F = Total wet weight of fine aggregate in batch, in pounds.

W_C = Total wet weight of coarse aggregate in batch, in pounds.

W_w= Total weight of mixing water added to batch, in pounds

W= Weight of concrete in lbs. per cu. ft.

(3) Yield

$$Y=\frac{S}{N}$$

Where:

Y = Yield of concrete produced per 94 pound bag of cement in cubic feet.

S = Volume of concrete produced per batch, in cubic feet.

N = Number of bags of cement in the batch

(4) Relative Yield: Relative yield is the ratio of actual volume of concrete obtained to the volume as designed for the batch and shall be calculated as follows:

$$R_Y = \frac{S}{V_d \times 27}$$

Where:

R_Y = Relative Yield.

S = Volume of concrete produced per batch, in cubic feet.

V_d = Volume of concrete which the batch was designed to produce in cubic yards.

NOTE: A value for R_Y greater than 1.00 indicates that an excess volume of concrete is being produced, whereas, a value less than 1.00 indicates the batch to be "short" of its designed volume.

(5). Yield Cement Factor – Shall be calculated as follows:

$$Y.C.F. = \frac{6.75}{Y}$$

Where:

Y.C.F. = The cement factor for the concrete being produced as determined from the unit weight of the concrete.

Y = Yield of concrete produced per 94 pound bag of cement in cubic feet.

(6) Air Content – The air content shall be calculated as follows:

$$A = \frac{T-W}{T} \times 100$$

Or by the formula

$$A = \frac{S-V}{S} \times 100$$

Where:

A = Air content (percentage of voids) in the concrete.

T = Theoretical weight of the concrete, in pounds of cubic feet, computed on an air-free basis.

W = Weight of concrete, in pounds of cubic feet.

S = Volume of concrete produced per batch, in cubic feet.

V = Total absolute volume of the component ingredients in the batch, in cubic feet.

NOTE: When the same materials and proportions are used to prepare different batches of concrete, it is assumed that the theoretical, air-free, mass per cubic meter (foot) of the concrete is constant for all batches. It is calculated from the formula:

$$T=\frac{W_I}{V}$$

Where:

T = Theoretical weight of the concrete, in pounds of cubic feet, computed on an air-free basis.

WI = Total weight of the component ingredients in the batch, in pounds.

V = Total absolute volume of the component ingredients in the batch, in cubic feet.

The absolute volume of each ingredient is calculated in accordance with subsection 5.17.01. For the aggregate components, the bulk specific gravity and weight should be based on the saturated, surface-dry condition. For the cement, a value of 3.20 may be used unless the actual specific gravity is known.

(7) Actual Cement Factor: Cement factor based on cu. yds. of concrete required and actual quantity of cement used is calculated as follows:

$$A.C.F.=\frac{A}{B}$$

Where:

A = Actual cement used, in bbls.

B = Theoretical volume of concrete, in cu. yds.

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
TO THE
STANDARD SPECIFICATIONS
EDITION OF 1973

NOTE: Whenever this Special Provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

73P-281 R: BRIDGE DECK SURFACING

1.0 DESCRIPTION: This work shall consist of constructing a wearing course consisting of Portland cement concrete on the prepared surface of a reinforced concrete bridge deck. The work shall be done in accordance with this specification and in reasonably close conformity with the grades, thicknesses and cross-sections shown on the plans or as directed by the engineer.

Bid Item: Bridge Deck Surfacing (*)

* Denotes thickness

2.0 MATERIALS:

(A) Portland Cement, Type II, Standard Specifications, Edition of 1973.

(B) Coarse Aggregate. Standard Specifications, Edition of 1973, Article 1001.02 (A). Except Grading, which shall be as follows:

Sieve Size	**Percentage Retained**
¾”	0
½”	0-10
3/8”	30-50
#8	90-100

(C) Fine Aggregate. Standard Specification, Edition of 1973, Article 1001.02 (C), Type FA-A.

(D) Fine Aggregate for Grout. Standard Specifications. 1973 Edition. Article 1001.02 (E), Type FA-M. In lieu of using FA-M it will be permissible to furnish aggregate complying with the grading requirements of FA-A provided the plus No. 4 materials are removed.

(E) Water. Standard Specifications, Edition of 1973, Subsection 1014.01.

(F) Curing Materials. Standard Specifications, Edition of 1973, Subsection 1004.

(G) Admixtures.

(1) Air Entraining Admixture. Standard Specifications, Edition of 1973, Section 1004.

(2) Water Reducing Admixture - ASTM C494, Type A. Basis of acceptance shall be by Type D Certification. Water Reducing Admixture only may be used.

(H) Precure Material. This material shall be an approved material such as Master Builders "Confilm" or equal, capable of producing a monomolecular film over freshly placed concrete and grout.

3.0 EQUIPMENT: Equipment used shall be subject to approval of the Engineer and shall comply with the following:

(A) Surface Preparation Equipment shall meet the following requirements:

(1) Sand-Blasting and Water Jetting Equipment shall be capable of removing rust, oil, dirt, loose disintegrated concrete and concrete laitance from the existing surface of the bridge deck. Wet sand blasting shall not be permitted.

(B) Proportioning and Mixing Equipment. This equipment shall meet the requirements of Section 401 of the Standard Specifications with the following exceptions:

A construction skip type mixer, stationary concrete mixer of the rotating-paddle type, or a continuous mixer used in conjunction with volumetric proportioning, will be required. For batch mixers, a two (2) minute minimum mix time is required. Sufficient mixing capacity or mixers shall be provided to permit the intended pour to be placed without interruption.

(C) Placing and Finishing Equipment. This equipment shall include adequate hand tools for placement of stiff plastic concrete and for working down to approximately the correct level for striking-off with the finishing screed. A finishing machine complying with the following requirements shall be used. The finishing machine shall be inspected and approved by the Engineer before work is started on each project.

The finishing machine shall consist of a mechanical strike-off capable of providing a uniform thickness of concrete slightly above finish grade in front of an oscillating screed or screeds.

At least one oscillating screed shall be designed to consolidate the concrete by vibration to 100 percent of the rodded unit weight. A sufficient number of identical vibrators shall be effectively installed such that at least one vibrator is provided for each 5 feet of screed length. The bottom face of this screed shall be at least 5 inches (12.7 centimeters) wide with a turned up or rounded leading edge to minimize tearing of the surface of the plastic concrete. Each screed shall have an effective weight of at least seventy-five pounds for each square foot of bottom face area. Each screed shall be provided with positive control of the vertical position, the angle of tilt, and the shape of the crown. Design of the finishing machine together with appurtenant equipment shall be such that positive machine screeding of the plastic concrete will be obtained as close as practical to the face of the existing curb line. The length of the screed shall be sufficient to extend at least 6 inches (15.2 centimeters) beyond the line where a joint is intended to form the edge of a subsequent placement section, and shall overlap the sawn edge of a previously placed course at least 6 inches (15.2 centimeters). The finishing machine shall be capable of forward and reverse motion under positive control.

Supporting rails upon which the finishing machine travels will be required on all projects. The support rails shall be fully adjustable (not shimmed) to obtain the correct profile. They shall be sufficiently rigid that they do not deflect under the weight of the machine. Anchorage for supporting rails shall provide horizontal and vertical stability. When placing concrete in a lane abutting a previously completed lane, the side of the finishing machine adjacent to the completed lane shall be equipped to travel on the completed lane.

Manufacturer's specifications and/or certification may be used as verification of the finishing machine requirements.

(D) General. The overall combination of labor and equipment for proportioning, mixing, placing and finishing new concrete shall be of such minimum capability as to meet the following requirements except when noted otherwise on the plans:

TOTAL SURFACE AREA (SQ. YD.)	MINIMUM REQUIREMENT PER BRIDGE (C.Y. /HR.)
0-328	1.0
329-492	1.5
493-656	2.0
Over 656	2.5

The finishing machine shall be so designed that, when concrete is being mixed and placed at the Specified minimum rate, under normal operating conditions, the elapsed time between depositing the concrete on the floor and final screeding shall not exceed 10 minutes unless otherwise authorized by the engineer.

CONSTRUCTION REQUIREMENTS:

(A) Proportioning. Concrete for Bridge Deck Surfacing shall comply with the following requirements:

(B)

Lbs. of Cement Per Cu. Yd., Minimum	Gallons of Water Per sack, Maximum	Percent of Air By Volume
825 lbs.	4.0	6.5 ± 1.0 **

** As determined by KT-19 only (Rollometer)

A water-reducing admixture for improving workability may be required. Use of such admixture shall be approved by the engineer.

The slump shall not exceed 3/4 inch. (1.9 cm).

The commencement of tests shall be delayed from 4 to 4 1/2 minutes after the sample has been taken from a continuous mixer. If a batch type mixer is used the tests shall be taken at the point of placement and shall commence immediately.

Aggregates shall be combined such that the proportions of course and fine aggregate shall be equal by weight.

(B) Portland Cement Grout. Grout shall consist of a one-to-one (1:1) by weight mixture of Portland cement and Fine Aggregate (FA-M) with sufficient water added to produce a "heavy cream" consistency.

The consistency of the grout slurry shall be such that it can be applied with a stiff brush or broom to the previously placed concrete in a thin, even coating that will not run or puddle in low spots.

For sealing vertical joints between adjacent lanes at the curbs, this grout may be thinned to paint consistency.

(C) Preparation of Surface.

(1) Old, Existing Concrete Decks. Prior to application of grout in preparation for placement of new concrete, a final cleanup shall be made by using a high pressure water jet with a minimum pressure of 3,500 psi to remove all loose disintegrated concrete, dirt, oil, laitance from full depth patches that have been filled and other foreign material from. The surface of the prepared deck and bottom 3" of hubguard. It is not intended that the old, existing concrete deck, which has been prepared for surfacing, be presaturated before grout and concrete overlay is placed. There shall be no free water and the surface should be dry to allow some absorption of the grout.

(2) New Concrete Decks. All loose, disintegrated, or unsound concrete shall be removed from the bridge floor as designated by the Engineer.

Prior to applying grout in preparation for placement of new concrete, the surface shall be sand blasted followed by an air blast. The sand blast shall be of such an extent as to remove all dirt, oil and other foreign material, as well as any unsound concrete or laitance from the surface, the bottom 3" of hubguard, and edges against which new concrete is to be placed. Metal floor drains and areas of the curb or railing above the proposed surface shall be protected from the sand blast. It is desired that the surface be roughened by the sand blast to provide satisfactory bond with the surfacing concrete, it is not intended or designed that existing concrete, prepared for surfacing, be presaturated before grout and new concrete is placed. The prepared surface shall be dry to allow some absorption of the grout.

The thickness of all new concrete above the prepared surface shall be as specified on the plans; the finish machine clearance shall be checked before concrete is placed.

(D) Proportioning and Mixing of Concrete Materials. The applicable provisions of Section 402 of the Standard Specifications shall apply with the following exceptions and additional provisions:

(1) Concrete shall be mixed at the project site. Ready-mixed concrete will not be approved. Continuous mixers, if used, shall be charged at the site.

(2) Water-reducing admixture for improved workability, if used, shall be mixed and incorporated in the concrete mixture in accordance with the manufacturer's recommendations and the Engineer's instructions.

(E) Placing and Finishing Concrete. A finishing machine meeting the requirements stipulated in section 3.0 (C) will be required. Screed rails shall be placed and fastened in position to insure finishing the concrete to the required profile. The supporting rails upon which the finishing machine travels shall be placed outside the area to be concreted. A hold-down device shot into concrete will not be permitted unless the concrete is to be subsequently surfaced. Hold-down devices of other types leaving holes in exposed areas will be approved provided the holes remaining are grouted full. Methods for anchoring and supporting the rails and the concrete placing procedure shall be approved by the engineer,

Longitudinal joints will be located in accordance with details shown on the Plans or as approved by the Engineer. The joints shall be kept clear of wheel paths as much as practical.

The concrete shall be produced and placed within the specified limits in as continuous and uniform of an operation as practical. After the surface has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the dry, prepared surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete. If the grout is allowed to dry out, a header shall be placed and no further concreting shall be done until the old grout has been removed and the surface again sandblasted. The new concrete shall be manipulated, mechanically struck off and mechanically consolidated to within a minimum of 98% of the rodded unit weight and screeded to final grade. Hand tamping is encouraged to assist in consolidation and bonding of the concrete. The engineer may use an approved nuclear density measuring device to monitor in-place density. Hand floating operations may be required to produce a tight, uniform surface. The Contractor shall take every reasonable precaution to secure a smooth riding bridge deck. Surface variations exceeding 1/8 inch (3 mm) in 10 feet (3.05 meters) shall be corrected.

When a tight, uniform surface has been achieved, the surface shall be given a suitable texture by transverse grooving with a wire broom or comb having a single row of tines. The grooving may vary from 1/8 inch (0.3 centimeters) width at 1/2-inch (1.3 centimeters) centers to 3/16-inch (0.5 centimeters) width at 3/4-inch (1.9 centimeters) centers and the groove depth should be approximately 1/8 inch to 3/16 inch. This operation shall be done at such time and in such manner that. The desired texture will be achieved while minimizing displacement of the larger aggregate particles. The transverse grooving should terminate approximately 2 feet (0.6 meters) in from the gutter line at the base of the curb. This area adjacent to the curbs should be given a light broom finish longitudinally. As soon as finishing has been completed, all vertical joints with adjacent concrete shall be sealed by painting with thinned grout.

The exposed edge of the end spans of bridges which form a part of the road surface shall" be finished with an edger having a one-fourth (1/4) inch radius.

(F) Curing. Immediately after completion of finishing operations, the concrete surface shall be cured by one of the following methods: wet burlap cure, polyethylene sheets or a minimum of 2" of wet sand. The curing material shall be kept in place on the surface of the concrete and continuously wet for a period of 72 hours.

The curing material shall be applied as soon as possible after the finishing operation without marring the surface as directed by the engineer. Damage created by failure to apply curing materials at the proper time may be cause for rejecting the work so affected. Surface concrete in the rejected area shall be removed and replaced at no additional cost to the contracting authority.

(G) Concreting in hot weather. Standard specifications concerning hot weather concreting shall apply and in addition monomolecular film may be used to prevent rapid evaporation of water rising to the surface of the concrete. It should not be used to work up grout as an aid to finishing operations. Use of this film in no way alters the requirements for curing as provided. It is used only to prevent rapid evaporation between the initial strike off and brooming prior to covering with the curing media. One or more light applications of this material may be required depending on the weather, and sequence of consolidating and finishing operations. Monomolecular film may be used at temperatures over 70 °f (21 °c) or when combinations or temperature, low humidity, and wind create conditions which, in the judgment of the engineer, require hot weather procedure.

(h) Concreting in cold weather. Except by specific written authorization concreting operations

Shall not be continued when a descending air temperature in the shade and away from artificial meat falls below 45 °f (7 °c) nor shall operations be started or resumed until am ascending air temperature reaches 40° F (4 °C) nor shall operations be carried on when night time temperatures are expected to fall below 35 °F (2 °C).

(I) limitations operations. Work on the surface overlay shall not commence when a new deck is involved, until the lower course meets the time requirements of section 701 of the standard specifications unless specified otherwise on the plans.

Concrete shall not be placed adjacent to a surface course less than 36 hours old; however, this restriction does not apply to a continuation of placement in a lane or strip beyond a transverse joint in the same lane or strip.

In areas where there is no traffic, preparation of the area may be started in a lane or strip adjacent to newly placed surface the day following its placement. If this work is started before the end of the 72-hour curing period, the work will be restricted as follows:

Sawing or other operations shall interfere with the curing process for the minimum practical time only, and in the immediate work area only, and the curing shall be resumed promptly upon completion of the work. The exposed areas shall be kept damp until such time as curing media is replaced. No power-driven tools heavier than a 15-pound chipping hammer shall be used.

No traffic shall be permitted on a finished surface course until 72 hours after placement. At temperatures below 55 degrees f., the engineer may require a longer waiting time.

(J) Placement of Centerline Form and Headers. If these forms cannot be held in place in a manner preventing movement during consolidating and finishing the following procedure shall be required. Before new concrete is placed against hardened concrete from previous placements the older concrete shall be sawed back six (6) inches {15 cm) and chipped away before mew concrete is placed.

(k) Correction of unbonded areas. If, during construction of the project newly overlain areas

Are discovered by tapping to be unbonded, concrete from such areas shall be outlined by sawing, removed with small air tools and replaced by the contractor at no additional compensation.

4.0 method of measurement: bridge deck surfacing will be measured by the square yard to the nearest 0.1 Sq. Yd. Complete in place.

5.0 basis of payment: the amount of completed and accepted work, measured as provided above, shall be paid for at the contract unit price bid, per square yard for "bridge deck surfacing", which shall be full payment for furnishing and placing all materials, equipment, forms, tools, labor and incidentals necessary to complete the work.

Water reducing admixture, if used, will be paid for in accordance with section 402.09 of the standard specifications.

4-27-79

KANSAS DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION TO THE STANDARD SPECIFICATIONS EDITION OF 1980

NOTE: Whenever this Special Provision conflicts with the Plans or Standard Specifications, this Special Provision shall govern.

SECTION 720

BRIDGE DECK OVERLAY

Delete Sections 718 and 720 and add the following as a revision.

720.01 DESCRIPTION - This work shall consist of constructing a wearing course consisting of Portland cement concrete on the prepared surface of a reinforced concrete bridge deck. The work shall be done in accordance with this specification and in reasonably close conformity with the grades, thicknesses and cross- sections shown on the Plans or as directed by the Engineer.

BID ITEM

Bridge Deck Overlay (*)

* Denotes Thickness
720.02 MATERIALS Fly Ash modified concrete shall be permitted.
(a) Portland Cement, Section 2001, except only Types IP, I (PM) or II shall be permitted.

(b) Coarse Aggregate. Standard Specifications, Section 1102 except grading, which shall be as follows:

SIEVE SIZE	PERCENTAGE RETAINED
3/4"	0
1/2"	0-10
3/8"	30-50
1/8	90-100

(c) Fine Aggregate. Standard Specifications, Type FA-A.

(d) Fine Aggregate for Grout. Standard Specifications, Section 1102 Type FA-M. In lieu of using FA-M it will be permissible to furnish aggregate complying with the grading requirements of FA-A provided the plus No. 4 material is removed.

(e) Water. Standard Specifications, Section 2401.

(f) Curing Materials. Standard Specifications, Section 1400.

(g) Admixtures.

(1) Air Entraining Admixture. Standard Specifications, Section 1400.

(2) Water Reducing Admixture-ASTM, C494, Type A. Basis of acceptance shall be by Type D Certification. Water Reducing Admixture only may be used.

(h) Precure Material. This material shall be an approved material capable of producing a monomolecular film over freshly placed concrete.

720.03 EQUIPMENT - Equipment used shall be subject to approval of the Engineer and shall comply with the following:

(a) Surface Preparation Equipment shall meet the following requirements:

(1) Sand-Blasting and Water Jetting Equipment shall be capable of removing rust, oil, dirt, loose disintegrated concrete and concrete laitance from the existing surface of the bridge deck. Wet sand blasting shall be used only with permission of the Engineer.

(b) Proportioning and Mixing Equipment. This equipment shall meet the requirements of Section 401 of the Standard Specifications with the following exceptions:

A construction skip type mixer, stationary concrete mixer of the rotating-paddle type, or a continuous mixer used in conjunction with volumetric proportioning, will be required. For batch mixers, a two (2) minute minimum mix time is required. Sufficient mixing capacity of mixers shall be provided to permit the intended pour to be placed without interruption.

(c) Placing and Finishing Equipment. This equipment shall include adequate hand tools for placement of stiff plastic concrete and for working down to approximately the correct level for striking-off with the finishing screed. A finishing machine complying with the following requirements shall be used. The finishing machine shall be inspected and approved by the Engineer before work is started on each project.

The finishing machine shall consist of a mechanical strikeoff capable of providing a uniform thickness of concrete slightly above finish grade in front of an oscillating screed or screeds.

At least one oscillating screed shall be designed to consolidate the concrete by vibration to 100 percent of the rodded unit weight. A sufficient number of identical vibrators shall be effectively installed such that at least one vibrator is provided for each 5 feet of screed length. The bottom face of this screed shall be at least 5 inches wide with a turned up or rounded leading edge to minimize tearing of the surface of the plastic concrete. Each screed shall have an effective weight of at least seventy-five (75) pounds for each square foot of bottom face area. Each screed shall be provided with positive control of the vertical position, the angle of tilt, and the shape of the crown. Design of the finishing machine together with appurtenant equipment shall be such that positive machine screeding of the plastic concrete will be obtained as close as practical to the face of the existing curb line. The length of the screed shall be sufficient to uniformly strike-off and consolidate the width of the lane to be paved. The finishing machine shall be capable of forward and reverse motion under positive control. Supporting rails upon which the finishing machine travels will be required and shall be fully adjustable (not shimmed) to obtain the correct profile, unless otherwise approved by the Engineer. Other methods or equipment to support the finishing machine may be approved by the Engineer. Supports shall be sufficiently rigid that they do not deflect under the weight of the machine. Anchorage for supporting rails shall provide horizontal and vertical stability. When placing concrete in a lane abutting a previously completed lane, the side of the finishing machine adjacent to the completed lane shall be equipped to travel on the completed lane.

Manufacturer's specifications and/or certification may be used as verification of the finishing machine requirements.

(d) General. The overall combination of labor and equipment for proportioning, mixing, placing and finishing new concrete shall be of such minimum capability as to meet the following requirements except when noted otherwise on the Plans:

TOTAL SURFACE AREA (SQ. YD.)	**MINIMUM REQUIREMENT PER BRIDGE (C.Y./HR.)**
0-328	1.0
329-492	1.5
493-656	2.0
Over 656	2.5

The finishing machine shall be so designed that, when concrete is being mixed and placed at the specified minimum rate, under normal operating conditions, the elapsed time between depositing the concrete on the floor and final screeding shall not exceed 10 minutes unless otherwise authorized by the Engineer.

720.04 CONSTRUCTION REQUIREMENTS (a) Proportioning. Concrete for Bridge Deck Overlay shall comply with the following requirements:

LBS. OF CEMENT PER CU. YD., MIN	POUNDS OF WATER PER LB. OF CEMENT, MAX	PERCENT OF AIR BY VOLUME
625 Lbs.	0.40	6.0 ±2 **

** As determined by KT-19 only (Rollometer)

A water-reducing admixture for improving workability may be required. Use of such admixture shall be approved by the Engineer.

The slump shall not exceed 3/4 inch.

The commencement of tests shall be delayed from 4 to 4 1/2 minutes after the sample has been taken from a continuous mixer. If a batch type mixer is used the tests shall be taken at the point of placement and shall commence immediately.

Aggregates shall be combined such that the proportions of coarse and fine aggregate shall be equal by weight.

(b) Portland Cement Grout. Grout shall consist of a one-to-one (1:1) by weight mixture of Portland Cement and Fine Aggregate (FA-M) with sufficient water added to produce a "heavy cream" consistency.

The consistency of the grout slurry shall be such that it can be applied with a stiff brush or broom to the previously placed concrete in a thin, even coating that will not run or puddle in low spots.

For sealing vertical joints between adjacent lanes at the curbs, this grout may be thinned to paint consistency.

(c) Preparation of Surface. (1) Old, Existing Concrete Decks. Prior to application of grout in preparation for replacement of new concrete, a final cleanup shall be made by sand blasting followed by an air blast to remove all loose disintegrated concrete, dirt, oil laitance from patches and other foreign material from the surface of the prepared deck and bottom 3" of hubguard. It is not intended that the old, existing concrete deck, which has been prepared for overlaying, be presaturated before grout and concrete overlay is placed. There shall be no free water and the surface should be dry to allow some absorption of the grout.

(2) New Concrete Decks. All oil, dirt, loose, disintegrated, or unsound concrete and concrete laitance shall be removed from the bridge floor as designated by the Engineer.

Prior to applying grout in preparation for placement of new concrete, the surface shall be sand blasted followed by an air blast. The sand blast shall be of such an extent as to remove all dirt, oil and other foreign material, as well as any unsound concrete or laitance from the surface, the bottom 3" of hubguard, and edges against which new concrete is to be placed. Metal floor drains and areas of the curb or railing above the proposed surface shall be protected from the sand blast. It is desired that the surface be roughened by the sand blast to provide satisfactory bond with the surfacing concrete. It is not intended or designed that existing concrete, prepared for overlaying, be presaturated before grout and new concrete is placed. The prepared surface shall be dry to allow some absorption of the grout.

The thickness of all new concrete above the prepared surface shall be as specified on the Plans. The finish machine clearance shall be checked before concrete is placed.

(d) Proportioning and mixing of Concrete Materials. The applicable provisions of Section 402 of the Standard Specifications shall apply with the following exceptions and additional provisions:

(1) Concrete shall be mixed at the project site. Ready-mixed concrete will not be approved. Continuous mixers, if used, shall be charged at the site.

(2) Water-reducing admixture for improved workability, if used, shall be mixed and incorporated in the concrete mixture in accordance with the manufacturer's recommendations and the Engineer's instructions.

(e) Placing and Finishing Concrete. A finishing machine meeting the requirements stipulated under equipment above will be required. Screed rails shall be placed and fastened in position to insure finishing the concrete to the required profile. The supporting rails upon which the finishing machine travels shall be placed outside the area to be concreted. A hold-down device shot into concrete will not be permitted unless the concrete is to be subsequently overlaid. Hold-down devices of other types leaving holes in exposed areas will be approved provided the holes remaining are grouted full. Methods for anchoring and supporting the rails and the concrete placing procedure shall be approved by the Engineer.

Longitudinal joints will be located in accordance with details shown on the Plans or as approved by the Engineer. The joints shall be kept clear of wheel paths as much as practical.

The concrete shall be produced and placed within the specified limits in as continuous and uniform of an operation as practical. After the surface has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the dry, prepared surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete. If the grout is allowed to dry out, a header shall be placed and no further concreting shall be done until the old grout has been removed and the surface again cleaned by sand blasting. The new concrete shall be manipulated, mechanically struck off and mechanically consolidated to a minimum of 98% of the rodded unit weight and screeded to final grade. Hand tamping is encouraged to assist in consolidation and bonding of the concrete. The Engineer may use an approved Nuclear Density Measuring Device to monitor in-place density. Hand floating operations may be required to produce a tight, uniform surface. The Contractor shall take every reasonable precaution to secure a smooth riding bridge deck. Surface variations exceeding 1/8 inch in 10 feet shall be corrected unless directed otherwise by the Engineer.

When a tight, uniform surface has been achieved, the surface shall be given a suitable texture by transverse grooving with a finned float having a single row of fins. The grooving shall be approximately 3/16-inch in width at 3/4-inch centers and the groove depth should be approximately 1/8-inch. This operation shall be done at such time and in such manner that the desired texture will be achieved while minimizing displacement of the larger aggregate particles. The transverse grooving should terminate approximately 2 feet in from the gutter line at the base of the curb. This area adjacent to the curbs should be given a light broom finish longitudinally. All vertical joints with adjacent concrete shall be sealed by painting with thinned grout after 24 hours minimum curing of the overlay or in accordance with notes shown on the plans.

The exposed edge of the end spans of bridges which form a part of the road surface shall be finished with an edger having a one-fourth (1/4) inch radius.

(f) Curing. Immediately after completion of finishing operations or as directed by the Engineer, the concrete surface shall be cured by one of the following methods: Burlap kept continually wet by the use of a sprinkler system or wet burlap covered with polyethylene sheets. The curing material shall be kept in place on the surface of the concrete and continuously wet for a period of 72 hours.

(g) Weather Limitations. (1) Concreting in Hot Weather. Standard Specifications concerning hot weather concreting shall apply.

(2) Concreting in Cold Weather. Except by specific written authorization concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 45 F nor shall operations be started or resumed until an ascending air temperature reaches 40 °F nor shall operations be carried on when night time temperatures are expected to fall below 35 °F.

(h) Concreting in Adverse Weather. When the Engineer deems it necessary, monomolecular film may be used to prevent rapid evaporation of water rising to the surface of the concrete. When used, the film shall be uniformly spread over the entire roadway width. Use of this film in no way alters the requirements for curing as provided. It is used to prevent rapid evaporation between the initial strike off and texturing prior to covering with the curing media. One or more light applications of this material may be required depending on the weather and sequence of consolidating and finishing operations. When in the judgment of the Engineer, a combination of temperature, low humidity and wind create adverse conditions, monomolecular film may be used to help obtain a more uniform finish.

(i) Limitations of Operations. Work on the surface overlay shall not commence, when a new deck is involved, until the lower course meets the time requirements of Section 701 of the Standard Specifications unless specified otherwise.

Concrete shall not be placed adjacent to a surface course less than 36 hours old; however, this restriction does not apply to a continuation of placement in a lane or strip beyond a transverse joint in the same lane or strip.

In areas where there is no traffic, preparation of the area may be started in a lane or strip adjacent to newly placed surface the day following its placement. If this work is started before the end of the 72-hour curing period, the work will be restricted as follows:

Sawing or other operations shall interfere with the curing process for the minimum practical time only, and in the immediate work area only, and the curing shall be resumed promptly upon completion of the work. The exposed areas shall be kept damp until such time as curing media is replaced. No power-driven tools heavier than a 15-pound chipping hammer shall be used.

No traffic shall be permitted on a finished surface course until 72 hours after placement. At temperatures below 55 degrees F., the Engineer may require a longer waiting time.

(j) Placement of Centerline Form and Headers. If these forms cannot be held in place in a manner preventing movement during consolidating and finishing the following procedure shall be required. Before new concrete is placed against hardened concrete from previous placements the older concrete shall be sawed back six (6) inches and chipped away before new concrete is placed.

(k) Correction of Unbonded Areas. If, during construction of the project newly overlain areas are discovered by tapping or chaining to be unbonded, concrete from such areas shall be outlined by sawing, removed with small air tools and replaced by the Contractor at no additional compensation.

720.05 METHOD OF MEASUREMENT - Bridge Deck Overlay will be measured by the square yard to the nearest 0.1 sq. Yd. Complete in place. Quantity for which payment will be made may be the quantities shown on the Plans provided the project is constructed as shown on the Plans. When the Plans have been altered or when disagreement exists between the Contractor and Engineer as to accuracy of the Plan quantities, either party shall have the right to request and cause the quantities to be measured.

720.06 BASIS OF PAYMENT - The amount of completed and accepted work, measured as provided above, shall be paid for at the contract unit price bid, per square yard for "Bridge Deck Overlay", which price shall be full payment for furnishing and placing all materials, equipment, forms, tools, labor and incidentals necessary to complete the work.

Water reducing admixture, if used, will be paid for in accordance with Section 402.09 of the Standard Specifications.

1-28-86

BRIDGE DECK WATERPROOFING – LIQUID MEMBRANE

1.0 DESCRIPTION
This work shall consist of the surface preparation, materials and application of materials for waterproofing the concrete deck of the bridge prior to the application of the asphaltic concrete. Any of the following systems may be used, however, only one system will be allowed on any one bridge deck.
System (I-L) Superseal 4000LT waterproofing system manufactured by Superior Products Company.
System (II-L) Gacoflex UWM-2812 waterproofing membrane system manufactured by Gates Engineering Co., Inc.
System (III-L) Petromat protective membrane system manufactured by Philips Fibers Corporation.
Note: The sections pertaining solely to either System (I-L) or System (II-L) have been omitted from this report.

Bid Item
Bridge Deck Waterproofing

4.0 SYSTEM (III-L)
4.1 MATERIALS
4.1.1 Requirements- The materials used in this waterproofing system shall consist of an asphalt cement applied to the deck followed by a non-woven polypropylene fabric. This system shall be the Petromat System with the fabric manufactured by Philips Fibers Corporation.

4.1.1.1 The polypropylene fabric shall meet the following requirements:

Tensile strength, either direction, min	125 lbs.
Elongation, at break, Typical	70%
Weight, ounce, sq. yd., Min	5 oz.
Color	Black
Width, inches	75 and 105

4.1.1.2 The impregnated binder to be applied to the bridge deck surface ahead of the polypropylene fabric shall be an asphalt cement (AC-5) or (AC-7) which meets the requirements of Section 1200 of the Standard Specifications.

4.1.2 Methods of Tests

4.1.2.1 Polypropylene Fabric. This material shall be tested in accordance with the applicable procedures in ASTM D 1682.

5.0 BASIS OF ACCEPTANCE (III-L) The Asphalt Cement will be accepted based on receipt and approval of a Type D certification as defined in Section 2600 of the Standard Specifications.

6.0 CONSTRUCTION REQUIREMENTS

6.9 SURFACE PREPARATION (III-L)

6.9.1 The surface of the deck and the sides of the curbs, for a height of at least two inches above the proposed asphaltic concrete overlay, shall be thoroughly cleaned by the use of air jets, sandblasting, mechanical sweeper, hand brooms, or other approved methods, or as directed by the Engineer until the deck surface and sides of the curbs are free of all clay, dust, salt deposits, oil or grease deposits, sharp or angular protrusions and all loose or foreign matter.

6.9.2 All asphalt shall be removed to clean sound concrete.

6.9.3 Concrete patches shall be at least 14 days old.

6.10 APPLICATION OF SEALANT (III-L)

6.10.1 Uniform application of the asphalt sealant is especially important to insure an optimum quality membrane. Precalibration of the distributor shall be made to confirm a controlled rate of application. The quantity of asphalt specified will vary with porosity or texture of the deck to be covered. In most cases, however, this will approximate 0.35 gallons per square yard residual asphalt. For heavily textured decks, the rate of application may be increased to 0.4 gallons per square yard residual or as determined by the Engineer.

6.11 FABRIC LAYDOWN (III-L)

6.11.1 Bridge deck grade Petromat fabric should be handled such that the softer (textured) side of the material faces down, making contact with the old bridge deck surface.

After spraying the first asphalt course the fabric is machine placed into the sealant. With proper care, the fabric can be placed essentially wrinkle free. Brooming will remove air bubbles and insure complete contact with the road surface. Small wrinkles which flatten under compaction have not been found detrimental to performance of a Petromat membrane. Wrinkles large enough to cause folds should be avoided. If they occur, tops of the wrinkles are slit, laid flat, then compacted. Additional sealant may be required to satisfy the resulting double fabric layer. In some cases, it may be expedient to replace a heavily wrinkled section.

6.11.2 Fabric Laps and Joints: The fabric should overlap adjacent fabric panels from 4 to 6 inches. Additional sealant must be applied to make the joints. This can be applied by the distributor in the case of longitudinal joints of adjacent panels. It is normally a hand operation at transverse joints. For good drainage, particularly in the event of rain prior to paving, the joints should be “shingled” to facilitate runoff. Transverse joints can be shingled in the direction of paving to prevent in order to prevent edge pick-up by the paver.

6.11.3 Curb Seals: To provide an effective seal the fabric is usually turned up onto the curb approximately the height of overlay to be placed. Use of paint brush or trowel to apply asphalt cement (or an asphalt mastic sealer) along the curb provides adequate bonding. Following overlay, the seals further improved by installing a suitable mastic “bead” along the curb line joint. An alternate seal can be fabricated by inserting lengths of a suitable filler board along the curb above the membrane at time of overlay; these are removed following overlay, and the void area filled with sealant.

6.12 FABRIC OVERLAY (III-L)

For best results, paving operations should follow membrane placement as soon as the membrane has cured. Turning of the paver and other vehicles should be gradual and kept to a minimum to avoid damage to the membrane. If equipment tires tend to stick to the membrane during paving, a small quantity of hot mix may be broadcast ahead of the vehicle wheel paths to relieve this problem. Temperature of the hot mix should not exceed 325° F in any case. Most satisfactory laydown of the mix can be accomplished at a temperature of almost 275° F.

6.13 TEMPERATURE (III-L)

Temperature of the asphalt sealant must be sufficiently high to permit a uniform spray pattern. For asphalt cement, the minimum recommended temperature is 290° F. To avoid shrinkage or damage to the fabric, however, distributor tank temperatures must not exceed 325° F.

Air temperature should be sufficient to allow adequate “tack” to hold the fabric in place. While this will vary for different asphalt types, a rule-of-thumb minimum air temperature will approximate 50° F.

6.14 TACK COAT (III-L)

It is usually not necessary to tack coat the fabric prior to placement of a premix overlay. However, there may be circumstances such as delay of overlay, dust accumulation or under-application of binder which would make tack coating desirable. This decision shall be made by the field engineer.

7.0 METHOD OF MEASUREMENT

The area of Bridge Deck Waterproofing shall be computed to the nearest square yard. This area shall be measured longitudinally from end of wearing surface to end of wearing surface and transversely between roadway face of curbs and median, excluding from measurement the area of vertical face of curbs, drains and expansion devices. Final measurement will not be made except for authorized changes during construction, or where appreciable errors are found in the contract quantity. The revision or correction will be computed and added or deducted from the contract quantity.

8.0 BASIS OF PAYMENT

Bridge Deck Waterproofing will be paid for at the contract unit price per square yard, which price shall be full compensation for furnishing and placing all materials, for all labor, equipment, tools and incidentals necessary to complete the work.

APPENDIX B - COMPLETE DATA

Experimental Number	73P-1210 no. 1
Bridge Name and Number	Industrial Ave over I-35 35-56-11.58 (008)
Construction Project Number	35-56 I-IR-35-2 (14) 218
Research Project Number	NEPT KS 78-02A
Original bridge construction	1967
Overlay construction	June 1978
End of overlay service	Bridge Replaced 1993

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
6/21/1977	pre-overlay condition	11	52	100	0.16	32
7/17/1978	survey	0	0	0	0	8.7
9/17/1979	survey	1	0.2	0	0	41
9/19/1980	survey	2	1.8	0.21	0.14	44
9/9/1981	survey	3	0.2	0.39	0.56	3.6
11/3/1982	survey	4.5	3.1	0.42	0.64	3.4
1/24/1984	survey	5.5	8.1	0.44	0.67	3.1
11/15/1984	survey	6.5	4.8	0.44	0.67	3.4
4/22/1986	survey	8	13.22	0.44	0.68	3.12
11/6/1986	survey	8.5	16.12	0.44	0.68	12.5
9/22/1987	survey	9	18.9	0.44	0.68	3.64
9/8/1988	survey	10	20.8	0.47	0.71	2.6
10/31/1989	survey	11	22.3	0.5	1.21	3.38
10/18/1990	survey	12	23.6	0.66	1.33	3.38
9/5/1991	survey	13	24.43	1.34	1.55	3.64

Experimental Number	73P-1210 no. 2
Bridge Name and Number	I-470 EB over Shunganunga Creek 470-89-2.87(057)
Construction Project Number	470-89 I-IR-470-5 (141) 359
Research Project Number	NEPT KS 78-02B
Original bridge construction	1960
Overlay construction	July 1979
End of overlay service	Overlay replaced 1990

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
6/30/1977	Pre-overlay survey	17	18			47
8/31/1979	survey	0	0.4	0	0.11	26.8
9/30/1980	survey	1	2.0	0.19	0.76	5.9
9/30/1981	survey	2	2.0	0.79	0.95	6
9/30/1982	survey	3	8.1	2.32	1.3	6.5
9/30/1983	survey	4	7.2	2.32	1.3	6.5
11/30/1984	survey	5	7.9	2.32	1.3	4.2
11/30/1986	survey	7	12.7	1.3	2.25	27.2
9/30/1987	survey	8	13.8	2.35	1.72	14.18
9/12/1988	survey	9	15.1	2.35	1.73	8.05
8/30/1989	survey	10	21.3	2.56	2.25	15.71

Experimental Number	73P-1210 no. 3
Bridge Name and Number	I-470 WB over Shunganunga Creek 470-89-2.87(056)
Construction Project Number	470-89 I-IR-470-5 (141) 359
Research Project Number	NEPT KS 78-02B
Original bridge construction	1960
Overlay construction	1977
End of overlay service	Overlay replaced 1990

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
6/22/1977	Pre-overlay survey	17	48	0	0	52
8/31/1979	survey	2	3	0	0	26.8
9/30/1980	survey	3	3.7	0.16	0.19	7.3
9/30/1981	survey	4	5.1	0.23	0.35	7.6
9/30/1982	survey	5	13.8	0.26	0.47	6.9
9/30/1983	survey	6	28.6	0.26	0.47	4.6
11/30/1984	survey	7	23.7	0.26	0.47	7.3
10/21/1986	survey	9	40.4	0.67	0.87	16.86
9/24/1987	survey	10	49.3	0.67	0.87	10.7
9/7/1988	survey	11	50.4	0.69	0.87	6.51
9/11/1989	survey	12	50.8	0.69	0.87	20.08

Experimental Number	73P-1210 no. 6
Bridge Name and Number	Milford Lake Road (FAS 270) over I-70 70-31-1.03 (002)
Construction Project Number	70-31 I-IR-70-5 (149) 290
Research Project Number	NEPT KS 78-02C
Original bridge construction	1959
Overlay construction	June 1979
End of overlay service	2008

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
5/31/1978	Pre-overlay survey	19	37			66
6/30/1979	survey	0	0	0.00	0.00	61.30
6/30/1980	survey	1	0.2	0.35	0.35	3.30
9/30/1981	survey	2	1.0	0.43	0.49	5.00
9/30/1982	survey	3	3.1	0.94	0.49	5.00
2/29/1984	survey	4.5	2.1	0.94	0.49	1.60
11/30/1984	survey	5	2.3	0.94	0.49	17.40
11/30/1986	survey	7	7.6	1.29	0.98	7.80
9/30/1987	survey	8	9.7	1.30	0.98	4.40
9/12/1988	survey	9	10.3	1.36	1.00	4.66
8/30/1989	survey	10	14.3	1.49	1.13	6.21
9/11/1990	survey	11	18.8	1.49	1.13	5.60
8/7/1991	survey	12	21.7	2.51	2.43	7.14
8/28/1992	survey	13	25.4	2.51	2.43	9.62
8/6/1993	survey	14	28.4	2.63	2.67	9.94
7/21/1994	survey	15	29.0	2.65	2.71	9.94
8/25/1995	survey	16	31.6	2.65	2.71	8.70
8/28/1996	survey	17	32.2	3.06	3.06	13.40
7/23/1997	survey	18	33.9	3.12	3.06	19.90
9/17/1998	survey	19	34.7	3.23	3.28	17.70
12/29/1999	survey	20	35.0	3.24	3.30	22.40
2000	survey	21	35.9	3.39	3.46	14.30
2001	survey	22	36.4	3.39	3.47	20.10
2002	survey	23	38.0	3.39	3.47	32.00
2003	survey	24	38.0	3.39	3.47	36.00

Experimental Number	73P-1210 no. 34
Bridge Name and Number	I-470 EB over Huntoon Street 470-89-1.04 (050)
Construction Project Number	470-89 I-IR-470-5
Research Project Number	470-89 I-IR-470-5
Original bridge construction	1959
Overlay construction	June 1980
End of overlay service	Bridge replaced 1991

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
9/30/1979	Pre-overlay survey	20	39			61.00
9/17/1980	survey	0.5	0	0.00	0.04	32.20
8/11/1981	survey	1	0.5	0.77	1.08	19.60
9/21/1982	survey	2	2.8	3.44	4.79	14.30
9/22/1983	survey	3	9.3	3.44	4.79	4.10
10/24/1984	survey	4	9.9	3.44	4.79	5.30
3/4/1986	survey	5.5	13.5			4.40
7/22/1986	survey	6	10.0	0.49	0.77	9.00
9/21/1987	survey	7	16.6	0.49	0.77	4.15
9/22/1988	survey	8	20.8	0.49	0.77	5.29
9/7/1989	survey	9	23.2	1.75	1.74	12.67
9/6/1990	survey	10	28.8	1.75	1.74	4.84
4/1/1991	survey	11	33.2	1.75	1.80	10.37

Experimental Number	73P-1210 no. 35
Bridge Name and Number	I-470 EB over Wanamaker Street 470-89-1.20 (052)
Construction Project Number	470-89 I-IR-470-5
Research Project Number	NEPT KS 78-02
Original bridge construction	1960
Overlay construction	May 1979
End of overlay service	Bridge replaced 1991

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
9/30/1979	Pre-overlay survey	19	5.1			20.00
9/30/1980	survey	1	0.0	0.00	0.00	5.00
8/31/1981	survey	2	0.0	0.15	0.61	12.40
9/30/1982	survey	3	1.1	0.93	4.46	2.20
9/30/1983	survey	4	1.2	0.93	4.46	2.50
10/23/1984	survey	5	1.4	0.93	4.46	1.90
1/16/1986	survey	6	1.6	0.51	1.44	21.00
11/5/1986	survey	7	2.0	0.51	1.45	3.40
9/18/1987	survey	8	3.1	0.51	1.45	2.17
9/12/1988	survey	9	3.4	0.51	1.52	7.76
8/30/1989	survey	10	3.9	0.53	1.52	10.60
9/11/1990	survey	11	5.0	0.76	1.53	14.30

Experimental Number	73P-281 no. 14
Bridge Name and Number	I-70 EB over K-4 (Auburn Road) 70-89-7.08 (013)
Construction Project Number	70-89 I-IR-70-5 (153) 353
Research Project Number	NEPT KS 78-02
Original bridge construction	1958
Overlay construction	September 1978
End of overlay service	Bridge replaced 2002

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
4/30/1978	Pre-overlay survey	20	12			5.00
10/11/1979	survey	0	0	0.00	0.00	6.50
9/16/1980	survey	1	0	3.70	0.00	8.30
9/8/1981	survey	2	0	2.81	0.00	2.00
9/8/1982	survey	3	0	5.34	1.29	8.70
9/21/1983	survey	4	0.2	5.34	1.29	6.60
10/23/1984	survey	5	0	5.34	1.29	9.60
1/16/1986	survey	6.5	0.1	5.34	1.29	9.80
11/5/1986	survey	7.5	0.1	5.34	1.29	8.70
9/18/1987	survey	8	0.1	5.16	1.25	9.60
9/12/1988	survey	9	0.1	5.16	1.25	8.29
8/30/1989	survey	10	0.2	5.16	1.25	7.86
9/11/1990	survey	11	0.6	5.16	1.25	7.60
8/7/1991	survey	12	0.6	5.16	1.25	2.62
8/28/1992	survey	13	0.6	5.37	1.28	78.90
8/6/1993	survey	14	0.8	5.38	1.28	5.24
7/21/1994	survey	15	1.3	5.37	1.28	14.41
8/25/1995	survey	16	1.5	5.45	1.38	11.45
8/28/1996	survey	17	1.6	5.46	1.39	19.20
7/23/1997	survey	18	2.2	5.49	1.40	28.40
9/17/1998	survey	19	3.3	5.50	1.47	28.80
12/29/1999	survey	20	3.6	5.50	1.47	7.00

Experimental Number	73P-281 no. 24
Bridge Name and Number	I-470 EB over 10th Street 470-89-0.36 (048)
Construction Project Number	470-89 I-IR-470-5 (156)
Research Project Number	NEPT KS 78-02
Original bridge construction	1960
Overlay construction	1979
End of overlay service	Overlay replaced 2002

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
12/31/1978	Pre-overlay survey	18	34			47.00
9/16/1980	survey	1	0	0.00	0.02	43.50
8/12/1981	survey	2	0	0.97	0.97	20.70
9/13/1982	survey	3	4.0	5.07	5.88	17.90
9/21/1983	survey	4	9.6	1.14	1.96	13.90
10/23/1984	survey	5	6.6	1.14	1.96	6.70
3/3/1986	survey	6.5	12.8			7.30
10/20/1986	survey	7	13.5	1.41	1.22	21.70
9/17/1987	survey	8	14.8	1.81	1.23	11.30
9/9/1988	survey	9	20.6	1.81	1.23	5.65
9/1/1989	survey	10	25.4	2.24	1.27	10.42
11/15/1990	survey	11	27.4	2.45	1.28	9.50
3/29/1991	survey	12	30.7	2.60	1.30	12.20

Experimental Number	73P-87R no. 1
Bridge Name and Number	I-70 EB over Mulberry Creek 70-85-17.46 (063)
Construction Project Number	70-85-I-70-4(52)
Research Project Number	NEPT KS 76-03
Original bridge construction	1961
Overlay construction	August 1976
End of overlay service	1999

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
Jul-76	preconstruction survey	15	30.			43.00
Feb-77	survey	0.5	0.03	0.12	0.39	26.60
Nov-77	survey	1	1.0	0.33	1.07	35.00
Sep-78	survey	2	1.5	0.33	1.10	
Sep-79	survey	3	5.3	0.37	1.19	20.30
Jun-80	survey	4	6.7	0.53	1.91	30.80
Sep-82	survey	6	24.3			14.30
Oct-83	survey	7	21.3	0.58	1.96	17.80
Nov-84	survey	8	40.2	0.58	1.96	28.60
Apr-85	survey	9	26.5	0.58	1.96	34.30

Experimental Number	73P-87R no. 2
Bridge Name and Number	I-70 EB over Solomon River 70-85-28.8 (077)
Construction Project Number	70-85-I-70-4(52)
Research Project Number	NEPT KS 76-03
Original bridge construction	1961
Overlay construction	October 1976
End of overlay service	Overlay replaced 1999

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
Jul-76	preconstruction survey	15	15			47
Feb-77	survey	0.5	0	0.00	0.00	9.00
Nov-77	survey	1	0	0.07	0.39	7.00
Sep-78	survey	2	0	0.35	1.79	7.00
Sep-79	survey	3	0	0.38	1.95	25.00
Jun-80	survey	4	0.9	0.45	2.49	24.20
Oct-81	survey	5	1.0	0.45	2.49	7.60
Sep-82	survey	6	4.5	0.47	2.61	10.90
Oct-83	survey	7	3.9	0.47	2.61	32.90
Apr-85	survey	9	5.2	0.47	2.61	31.00

Experimental Number	73P-87R no. 3
Bridge Name and Number	I-70 EB over Saline River 70-85-18.64 (066)
Construction Project Number	70-85-I-70-4(52)
Research Project Number	NEPT KS 76-03
Original bridge construction	1961
Overlay construction	September 1976
End of overlay service	2007

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
Jul-76	preconstruction survey	15	26.2			37.00
Feb-77	survey	0.5	0	0.02	0.10	5.30
Nov-77	survey	1	0	0.21	1.24	25.00
Sep-78	survey	2	0	0.44	2.49	17.00
Sep-79	survey	3	0.8	0.45	2.54	6.60
Jun-80	survey	4	1.5	0.50	2.81	17.00
Oct-81	survey	5	0.8	0.50	2.81	6.70
Sep-82	survey	6	6.4	0.50	2.83	10.00
Oct-83	survey	7	4.9	0.50	2.83	5.70
Nov-84	survey	8	7.2	0.50	2.85	14.40
Apr-85	survey	9	3.8	0.50	2.85	30.50

Experimental Number	73P-87R no. 4
Bridge Name and Number	I-70 WB over Saline River 70-85-18.65 (065)
Construction Project Number	70-85-I-70-4(52)
Research Project Number	NEPT KS 76-03
Original bridge construction	1961
Overlay construction	November 1976
End of overlay service	2004

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
Nov-75	preconstruction survey	14	32			
Feb-77	survey	0.5	0	0.00	0.00	20.00
Nov-77	survey	1	0	0.04	0.24	6.60
Sep-78	survey	2	0	0.23	0.98	4.90
Sep-79	survey	3	0	0.26	1.09	10.40
Jun-80	survey	4	0.1	0.37	1.50	21.50
Oct-81	survey	5	0.3	0.37	1.50	54.10
Sep-82	survey	6	3.2	0.47	1.58	3.30
Oct-83	survey	7	2.8	0.47	1.58	1.10
Apr-85	survey	8	2.1	0.47	1.58	3.60

Experimental Number	80P-129 R3 no. 5
Bridge Name and Number	K-18 over South Solomon River 18-33-0.69 (44)
Construction Project Number	18-33-K-3100(2)
Original bridge construction	1961
Overlay construction	1986
End of overlay service	1993

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
1986	preconstruction survey	15	27.7			14.00
1986	survey	0.5	0.3	0.00	0.00	3.17
1987	survey	1	1.5	0.01	0.00	1.58
1988	survey	2	1.6	0.04	0.01	1.02
1989	survey	3	3.1	0.35	0.25	1.90
1990	survey	4	4.7	0.39	0.33	3.40
1991	survey	5	8.2	0.50	0.65	2.60

Experimental Number	80P-129 R3 no. 6
Bridge Name and Number	FAS 511, Osage Co. 000000000700090
Construction Project Number	70C-1491-01
Original bridge construction	1970
Overlay construction	August 1987
End of overlay service	In service as of January 2009

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	Corrosion potential over 0.35V, percent
1987	preconstruction survey	17	30	0.33		1.20
Dec-87	survey	0.01	0.3	0.00	0.00	0.00
1988	survey	0.5	1.0	0.00	0.00	0.00
1989	survey	1	1.2	0.00	0.00	0.00
1990	survey	2	1.6	0.00	0.00	0.00
1991	survey	3	2.9	0.10	0.00	0.00
1992	survey	4	3.0	0.10	0.00	0.24
1993	survey	5	3.3	0.12	0.02	0.00
Jun-93	survey	6	1.9	0.12	0.02	0.00
Jul-94	survey	7	2.4	0.13	0.01	0.00
Jun-95	survey	8	2. 9	0.13	0.01	0.00
Jul-96	survey	9	3.9	0.13	0.02	0.00
Jul-97	survey	10	4.3	0.15	0.02	0.00
Sep-98	survey	11	5.2	0.16	0.06	0.00
Jul-99	survey	12	5.2	0.16	0.06	0.00
2004	survey	17	8.9	0.19	0.09	0.00

Experimental Number	Membrane 1
Bridge Name and Number	I-235 SB over Zoo Blvd 235-87-10.07(094)
Construction Project Number	235-87-I-235-I(35)
Research Project Number	NEPT KS 85-01
Original bridge construction	1961
Overlay construction	1986
End of overlay service	Overlay replaced 2000

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	2,000 ohms	10,000 ohms	100,000 ohms
Nov-86	survey	1.5	0.00	0.00	0.00	100.00	78.57	55.36
May-87	survey	2	0.03	0.00	0.00	98.20	75.00	48.20
Oct-87	survey	2.5	0.90	0.00	0.00	100.00	95.50	53.60
Nov-88	survey	3.5	1.10	0.00	0.00	100.00	100.00	92.00
Sep-89	survey	4.5	6.73	0.00	0.00	100.00	90.20	61.60
Oct-90	survey	5.5	6.73	0.00	0.00	100.00	99.10	92.00
Sep-91	survey	6.5	6.94	0.00	0.00	100.00	100.00	92.90
Oct-92	survey	7.5	1.16	0.00	0.04	99.10	91.00	64.20
Nov-93	survey	8.5				100.00	84.80	54.50
Sep-94	survey	9.5	1.87	0.00	0.04	91.10	78.60	58.90
Oct-95	survey	10.5	3.10	0.00	0.04	97.10	90.10	74.10
Oct-97	survey	12.5	3.59	0.00	0.04	83.00	73.20	64.30
Sep-99	survey	14.5	4.29	0.04	0.10	88.40	66.10	47.30

Experimental Number	Membrane 2
Bridge Name and Number	I-235 SB over Flood Canal 235-87-12.39(099)
Construction Project Number	235-87-I-235-I(15)
Research Project Number	NEPT KS 85-01
Original bridge construction	1962
Overlay construction	1986
End of overlay service	Overlay replaced 2000

Date	Event	Age	Unbonded area, percent	Longitudinal cracks (ft/ft^2)	Transverse cracks (ft/ft^2)	2,000 ohms	10,000 ohms	100,000 ohms
Apr-87	survey	2	0.00	0.00	0.00	100.00	96.50	71.90
Oct-87	survey	2.5	0.00	0.00	0.00	100.00	100.00	99.20
Nov-88	survey	3.5	0.00	0.00	0.00	100.00	100.00	99.60
Sep-89	survey	4.5	0.00	0.00	0.00	100.00	100.00	96.50
Oct-90	survey	5.5	0.81	0.03	0.01	100.00	100.00	98.80
Sep-91	survey	6.5	1.04	0.21	0.09	100.00	100.00	98.00
Sep-92	survey	7.5	0.90	0.28	0.12	100.00	100.00	96.40
Nov-93	survey	8.5	1.49	0.43	0.29	100.00	99.20	84.80
Sep-94	survey	9.5	1.78	0.51	0.36	99.60	93.00	59.00
Oct-95	survey	10.5	2.40	0.60	0.46	99.60	98.40	90.60
Oct-97	survey	12.5	3.48	0.65	0.54	99.60	98.40	75.80
Sep-99	survey	14.5	3.63	0.68	0.55	100.00	97.30	88.70

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