The Kansas Experience with Polymer Concrete Bridge Deck Overlays

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ABSTRACT

The Kansas Department of Transportation (KDOT) uses multi-coat polymer concrete overlays for bridge preservation. The first multi-coat polymer concrete overlay was placed in 1999 on Bridge No. 46 in Shawnee County, Kansas, as a research project.

Four suppliers were invited to place materials on the structure. Each material was allotted 100 linear ft of deck, 333 square yards per supplier. To this point in time, KDOT has placed over 90 polymer overlays all with the intent of minimizing chloride and water intrusion to preserve the structures.

Typically, candidate structures have had minimal spalling that has been repaired, and may have cracked delaminated silica fume or high density overlays with no failure of the surface itself. There are a number of structures under heavy traffic and no failures have been found due to delaminated concrete overlays. The intent of KDOT in using the polymer overlays is to place them on structures that are not seriously deteriorated and require minimal deck repair, thus preserving structures that are still very serviceable.

Three new structures in Kansas have had polymer overlays placed on them due to construction errors which resulted in cracked bridge deck concrete or a loss of concrete cover due to settings of the placement machine. One structure has had an overlay placed when new by design.

The average savings of using a polymer overlay over a silica fume overlay as a maintenance bridge preservation action is $16 per square yard. Significant savings are also found in user costs and traffic control costs. Most of the structures that the polymer overlays have been placed on in Kansas are relatively short, 200 to 400 ft. However, two structures in Sedgwick County 12,496 and 12,110 ft long, with approximately 42,500 vehicles per day in each direction and approximately 7% trucks, were overlaid in 2007 and 2008.

The Kansas experience in general has been very good; however, it has not been without some problems and a learning curve. Additional wording has been added to the Kansas Standard Specification to provide additional attention to eliminating problematic issues such as spillage of resins, moisture, and preventing contamination after shot blasting. Familiarity with the specification is important. There are now several contractors in Kansas with significant experience placing the polymer overlays.

KDOT is planning on the continued use of the multi-coat polymer concrete overlay for preservation purposes and intends to begin using the overlays on new bridge structures.

Key words: bridge preservation—multi-coat polymer concrete
INITIAL APPLICATION

The Kansas Department of Transportation (KDOT) began working with Epoxy Polymer Overlays in 1999 when a polymer overlay was placed on Bridge No. 46 in Shawnee County, Kansas. The structure was a concrete box girder structure, 398.5 ft long and 30 ft wide, on the ramp connecting westbound I-470 to westbound I-70 with an annual average daily traffic (AADT) of 6620 vehicles with 30% heavy trucks. The structure was built in 1959. The deck was patched and a high-density concrete overlay was placed in 1992; this overlay had significant cracking by 1999 when the polymer overlay was placed.

Bridge 46 was curved and had a significant slope so deicer was heavily used on the structure. Therefore, the intention in placing the polymer overlay was to seal the cracks in the high density overlay to prevent additional chlorides and water from reaching the uncoated reinforcing steel. The aggressive surface that was achieved with the flint rock broadcast aggregate was an added advantage.

As the application of the polymer overlay was a research project, four suppliers were invited to place materials on the structure. As stated earlier, the structure was nearly 400 ft long. Each material was allotted 100 linear ft of deck, 333 square yards per supplier. As expected, all four of the materials placed were very similar in physical properties and all materials were placed the same day by the same contractor. The bridge deck was shot blasted as per the specification (ICRI CSP 5-7) (see Figure 1). Costs included material, placing of the material, and shot blasting. The aggregate was a flint rock from Pitcher, Oklahoma, meeting the specified gradation. This material is still used on all polymer overlays in Kansas today. The KDOT specification was and still is fashioned around the suggested specification noted in the AASHTO-ARTBA Task Force 34 document and the Virginia Polymer Overlay specification. The placement of the materials went as expected with no problems.

In June of 2000, bond failure of the overlay materials was noted on the bridge. The failures were distributed longitudinally on the bridge and appeared to be large spills or splashes. All materials were failing similarly. The research unit evaluated the failures and took samples of the concrete for chemical evaluation. The evaluation indicated the presence of fusel oil; this material is a byproduct of alcohol production and is used in bond breaker for concrete. The overlay was sounded and all loose material was identified. Saw cuts were made well outside the sounded areas to ensure all material was removed from the contaminated concrete. The contaminated concrete was removed by aggressive sand blasting and some chipping. The concrete was again tested and no contamination was found. The overlay was replaced in the same sequence as it was originally constructed. After this failure, subsequent specifications for the polymer overlay called for an ICRI SPS of 6–7.

![Figure 1. Concrete surface preparation samples](image)
The overlay has been in place for 9 years and has no indication of any additional significant failures. It has had approximately 21,000,000 total vehicles of which 30% have been heavy trucks. In 2003, the skid coefficient was found to be 53 using the Pavement Surface Friction Tester (ASTM C 274) with a ribbed tire. Recently, the overlay was re-evaluated and was found to have some reflective cracking and several small areas that have spalled. This spalling may be due to some repairs performed on the structure that required cutting through the overlay and replacing it. There are plans to lightly shot blast the surface and place a single coat overlay to upgrade the surface.

PRESENT EXPERIENCE

As previously stated, KDOT placed the first polymer overlay to seal the cracked bridge deck, protect the uncoated reinforcing steel from additional chloride and water intrusion, and prevent damaging corrosion. To this point in time, KDOT has placed over 90 polymer overlays all with the intent of minimizing chloride and water intrusion to preserve the structures. Some structures have had minimal spalling that was repaired, and many have delaminated silica fume or high density overlays that have been delaminated for a number of years with no failure of the surface itself. On these structures, KDOT has chosen not to remove the overlay but simply shot blast the surface and place the polymer. There are a number of these structures under heavy traffic, and no failures have been found. If a deck is found to have shallow delaminations, the loose concrete is removed, the areas are repaired, the deck is shot blasted, and the polymer is placed. The intent of KDOT in using the polymer overlays is to place them on structures that are not seriously deteriorated and require minimal deck repair, thus preserving structures that are still very serviceable.

Three new structures in Kansas have had polymer overlays placed on them due to construction errors which resulted in cracked bridge deck concrete or a loss of concrete cover caused by errant settings of the placement machine. A polymer overlay was placed on Bridge No. 41 in Mitchell County due to concrete consistency problems encountered during placement of the deck, resulting in high permeability and low density concrete with some cracking and small voids. The bridge was determined to be structurally sound and the overlay was placed to protect the structure. On Bridge No. 24 in Sheridan County, the setting on the depth screed slipped, reducing the cover over the reinforcing steel to 2 in. rather than the standard 3 in. The overlay was placed to provide the lost protection. Both of the structures listed above received single-coat polymer overlays; however, the polymer was placed at a rate of 1.5 times that of a typical first layer of an overlay.

The third new structure to have a polymer overlay placed on it was Bridge 48 in Lyon County. A corrosion-inhibiting admixture was used in the bridge deck concrete and extensive cracking of the deck occurred. The polymer overlay was placed on the deck to seal the cracks and achieve the expected structure life. This overlay was a standard two-coat system.

Bridge 206 in Sedgwick County is the only new structure on which a polymer overlay was placed before opening to traffic by design. This structure is located on a roadway that is directly off of KDOT property and all of the salt/sand trucks used for snow and ice control cross the structure coming and going to the KDOT shop. The previous structure had an excess of 11 lbs of chlorides per cubic yard before removal. The purpose of the overlay was to give additional protection from chloride intrusion.

KDOT placed one polymer overlay in 1999, 2000, 2001, and 2002; placed five overlays in 2003; four in 2004; 14 in 2005; 19 in 2006;15 in 2007; 26 in 2008; and 12 will be let in 2009. The success of the polymer overlays in the early years of application was tracked by the bridge management unit of KDOT Bridge Design, and by district managers. The use of the overlays has grown rapidly. At this point in time, five counties in Kansas have placed a total of 14 polymer overlays with one county placing 11 overlays.
Shawnee County has just finished placing a polymer overlay on a structure that is 1296 ft long and 28 ft wide, a total of 4035 square yards. The reason for the popularity of the polymer overlay is not just the material-cost differential between a silica fume overlay and a polymer overlay, but also the significant difference in the cost of traffic control and user costs due to lane closers.

**COST COMPARISON**

What follows is a cost comparison summary between a typical polymer overlay and typical silica fume overlay.

The typical rehabilitative silica fume overlay involves milling of the bridge deck, and removal and replacement of deteriorated concrete, which usually costs more than expected due to the aggressive action of the milling machine and placement of the overlay. The average cost for placement of a silica fume overlay between 2001 and 2008 was $19.80 per square yard for milling, and $51.40 per square yard for placement of the silica fume overlay. This is a total cost of $71.20 per square yard. The average cost of a polymer overlay for the same period was $55.05 per square yard, a savings of $16.00 per square yard. As previously stated, significant savings are also found in user costs and traffic control costs.

Costs listed above for the polymer overlays include deck prep and placement of the Polymer Overlay. They do not include patching, if any, or traffic control, as traffic control is a very fluid cost on projects. What follows is a cost comparison of a “typical” project traffic control.

Typically an existing structure with a distressed deck would be milled, patched, and a silica fume overlay would be placed on the deck to reduce chloride intrusion and slow the corrosion process of the reinforcing steel. Most decks that would receive this “maintenance overlay” would be old enough to have black reinforcing steel rather than epoxy-coated reinforcing steel. KDOT also places silica fume overlays on high-traffic volume new structures that have epoxy-coated steel. Kansas began using epoxy coated steel in the mid 1980s.

The following is a summary of traffic control costs for a two-lane structure silica fume overlay and polymer overlay on both a two lane and four lane highway:

- **Two lane highway silica fume**
  - $700 per day with signals, and lane closed overnight for 20 working days
- **Four lane highway silica fume**
  - $800 per day and lane closed overnight for 20 working days
- **Two lane highway polymer**
  - $1200 per day using live flaggers, and lane is open overnight for five working days
- **Four lane highway polymer**
  - $335 per day, lane is open overnight for five working days

Placing of a silica fume overlay on two lanes of an average Kansas structure (350 ± feet) involves milling of the bridge deck, patching of the deck, and placing and curing of the silica fume overlay. These costs will not be addressed due to bidding procedures and variability. Placing of the polymer overlay on the same structure would involve patching, shot blasting to the proper surface texture, and placing of the overlay. The significant difference in time required to complete these two projects is mostly due to cure time required for the silica fume concrete. It would typically be seven days before traffic is allowed on the structure. The time required to place the silica fume overlay on the deck indicated above would require
approximately 20 days and overnight lane drops. The time required to place a polymer overlay on the same structure would require approximately five days with no overnight lane drops.

On a two lane road the traffic control for placement of a silica fume overlay would require signals at a cost of approximately $700 per day for approximately $14,000. Applying a polymer overlay to the structure would require five days and human flagging at a cost of $1,200 per day for approximately $6,000. This indicates a savings of $8,000 for traffic control using a polymer overlay.

On a four lane road the traffic control for placement of a silica fume overlay would cost approximately $800 per day for approximately $16,000. Applying a polymer overlay to the structure would require five days and minimal flagging at a cost of $335 per day for approximately $1,675. This indicates a savings of $14,325 for traffic control using a polymer overlay and 15 days of user costs.

SPECIAL APPLICATIONS AND STRUCTURES

Most of the structures that the polymer overlays have been placed on in Kansas are relatively short (200 – 400 ft). There have been a few larger structures, but two structures in particular are worth some detailed discussion: the structures are Bridges 290 and 291 in Sedgwick County. These two structures are on I-135 with three lanes each and access ramps. The structures are basically twin viaducts 12,496 and 12,110 ft long and approximately 42,500 vehicles per day in each direction with approximately 7% trucks.

Due to the high traffic volume on these structures, the construction process was changed considerably to increase the production and minimize lane closures. The contractor was allowed to work from 7:00 p.m. until 6:00 a.m. Sunday through Thursday nights with a large penalty for late lane opening in the morning. The bridge deck was shot blasted to the required surface relief as usual, but the process was started well ahead (two weeks) of polymer placement to prevent the preparation of the deck from slowing the placing of the polymer overlay. The contractor placed one coat of polymer on an area approximately 1,500 ft long and two lanes plus the shoulder width (5,000 square yards) each night. Before the placement of the polymer, the area was quickly re-shot blasted to clean off contamination that may have occurred after the initial preparation, and one coat of polymer with aggregate was placed per night. Traffic was allowed on the first coat the next day. The following night the first coat was quickly and lightly shot blasted to remove contamination that may have occurred during the day, and the second coat of polymer with aggregate was placed, thus completing a significant section of the bridge each of the two days, but allowing the opening of the bridge to traffic each morning.

The southbound structure and approximately half of the northbound structure was completed in the summer of 2007. The remainder of the northbound structure was completed in the spring of 2008 using the same procedures and epoxy materials.

SPECIFICATION CHANGES

The Kansas experience in general has been very good as can be seen from the increase in the use of the polymer overlays. However, it has not been without some problems and a learning curve as previously stated. The experiences have prompted KDOT to change the specifications to improve the quality of the completed overlays. After the de-bonding occurred on the first polymer, the specification was changed so that the surface preparation requirement was changed to ICRI CSP 6 or 7 to ensure removal of contaminated concrete.
Additional wording has been added to the specification to provide additional attention to eliminating problematic issues such as spilling of the polymer components on the deck surface, evaluating a deck for moisture after a rain, cleaning of the surface after a rain, and preventing contamination of the prepared deck by tracking materials on the shot-blasted surface. The specification now requires that the shot blasters be emptied at least 50 ft from the end of the bridge deck or area being prepared. This focus on contamination is due to finding small delaminated areas on several structures after completion of the project, see Figure 2. These areas are small, irregular and scattered. This indicates small areas of contamination. The contamination is probably due to dust being tracked onto the prepared deck or liquid spots on the deck that were not seen before placement of the polymer.

To improve the quality of the overall project, the polymer is now placed to a minimum height of 6 in. on the surface of the curb or barrier rail to ensure sealing of the joint at the deck surface and eliminate intrusion under the overlay of water and chlorides. Also, distribution equipment must be capable of verification of the mix ratio of the components and verification of the amount of material placed on the bridge deck. Kansas also now requires that a material supplier have a three year application history in Kansas before the material will be placed on the pre-qualified materials list.

An additional change in procedures, but not in the specification, is that if a known experienced contractor uses material that has sufficient application history in Kansas, the overlay may be placed on the prepared deck previous to performing a test pull-off of the overlay material to expedite the project and minimize traffic delays. The pull-off test is performed after the overlay is in place and cured. All pull-off tests are performed by the contractor.

The KDOT Standard Specification has also been changed slightly to accommodate the use of the polymer overlays on new structures. Changes include concrete cure time for full-depth deck applications.

**GENERAL INFORMATION**

Kansas has had significant success with removing only shallow delaminations and repairing only those areas that are spalling. Delaminated concrete overlays that have not begun to break up are left in place. A number of the bridge decks that have had the polymer overlays placed on them have had high density overlays with a considerable amount of delamination. The high density overlays on these bridges were cracked but not coming apart and spalling. As the shot blasting is not an aggressive treatment, it is felt that if the overlays are withstanding the impacts of traffic without the polymer overlay, they will be
reinforced by the polymer overlay. All but one of the overlays in place are epoxy, one structure has had a methacrylate base polymer overlay applied.

CONCLUSIONS

The polymer concrete bridge deck overlays have become very valuable tools for preserving bridge structures in Kansas. The KDOT has more than 90 polymer overlays in place, and Kansas Counties are beginning to see the value of the polymer overlay with additional county bridges being protected on a regular basis.

The KDOT will continue to use this preservation tool in the future, with applications for new bridge decks in an effort to reduce the use of silica fume overlays on new decks.