Abridgment

Kansas' Experience with Interlayer Membranes on Salt-Contaminated Bridge Decks

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ABSTRACT

Nearly 12,000 yd^2 of interlayer membranes were installed on salt-contaminated decks in Kansas between 1967 and 1974. The decks were from 6 to 50 years old when the membranes were placed. All of the membranes are performing well after 12 to 16 years. Traffic over the membranes during that time ranged from 3 to 160 million vehicles. The majority of resistivity readings taken in 1982 were greater than 500,000 $ohms/ft^2$. The asphalt wearing surfaces over the membranes were judged satisfactory to excellent. The 16-year-old membrane covered only part of a deck, but that part is in far superior condition than the remaining bare deck. In 1926 an asphalt-cotton fabric membraneous waterproofing system was placed over 1,437 yd^2 of a new Kansas bridge deck. The membrane was covered with a cement-sand mortar layer that was topped with paving bricks. After 56 years of service and about 50 million vehicle passes the concrete below the membrane contained less than 0.75 lb of chloride ion per cubic yard of concrete. In Kansas the evaporation rate is higher than the precipitation rate. This may be one reason why membranes work well on salt-contaminated decks in Kansas.

A Kansas Bridge Deck Deterioration Study (1) of the early 1960s considered protection of the bridge deck surfaces from salt intrusion in some phases of the study. Hot-mix overlays were unsatisfactory and were not recommended unless they were placed over a membrane (1,2).

The formal study of interlayer membrane performance in Kansas began with an installation in 1967 on a 6-year-old, salted, rural Interstate interchange bridge. The first installation (membrane system 52a; see Tables 1 and 2) was also the first installation of this proprietary membrane on a bridge deck anywhere in the world. The material, a polypropylene fabric, was placed on one quadrant of the bridge deck. The installation was about 72 ft long and one lane wide. The remaining deck was left bare. The membrane was covered with a wearing surface consisting of 0.7 to 0.8 gal/yd^2 of a cationic emulsified asphalt and hand-placed crushed-chert-type chat aggregate. A 20 percent excess of aggregate was applied to assure a good heavy coverage. By 1970 the performance was satisfactory enough that Kansas decided to evaluate other membranes on old decks.

From 1970 to 1974 four different types of mem-

TABLE 1 Interlayer Membrane Systems Used on Old Decks in Kansas

NCHRP 165 System No.[a]	System Type	Description
12	Preformed	A pliable sheeting construction from polypropylene and coal tar placed over a primer; a hot-mix overlay covers the membrane
52a	Liquid/ preformed	An applied in-place nonwoven polypropylene fabric with cationic emulsified asphalt; chat (chert) aggregate was rolled into RS-2K emulsion for the wearing course
52b	Liquid/ preformed	Same as 52a, except that the fabric was placed over a thin coat of AC-5 and covered with a hot-mixed asphalt-concrete (AC) overlay
67	Liquid	A cold-applied, coal-tar modified, elastomeric polyurethane with a 55-lb grade asphalt-impregnated roofing sheet over it; all overlaid with 2.5 in. of hot-mix AC
80	Liquid	A coal-tar modified polyurethane elastomer cold-applied with catalyst (curing agent) added before application; the material was covered with no. 40 asphalt roofing sheet, which was topped with a hot-mix overlay

[a]See Table 9 of NCHRP Report 165 *(2)*.

TABLE 2 Membrane Installation Data

Bridge ID	Type of Membrane System[a]	Date Membrane Installed	Date Bridge Constructed	Material Installed (yd^2)	Overlay Thickness (in.)	Bridge Type[b]
A	52a	1967	1961	112	0.125	RBGC
B	12	1970	1936	700	1.5	Cont. I-Beam
C	80	1971	1958	283	1.5	Cont. RC slab
D	80	1971	1959	404	1.5	Cont. RCDG
E	52b	1971	1953	254	2	Cont. RC slab
F	52b	1971	1936[c]	1,035	2	RCDG
G	80	1971	1936[c]	1,313	1.5	Steel I-beam
H	67	1974	1924[d]	7,700	2.5	RC slab and Cont.
I	-	1926	1926	1,437	3.5	SBMS/SSGC

[a]See Table 1 for description (2, Table 9).
[b]Bridge types are as follows: RBGC = reinforced box-girder continuous; RCDG = reinforced-concrete deck girder; RC = reinforced concrete; Cont. = continuous; and SBMS/SSGC = steel beam simple/steel girder, stringer floor beam continuous.
[c]Widened in 1971.
[d]Widened in 1974.

branes totaling nearly 12,000 yd^2 were placed on seven more salt-contaminated bridge decks that were 12 to 50 years old when the membranes were installed. All seven decks had typical salt-related damage, such as hollow planes, shallow spalls, and patched areas. The shallow spalls were not patched before installing the membranes. The data in Table 1 describe the membranes used, and the data in Table 2 provide pertinent information about the installations.

PERFORMANCE

All of the test bridges with membranes were observed in 1982 or 1983. Resistivity measurements were made on bridges A through F (Table 2). Bridges G and H are in high traffic urban areas, and the accident risk outweighed the value of the resistivity measurements; therefore, measurements were not taken.

The 1967 membrane test section, membrane type 52a (Tables 1 and 2), showed a great contrast in condition between the covered and uncovered parts of the deck in 1983 (see Figure 1). (Note in Figure 1 that the deck under the membrane is in far better condition than the bare deck on the left.) All of the corrosion potentials on the uncovered deck measured more negative than -0.35 V. No measurements were made through the membrane. One-third of the resistivity readings on the membrane were more than 500,000 $ohms/ft^2$. Patches, spalls, and hollow planes were present on 91 percent of the uncovered deck area. Only 6.5 percent of the deck in the membrane area experienced delaminations, and they were all at the edges of the membrane adjacent to the uncovered deck or along the curb. There were no spalls or patches in the membrane area. The uncovered part of the deck contained from 6 to 16 lb of chloride per cubic yard of concrete, whereas the concrete under the membrane contained only 1.5 to 3 lb Cl^-/yd^3. The bridge had been salted for 6 years before the membrane was placed. It is possible the deck already had as much as 3 lb of chloride per cubic yard of concrete in 1967 when the membrane was placed. The salt content was not determined at that time, however. Total traffic over the membrane had been about 3 million vehicles up to the time of the 1983 evaluation.

FIGURE 1 A 16-year-old polypropylene fabric membrane covering part of the deck in right foreground.

The membranes on bridges B through G (Table 2) were 12 and 13 years old in 1983; the membrane on bridge H was then 9 years old. In that time they have been subjected to numerous salt applications for snow and ice control as well as from 6.5 million to 160 million vehicles. Trucks made up from 1.4 to 19 percent of the total vehicle traffic. Skid resistance on the overlays that were subjected to traffic of from 76 million to 160 million vehicle passes was from the mid to upper 20s. At lower traffic, the skid number ranged from the upper 30s to low 50s.

The only membrane that has partly failed was the 9-year-old membrane. Failure was caused by the membrane being placed on too steep a downhill slope with a stop light at the bottom end of the bridge and an average of 8 million vehicle passes annually. Only part of the membrane failed. The membrane and its overlay farther away from the light on a flatter slope is still in place after more than 76 million vehicle passes over the bridge.

Resistivity measurements made in 1982 on five of the bridges, then 11 and 12 years old, indicated that two of them had all readings greater than 500,000 $ohms/ft^2$. Two others had more than 90 percent of the readings greater than 500,000 $ohms/ft^2$. The fifth one had only 36 percent of the readings greater than 500,000 $ohms/ft^2$.

The appearance of the asphalt riding surface in each installation was from satisfactory with some cracking to excellent. Surface cracking after 11 and 12 years ranged from 0.8 to 1.8 lineal inches per square foot of area. The overlays exhibited unbonding from 2 to 22 percent of the deck areas. In spite of this, little maintenance has been performed on any of the overlays (other than the 9-year-old one) since the membranes were placed.

Before the installation of the membrane some of the bridges had considerable seepage of water from the bottom of the deck during rainy or snowy seasons. This condition did not recur after the membranes were placed.

Salt or corrosion studies below the membranes have not been made because the researchers did not want to puncture them. Furthermore these membranes were installed before those studies began; therefore, there was no base point control. It should be remembered that all of the decks had been routinely salted during snow and ice storms and exhibited typical salt damage to the reinforced concrete before the membranes were placed.

A 56-year-old Kansas membrane installation was investigated in 1982. It was about 0.25 in. thick and was made up of asphalt with two layers of cotton fabric. The plans merely referred to it as membraneous waterproofing. No data concerning makeup or mode of placement were given; hence it is not described in Table 1, although it is included in Table 2 as bridge I. The membrane was installed over a 6.75-in.-thick concrete deck at the time of construction in 1926. The membrane was covered with a cement-sand mortar layer 0.5 in. thick. A riding surface layer of 3-in.-thick pavement bricks was embedded in the top of the mortar layer. Sometime during the 1960s an asphalt overlay was added because the deck was getting rough from the loss of some bricks.

In 1982 a condition survey of this structure was made and 41 samples of the concrete were taken from below the membrane. Tests for chloride showed that none of the samples taken contained even 0.75 lb of chloride per cubic yard, and 81 percent contained less than 0.4 lb/yd^3. Copper-copper sulfate half-cell corrosion potential measurements were made in core holes. Only 10 percent of the readings were more negative than -0.35 V. That corrosion may have begun when the cores were taken.

Damage to the concrete bridge deck was limited essentially to the unprotected sidewalks and the areas adjacent to the edge of the membrane where water had penetrated. It is obvious that the membraneous waterproofing has served its purpose well for those 56 years. During that time the bridge carried an estimated 50,000,000 vehicles. About 15 percent of them were trucks.

The performance of membranes on new decks is covered by Frascoia in a paper elsewhere in this Record. The 56 years of satisfactory performance of a membrane in Kansas supports his long-term projections for membrane performance.

SOME PERTINENT POINTS ABOUT KANSAS CLIMATE

Kansas sometimes is referred to as the mixing pot for the weather. Most Kansas bridges undergo an average of 60 or more freeze-thaw cycles each year. They are subjected to an average of five or six winter snowstorms and one to three ice or sleet storms each year. The snow and ice are usually removed by snowplows and deicing salts. Kansas bridge decks receive about 20 applications of salt per year at the rate of 1,300 lb per 2-lane mile (3).

Bridges in Kansas may be subjected to air temperatures as low as -40°F in the winter and as high as 120°F in the summer. Winter wind-chill factors may reach -65°F in the winter, whereas the summer temperature of asphalt overlays often reaches 160°F. Rapid changes in temperature are not uncommon. Parts of Kansas average about 7,000 degree hours greater than 85°F. Precipitation ranges from more than 40 in. in the southeast part of the state to about 16 in. in the southwest. The evaporation rate is higher than the precipitation rate all across the state. The greatest differential is in southwestern Kansas, where lake evaporation is as high as 62 in. per year and precipitation is as low as 16 in. per year, on average. It is believed that if the membranes can retard the downward movement of water and chlorides, evaporation will soon take over and keep them near the surface.

SUMMARY AND CONCLUSIONS

Nearly 12,000 yd^2 of interlayer membranes have been installed on old salt-contaminated decks in Kansas. They have served quite well with little maintenance for 12 to 16 years. If the 16-year-old membrane had covered the entire deck, it is probable there would have been one less Kansas bridge that needed extensive deck repair. One 1,437-yd^2 membrane placed on a new deck has served well for 56 years.

In Kansas the evaporation rate is higher than the precipitation rate. This probably influenced the satisfactory performance. Care in installation and proper timing of all procedures is also necessary to give the membranes a chance to work. Sealing the overlay-hubguard contact would be beneficial.

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