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A Programmatic Approach to Long-Term Bridge Preventive Maintenance

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Research Report
KTC-16-22/SPR15-504-1F

A Programmatic Approach to Long-Term Bridge Preventive Maintenance

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16. Abstract State transportation agencies use cost-effective preventive maintenance (PM) programs to preserve existing roadway systems, slow down their deterioration, and improve their functional condition. Currently, KYTC's bridge inventory includes approximately 10,000 structures, and by 2018, most of these structures will have been in use for at least 50 years. Because there is insufficient funding available to pursue a large-scale bridge replacement program, it is critical for the Cabinet to prolong the lives of its bridges by using economical strategies. This report provides guidance that the Kentucky Transportation Cabinet (KYTC) can use to develop and implement a statewide bridge PM program. Drawing from previous Kentucky Transportation Center (KTC) research studies and interviews with other state transportation agencies, the report describes eight bridge PM activities that KYTC can leverage to maintain and enhance its current portfolio of bridges. It provides technical overviews of each activity. These activities include: 1) resealing and repairing joints; 2) cleaning and sealing bearings; 3) bridge washing; 4) sealing decks; 5) spot painting; 6) patching bridge decks; 7) cleaning and painting pier caps and abutments; and 8) scour, drift, sediment, and bank stabilization. KYTC would benefit from incorporating PM activities into a holistic bridge preservation program to extend the service lives of its bridges.			
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EXECUTIVE SUMMARY

State transportation agencies use preventive maintenance (PM) programs as cost-effective measures to preserve existing roadway systems, slow down their deterioration, and improve their functional condition. The Kentucky Transportation Cabinet (KYTC) bridge inventory includes approximately 10,000 structures, and by 2018, most of these structures will have been in use for at least 50 years. Because there is insufficient funding available to pursue a large-scale bridge replacement program, it is critical to use cost-effective strategies to prolong the lives of Kentucky's bridges. This report provides guidance that KYTC can use to develop and implement a statewide bridge PM program, resulting in the best approach for keeping Kentucky's bridges in a good state of repair.

Drawing from previous Kentucky Transportation Center (KTC) research and newly conducted interviews with other state transportation agencies, the report describes the *8 Basic PM Activities* for bridges. These activities target high-maintenance bridge components, such as decks, joints and coatings, all of which demand significant attention from bridge owners. Putting the *8 Basic PM Activities* into use will assist KYTC in its efforts to maintain and enhance its current inventory of bridges. This report summarizes each PM activity by providing technical overviews, task descriptions for executing each activity, anticipated costs, and the expected durability (where available). The *8 Basic PM Activities* include: 1) resealing and repairing joints; 2) cleaning and sealing bearings; 3) bridge washing; 4) sealing decks; 5) spot painting; 6) patching bridge decks; 7) cleaning and painting pier caps and abutments; and 8) scour, drift, sediment, and bank stabilization. During the initial stages of building its PM program, KYTC should focus on the effectiveness of PM activities, which entails identifying best maintenance practices (including developing work standards and specifications for contractor work); developing/providing training for KYTC supervisors, field crews and inspectors (and possibly contractor personnel); and determining what materials are most likely to provide the greatest durability. Over the long-term, KYTC will benefit by incorporating PM activities into a holistic bridge preservation program to extend the service lives of its bridges and provide the lowest life-cycle costs. Based on its research, KTC advances the following recommendations for implementing a comprehensive PM program.

- Initiate a pilot PM program in one or two districts with additional funding allocated for PM activities. The pilot program should last 1–2 years and implement the *8 Basic PM Activities* described in this report. KYTC should audit and review the program by looking at the performance of each activity and the work performed each year.
- The pilot program could be expanded to all KYTC districts once it has matured.
- KYTC could integrate PM work into a holistic bridge preservation program that addresses PM, rehabilitation, and bridge replacement in a structured, systematic manner.

INTRODUCTION

Preventive maintenance (PM) is the strategy of applying cost-effective treatments to an existing roadway system and its associated features and structures with the goal of preserving the system, slowing its future deterioration, and maintaining or improving its functional condition (without substantially increasing structural capacity) (*Source: AASHTO Subcommittee on Maintenance (1)*).

The Kentucky Transportation Cabinet's (KYTC) bridge inventory currently includes approximately 10,000 structures. Most of these bridges will have been in service for 50 years or more by 2018. However, KYTC's bridge replacement funding is insufficient to address its aging bridge inventory. In 2011, the Kentucky Transportation Center (KTC) estimated that the total cost of replacing all deficient KYTC bridges was twice the Cabinet's total annual budget.

Lacking the budget for large-scale bridge replacements, the service lives of KYTC bridges must be extended through a statewide bridge PM program that combines preventive maintenance (cyclical and condition-based) and rehabilitation. A correctly designed PM program will reduce the number of bridges needing major repairs or replacement and lessen bridge lifecycle costs.

Implementing a PM program will require that the Cabinet increase its emphasis on keeping bridges in a state of good repair, including the performance of bridge maintenance activities more routinely – especially proactive cyclic maintenance activities. A major challenge lies in ramping up these activities and maintaining a large-scale, long-range program that efficiently delivers effective bridge preservation activities throughout the state.

Prior to this study, KYTC had considered piloting a PM program in one of its 12 districts on a trial basis. At that time, the Cabinet planned to gradually expand the program after testing it in the pilot district. This study contributed to the formative process of the pilot program. A previous study, KYSPR 11-424 *Preventive Maintenance Program for Bridges*, offered a general overview of PM activities employed by DOTs throughout the country. KTC identified many potential cyclical and condition-based PM activities, some of which were not germane given KYTC requirements (2). To implement the pilot program, a more focused research study was needed to identify a small number of PM activities relevant to Kentucky that could be piloted on a trial basis and describe the required work (including key equipment and treatment materials) in sufficient detail to enable the selected KYTC district to start up a PM program.

OBJECTIVES

The study's research objectives included:

1. Identifying effective bridge PM activities.
2. Interviewing KYTC and other state DOTs to identify and evaluate bridge PM activities, with a specific focus on their issues such as their limitations, costs, and service life.
3. Identifying materials to place on approved product lists for bridge PM activities. Describing procedures for proper field application of activities/best management practices (BMPs) either by state forces or by contract.
4. Recommending bridge PM activities based on bridge type, age, and condition.

KTC performed the following tasks to achieve these goals:

1. A literature review identified effective bridge PM activities.
2. A regional survey of DOTs and other transportation entities established effective bridge PM activities, costs and materials.
3. Discussions with contractors, vendors and state DOTs helped to obtain unit/lifecycle costs for specific PM activities and to develop estimates of the unit/life cycle costs for implementing specific BMPs.
4. Effective bridge PM activities were grouped into sets (identified in Task 1) that can be employed on bridges based upon their age and/or condition.
5. Results were summarized in a final report.

RESEARCH APPROACH

IDENTIFICATION OF PREVENTIVE MAINTENANCE ACTIVITIES

To obtain background information on bridge PM activities, KTC relied on work performed as part of KYSPR 11-424, *Preventative Maintenance Program for Bridges*. Using tables from Hopwood et al. (2015), a list of potential PM activities was prepared (Appendix A). It contained 27 cyclical PM activities, 72 condition-based PM activities, 34 rehabilitation actions, and three actions classified as enhancements. KTC provided the listings of rehabilitation and enhancement activities to KYTC so personnel unfamiliar with PM activities could distinguish between the three classes of activities. The list also contained a blank table that KYTC personnel could use to submit proposed PM activities outside of the prepared list.

KTC scheduled meetings with KYTC district offices to discuss the implementation of bridge PM activities. The Center sent the list of potential PM activities to all districts prior to the meetings so that district personnel could review them. KTC researchers met with KYTC district personnel (Districts 1, 2, 3, 4, 5, 6, 9, 10, 11) between January and March 2015. The group discussed PM activities that KYTC personnel believed would be important in their districts. The study advisory chair attended and facilitated most of these meetings. PM activities identified during the district interviews were then summarized (Table 1).

Next, KTC researchers surveyed several Midwest DOTs to obtain additional information on their bridge PM activities (Appendix B). DOTs from Oklahoma, Missouri, Kansas, Michigan, and West Virginia participated. By June 2016, all of the DOTs responded and a follow-up email was sent to each participating DOT requesting that they identify their top five PM activities. KTC generated a consolidated list of the top eight PM activities based upon a combination of the DOT rankings and KYTC district summaries (Table 1). KTC termed these the *8 Basic PM Activities* because they were most frequently cited in the rankings of both sources. Table 2 includes a list of other PM activities identified by the Midwest Bridge Preservation Partnership (2011) that were not considered in this project.

Table 1. The 8 Basic Preventive Maintenance Activities Identified by DOTs and KYTC Districts

State Agency	Deck Patching	Re-seal and Repair Joints	Sealing Decks	Bridge Cleaning & Washing	Spot Painting	Clean/ Paint Pier Caps and Abutment Seats	Clean & Seal Bearings	Scour, Drift, & Bank Stabilization
MDOT	X	X						
MoDOT		X	X	X	X			X
ODOT		X	X	X	X			
KSDOT								
KYTC D1							X	X
KYTC D2		X				X		
KYTC D3								
KYTC D4		X				X	X	
KYTC D5								
KYTC D6			X					

KYTC D9				X			X	
KYTC D10		X		X				
KYTC D11	X						X	
Frequency	2	6	3	4	2	2	4	2

Table 2. Other Common Preventive Maintenance Activities

Cyclical Preventive Activities	Condition-Based Preventive Activities
Approach Pavement Relief Joints	Approach Slab Overlay
Clean/Flush Deck	Cut Relief Joints in Approach Pavement
Coat Concrete Barrier/Deck Fascia	Deck Fascia/Overhang Repair
Seal Bridge Deck Cracking (e.g. Crack Chaser)	Deck Joint Replacement
Seal Deck - Aggregate (e.g. Chip Seal)	Deck Repair - Full Depth
Slope Paving Repair	Deck Repair - Half Sole (Depth)
	Epoxy Overlay
	HMA Overlay (Cap – No Membrane)
	Leveling/Lifting/Stabilization (e.g. Wedging, Mud Jacking) in Approach Pavement
	Patching with HMA Overlay (No Water Proofing Membrane)
	Patching with HMA Overlay (With Water Proofing Membrane)
	Painting Railing
	Shaving Approach Shoulders

Only tasks that were listed by several respondents – including at least one KYTC district – were considered for inclusion in the list (Table 1). Activities performed by state workers and contractors were included.

8 BASIC PREVENTIVE MAINTENANCE ACTIVITIES

The following sections describe the *8 Basic PM Activities* identified by KTC researchers. Where appropriate, the discussion includes a description of bridge components impacted, the reasons for using, and issues associated with each activity, work tasks, materials/special equipment, and frequency of use (for cyclical maintenance) and costs (first/lifecycle).

1. RE-SEAL AND REPAIR OF JOINTS

Bridge deck expansion joints accommodate longitudinal movements of a bridge deck as well as those occurring in the superstructure. They are caused by live loads, thermal changes and the physical properties of bridge materials. Another function of some deck joints is to protect the substructure and superstructure elements below the deck from water runoff and debris spillage (3).

Bridge deck joints are classified as open or closed systems (Figure 1). Open joint systems let water and debris pass through a joint to the elements below the deck, while closed joint systems are sealed to prevent water and debris from passing through a joint. Open joints are typically less costly to install and maintain, but their popularity has declined due to the increased use of corrosive deicing chemicals. Some open joint systems include a trough under the joint to provide drainage. Examples of open joints are butt joints, sliding plates and finger joints. Closed joints include compression seals, strip seals, plug seals, poured seals, cushion seals and modular joints.

Open Joints (4):

1. Butt joints are typically used to accommodate movements up to one inch. They can be installed with or without armor facing. The armor facing is a metal angle embedded on both sides of a joint and anchored into the concrete.
2. Sliding plate joints are not watertight but do prevent most debris from passing through a joint. Sliding plate joints are normally used to accommodate movements of one to three inches. Those are installed in a similar fashion as the armor edge, with a horizontal plate attached to one side that extends across the opening.
3. Finger joints are typically used on long-span bridges where movement more than four inches is expected. Finger joints are typically installed with troughs. When installed with a drainage system, these joints can be a cost-effective alternative to more complex modular joints.

Closed Joints (op. cit. 4):

1. Pourable joint seals are typically used on short spans where movements of less than one inch are expected. However, some newer materials have been reported to accommodate movement up to three inches. The seals consist of a polyethylene foam backer rod, which fills the joint, and a self-leveling two-component polymer material. An advantage of this type of joint is that the performance is generally unaffected by irregularities within the joint walls. It is also relatively inexpensive to install and maintain.
2. Compression seals can accommodate movement up to approximately three inches. There are two types of compression seals: open cell and closed cell foam. Both types rely on compression to maintain a watertight seal. They are installed using a two-component adhesive, which also acts as a lubricant during installation.

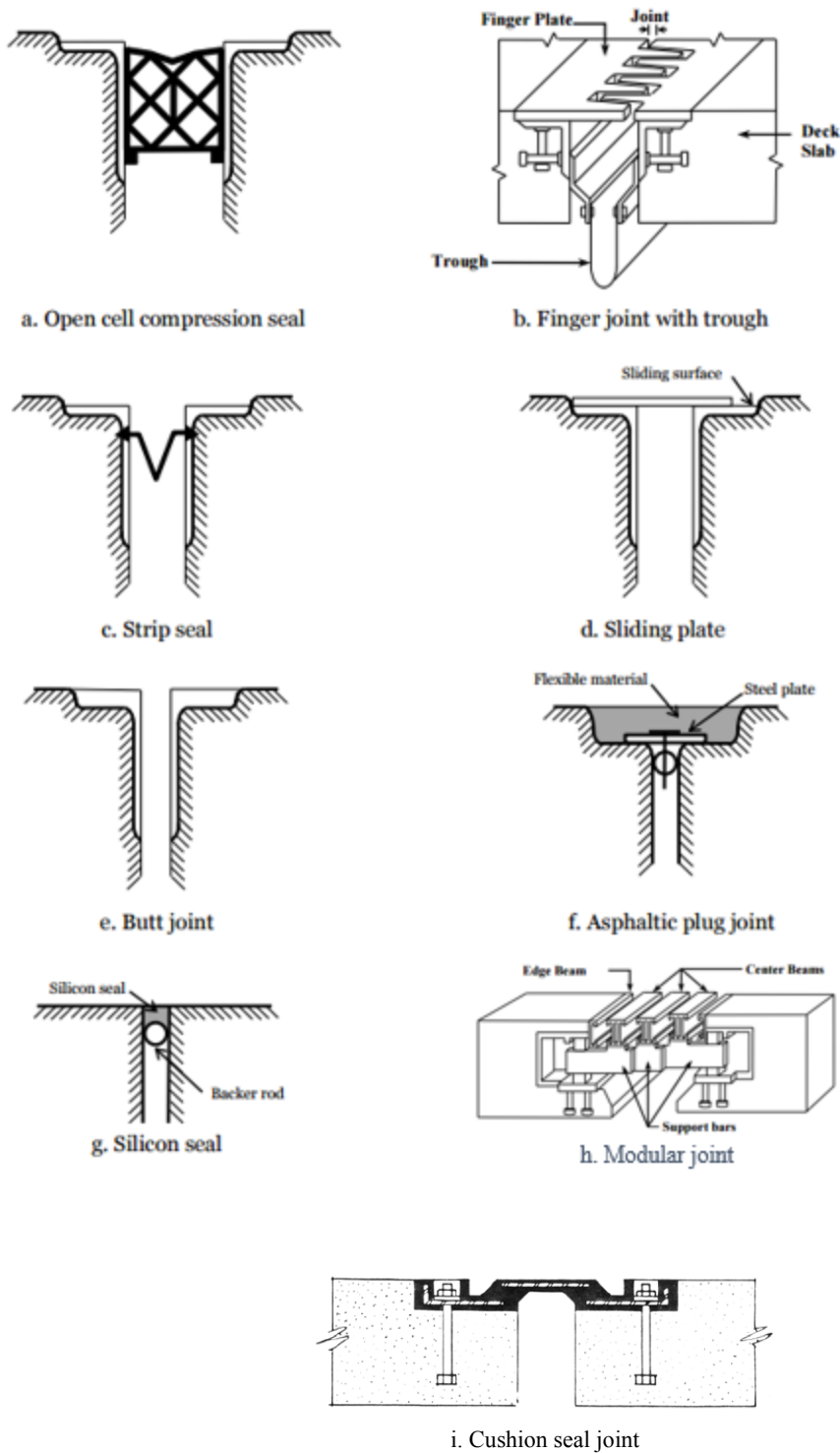


Figure 1. Examples of Expansion Joints (3, 5)

3. Strip seals are strips of specially shaped elastomeric material mechanically locked into a joint opening. Strip seals are available in a variety of configurations and are typically used to accommodate movements of up to four inches.

4. Plug seal joints are typically used on decks to accommodate movements of less than two inches. An elastic material (usually polymer modified asphalt) is placed in a cutout (blockout) area of the deck over the joint opening. A steel plate supports the elastic material over the opening.
5. Cushion seal joints – also called plank or segmental joints – consist of steel-reinforced neoprene pads recessed into the deck over a joint opening and rigidly attached to both sides by bolting them to embedments that are chemically bonded to the deck ends. They can accommodate movements of 3 to 15 inches.
6. Modular expansion joints are used to accommodate the larger movements in long-span bridges. There are three major components of a modular joint: seals, separator beams, and support bars. Bearings and springs are also used to accommodate movements of greater than four inches. The complexity and required maintenance of this type of joint system presents challenges, which makes PM critical.

REASONS FOR AND ISSUES WITH EXPANSION JOINTS

While expansion joints are a relatively small component of the overall bridge structure, their failure to perform correctly can result in major problems (6). When a joint is unable to accommodate the movement of the deck, the deck and other elements of the bridge and/or the joint itself become overstressed. A common problem with open joint systems that have troughs installed is poor drainage that results from debris buildup misdirecting runoff. Closed joint systems can, and often do, leak. Misdirected runoff and leakage let debris accumulate on bridge elements below the deck. This leads to the retention of moisture and the accumulation of deicing chemicals. If left unchecked, deck ends, beam ends, abutment seats, pier caps and bearings may undergo significant deterioration. Another problem common to all joints is damage from snowplows, especially if the plow angle is similar to the skew of the joint. An improperly maintained joint can cause the deterioration of every major bridge component (deck, superstructure, and substructure).

The following lists summarize problems that occur commonly with open and closed joints:

Open Joints (7):

1. Butt joints without drainage systems pass water and debris spill through the joint onto the underlying structure. The installation of drainage systems can lead to debris accumulation, which creates similar issues and requires additional maintenance. Armor edges can loosen over time and become detached, creating traffic hazards. Spalling and deterioration of the deck and approach can occur around joints with no armor edges.
2. Sliding plate joints can loosen over time, which is indicated by excessive noise as traffic passes. As a plate loosens it can become detached, which creates traffic hazards. This can be caused by issues such as corrosion of the anchoring studs, excess fatigue from traffic, and misalignment issues due to roadway deterioration. Excess debris can build up and prevent the joint from functioning properly.
3. Finger joints encounter similar problems as sliding plate joints. Most finger joints have drainage troughs that can become clogged with debris. Debris can also become lodged in the fingers, causing excess pressure and the potential for broken or misaligned fingers. Other potential problems include broken or loose bolts and concrete anchors.

Closed Joints (op. cit. 7):

1. The functionality of pourable joint seals depends on the poured material adhering to the vertical wall of the joint to achieve water tightness. Once the integrity of the joint is compromised, the backer rod begins to deteriorate and result in leakage. The joint can become clogged with debris and encounter problems similar to those of an open butt joint.
2. Compression joint seal placement and dimensioning is critical for proper performance. If not sized properly the joint can compress during hot weather to the point of damaging the seal, bridge elements, or both. During cold weather, excess tension on the seal can separate it from the wall of the joint, creating leakage. If not installed properly, during compression, the seal can bulge above the roadway and suffer damage from traffic. Traffic impact over debris-filled joints can cause damage and excess wear to the seal. Another problem area to consider is the gutter line, where the seals transition from horizontal to vertical. Debris tends to accumulate in these areas and create problems.
3. The failure of properly installed strip seals is primarily caused by debris build up. Debris can accumulate in the joint during cold weather. When a seal is compressed during hot weather, it can be damaged. The impacts of traffic atop debris-filled joints can damage and cause excess wear to a seal. Another problem area to consider is the gutter line, where the seals transition from horizontal to vertical. Debris tends to accumulate in these areas, creating problems such as seal de-bonding.
4. Plug seals can soften during hot weather, causing debonding at the pavement/joint interface. Cold weather can cause cracking. Over time, plug seals can become rutted from traffic or delamination may occur. This type of seal is not recommended for use on bridge decks with curbs, barriers, or parapets. Since the plug seal will not work for vertical applications, an alternative sealing method must be used. In these cases, the transition between the two types of seals can be problematic.
5. Cushion seal joints are susceptible to snow plow damage and joint leakage. Caps covering the anchor nuts can dislodge due to adhesive failure and traffic.
6. Modular joint seals, due to their complexity, can have problems not seen with other seals. Common problems include damage to equalizer springs, supports, sealer material, fatigue cracking of welds and damage from snowplows. Accumulation of debris also results in problems.

Since an expansion joint that performs poorly can affect every major bridge component, PM should be a top priority. Given the issues associated with increasing maintenance costs and extended traffic disruptions caused by deteriorating bridge components, proper PM has the potential to produce significant financial benefits. PM is critical for ensuring satisfactory performance and extending the entire bridge's service life. It should be a major component of any maintenance program. An effective PM program will plan and inspect for, and identify joint problems before failures arise.

TASK DESCRIPTIONS FOR EXPANSION JOINTS

The planning stage of PM encompasses more than just scheduling activities. It involves reviewing documentation from previous work and modifying activities as necessary. Documentation should be maintained to track performance, determine frequency of inspections and schedule cyclical PM activities.

Inspection (Table 3) involves assessing the condition of the expansion joint as well as the adjacent area and surrounding elements. This includes joint seals (closed joints), deck and approach surfaces, deck drains, beam ends, bearings, abutment seats and other elements under the joint. To identify problems, the inspector should have a good working knowledge of expansion joints' function and how well they perform that function.

Thoroughly clean expansion joints before inspecting them. When possible, pair cleaning with other activities, such as deck washing, drain cleaning and bearing cleaning. Pressure washing at a low pressure (< 3000 psi) should be sufficient. Once necessary environmental permitting has been acquired and proper traffic control is in place cleaning proceeds according to the following protocols:

- Remove large debris from the areas slated for cleaning with shovels, brooms, scrapers or other tools.
- If combined with deck washing, a sweeper truck can be used.
- Remove overgrown vegetation that impedes access to areas that will be cleaned.
- Use potable water and low pressure (< 3000 psi) to clean the entire area. Begin at the top and work downward.
- Pay close attention to the drainage systems for open joints. It can be difficult to clean drainage troughs, but it is very critical to do so.

Table 3. Expansion Joint Inspection (op. cit. 6)

Inspection	Action
Inspect for excess debris accumulation on the deck, around deck drains, and in the joints.	Remove debris and pressure wash
Inspect open joints for debris in the drain trough or wedged in the joint opening.	Remove debris and pressure wash
Inspect closed joint seals for cracks, punctures and excess wear. Note any protrusion above the opening.	Minor irregularities can be repaired during PM. Extensive repairs must be scheduled unless it creates traffic hazards, in which case they should be addressed immediately.
Look for loose or dislodged armor edging. Note any deterioration (e.g., cracking, spalling) of the roadway on either side of the joint.	Minor patching (small areas above the top layer of reinforcement) can be addressed during PM. Extensive repairs must be scheduled unless the problem creates traffic hazards, in which case it should be addressed immediately.
Look for evidence of water leakage on the back wall and pier caps, standing water and/or debris on the abutment seats. Note any deterioration of bearings or beam ends.	Schedule maintenance/spot painting of deteriorated steel elements and patching, and sealing of concrete elements.

Do not neglect the area below a joint while cleaning. Removing debris, trapped moisture and deicing chemicals that have accumulated on and around the abutment seat and bearings is critical

to avert future maintenance problems. During and after cleaning, inspect the joint and surrounding areas for items that need attention. Inspections should be conducted annually; however, the frequency of inspection can be adjusted based on the route and ADT. KTC recommends frequent inspections of bridges having high ADTs and/or heavy debris accumulation.

REPLACEMENT AND REPAIR

Poured, compression, and strip seals benefit from routine cyclical PM, however, eventual replacement will be necessary. Regardless of condition, the Virginia DOT treats closed joint PM as cyclical maintenance, replacing the joints on a five-year cycle regardless of condition. Follow the manufacturer's recommendations when installing new seals. If deck ends are cracked/spalled, repair the concrete (and reinforcing steel if necessary) and replace the seals of closed joints. Typical maintenance for open joints, other than cleaning troughs, involves joint replacement. Consider the following general guidelines:

Blockouts

A blockout is a rectangular section of bridge deck next to the joint that is removed and rebuilt using an elastomeric (polymer) concrete (Figure 2). It is used to size the joint opening and position and anchor the seal assembly. Typically, the concrete at the deck ends is jackhammered out to roughly form the blockout, and the joint anchors are positioned before placement of the polymer concrete. For compression seals, foam spacers are placed between the deck blockouts to set the gap spacing. Elastomeric concrete conforms to the irregular shape of the blockouts and any spalls at the deck ends. Blockouts are used for both joint repairs and to accommodate deck overlays.



Figure 2. Installation of a Blockout Prior to Seal Installation. Foam stripping between the blockouts acts as a form and controls joint opening size.

Poured Seals

Apply hot poured sealants when the air temperature is between 45° F to 80° F. There should be no significant precipitation forecast during the 24-hour period following application. Remove the remnants of the old seal and any debris to a depth at least three times the width of the joint. Repair the joint as necessary. Ensure that the joint edge surfaces are dry. Install a backer rod to one inch below the roadway surface. Clean out the area with an air compressor and apply the sealant.

Apply cold poured silicone sealants when the air temperature is between 55 °F to 80 °F. There should be no precipitation forecast during the 36 hours following application. Only perform this repair on joints with adjacent deck surfaces that are clean and sound. Old sealants and debris should be removed to a depth three times the joint's width. Sandblast and inspect the joint surfaces to ensure no residue remains. Joint surfaces should be primed per the manufacturer's recommendations. Install the backer rod and silicone sealant in accordance with the manufacturer's directions (Figure 3). The sealer should be concave so that its cross section is the thinnest at its center. This facilitates stretching of the sealer within a thin cross section at its center, which prevents the creation of stretching and/or larger forces at the sealer ends that could de-bond the sealer from the joint wall.



Figure 3. Worker Installing a Poured Joint Seal

Compression Seals

Remove existing seals and other debris from the joint opening. Sandblast and clean the joint edges. Elastomeric or concrete headers are both suitable. Coat the seal with an adhesive. This serves as a lubricant until the material becomes tacky. Before installing the seal, determine the correct seal size. The best practice is to install compression seals in cooler temperatures.

Compression seals can also be modified to turn up a curb or parapet. Figure 4 shows the proper technique for drilling holes into the seal and making cuts to the holes to provide upturns, and the method to cut 90° wedges to make 90° downturns. Installation of seals at the curbs and parapets follows a similar procedure to the deck joint opening.

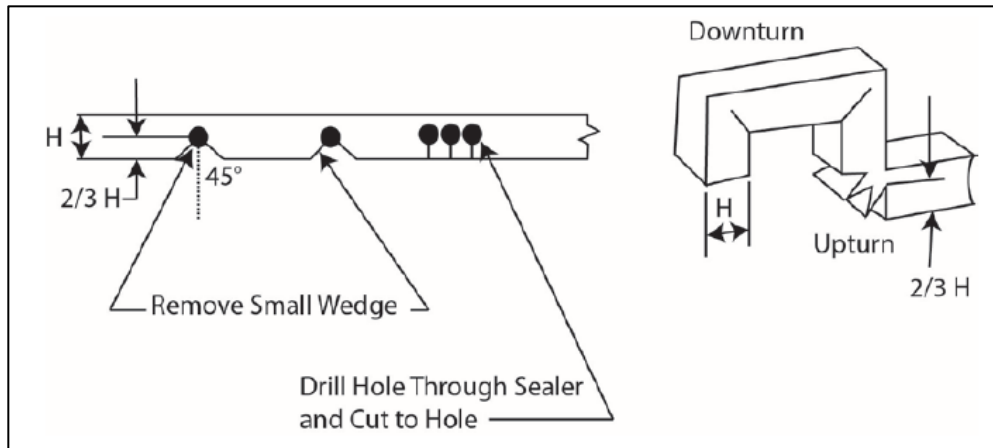


Figure 4. Compression Seals Modified for Turns (op. cit. 7)

Cushion Seals

Inspect the joints for water tightness and the condition of anchors/caps. Replace missing caps as well as damaged cast-in-place anchors with chemical-type anchors. Use sealer/adhesives to maintain water tightness.

Strip Seals

Strip seals (also referred to as gland or membrane seals) may need replacement if the headers are deteriorated or if the extrusions are bent, loose, deformed or corroded. Seals may also need replacement if they are torn, missing or significantly detached. To replace a strip seal, first remove the remaining sections of the gland. Heat may be required to melt the adhesives. Second, remove and replace deteriorated extrusions and re-anchor to the header. Lastly, replace the gland using adhesives and tools suggested by the manufacturer.

A strip seal replacement procedure published by Michigan DOT is available at: http://michigan.gov/documents/mdot/StructureMaintenanceBulletin4_Final_381367_7.pdf.

DURABILITY AND COST

The TSP2 West Bridge Preservation Partnership's 2015 survey of state DOTs indicated that approximately 50% of respondents believed poured joints have life expectancies of 0-5 years, while 35% of respondents thought poured joints last 5-10 years. Fifty percent of the respondents thought that compression seals last from 0-10 years and another 45% felt they last 10-15 years. Approximately 60% of the respondents stated that strip seals have life expectancies of 10-20 years, while 25% of respondents thought they would last 20+ years.

A 2011 survey by the TSP2 Midwest Bridge Preservation Partnership member DOTs provided limited data on cleaning/sealing expansion joints. Prices varied from \$150/bridge (Wisconsin DOT) to \$70-123/LF (Iowa and Minnesota DOTs, respectively). DOTs reported that cleaning occurred annually. In 2012, Hearn reported maintenance costs for various DOTs (8). Florida DOT's (FDOT) 2009 cost data indicated that open expansion joint rehabilitation was approximately \$110/LF. FDOT reported pourable joint replacement costs of approximately \$37/LF and compression seal replacement at \$63/LF. The cost to patch/reset/clean strip seals was \$84/LF. Delaware's DOT (2009) reported that it cost \$46/LF to clean joints and replace seals.

KYTC has stated that the cost of compression seal and adjacent concrete repair for two-inch joints is \$376.05/LF and \$441.19/LF for 2-1/2-inch joints. Strip seal and nosing repair costs for four-inch strip seals averages \$645.31/LF (9).

2. CLEANING AND SEALING OF BEARINGS

Bridge bearings transfer loads from the superstructure to substructure while accommodating deflections from loading (traffic) and thermal movement. There are two categories of bearings – fixed and expansion. Fixed bearings resist a bridge’s lengthwise movement but permit rotation of the superstructure caused by deflections or bending. Expansion bearings permit longitudinal movement, which is mostly caused by expansion and contraction due to thermal changes, and the rotation of the superstructure triggered by deflections or bending. While this section focuses on bearings, joints that perform poorly have a detrimental impact on the performance and longevity of bridge bearings (op. cit. 6).

BEARING TYPES

Rocker Bearings

Rocker bearings allow expansion, contraction and rotation of the superstructure through a back-and-forth rocking motion. This type of bearing generally consists of a sole plate, pin, rocker and masonry plate. Rocker bearings can be either pinned (Figure 5) or unpinned (Figure 6).

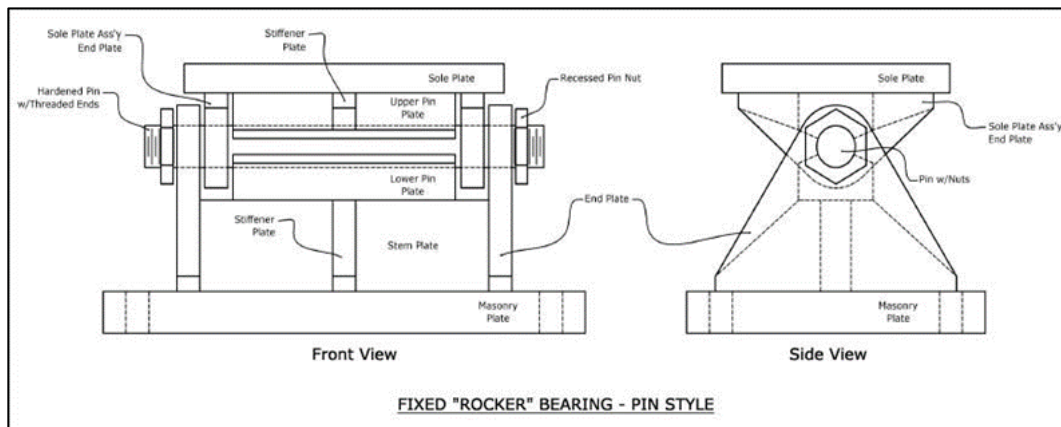


Figure 5. Pinned Rocker Bearing (10)

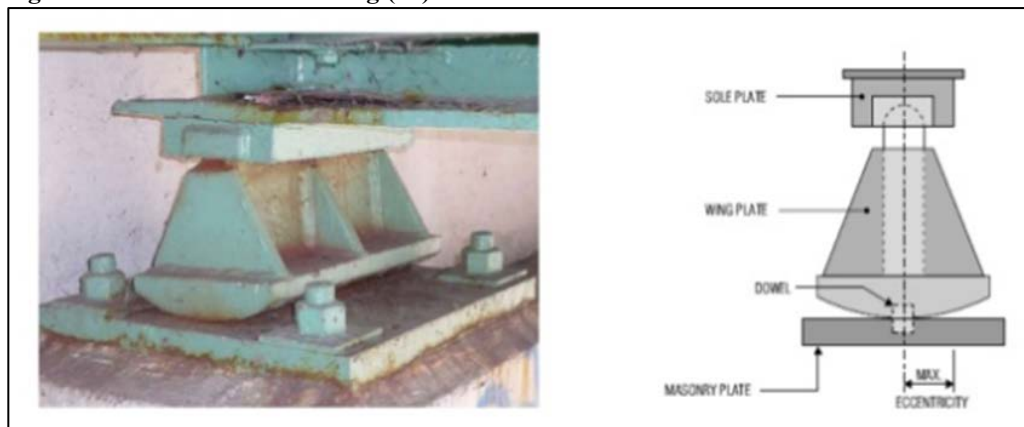


Figure 6. Unpinned Rocker Bearing (11)

Elastomeric Bearings

Plain elastomeric bearings (Figure 7) consist of layers of elastic materials – typically rubber – that are compressed together. Elastomeric bearings can be rectangular or circular. They are flat or have internal beveled steel plates to accommodate steep profiles or beam cambers. Like plain elastomeric bearings, reinforced elastomeric bearings consist of compressed layers of rubber, but they also contain layers of steel plates or fabric, which provide internal reinforcement. The thickness of steel reinforcing plates varies; however, they are generally around 11-gage thickness (0.1196 inch). Reinforced elastomeric bearings can typically withstand higher loads and superstructure forces than unreinforced bearings (op. cit. 6).

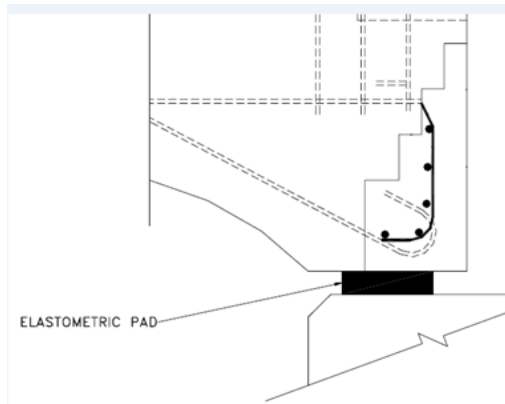


Figure 7. Elastomeric Bearing Pad (op. cit. 7)

Sliding Bearings

Sliding bearings (Figure 8) permit the beams to slide when the superstructure expands or contracts. Sliding bearings generally consist of a sole plate, sliding or rotation plate and a masonry bearing plate that slide on each other. The flat surface enables a translation from expansion and contraction, while the curved surface lets the beam rotate. The plates may be constructed from similar or dissimilar materials (op. cit. 6).



Figure 8. Sliding Bearing (11)

Pot, Disc and Spherical Bearings

Pot, disc and spherical bearings can sustain high loads and can rotate in any direction (Figure 9). They can be fixed or employ sliding surfaces, enabling their use as expansion bearings.

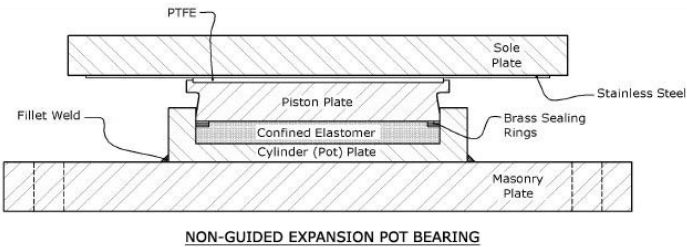


Figure 9. Sliding Pot Bearing (12)

Roller Bearings

Roller bearings (Figure 10a and 10b) generally consist of cylinders that bear and roll on a masonry plate. Other types of roller bearings consist of a beam end that sits on a nest of encased ball bearings or rollers. Generally, the encased roller bearing is difficult to maintain because access to the bearing assemblies is typically not achievable (op. cit. 6).



Figure 10. Roller Bearings (13). (10a) Single on left, (10b) Nested on right

Pin and Hanger Bearings

Pin and hanger bearings (Figure 11) are used for bridge trusses, girders and beams that connect a cantilevered span and a suspended span of a bridge where there is no substructure. Pin and hanger bearings are typically located under deck expansion joints. Significant deterioration can occur in this area. This can lead to freezing pins and overstressing of the pins, hangers, and chord members (op. cit. 6).

ISSUES WITH BEARINGS

Bearings are located underneath the bridge deck's surface. As such, they are exposed to leaking deck joints, bridge deck runoff, deicing salts, grit, and road debris. Road debris often accumulates around bearings, trapping moisture and exposing their steel components to constant wetting and corrosive action caused by salt-laden moisture. As bearings corrode and deteriorate, or as sliding surfaces become fouled, bearings can lock up and no longer function properly (Figure 12), which hinders their ability to accommodate thermal movement and rotation under bridge loading conditions. As a result, structural members that do not see relief from thermal loads or that are restrained from rotation have to endure secondary stresses for which they were not designed. Member damage or failure can result.



Figure 11. Pin and Hanger Bearing (13 op. cit.)



Figure 12. Tilted Rocker Bearing Requiring Cleaning and Resetting (14)

PREVENTIVE MAINTENANCE FOR BEARINGS

The best PM to ensure that bridge bearing components function properly is to maintain watertight deck joint seals. However, maintaining joint integrity is an ongoing struggle. Because joints inevitably fail, periodic washing and painting and/or lubricating of bridge bearings is required.

TASK DESCRIPTIONS FOR BEARINGS

Annual Flushing

Flushing is imperative because it removes contamination that results from the application of deicing chemicals. To flush the bearings and surrounding environment, use a power washer at a low-pressure setting (1000 psi to 4000 psi) and minimum flow rate of 3.5 gallons per minute. Always wash from top to bottom. These locations should be power washed annually after the winter/deicing season has concluded.

Lubrication

The minimum level of surface preparation should be SSPC SP2 (Hand Tool Cleaning). Use implements such as wire brushes, scrapers and hammers to prepare the surface. Remove rust and scale from bearings by hammering, scraping, and wire brushing. Clean out foreign material such as dirt, debris and vegetation from the bearings, abutments and pier caps.

After flushing (described above), let the power-washed surfaces dry for 24 hours. After they have dried, apply a layer of approved lubricant/grease approximately 30 mils thick to cover all exposed bearing surfaces (Figure 13). Coat the bearings within 48 hours of drying.



Figure 13. Lubricating a Clean Bearing

Painting

Perform cleaning as described in the *Lubrication* section. Mask non-metal bearing surfaces, such as laminated neoprene pads, elastomeric pads, or Teflon slide surfaces. Perform abrasive blasting of steel bearing surfaces to remove rust and corrosion. The resident engineer should determine the required level of surface prep. Residual grit can trap moisture, inhibit surface-to-surface sliding, or restrict rotation. Remove it with a vacuum or compressed air blow-down using oil-free compressed air. Ensure that steel surfaces are clean and dry prior to painting. Paint all exposed bearing surfaces via brush or airless spray with an approved coating system per manufacturers' recommendations.

Anchor Bolts

Inspect bearings for loose anchor bolts. If an inspection reveals a bearing with loose anchor bolts, they should be tensioned properly, especially for a fixed bearing assembly, and even for an expansion bearing if uplift is a concern. If a bearing assembly has loose anchor bolts, the bearing may not function properly, causing stress to the superstructure or substructure as well as to the bearing, which may not be visible. If anchor bolts are not properly torqued, uplift may also occur.

Reset Bearings

Thermal movement of a bridge that exceeds the travel range of slide bearings or the rotational capacity of a rocker bearing may require the bearings to be reset. Excessively tilted rocker bearings or neoprene bearing pads that walk out of position can be reset by jacking the supported beam to remove the live and dead loads (as approved by the engineer) and resetting the bearing. If the horizontal deformation of an elastomeric bearing is over half of its height, replace it – do not reset

it. It may be necessary to jack all the beams. Prior to resetting/replacing bearings, clean existing surfaces of steel beams by abrasive blasting or grinding. The abutment/pier seat may be ground or shimmed as necessary to align with the bottoms of the beams. Pot, disc and spherical bearings are relatively free of maintenance problems but should be evaluated to determine whether they are in good functional condition.

DURABILITY AND COST

KYTC typically cleans and greases bearings in conjunction with bridge cleaning operations. Therefore, costs for that work are not available. KYTC bearing greasing work (outsourced) has been performed well to date with few problems (minor uncoated spots). Durability is expected to depend on initial surface condition. Based upon performance of existing projects, KTC researchers estimate that the grease on the bearings will last 4-10 years, although none of the KYTC projects are that old. FDOT 2009 data reported by Hearn (op. cit. 8) provided the following costs:

- Elastomeric bearings – reset \$1,274 ea.
- Movable Bearing – clean and paint \$ 986 ea.
- Enclosed Bearing – rehab unit \$ 1,850 ea.
- Fixed Bearing – clean and paint \$ 918 ea.
- Pot Bearing (minor deterioration) - \$ 2,055 ea.

Delaware DOT (2009) reported the cost to clean, grease and paint bearings was \$165/ea. Rehabilitating the supports cost \$779/ea. while complete unit replacement was \$7,265/ea. The Louisiana Department of Transportation and Development (DOTD) (2009) reported a price of \$650/ea. to clean and paint bearings.

3. BRIDGE WASHING

All major bridge elements, decks, superstructure, and substructure are exposed to a range of service environments. Bridge decks are impacted by the harmful buildup of soil, debris, wastes and residual chemicals originating from vehicular traffic, airborne solid pollutants, trespassers and winter roadway deicing chemicals. Deck runoff and debris from open and leaking joints fall onto superstructure and substructure components including beam ends, bearings, abutment seats and caps, and pier caps. Additionally, people trespassing on and around bridges leave a significant amount of trash on horizontal surfaces (Figure 14).

Bridge elements and their components deteriorate due to the net effects of exposure to debris and contamination. Vehicular debris and dirt can build up on the edge of a bridge deck and clogs gutter lines and drains, preventing proper drainage from the deck. This can result in water ponding on the deck, which presents a hazard to motorists and accelerates deterioration of the bridge deck. Deicing chemicals can penetrate the surface of bridge concrete and corrode the reinforcing steel and concrete. Debris buildup on joint seals can result in seal failures, allowing water runoff onto superstructure and substructure components. Runoff contaminated with deicing chemicals can leak onto steel beam ends and with extended time of wetness on structural steel, can result in premature coating failure and corrosion. As with concrete bridge decks, deicing chemicals can penetrate concrete beam ends and trigger corrosion of reinforcing steel and tendons. Deicing chemical runoff leaking onto the bridge abutments and pier caps can also corrode the reinforcing steel and

significantly deteriorate structural concrete. Dirt and trash buildup on horizontal surfaces, such as beam flanges and pier/abutment caps, can attract and retain moisture, instigating corrosion. Washing splash zones on through truss and arch bridges as well as overpass bridges removes soluble salts from aerosols kicked up by traffic.



Figure 14. Trash Build-Up on a Bridge Abutment

PREVENTIVE MAINTENANCE BY BRIDGE WASHING

Periodic cleaning, including removal of dirt and debris, limits bridge deterioration and extends the service life of a bridge without requiring extensive remedial actions. Cleaning operations can involve the use of sweeper/vacuum trucks to collect debris from gutter lines and joints as well as hand work (e.g., brooming and shoveling of collected waste). Workers can collect and dispose of trash deposited on abutments and pier caps. Augers/sewer rods (handheld or truck-mounted devices) can open clogged drains.

Washing can remove embedded surface soils and residual deicing chemical contaminants from affected surfaces. Some DOTs conduct annual operations to wash most of the bridge (for mainline deck girder structures). For overpass bridges, deck truss, K-truss and through truss and tied arch bridges, locations requiring washing should be identified before this work begins (e.g., splash zones).

Different methods can be used to wash bridges – low-pressure, high-volume washing or higher-pressure, low-volume washing. Low-pressure, high-volume washing typically uses water supplied in tanker trucks or “clean” water from underlying waters (e.g., streams, embayments, rivers). High-pressure, low-volume washing typically relies on potable water tanked to a bridge site. To ensure removal of deicing chemicals that have accumulated over the winter months, the ideal time to wash bridges is during the spring and early summer. Other complimentary tasks can be performed simultaneously, such as the removal of rust build-up on steel bridge components and/or coating those components to improve their durability.

If KYTC contracts out bridge washing, it must stipulate in the contract precautions related to environmental and worker safety needs; state workers performing these tasks must adhere to established regulations and standards.

Existing Lead Paint

Bridges built prior to 1990 may contain lead paint, while bridges painted between 1993 and 2004 may have lead paint that was over-coated with other non-hazardous coatings. For bridges built or painted in those periods, a determination needs to be made whether they still contain lead paint. No bridge steel with lead paint may be washed if the coating's condition rating is Poor or Severe. Do not disturb or remove paint during cleaning operations (e.g., rust removal) if it contains lead. *Note: if lead paint is present, it is recommended that a paint contractor competent for working on leaded bridges be employed for cleaning and collection of any paint residue that is generated [per SSPC-QP2, Standard Procedure for the Qualification of Painting Contractors (Field Removal of Hazardous Coatings from Complex Structures)].*

Endangered Species and Biological Issues

Notify the KYTC-DEA biologist if nest sites, birds, or bats are observed on a bridge. The identification of the species will affect the actions required to comply with regulations.

TASK DESCRIPTIONS FOR BRIDGE WASHING

Currently, KYTC performs bridge cleaning operations and attendant work by contract. At the Cabinet's discretion, bridge cleaning and washing may be combined with other operations, including the removal of pack/stratified rust, covering of those areas with a conversion coating, greasing bearings and coating structural concrete. The following work standard primarily addresses bridge cleaning, as specified by KYTC.

The general progress of work should be from the bridge deck down (for deck girder bridges). Where practical, perform dry work prior to wet work. The initial deck work should include the removal of all debris and vegetation from gutter lines and joints. A sweep/vacuum truck can be used for this task or it is collected manually using brooming and shoveling. Provide controls to prevent debris from entering any body of water, drainage system or roadway lanes under traffic. All debris and trash located on or adjacent to the bridge superstructure and substructure components should be collected and disposed offsite. Disposal procedures must adhere to KYTC's Division of Environmental Analysis requirements for the disposal of non-hazardous waste.

Dry clean the bearings, bearing seat areas, superstructure members (girders, diaphragms and stiffeners), abutment and pier caps under deck joints and expansion joints. If the joint is open with a trough, clean all debris from the trough. Dispose of wastes following the procedures noted above. Use mechanical means (shoveling, rodding and/or auguring) to clean out the scuppers and drain pipes of deck drains. Cover or plug scuppers before washing the bridge.

Use potable water for bridge washing. Wash the bridge concrete at a pressure of 1,000 psi \pm 200 psi using wands with 30° fan tips. Keep the wand tip approximately perpendicular to and no more than 24 inches from the working surface. In the deck area, wash inside faces of plinths and gutter lines three feet onto the deck for the entire length of the bridge, including end bents/wing walls (Figure 15). Wash the entire abutment, including the back walls, caps and sides. Wash pier caps and sides of caps to a distance three feet below the top of the cap.



Figure 15. Workers Washing Gutter Line of Bridge Deck (Picture Courtesy of NYSDOT)

Wash all exposed steel surfaces at a pressure of 4,000 psi \pm 500 psi with a 0° spinner tip using a minimum flow rate of 3.5 gal/minute. Equip the wand with a 5,000-psi dial gage to indicate operating pressure. Keep the wand tip approximately perpendicular to the working surface at a distance of no more than 18 inches. Reduce the pressure as necessary to ensure pressurized water does not damage any components of the structure. Wash from the top of the work piece downward. Wash all exposed steel within 10 feet of a joint (Figure 16). Do not let wastewater contact previously washed surfaces.



Figure 16. Worker Washing a Steel Beam End Under a Joint

DURABILITY AND COST

Data from other DOTs suggest that many do not flush the entire bridge deck, although some information exists that indicates doing so may be beneficial (15, 16).

Bridge washing frequency varies from *as needed* (condition based) to *cyclical* (one- to five-year intervals). In 2011, the TSP2 Midwest Bridge Preservation Partnership found that the cost to clean and flush bridge decks ranged from \$300 to \$12,500 per structure (Wisconsin and Iowa), which shows that price varies significantly according to size (not provided by either DOT). Cost is also

influenced by who performs the work – state personnel or contractors. The New York State DOT (NYSDOT) paid cleaning/washing costs of approximately \$4,600 per bridge in 2011. In 2010, NYSDOT used state forces to wash the decks and substructures of 789 bridges, and the superstructures of 507 of those bridges, for a total cost of \$1,924,000. This figure included traffic control, mobilization and workforce salaries and the cost of traveling to the site and performing the work. NYSDOT’s official wash cycle is once every two years, although 90% of its bridges are washed every year.

4. SEALING OF DECKS

Bridges are exposed to many environmental factors as well as variable loading conditions. The application of deicing salts and the constant variations in loading caused by passing vehicles contribute to bridge deterioration. Concrete bridge decks are susceptible to spalling, cracking, and the formation of potholes, all of which are caused by water contaminated with deicing chemicals passing through micro-cracks and pores in the concrete. Trapped moisture expands during freeze-thaw cycles, and chloride ions attack the reinforcing steel in the concrete deck. Both these actions expand the micro-cracking and produce larger cracks, spalls, and potholes. Problems are most obvious where moisture ponds and accumulates adjacent to barrier rails, on the underside drip line of the bridge deck and at natural depressions such as at bridge scuppers. Cyclical loading from wheel impact attacks the edges of joints embedded at angles, causing stress-induced concrete cracking and deterioration. As concrete deck deterioration progresses, map cracking and signs of leaching on the deck’s underside may become increasingly conspicuous (op. cit. 8). All existing concrete bridge decks with a National Bridge Inspection Standards (NBIS) condition ratings of Fair or better should be sealed. For new bridges and rehabilitated existing bridges, the decks and parapets should be sealed as part of the initial construction process.

TYPES OF SEALERS

Table 4 lists common waterproofing treatments. Sealers can be divided into two general classes – penetrating sealers and film formers. Silanes, siloxanes, and High Molecular Weight Methacrylates (HMWM) penetrate surface cracks and voids in the concrete, limiting the ability of water and salts to penetrate the concrete. They do not leave a film on the surface (Figure 17).

Epoxy healer sealers, methacrylates, and polyurethanes produce a thin film that covers the surface of the treated deck or slab, protecting them from intrusive water and salts. A thin epoxy overlay penetrates and creates a film. These treatments generally serve as a preventive treatment for reinforced concrete decks and slabs that are new or in good overall condition (op. cit. 6). The chloride content at the level of the upper reinforcing mat should be less than what is required to initiate corrosion – approximately 1.2 lb. /yd³ concrete – at the time of application. However, it may be possible to realize some benefits at higher chloride contamination levels.



Figure 17. Sealing a Bridge Deck with a Silane

Table 4 Types of Concrete Sealers

Sealer	Type	Thickness
Silane	Penetrating	0
Siloxane	Penetrating	0
High Molecular Weight Methacrylate (HMWM)	Penetrating	0
Epoxy Healer Sealer	Penetrating/Film Former	3 – 10 mils
Thin Epoxy Overlay	Film Former	250 – 375 mils
Methacrylate	Penetrating/Film Former	20 – 30 mils
Polyurethanes	Film Former	3 – 5 mils

Penetrating Sealers

Penetrating sealers inhibit capillary action at the surface, which prevents water and chloride ions from infiltrating the concrete deck. Penetrating sealers, when applied to a concrete deck surface, react in one of two ways. One group (silanes, siloxanes, and siliconates) “wets” the surface and limits the penetration of chlorides and water into the concrete. The second group (silicates) reacts chemically with concrete components and forms precipitates to seal the pores at or below the surface of the concrete. Concrete densifiers are typically water-based and include sodium, potassium, or lithium silicates. These produce a hydrophobic silica gel that fills the concrete pores. These products are differentiated by their molecule size, silanes being the smaller of the two. This gives silanes the advantage of infiltrating deeper into concrete than siloxanes and silicones. Silanes require some moisture in the concrete to trigger the chemical reaction, which forms silica gel. However, too much moisture obstructs silane penetration. Siloxanes are less volatile than silanes and provide similar initial surface protection.

For both hydrophobic and pore-blocking sealers, penetration depth is an important property. Sealers must penetrate deeply enough so they are adequately protected against wear, weathering and ultraviolet radiation. The optimal penetration depth is approximately 6 mm (3 mm is the recommended minimum). Concrete quality is a major factor that affects penetration depth. Sealers may penetrate more deeply into poor quality concrete. Different sealer types also result in different penetration depths: 2.5 mm to 6.4 mm for silanes and 1.5 mm to 3.8 mm for siloxanes (17). Silanes,

siloxanes, and High Molecular Weight Methacrylate (HMWM) penetrate surface cracks and voids in the concrete and limit the penetration of water and salts without leaving a film on the surface.

Film Formers

Healer/sealers, such as epoxy healer sealers, methacrylates and polyurethanes, produce a thin film that covers the surface area of the treated deck or slab. This film protects concrete from water and salts. Thin epoxy overlays both penetrate and form a film. These treatments are generally used as a preventive treatment on reinforced concrete decks and slabs that are new or in good overall condition. On decks, an abrasive such as sand is spread on the deck during curing and the loose material subsequently removed to provide skid resistance.

PREVENTIVE MAINTENANCE FOR SEALING

New concrete bridge decks and decks that have cracks up to 0.010” wide are good candidates for penetrating sealers. Penetrating sealers are sprayed or poured onto bridge decks and spread over the entire area using brooms or squeegees. Penetrating sealers are typically low viscosity, which allows them to be drawn into concrete cracks through capillary action. Viscosity is measured by the force per unit area resisting a flow in the units of centipoise (cP) (Table 5). Consider the use of more viscous materials for decks with larger cracks.

Sealers fill concrete cracks and voids. After curing, sealers form bonds to the walls of the cracks that effectively seal them. The seal significantly reduces concrete permeability. The reduction in permeability helps minimize the infiltration of water and chlorides sourced from road salts or deicing chemicals. There is a variety of commercially available penetrating crack sealers that are designed for specific applications. Selecting the appropriate crack sealer is contingent on a number of variables, including crack width, available cure times and desired flexibility of the cured product.

Concrete deck cracks that are discrete or localized can be sealed or injected with epoxy resins or other polymers to fill voids and re-bond the concrete surfaces. Injecting epoxy can help restore structural integrity and reduce moisture penetration through concrete cracks greater than or equal to 0.002 inches in width (18).

Table 5 Viscosity of Concrete Sealers

Material	Approximate Viscosity (cP)
Water	1
Methacrylates	10
Epoxy-based healer sealers	80
Epoxy-based thin epoxy overlay	1500 (Similar to honey)

Full-depth deck cracks must be capped from both the top and bottom of the deck before they are pressure injected. Caps have been successfully installed using epoxies, polyesters, paraffin wax, and silicone caulk. Be attentive to the following criteria when selecting a cap material: non-sag consistency (for overhead applications), moisture tolerance; working life, and rigidity – modulus of elasticity (op. cit. 18).

For working cracks that open and close under traffic loads, a flexible elastomeric crack sealer may be warranted. The sealer material should be designed and selected based on the anticipated movement of deck cracks.

TASK DESCRIPTIONS FOR SEALING OF BRIDGES

Conducting a visual inspection is usually the first and often most important method to evaluate the surface condition of bridge decks. Knowledge gained from inspections can determine the need for additional tests. The goal is to determine the percent deck distress and gather information on the quality of the deck surface, the need for drainage or slope corrections, cracking patterns, general concrete distress and to guide additional testing.

Begin inspections with a quick walk of the entire deck and note any variations in deck condition. Counting transverse deck cracks in each span is a good source of information on cracking frequency. On large decks, identify representative areas for in-depth study. Measure typical crack surface widths with a visual crack gauge or – preferably – a magnifier crack gauge. Mark plan drawings to illustrate the condition of the in-depth study areas, including cracking patterns, crack widths, spalling, patching, and other distress typical of the overall deck. The mapping effort will depend on the size of the deck and the uniformity of deck conditions.

Often, different spans have different conditions. When this occurs, evaluate each span's condition separately. This is critical because the best repair action may vary among spans. Deck appearance can change significantly under different lighting conditions, especially when the deck is wet. If practical, avoid conducting visual deck surveys at night or when the deck is completely wet. Moistening a deck and watching it dry during the day can provide valuable information on the micro-cracking present, since cracks dry slower than the deck surface and fine cracks become more observable as a moistened deck dries (19).

Most cracks penetrate decks down to the top layer of reinforcing steel or further. Usually, transverse deck cracks penetrate the entire deck thickness, exposing the top and bottom mats of steel as well as any supporting girders or beams to deicing chemical-laden water. Even hairline cracks enable the ingress of water contaminated with deicing chemicals into the deck.

Due to the heavy use of salts and other deicing chemicals, a penetrating sealer or crack repair resin should be applied to extend a deck's service life. If cracks are few and discrete, inject the cracks with epoxy or topically fill them on an individual basis. However, if cracking is widespread or the deck's concrete surface requires sealing, perform a complete topical application. While cracking exposes only a small percentage of the deck steel, corrosion often begins and progresses rapidly at crack locations, potentially causing spalling and premature distress.

Crack injection is most commonly performed using epoxy resins, although other polymers are sometimes used. Topically applied crack repair resins include high molecular weight methacrylate resins (HMWM) and sometimes very low viscosity epoxy resins. Concrete surface sealers or penetrating sealers, such as silanes, can also effectively seal in fine and hairline cracks (approximately 0.010 in. or less). Penetrating sealers do not physically fill and bond the cracks; they make the sides of the cracks hydrophobic, preventing the ingress of water. Conduct trials and evaluations of crack repair systems to ensure the system chosen is appropriate for a deck's unique

features. Obtain small diameter (2-3 in.) core samples from treated crack locations to determine the depth of sealer or resin penetration. Typically, penetration depths within the crack of 1/2 in. or greater indicate reasonable protection (op. cit. 19).

DURABILITY AND COST

Results from the TSP2 Midwest Bridge Preservation Partnership's 2011 survey indicated that prices for healer/sealers range from \$2.50 to \$7.50/ft², with re-treatments in 5-7 years. Prices for liquid sealers range from \$0.56 to 1.67/ft², with re-treatments after 4-5 years.

5. SPOT PAINTING

Steel bridge coatings are employed primarily to protect bridge steel from corrosion.

COATINGS TYPES

Typically, bridge coatings consist of coatings systems made up of various layers: 1) a primer that bonds to the substrate (mill scale or steel) and provides some level of corrosion protection, 2) an intermediate coat that provides barrier protection and 3) a topcoat that provides resistance to weathering (UV degradation). In some cases, two-coat systems have been used, eliminating the intermediate barrier coat (e.g., inorganic zinc/vinyl). Older (pre-1985) bridge coatings primarily consisted of lead-based alkyds applied over mill scale surfaces. These coatings may have been used intermittently up to about 1990. Inorganic zinc/vinyl systems were used primarily in overblasted steel substrates from the mid-1980s through the early-1990s. In the 1990s, KYTC began using for new construction three-coat systems that incorporate zinc-based primers (inorganic zinc and organic zinc) over blasted steel substrates. During the same period, KYTC performed bridge maintenance painting by overcoating (painting over old alkyds and inorganic zinc/vinyl systems). These overcoating systems were typically moisture-cured and two-component urethanes. In the 2000s, KYTC introduced the use of three-coat systems that incorporated zinc-based primers (primarily inorganic zinc for new construction and organic zinc for maintenance) over blasted steel substrates.

COATINGS PROBLEMS

Coatings have a finite lifespan. Over time, they degrade and eventually require repair or replacement. Maintenance of coating projects that entail the removal and replacement of coatings typically cost \$10 - \$20/ft². Coating larger Ohio River bridges may significantly exceed those unit costs.

The coating deterioration process is accelerated at bridge locations where the coatings are stressed by weathering or corrosion. They typically fail earlier than coatings that are subjected to exposures that are more moderate. The primary stresses on bridge coatings are time of wetness (TOW), contaminants and ultra-violet light. Premature coating failures may also be attributed to variations in substrate condition, quality of application, and quality of material.

Frequently, bridge coatings experience small areas of localized failure. Despite localized failures, if most of the coatings remain intact they are capable of years of additional service. In these situations, the failed coating areas can be repaired by recoating them. This can be done without affecting the balance of the intact coating (i.e., spot painting). Typically, a coating assessment

should be made on the bridge to accurately determine coating condition and performance. Thereafter, a decision can be made regarding whether to paint and, if so, the appropriate painting option (spot painting, zone painting, overcoating, or removal and replacement).

PREVENTIVE MAINTENANCE BY SPOT PAINTING

When deciding on the appropriate maintenance option for coatings, the selection of spot painting depends upon the number, area, and disposition of coating failure sites that require repair, along with the condition/type of the intact existing paint. Other issues such as structure location, traffic, and available funding must also be factored into decision-making. Industry-issued guidance recommends spot painting under the following circumstances:

- Repairs are hidden and unimportant to aesthetics
- Owner maintenance crews are available for this work
- Structures are small and repair locations are readily accessible
- Corrosion and degradation are limited to isolated small areas
- A decision has been made to upgrade deteriorated bridge components/locations

Spot painting is performed over 1) an area where the existing coating has failed, 2) a border between the failed area and existing coating, and 3) the intact existing coating. Typically, the failed area contains a surface consisting of rust, mill scale, cohesive/adhesive failed existing coating or some combination of those (Figure 18). In general, for spot painting to be practical, the failure area needs to be less than about 2 percent the total area, and the anticipated service life of the intact existing coating should be 10 years or greater.



Figure 18. Spot Coating Failure

Spot painting includes surface preparation, soluble salt treatment (where necessary) and

application of the coating. There are three key reasons to prepare the surface before painting:

1. Ensure that the coating system adheres to the substrate by removing all loose or tightly bonded contamination and foreign matter, including rust and mill scale.
2. Create an anchor profile on the substrate when exposing bare steel.
3. Prevent residual surface soluble salts from inhibiting the protective mechanism of the coating system.

Cleaning by power tools should be supplemented with other cleaning methods and coatings employed should have some surface tolerance to overcome the method's inability to effectively cover with the four spot painting methods. Removing soluble salts is necessary to provide maximum durability of a spot coating. The type of existing coating on the bridge and the existing substrate (mill scale or blasted steel) will dictate the type of surface preparation method/coatings that may be selected for use.

TASK DESCRIPTIONS FOR SPOT PAINTING

Before applying coatings, properly clean substrates. This includes removing loose chalked paint, soils, bird droppings, stratified rust and oils/greases/tar (Figure 19).



Figure 19. Diaper Placed Under a Bridge to Catch Paint Debris

Follow the SSPC SP 1 (*Solvent Cleaning*) specification when initially cleaning the repair area. Solvent cleaning involves the use of mineral spirits and other solvents to remove all visible oils and grease (e.g., diesel fume residues) and other soluble contaminants. This usually entails wiping surfaces with rags saturated mineral spirits. After initially cleaning the surface, use hand tools to remove all loose surface material, including partially de-bonded paint and stratified rust (following the specifications laid out in SSPC SP 2 (*Hand Tool Cleaning*), *Hand Tool Cleaning*) (Figure 20). Hand tools include scrapers, wire brushes, hammers and chisels. Solvent cleaning can also be performed after the mechanical surface preparation of rusted steel. Pressure washing

(3,000-5,000 psi using a spinner tip) can be used as a preliminary cleaning treatment. However, pressure washing poses environmental problems when performed over lead-bearing coatings. Further, the washed substrate must be given adequate time to dry before painting operations can move forward. Other cleaning options may include dry wiping surfaces with rags or burlap to remove chalked paint and soils.

After the initial cleaning, prepare the area that will be spot painted in accordance with SSPC SP 3 (*Power Tool Cleaning*), SP 11 (*Power to Cleaning to Bare Metal*) or SP 15 (*Commercial Grade Power Tool Cleaning*). The first method removes loose surface debris while the other two methods can be used to provide steel substrates sufficiently clean to employ zinc-based primers.

There are four basic forms of power tools: 1) reciprocating sanders, 2) rotary or impact tools (e.g., rotary flappers, scarifiers, and bristle blasters), 3) grinders, and 4) reciprocating impact tools (e.g., needle guns and scabbers). Surface profiling tools include rotary impact flap assemblies. Needle guns equipped with 2-millimeter (mm) diameter needles can also be used along with the newer bristle blasters. SP 3 identifies a variety of power tools that are suitable for power tool cleaning (e.g., rotary tools, needle guns, and rotary impact tools). Rotary impact tools have good productivity and can impart an anchor pattern (beyond SP 3 requirements). Grinders are appropriate for flat surfaces where SP 3 surface preparation is sufficient. Use needle guns, scalers and bristle blasters on areas inaccessible to large rotary impact tools or grinders. Rotary impact tools have 5-7 times the productivity of needle guns. Impact or rotary impact tools generate the lowest levels of airborne contaminants, which is important if an existing coating contains lead.



Figure 20. Removing Loose Paint with a Scraper per SSPC SP2

Power tools can be electric (110 VAC) or pneumatic (at 90 psi). Reciprocating tools require the least amount of air, while larger sanders or rotary scarifiers need more air. Scabbers or chippers can be used to break up heavy rust, mill scale or coatings. Many of those tools have custom work pieces or come in a variety of sizes to accommodate various surface preparation requirements. Vacuum shrouds can minimize and assist with the collection of particulate matter generated during cleaning. The efficiency of dust collection is also an issue – especially with lead-based paint. Because of the range of safety issues associated with power tools, workers need to be familiar with their proper operation and use protective equipment.

Power tool cleaning is usually preferred over abrasive blasting, especially when containment is not employed.

Air powered tools require the use of a compressor. Each tool requires 10 cfm at about 90 psi. Several workers can be accommodated by a small compressor. Vacuum shrouded power tools are specialized equipment and come with the vacuum shroud attached to the tool (Figure 21). A collection/disposal container is included as part of the system. Air requirements for vacuum systems range from 150 to 200 cfm per tool. Some vacuum systems come with waste containers that fit multiple tools.

Mechanical surface preparation is usually conducted approximately 1-2 inches beyond the boundary of the failed area into the intact existing paint (2 inches specified by SSPC PA1). Mechanical surface preparation removes materials that would hinder the application of a coating and provides a suitable substrate on which to apply coatings. Surface preparation establishes a boundary (edge) between the damaged area and the coherent existing coating. SSPC PA 1 suggests feathering the edge of the existing coating (Figure 22), which can be done by hand using sandpaper or non-woven pads. Feathered edges are sometime prone to lifting when coated, requiring repair. Another option is to leave edges un-feathered and apply the coating with a brush. After surface cleaning, probe the exposed edges of the existing coating – whether feathered or un-feathered – with a blunt scraper to check for firm adhesion.



Figure 21. A Power Tool (Grinder) with Non-Woven Abrasive Pad and Vacuum Shroud

Some DOTs use spot abrasive blasting for surface preparation. This provides a substrate suitable for applying zinc primers. Exercise care when spot blasting brittle coatings, such as aged alkyds, as the periphery of the alkyd surrounding the blasted area may contain micro-fractures that can eventually result in a ring (donut) of failed coating around the spot repair.



Figure 22. Feathered Edges of Existing Coating Prior to Spot Repair

Treating Soluble Salts

Hand and power tool cleaning are not very effective for removing soluble salts (they remove 35-45 percent). Typically, this method is not sufficient to reduce soluble salt levels (e.g., chlorides) to levels low enough to ensure good spot coating durability.

Spot painting in salt-saturated environments introduces difficulties for SP 2/SP 3 surface preparation. Before performing this surface preparation, the repair area may need to be pressure washed and given a chloride reducing treatment. This type of cleaning, when used with a barrier coating, will eventually have problems with osmotic blistering as some surface chlorides will remain, interacting with moisture that infiltrates the coating. Where soluble salts are problematic, a better solution — if power tools are used — is to pressure wash. It may be appropriate to supplement this with a chemical treatment to limit surface chlorides and apply power tools to an SP11 surface preparation standard. This enables the use of an organic zinc primer that resists salt contamination more effectively than barrier coatings.

Coatings Application

After completing mechanical surface preparation, vacuum surfaces will be painted. Do not blow them down with compressed air to remove dust or loose debris prior to painting if the existing paint contains lead.

After the surface is prepared, paint the substrate as soon as possible (optimally, within 24 hours). Coatings may be single or multi-component materials. Manufacturer Product Data Sheets (PDS) contain instructions on how to properly store, mix and apply coatings. Proper application is essential for a successful painting project (e.g., mixing requirements, induction times, and pot lives).

Painters should follow manufacturer's guidelines concerning the coatings on the PDSs. These provide guidance on:

- Proper surface preparation
- Mixing and thinning instructions

- Pot life (if applicable)
- Induction time (if applicable)
- Film thickness (range) or coverage
- Application methods and equipment
- Safety (may be in separate Safety Data Sheets)

That includes recommended ambient and substrate conditions for painting. To avoid painting over surface moisture, painters should measure the relative humidity and surface temperature before painting gets underway. Relative humidity can be measured with humidity gages or dry bulb/wet bulb thermometers and psychrometric charts. Steel temperature can be measured with conventional surface contact thermometers or non-contact infrared thermometers. Criteria have been developed to evaluate whether atmospheric conditions are suitable for painting. For example, painting should not be performed during rainfall even in sheltered areas under a bridge. Prior to arriving at a bridge for painting work, the supervisor/foreman should check the weather to determine if it conforms to the coatings manufacturer's requirements.

Coatings need to be mixed (for two-component coatings) and agitated for the period specified by the manufacturer. Amine epoxy coatings require the longest set time – 30 minutes to react before application. Most two-component coatings have a limited pot life and must be applied within that period. Pot lives are usually given at 75 ° F. A rule of thumb is that pot life halves for every 20° F rise in temperature above the pot life stated for 75 ° F. To minimize waste, only to prepare the amount that will be used. Moisture-cure polyurethanes need to be mixed with stirrers attached to power drills rather than boxed (i.e., poured between buckets), to prevent atmospheric moisture from partially reacting with the coatings. Transfer coatings to the work area in sealed buckets, with painters using stirring sticks to agitate the coatings just prior to application. Some coatings will need to be re-agitated if they are not used within a short period. Moisture-cure polyurethanes usually do not require re-agitation.

Never apply coatings under the following circumstances:

- Dusty conditions, unless containment is used
- Light on the surface is less than 15 ft.-candles
- Ambient temperature is less than 45° F
- Relative humidity greater than 85 percent
- Surface temperature is less than 5° F above the dew point
- Surface temperature exceeds the manufacturer's recommendation
- Ambient temperature exceeds 95° F, unless the manufacturer allows a higher temperature

When a PDS does not provide detailed application information, these guidelines are generally safe to follow. If questions remain about application issues, the manufacturer's representative can usually provide the necessary information. Most coatings manufacturers also post their PDS online. Since most spot painting work will be short-term and not use containment or environmental controls, avoid performing it when most cold weather conditions are encountered, or if freezing conditions are forecast for the night.

Spot painting typically entails applying coatings to small areas. Application methods include the use of brushes, rollers, mitts, or sprayers. Brush, roller or mitt application methods are straightforward even for relatively unskilled workers and have limited environmental and worker safety impacts. Those methods work satisfactorily for 2-3 coat systems where high film builds are not required for each coat.

Brushing works best on irregular substrates and for working paint into edges of the existing paint (Figure 23). Rolling is typically used for flat work. Rolling is faster than brushing, but painters must be careful to not apply a coat that is too thin. For laced and riveted beams, paint mitts can be used to apply coatings. When painting over previously corroded substrates that were cleaned by hand or with power tools, use stiff brushes for priming and long nap rollers to apply the topcoat.

Airless sprayers use a pump to push the coating through a small hole in a spray gun. This atomizes the coating and deposits it uniformly on a surface. Small gasoline/electric powered units may be practical for spot painting projects. Larger pumps that require an air compressor can also be used. The pump sends paint through lines to the spray gun. The hose can be up to several hundred feet long. The gun applies the paint in a uniform fan pattern to the substrate. This equipment requires more experience and a more refined applicator technique than brushing or rolling. For larger repair areas, airless spray equipment can be used if skilled personnel and equipment are available. Small areas can be sprayed using battery-powered units. Spray equipment is the best option for coatings where one application can achieve high film builds. That is difficult to do by brushing or rolling. In some cases that involve larger spot repairs, a combination of methods can be employed. Spraying can deliver the coating to an area by spraying. Then, the coating may be brushed or rolled into irregular surfaces and brushing can be used to address pin holing. With spraying, solvent use is higher, and the paint may require thinning to be properly applied. Purge/clean the spray pump, lines and gun daily (for most coatings).



Figure 23. Spot Painting Applied with a Brush.

Some coatings (typically epoxies and polyurethanes) pose problems with overspray, which can travel far away from a bridge and damage buildings and vehicles. Care must be taken when painting in elevated or windy conditions, especially in urban areas. The use of brushes or rollers does not preclude overspray problems and in some cases, use of containment enclosures is a necessary precaution. Spray application is usually associated with overspray problems and it

typically requires containment. It typically requires containment around sensitive receptors (e.g. vehicles, homes and people).

When applying spot coatings, painters need to provide a uniform film build and avoid drips or misses. Use a tooth gage to measure wet film thickness. The dry film thickness can be estimated by multiplying the wet film thickness by the percent solids in a coating. For multi-coat systems, there is usually a minimum recoat time before applying a topcoat. That time depends upon the ambient temperature, surface temperature of the bridge steel and, for some coatings, the relative humidity. Some coatings have a recoat window that encompasses minimum and maximum recoat times. If the maximum recoat time is exceeded, the first coat must be abraded with fine sand paper to achieve an acceptable bond with the topcoat.

The selection of coatings should be based on the type of existing coating; the level of surface preparation used and desired durability. Most spot painting will involve two-coat systems. Typically, coatings with zinc-based primers (polyurethanes and epoxies) provide the greatest durability when used in conjunction with SSPC SP 11 or 15 surface preparation. When SSPC SP3 surface preparation is used, barrier coatings are best (e.g., epoxies) when applying primer to cleaned substrates. Aliphatic urethane or acrylic coatings can be applied over both types of primers to provide resistance to weathering. For added durability, a three-coat system can be used which incorporates an intermediate barrier coating.

Once a spot painting project is completed, the supervisor/foreman or coatings inspector should visit the bridge to ensure that all areas which need spot painting have been coated, and that the work was properly executed (in terms of appearance, coverage and coating thickness). Coating dry film thickness can be measured with a nondestructive test instrument. Low-cost simple devices, such as a “magnetic pull” gage, are suitable for assessing coating film thickness.

DURABILITY AND COST

Spot painting is often the painting option with the highest unit cost per area, but when applied to a suitable structure it has the lowest total coating cost from both the first cost and lifecycle cost perspectives. Even if a spot coating costs four times as much on a unit-cost-per-area-basis, it will only be performed on approximately 1 percent of a bridge’s total painted area. On a first cost basis, this is only about 0.25 percent of the first cost of total paint cost (assuming coating removal and replacement). Most estimates place the lifespan of spot painting between 5 and 10 years. KTC has applied experimental spot applications of coatings that have lasted 15+ years. With an estimated 10-year lifespan for the spot coating versus an estimated 20-year lifespan for a total paint project, the annual (lifecycle) cost of spot coating is less than 1/10 of the lifecycle cost for completely repainting a bridge. Hearn (op. cit. 8) reported 2009 costs for spot abrasive blasting and painting in Florida as:

- Steel deck (grid) – \$13.70/ft²
- Painted box girder –\$5,754/LF
- Painted steel stringer –\$58.91/LF
- Painted through truss –\$308.25/LF spot blast and clean; \$205.50/LF paint
- Painted deck truss –\$1,438.50/LF spot blast and clean; \$959/LF paint
- Painted floor beam –\$110.97 spot blast and clean; \$73.98/LF paint

- Pin/hanger –\$194.54/ea. spot blast and clean; \$969.96/ea. paint
- Painted steel column –\$274/LF surface clean; \$34.25/LF paint

Delaware DOT's (2009 data) spot painting costs depended on initial condition state (CoRe Bridge Management Element condition states); \$103.68/each, for condition state 3 and \$51.20/each for condition state 2. Louisiana DOTD (2009) reported the cost to surface clean (for condition state 2) and spot paint top coat on superstructure to be \$24.97/LF and a cost of substructure (for condition state 3) hand tool cleaning and painting to be \$35.98/LF.

6. PATCHING BRIDGE DECKS

Delamination of a concrete deck or slab is typically caused by corrosion of the reinforcing steel. That results in expansive corrosion of the reinforcing steel that cracks the concrete along rebar lines parallel to the surface of the deck or slab (Figure 24). Delamination can be identified using acoustic methods, such as chaining or impact echo methods, or through density test methods, such as ground penetrating radar (op. cit. 6). Corrosion of embedded reinforcing steel is the most common cause of concrete deterioration. When the steel is exposed to water, oxygen, and chlorides, it oxidizes and corrodes (rusts). The oxidized metal can expand up to 10 times its original volume, causing intense bursting forces in the surrounding concrete, which eventually cracks and delaminates. Likewise, reinforcing steel embedded in carbonated concrete corrodes in the presence of water and oxygen. This delamination will eventually create potholes, which cannot be tolerated since they adversely affect the rideability and safety of the deck. Rough decks also increase vehicular impacts to the bridge, accelerating the damage and potentially contributing to structural damage (op. cit. 7). The required repairs can be partial-depth (Figure 25). If deterioration is severe, a full-depth repair (Figure 26) may be required.

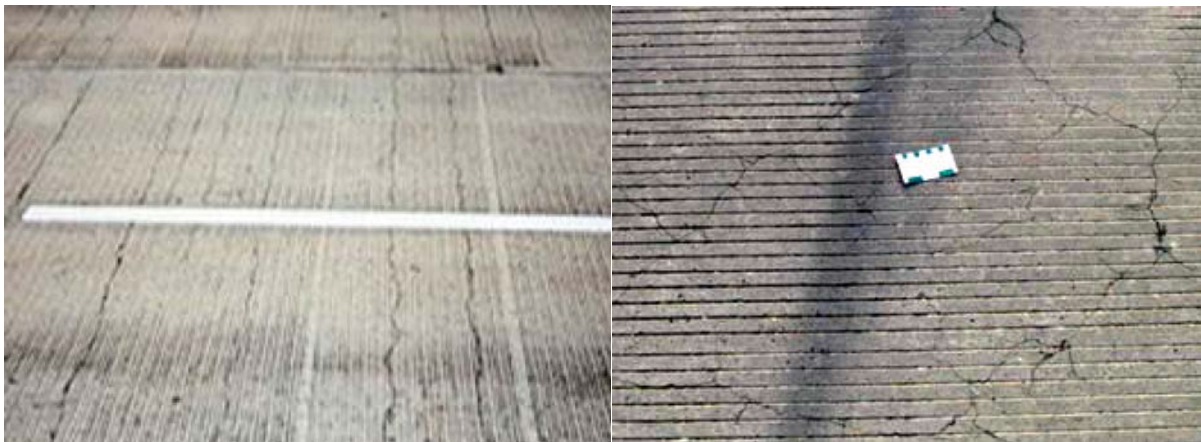


Figure 24. Concrete Cracking (20)



Figure 25. Partial depth repair (op. cit. 6)

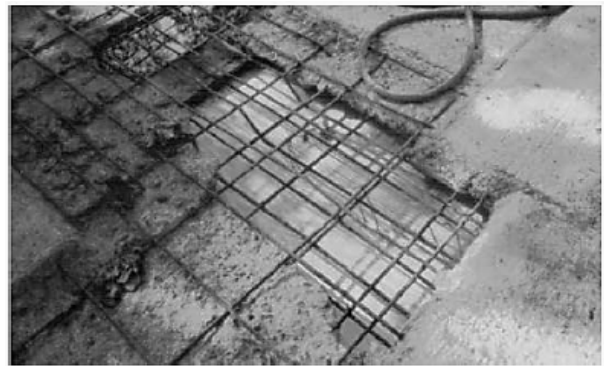


Figure 26. Full depth repair (op. cit. 6)

Deck patching serves as a temporary repair unless all chloride-contaminated concrete is removed before the deck is patched. Removing only the spalled and delaminated concrete results in the continued corrosion of the reinforcement steel and potentially the appearance of additional spalled areas. For permanent patching, an in-depth deck inspection is required to accurately identify the extent and limits of the contaminated concrete.

TYPES OF DECK PATCHING

To match the properties of the concrete being repaired as closely as possible, Portland cement concrete and mortar or other cementitious compositions are frequently the best materials to perform repairs. There is a wide variety of conventional and specialty materials available for repairing concrete. This provides the user a greater opportunity to match material properties with specific job requirements. It also increases the prospect of selecting inadequate material. ACI 546R-96, *Concrete Repair Guide*, is a good reference to examine when selecting repair material (21).

ISSUES WITH DECK PATCHING

Estimating the quantity of concrete that should be removed before executing repairs is a challenging task, especially if plans call for removing only unsound concrete. Errors made during the estimating process can be minimized by thoroughly surveying concrete condition as close as possible to when the work will be executed. Before starting concrete removal on a structural member, analyze the member to determine whether shoring or formwork is required. After the concrete is removed, the remaining section must support its weight, any superimposed dead load, live load (if the bridge is to be repaired under traffic), formwork, equipment, and the weight of plastic concrete. On a flexural member, the final dead load deflection must be compatible with the other members in the unit.

TASK DESCRIPTIONS FOR DECK PATCHING OF BRIDGES

Concrete Removal

A repair or rehabilitation project will usually involve removing deteriorated, damaged or defective concrete (Figure 27). Proper removal and preparation can be the most important factor in determining the repair's longevity irrespective of the material or technique used. Whenever concrete is removed using impact tools, the potential exists for small-scale cracking to damage the

surface of the concrete left in place. If this damaged layer is not removed, the replacement material will suffer what appears to be a bond failure. Thus, a perfectly sound and acceptable replacement material can fail due to improper surface preparation. To avoid this type of damage, saw cutting (Figure 28) may be desirable (avoid cutting reinforcing steel). This will also eliminate issues associated with feathering the repair material, which should be avoided.



Figure 27. Concrete Removal (op. cit. 6)



Figure 28. Concrete Sawing

All weak, damaged, and easily removable concrete should be chipped away. If the reinforcing bars are only partially exposed after all unsound concrete has been removed, it may not be necessary to remove additional concrete to expose the full circumference of the reinforcement. If during the removal process reinforcing steel is exposed and found to have loose rust or corrosion products or is not well bonded to the surrounding concrete, continue with concrete removal to create a clear space behind the reinforcing steel of 1/4 inch (6 mm) plus the dimension of the maximum size aggregate of the repair material.

Clean all exposed surfaces of the reinforcement thoroughly to remove all loose mortar, rust, oil, and other contaminants. The degree of cleaning required will depend on the repair procedure and material selected. For small areas, wire brushing or other hand methods of cleaning may be acceptable. Typically, abrasive blasting is the preferred method. When blasting or cleaning the steel and when blowing loose particles out of the patch area after cleaning, use clean, dry, oil-free air to prevent oil and moisture from impacting the repair area. Deteriorated steel that has a cross-sectional loss of 20% typically requires additional reinforcement. The usual method is to add additional reinforcement to the corroded bars. All lapped ends and intersecting bars should be tied to prevent movement while the patching material cures.

One of the most important steps in the repair or rehabilitation of a concrete deck is to properly prepare the surface that will be repaired. Preparation refers to those steps taken after removal of deteriorated concrete. The repair will be only as good as the surface preparation, regardless of the nature, sophistication or expense of the repair material. Take care to ensure an adequate bond and to reduce shrinkage of the patching material. After removing deteriorated concrete, remove all loose debris and/or other contaminants that may prevent bonding to the prepared surface. Ideally, after cleaning the surface it should be saturated with water, creating a saturated surface dry

condition. This may not be possible due to time constraints, but take steps to ensure adequate saturation as this helps prevent shrinkage cracks and a poor bonding.

Repair

Repair by conventional concrete placement is defined as the replacement of defective concrete with new concrete that is conventionally placed (Figure 29). This method is the most frequently used repair technique, and it is usually the most economical. Repair by conventional concrete placement is applicable to a wide range of situations, from repair of deterioration occurring over an extended period to defects caused by poor construction practices. This technique should not be used in situations where an aggressive factor has deteriorated the concrete that is being replaced. For example, if deterioration has been caused by acid attack, aggressive water attack, or even abrasion or erosion, if a repair is made with conventional concrete it is reasonable to assume that it will deteriorate again for the same reasons. However, Portland cement concretes modified with silica fume, acrylics, styrene-butadiene latex, or epoxy have been successful in extending service life (op. cit. 21).

Temporary Repair

Asphaltic concrete (ACC) can be used as a temporary fix in adverse weather conditions, but only to minimize further deck damage until conditions are suitable for making permanent repairs. ACC patches are typically installed when adverse weather conditions do not allow for the proper preparation of the repair area. ACC lacks the structural capacity of concrete and should not be used to permanently patch bridge decks, nor should it be used for full-depth deck patches. To complete a temporary repair, clean loose debris from the pothole and blow out any remaining debris with oil-free compressed air. Shovel cold patch (ACC) into the pothole, slightly overfilling the hole. Roll or tamp sufficiently for active traffic to run over patch material (op. cit. 7).



Figure 29. Placing and Finishing Repair Material

DURABILITY AND COST

The TSP2 Midwest Bridge Preservation Partnership’s 2011 survey reported that costs for half-depth deck repairs ranged from \$18 to \$37.5/ft², and full-depth repairs \$22 to \$70/ft². Hearn (op. cit. 8) reported the Delaware DOT cost for patching potholes in 2009 was \$1.12/ft² (possibly asphaltic concrete). A 1-3-inch-deep deck repair was \$36.10/ft² and a repair 3-inch-deep to full depth repair \$73.26/ft². The KYTC unit cost for partial depth patching was reported at \$819/yd³.

7. CLEAN/PAINT PIER CAPS AND ABUTMENTS

Substructure elements (piers and abutments) support the bridge superstructure and deck. Typically, some substructure elements are located at the ends of the beams/trusses/arches that support bridge decks. These elements rest on piers, and abutments and the decks usually contain joints that allow for the thermal expansion of decks and superstructures. The superstructure elements rest on bearing devices that transmit the deck/superstructure loads to the substructure elements. Those bearing elements accommodate thermal expansion of the decks/superstructures relative to the substructure elements.

BRIDGE CLEANLINESS PROBLEMS

All substructure elements under joints can potentially deteriorate due to runoff from leaking deck joints and troughs. Oftentimes, this runoff is contaminated with deicing chemicals (chlorides), which can penetrate the concrete and corrode the reinforcing steel, which causes the concrete to crack and spall (Figure 30). Substructure elements often have more problems with deterioration (cracking and spalling) than bridge decks. There are several reasons for this. The concrete used in substructure elements is often less dense than deck concrete. Pier caps and abutment seats often collect debris. Debris retains moisture and deicing chemicals that come into contact with the concrete. Typically, the only coating applied to substructures is a masonry coating, and it does very little to protect the concrete from moisture and salt intrusion. A previous KTC study indicated that chloride levels in pier caps and abutment seats are often in the 0.30% to 0.40% range of chloride to weight of concrete (22). The action levels for chloride contamination of concrete that result in steel corrosion are:

- 0.03 percent chloride to weight of concrete = initiation of corrosion
- 0.08 percent chloride to weight of concrete = accelerated corrosion
- 0.18 percent chloride to weight of concrete = major section loss of steel

The most effective treatments for preserving substructure elements are the application of protective coatings to uncontaminated (new) concrete or cleaning and applying protective coatings to existing concrete.



Figure 30. Abutment Cap Cracked Due to Leaking Joint and Deicing Chemical Damage

PREVENTIVE MAINTENANCE BY CLEANING AND PAINTING PIER CAPS/ABUTMENTS

Before painting structural concrete (e.g., pier caps and abutments) remove and dispose of accumulated debris and trash from pier and abutment caps. Problematic joint conditions such as damaged/missing seals and clogged joints can be addressed to prevent further runoff from leaking onto those substructure components. Remove embedded surface soils and residual deicing chemical contaminants by washing affected surfaces. Once the concrete surfaces have been properly cleaned, paint them with an approved coating.

TASK DESCRIPTION FOR CLEANING/PAINTING PIER CAPS AND ABUTMENTS

KYTC contracts out concrete cleaning and painting. At the Cabinet's discretion, bridge cleaning and painting may be combined with other operations such as removal of pack/stratified rust, covering those areas with a conversion coating, and greasing bearings and coating other structural concrete, including plinths and concrete beam ends. The following work standard primarily addresses pier cap and abutment painting.

The general progress of work should be from the bridge deck downward (for deck girder bridges). Where practical, perform dry work before wet work.

Dry clean the bearings, bearing seat areas, superstructure members (girders, diaphragms and stiffeners), and abutment and pier caps under deck joints and expansion joints. If the joint is open with a trough, clean the trough of all debris. All debris and trash located on or adjacent to the bridge superstructure and substructure components should be collected and disposed offsite according to the KYTC Division of Environmental Analysis's requirements for the disposal of non-hazardous waste.

Use potable water for bridge washing. Wash the bridge concrete at a pressure of 3,500 psi to 4,500 psi with a 0° spinner tip and/or fan tips as determined by the engineer at the working location with a minimum flow rate of 3.5 gal/min, provided these pressures do not damage any components of the structure. Keep the wand tip approximately perpendicular to the working surface at a maximum distance of 12 inches. In the deck area, wash inside faces of plinths and gutter lines three feet onto the deck for the entire length of the bridge, including end bents/wing walls. Wash entire abutments including back walls, caps, and sides. Wash pier caps and sides of caps to a distance three feet below the top of the cap. Ensure no wastewater contacts previously washed surfaces. Wash from the top of the work piece downward (Figure 31).

Coat all abutment/end bent and pier caps, pedestals, back walls, and end bent/abutment wing walls after debris removal and power washing. Use compressed air to remove any loose debris from the surfaces that will be coated after power washing. Apply coating to the abutment/end bent/pier caps, all horizontal surfaces including pedestals, all vertical surfaces one foot below the top of cap or ground line, whichever is least, and the front face of end bent/abutment back wall.

Coating thickness should fall within the manufacturer's recommended dry film thickness range. Comply with KYTC's *Standard Specifications for Road and Bridge Construction* (Section 614.03.02) and supplier-recommended conditions for applying coatings. Surfaces that will be coated should be allowed to dry for a minimum of 24 hours before any coating is applied. The

coating must be applied within 72 hours of pressure washing. Apply all coatings with brushes or rollers (Figure 32). No spray application is permitted. Coat all walking areas with a non-skid surface as per the coating manufacturer's directions.



Figure 31. Worker Pressure Washing Concrete Abutment Pedestal

If it is necessary to clean steel bearings/bearing plates, complete this work before washing the concrete and applying any coating. Grease bearings after the concrete coating has been applied.



Figure 32. Painting Concrete Pier Using Roller Application

DURABILITY AND COST

Currently, there are no published costs for coating the concrete on pier caps and abutments. It is estimated that the costs – including cleaning – should range from \$5 to \$7/ft². KYTC reports that concrete coatings costs for bridges including plinths and substructure elements adds \$2,000 to

\$4,000 to the price of cleaning projects (23). Based on a study of the concrete coatings applied by KTC researchers to the KY 676 Bridge over the Kentucky River in Frankfort and laboratory evaluations, it is likely that a concrete coating consisting of an epoxy primer with either a urethane or acrylic topcoat should last at least 10 years.

In 2015, the Ohio DOT coated approximately 170,000 yd² of new concrete with epoxy-urethane systems for about \$20/yd². In 2015, the agency let contracts for the removal of existing coating and application of an epoxy sealer/urethane topcoat to about 46,000 yd² of concrete bridges for approximately \$14/yd².

8. SCOUR, DRIFT, SEDIMENT, AND BANK STABILIZATION

Scour refers the loss of streambed material due to hydraulic action. A bridge is considered scour critical if there is reasonable chance that scour can undermine the bridge, for instance if a pier in the water does not have any piles, the piles it has are known to be too short, or if the depth of the foundation is unknown.

Waterborne debris (drift), composed primarily of tree trunks and large limbs, often accumulates at bridge piers, abutments, and under-deck elements (Figure 33). High water events can increase the amount of debris in a stream and will accelerate debris accumulation. Accumulated debris restricts and redirects water flows through the bridge opening. This can lead to flooding, damaging loads, and foundation scour. Significant amounts of drift can reduce the hydraulic opening of a bridge and cause water to spill over the bridge or damage due to lateral loading.



Figure 33. Drift Trapped at KYTC Bridge

Sediment is often transported downstream until it accumulates in, beneath, or near highway structures (Figure 34). Sedimentation occurs in all KYTC Districts, but it may pose the greatest challenges in watersheds where mining or logging results in excessive erosion.

Channel and embankment erosion are similar to scour, but impact an embankment or soil that is normally dry. Heavy rains can initiate vegetation stripping; without vegetation, soil is exposed and the streambank erodes. Erosion can be a problem at the ends of bridges with inadequate or poorly

maintained drainage details. Bank stabilization can be used to prevent erosion and bank slips or to stabilize an existing problem.



Figure 34. Loose Rock and Sediment Deposits at KYTC Bridge

ISSUES WITH SCOUR, DRIFT, SEDIMENT, AND BANK STABILIZATION

Scour that undermines bridge substructures is one of the most common causes of bridge failure. The factors contributing to scour (e.g., stream size, bed material, stream power) are difficult to assess, and their effects may be modified due to changes upstream of the bridge or at the bridge. Scour remediation efforts are often used to cope with changes in stream geomorphology.

How much drift accumulates at a bridge is often contingent on activities within a watershed or in the stream upstream of the bridge. Logging and/or stream bank erosion can produce drift material that is flushed downstream until bridges trap it. Drift may be a regular seasonal problem at some bridges. For other bridges, it may only be a problem after flooding occurs.

Sediment deposition in and near highway structures can create many issues. If in-channel sedimentation reduces the size of the hydraulic opening, overflow and flooding can result, which can damage the structure. Excess sedimentation can cause channel changes resulting in scour or erosion.

Bank stabilization is similar to scour remediation in that a stabilization effort might be repeated because the stabilization itself or other changes upstream can result in new erosion or bank slips.

The biggest issue encountered in remediating scour, drift, or bank stability is that each involves work within a streambed and directly affects the stream environment. Environmental restrictions and the permitting process can be problematic.

TASK DESCRIPTIONS FOR SCOUR, DRIFT, SEDIMENT, AND BANK STABILIZATION

One-Step Method

All practices for in-stream work should be implemented using the one-step method defined by the U.S. Army Corps of Engineers (USACE). The objective of this method is to remove or place material in a stream while minimally disturbing it. Material should be “lifted” into or out of the

stream (Figure 35) with equipment designed for “lifting” (i.e., cranes or end-loaders). After material is removed from the stream, it is loaded into a vehicle for disposal. Or it is placed far enough from the stream so that it is not entrained by moving water and reenters it. Bulldozers are not used for one-step method work. Stockpiling of material within the confines of the stream is prohibited. Good management and conservation measures must be used (24). The following sections describe guidelines and procedures for conducting preventive maintenance activities along streams.

Scour/Erosion Repair to Bridge Elements

- Notification to regulatory agencies may be required. Refer to Table 6 and General Conditions for requirements.
- Obtain necessary approvals prior to beginning work.
- Work only during no-flow or low flow periods unless it is an emergency.
- If possible, work from the roadway and avoid using equipment in the stream.
- Access the stream at one location and use the one-step method if equipment is placed in the stream.
- Use channel lining around bridge elements and culvert footings to minimize erosion.
- Excavate as needed, then use concrete to supplement existing footing.
- Use geotextile fabric for erosion control in the trench and on the embankment slope.
- Use A-Jacks to encourage sediment deposition in scour holes.
- Do not bring equipment into the stream unless it is necessary.
- Do not use bulldozers in the stream without approval from the USACE or KDOW.
- Do not remove streambank vegetation unless necessary.
- If equipment is placed in the waterbody, use one access point to the stream.
- If needed, revegetate disturbed streambanks following guidelines in the Kentucky Erosion Prevention and Sediment Control Field Guide.
- If there is the potential for sediment entrainment from disturbed soils, use sediment barriers.



Figure 35. One-Step-Method Removal of Drift from a Stream

Drift Removal

- Notify regulatory agencies if the one-step method cannot be used.
- Plan and obtain approvals for drift disposal method(s) prior to beginning the job.
- Work only during no-flow or low flow periods unless there is an emergency.
- Obtain approval from Transportation Engineering Branch Manager for Operations for emergency work performed between April 15th and June 15th.
- Use a cable and winch to remove large trees from the stream.
- Use chain saws to cut up large logs into smaller, more manageable pieces so they can be lifted into trucks for disposal.
- Put a front-end loader inside large culverts to move the debris to the opening. Then use the one-step method to lift debris from the stream.
- Where available, use long boom excavators to reach from the roadway to the streambed.
- If necessary, equipment designed to lift and trucks may enter the streambed.
- Do not perform drift removal activity between April 15th and June 15th unless it is an emergency.
- Do not place bulldozers in the stream without approvals from regulatory agencies.
- If equipment such as front-end loaders or cranes are placed in the waterbody, minimize the number of access points to the stream.
- Separate trash, tires, barrels, unknown or hazardous wastes.

Sediment Removal from Structures

- Notification to regulatory agencies may be required. Refer to Table 6 and General Conditions for requirements.
- Plan and obtain necessary approvals for waste disposal method(s) prior to beginning the job.

- Work only during no-flow or low flow periods unless there is an emergency.
- Remove sediment from the site using the one-step method.
- Access the stream at one location.
- Plan to reuse sediment as fill for roadway maintenance activities.
- Seed and mulch disturbed areas along the streambank.
- Do not begin work without approvals from the regulatory agencies.
- Do not remove streambank vegetation unless necessary.
- Do not remove large trees.
- Do not undercut banks.
- Do not channelize the stream or deepen the channel during this activity.
- Do not use bulldozers in the stream without approval of the USACE or KDOW.
- Do not place sediment in the stream channel or floodplain.
- Do not flush sediment into the stream.
- Do not place sediment on streambanks below the ordinary high water level.
- If equipment is placed in the waterbody, minimize the number of access points to the stream.
- If needed, revegetate disturbed streambanks following guidelines in the Kentucky Erosion Prevention and Sediment Control Field Guide.

Embankment Repair and Protection Using Channel Lining, Gabion Baskets, Railroad T-Rails

- Notification to regulatory agencies may be required. Refer to Table 6 and General Conditions for requirements.
- Work only during no-flow or low flow periods unless there is an emergency.
- If possible, work from the roadway and avoid using equipment in the stream.
- Access the stream at one location and use the one-step method if equipment is placed in the stream.
- Dump Class III channel lining or quarry shot rock onto eroded embankments and arrange with a backhoe or Gradall positioned on the roadway.
- Use a backhoe to place channel lining one bucket at a time if rock scatter is an issue.
- Use channel lining around bridge elements and culvert footings to minimize erosion.
- Use the one-step method if equipment is used to arrange rock in the stream.
- Do not bring equipment into the stream unless it is necessary.
- Do not use bulldozers in the stream.
- Do not remove streambank vegetation unless necessary.
- If equipment is placed in the waterbody, use one access point to the stream.
- If there is the potential for sediment entrainment from disturbed soils, use sediment barriers.

Environmental Permitting

Permitting is a major obstacle for DOTs when performing work related to streambeds. It may take several years to obtain a permit, and permitting fees may approach the total cost of the work to be performed. Due to the complexity of permitting and its impacts on KYTC's ability to perform the work, the scope of work and project costs, lengthy overview/guidance is necessary. The following subsections describe environmental permitting guidance pertinent to KYTC work in streams.

In-Stream Permits and Coordination

This section describes requirements for USACE Nationwide Permits (NWPs) and the Kentucky Division of Water (KDOW) Water Quality Certification (WQC) associated in-stream management practices. Of the 44 USACE NWPs, the following are relevant to KYTC activities described previously:

- NWP # 3(i): Maintenance – Repair, rehabilitation or replacement of existing structures.
- NWP # 3(ii): Maintenance – Discharge of dredge material.
- NWP # 13: Bank Stabilization.
- NWP # 18: Minor Discharges.
- NWP # 19: Minor Dredging.
- NWP # 33: Temporary Construction, Access and Dewatering.

Depending on the activity, project size and location, the USACE and KDOW may require notification. If notification is required and the NWP is granted, it authorizes activities that have minimal adverse effects on the aquatic environment and generally comply with related laws. In most cases, there will not be an individual review of each activity authorized by an NWP.

Table 6 summarizes the regulatory notification requirements for the in-stream practices described in this chapter. NWPs are supplemented by General Conditions. Regulatory agencies must be notified if one or more of the General Conditions cannot be met during the project. Two NWP General Conditions require a case-by-case review of all activities that may adversely affect federally listed endangered or threatened species or historic properties. In some situations, the regulating agencies may require an individual permit.

General Conditions

Notifying the regulatory agencies **is required** if one or more of the following conditions cannot be met during the project.

Soil Erosion and Sediment Controls

Effective sediment and erosion controls shall be employed on all projects. Use appropriate Best Management Practices (BMPs) from the Division of Conservation and Division of Water, Natural Resources and Environmental Protection’s *Kentucky Best Management Practices for Construction* manual.

Table 6 Regulatory Notification Requirements for Relevant In-Stream Practices

Activity	USACE Permit #	Notification to USACE is required if the following conditions occur:	Application for a KDOW WQC is required if the following conditions occur:
Drift Removal	3(ii)	• Notification is required if the one-step method of drift removal cannot be used.	• When the project does not qualify under the USACE nationwide permit.
Beaver Dam Removal	None	• Notification is not required for this activity	• Notification is not required for this activity
Sediment	3 (ii)	• Work area extends more than 200 feet in any direction from the structure.	• More than 200 feet of stream length will be affected

Removal from Structures	19	<ul style="list-style-type: none"> • More than 25 cubic yards of material are removed. 	<ul style="list-style-type: none"> • When the project does not qualify under the USACE nationwide permit.
Embankment Repair and/or Protection	13	<ul style="list-style-type: none"> • Length of bank stabilization activity is more than 500 feet • On average, more than one (1) cubic yard per foot of fill is placed below the ordinary high water mark. 	<ul style="list-style-type: none"> • Length of bank stabilization activity affects more than 200 feet of stream
Scour/ Erosion Repair to Bridge Elements	3 (ii)	<ul style="list-style-type: none"> • Work area extends more than 200 feet in any direction from the structure. 	<ul style="list-style-type: none"> • More than 200 feet of stream length will be affected
	18	<ul style="list-style-type: none"> • More than 10 cubic yards of material is placed below or removed from below the ordinary high water mark • More than 1/10 acre of special aquatic site (i.e., wetlands, vegetated shallows, riffle/pool complex) is affected. 	<ul style="list-style-type: none"> • When the project does not qualify under the USACE nationwide permit.
Bridge and Culvert Replacement	3 (i)	<ul style="list-style-type: none"> • Notification is not required for this activity unless one or more of the General Conditions is not met. 	<ul style="list-style-type: none"> • More than 200 feet of stream length will be affected
Temporary Construction, Access and De-watering	33	<ul style="list-style-type: none"> • A Notification is required for each project • A Restoration Plan is required for each project 	<ul style="list-style-type: none"> • When the project does not qualify under the USACE nationwide permit.
Minor Discharges	18	<ul style="list-style-type: none"> • More than 10 cubic yards of material is placed below or removed from below the ordinary high water mark • More than 1/10 acre of special aquatic site (i.e., wetlands, vegetated shallows, riffle/pool complex), is affected. 	<ul style="list-style-type: none"> • When the project does not qualify under the USACE nationwide permit.
Minor Dredging	19	<ul style="list-style-type: none"> • More than 25 cubic yards of material are removed. 	<ul style="list-style-type: none"> • When the project does not qualify under the USACE nationwide permit.

Scheduling

Perform all work within the stream channel during no-flow or low flow conditions. Emergency work may be performed within the confines of the stream channel from April 15 through June 15. Emergency work should be determined by the Transportation Engineering Branch Manager for Operations or the County Judge Executive, as applicable.

Sediment Disposal

Do not stockpile material removed from the channel or banks within the confines of the stream channel or wetland areas. Load all spoil material onto trucks and haul it to upland sites for later use, storage or disposal. Trucks must be covered to control dust. Material removed from bridge openings shall be limited to restoration of the original cross section. Minimize disturbances to the existing stream bank vegetation. Where practicable, use existing access roads into the stream channel to enter and exit the work area.

Equipment

Equipment type or operation shall conform to the one-step method. Do not use bulldozers to perform any work within the confines of the stream channel.

Materials Placement

Select and place materials for maintenance work so that they will not be washed downstream during normal or high flows.

Special Use Waters

Work shall not occur in Special Use Waters in wetlands adjacent to those waters or designated as follows: National Wild and Scenic River, critical habitat for federally listed threatened and endangered species, state natural heritage sites, Outstanding National Resource Water. An Individual Water Quality Certificate is required for activities in Outstanding State Resource Waters, Exceptional Waters and Cold Water Aquatic Habitat. The current reference is found at http://nrepcapps.ky.gov/special_waters/specialwaters.htm. Other locations of concern, such as state natural heritage sites, must be identified on a case-by-case basis.

Threatened and Endangered Species and Shellfish

No activity should jeopardize a threatened or endangered species listed under the Federal Endangered Species Act or amendments, or endanger the critical habitat of such species, or occur in areas of concentrated shellfish production. KYTC activities should be coordinated through the District Environmental Coordinator. For local agencies, contact the Nature Preserve Commission.

Historic Properties

Work will not affect Historic Properties without notifying the USACE Engineer. KYTC should address its concerns to the District Environmental Coordinator. Local agencies should contact the State Historic Preservation Officer.

Water Supply Protection

If work occurs within 2,000 feet upstream to 300 feet downstream of a public water supply intake operated by someone other than the permittee, the permittee will provide signed agreements from the intake operator allowing the work to be conducted within the stream reach.

Wetlands

Contact the Division of Environmental Analysis or the Division of Water if there is suspicion that the work may affect wetlands.

Compliance Certification

After completing the project, a Compliance Certification must be filed out for all work that requires the USACE be notified.

Notification Contents

When required by the terms of the NWP, including general conditions, provide a completed Pre-Construction Notification (PCN) to the District Engineer as early as possible. The PCN can be completed using the standard Individual Permit application form labeled PCN or a letter that includes the following information may also be provided:

1. Name, address, and telephone number of the applicant
2. Location of the project
3. Description and purpose of the project (including sketches expedites decision)
4. For NWP 18, delineation of affected special aquatic sites (wetlands, vegetated shallows, and riffle/pool complexes)
5. For NWP 33, a restoration plan
6. If there are federally listed threatened or endangered species that may be affected, list them.
7. List any properties listed or eligible for listing in the National Register of Historic Places.

Work may proceed under the NWP by written notification from the Engineer upon acquiring a Permit, or if written notice from the Engineer is not received within 45 days after the Engineer's receipt of the completed PCN.

DURABILITY AND COST

The durability of PM activities related to scour, drift, and bank stabilization varies. A Washington DOT official reported that silt buildup can occur annually and requires clean outs, estimating that work costs on a small tributary range from \$20,000-30,000/yr. He noted that recent scour work on bridges over creeks ranged from \$10,139 to \$15,186. Scour work on a river bridge costs \$103,020 with an additional \$148,569 going toward permitting costs. Typically, Washington DOT does not remove drift from bridges – it frees drift that is lodged against piers and is built up adjacent to the bridge, which releases the drift downstream. The cost for that work varies depending upon the amount of debris buildup (op. cit. 14). Ohio's DOT (ODOT) specifies that drift/debris cleaning costs \$1,000/pier with a frequency of every two years (26). For stream migration the ODOT costs/frequency of work were:

<u>RECOMMENDED REPAIRS</u>	<u>INITIAL COST</u>	<u>EXPECTED LIFE</u>
• Clean off debris from piers as needed	\$1,000/EA. Pier	2 years
• Remove bar upstream of bridge (note: this may require a permit)	\$5,000/EA. Pier	5 years
• Place dump rock along outside of curve to slow stream	\$10,000/EA. Pier	10 years
• Construct other accepted methods of slowing water in outside of curve such as spurs, jack field, willow saplings	\$15,000/EA. Pier	10 years

For streambed lowering that exposes or undermines foundations the Ohio DOT costs/frequency of work were:

<u>RECOMMENDED REPAIRS</u>	<u>INITIAL COST</u>	<u>EXPECTED LIFE</u>
• Place dumprock across stream immediately downstream of bridge	\$20,000/EA. Pier	10 years
• Construct low water check dam downstream of bridge using two lines of sheet piling filler with dumprock in between	\$30,000/EA. Pier	10 years

- Pave streambed under bridge with concrete slab and cut-off walls \$30,000/EA. Pier 10 years
- Place used precast concrete traffic median barriers across stream \$2,000/EA. Pier 3 years

Permitting has a major impact on these projects, delaying agencies' ability to perform the work and requiring DOTs to absorb high permit expenses. The former can delay work for several years, while acquiring permits can in some instances exceed the cost of doing the preventive maintenance work.

EMPLOYING PREVENTIVE MAINTENANCE ACTIVITIES

Depending on the activity, PM activities can generally be performed on bridges in fair to good condition. Typically, when a bridge's condition is rated as poor or severe it will require more significant repairs (sometimes called restorative maintenance) or replacement (26). KYTC will benefit from combining PM activities on one bridge and/or bundling projects to include the same activity (or group of activities) on several bridges located on the same route or clustered near each other. This will limit mobilization costs and, in some cases, increase savings through bulk purchases of materials such as sealants, patching materials and/or coatings.

Several of the *8 Basic PM Activities* can be performed alongside one another, either concurrently or sequentially. In some cases, redundant work can be eliminated (e.g., during bridge washing, joints can be flushed and bearings/pier caps/decks cleaned in preparation for subsequent greasing/painting/sealing). Historically, KYTC has effectively used contracts to group cyclical PM work (e.g., washing the bridge superstructure, cleaning bearings and piers, doing stratified rust removal, and applying protective materials [greases and/or conversion coatings] to bearings and beam-ends). Costs on these projects have typically been less than engineering estimates. This work can also be performed by state forces as can all of the *8 Basic PM Activities*. Several of these are more standalone activities, however (spot painting and scour, drift and bank stabilization).

One option to consider is performing all relevant *8 Basic PM Activities* or baselining a bridge with the intent of reapplying those in a 5- to 7-year period on a cyclical basis, while ideally avoiding the need for condition-based maintenance until the next PM cycle. Biennial inspections could be used to determine whether interim condition-based PM activities are required.

CONCLUSIONS

KTC has identified a limited number of PM activities based on a review of PM practices used by other state DOTs and KYTC's anticipated needs, as identified by district personnel. Other PM activities identified under this study and KTC's previous report (op. cit 2) would also be beneficial to creating the PM program. A district-based pilot/start-up PM program will ideally begin with a limited number of PM activities. Once district personnel have learned how to execute these efficiently, additional activities could be added. However, activities should not be added too quickly because it is imperative that district staff thoroughly understand each activity's work standards, learn how to perform it without problems, and competently inspect work quality. Once a pilot district has successfully integrated the *8 Basic PM Activities* into a PM program and the lessons learned are compiled, they can be adopted for statewide use by other KYTC districts.

The *8 Basic PM Activities* address high-maintenance bridge components – decks, joints and coatings – that have been widely considered to pose the greatest needs for bridge owners. The activities also address problems related to deteriorating structural concrete, which is an emerging problem in Kentucky bridges and probably nationwide (op. cit. 14). They also address streambed issues, which several KYTC districts have expressed concern over. The *8 Basic PM Activities* are applicable to the largest number of bridges and will have the greatest impact with the least amount of training/learning requirements for KYTC district personnel. Adopting them as the basis for a KYTC PM initiative constitutes a manageable approach that can be expanded throughout the state within a few years.

In adopting PM programmatically, KYTC should initially focus on the effectiveness of PM activities, which entails identifying best maintenance practices for each activity (including developing work standards and special notes); developing/providing training for KYTC supervisors, field crews, and inspectors (and possibly contractor personnel); identifying good materials to obtain the best performance from an activity; and achieving quality workmanship. Once those issues have been addressed in a satisfactory way, KYTC's focus can shift to providing low-cost delivery of PM activities. Efficiency relates more to first costs; effectiveness relates more to lifecycle costs. Actions to improve efficiency include targeting appropriate bridges for PM activities, improving worker/contractor productivity (including implementation of a continuous improvement effort), and the use of techniques such as activity bundling to achieve the lowest per bridge cost for the work (Figure 36).

As its PM program matures, KYTC should turn its focus to efficiency. However, effectiveness should remain a priority. The Cabinet can validate the effectiveness of its PM program by auditing work, implementing continuous improvement efforts (including use of performance measures), and identifying and using high-performing materials for repairs and treatments. For fieldwork, effectiveness can be determined by process conformance, end product quality and resulting life-cycle costs.

Once all KYTC districts reach an acceptable level of performance using the *8 Basic PM Activities*, additional activities could be added throughout the state or in specific districts where they are needed.

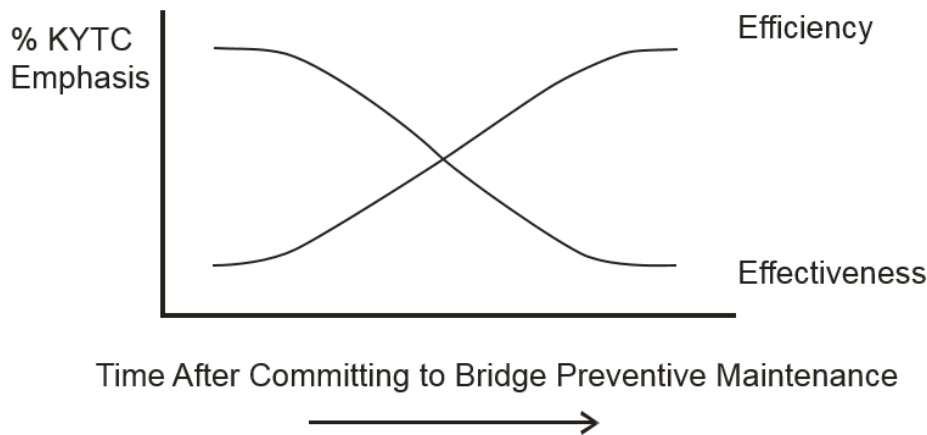


Figure 36. KYTC emphasis (Effectiveness vs Efficiency) after adopting preventive maintenance of bridges

As noted in a previous KTC report (op. cit. 2) PM activities should ideally be incorporated into a holistic bridge preservation program. That would allow coordinated decision-making on which actions should be taken on all KYTC bridges (preventive maintenance, rehabilitation, replacement or do-nothing). This will result in the most efficient use of PM activities and extend the service lives of bridges.

RECOMMENDATIONS

The following recommendations are provided for the project:

- Initiate a pilot PM program in one or two districts with additional funding allocated for PM activities. The pilot program should last 1–2 years and implement the *8 Basic PM Activities* described in this report. KYTC should audit and review the program. This will entail assessing the performance of each activity and the work performed each year.
- The pilot program could be expanded to all KYTC districts once it has matured.
- KYTC could integrate PM work into a holistic bridge preservation program that addresses PM, rehabilitation and bridge replacement.

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APPENDIX A – KYTC QUESTIONNAIRE

Cyclical Based Preventive Maintenance						
Activity	Frequency	Cost/Unit	State crew	Contract	Uses/year	Comments
Deck / Approach / Surface Items						
Clean/Flush Deck						
Clean/Seal Expansion Joints						
Seal Deck - Liquid (e.g., penetrating sealer)						
Seal Deck - Aggregate (e.g., chip seal)						
Seal Bridge Deck Cracking (e.g., Crack sealer)						
Drainage System Cleaning /Repair						
Coat Concrete Barrier / Deck Fascia						
Seal Entire Bridge Deck Cracking (e.g., Floodcoat, Healer Sealer)						
Seal Joints						
V Clean and Flush Drains/Scuppers						
Superstructure						
Superstructure Washing						
Fatigue Crack Mitigation						
Clean/Reset Bearings						
Steel Bearing Lubrication						
Coat Concrete Beams						
Waterproof Concrete Beams/Girders						
Substructure						
Seal Joints Along Parapet or Wingwalls						
Coat / Seal Concrete Substructure						
Clean and Flush Caps						
Clean and treat Bearings						
Other						
Vegetation Control						

Channel Clearing						
Install/Replace Bird Netting						
Cathodic Protection						
Maintain Navigation Protection						
Mechanical/Electrical Cleaning						
Clean Culvert Box Sediment						

Condition Based Preventive Maintenance

Activity	Frequency	Cost/Unit	State crew	Contract	Uses/year	Comments
Deck / Approach / Surface Items						
Minor Concrete Patching & Repair						
Repair Bridge Deck Asphalt Concrete						
Slope Paving Repair						
Mill Top of Backwall or Edge of Deck						
Epoxy Overlay						
Patching with Concrete						
Patching w/HMA Overlay (no waterproofing membrane)						
Patching w/HMA Overlay (w/waterproofing membrane)						
HMA Overlay (Cap) (no membrane)						
Deck Joint Repair						
Deck Joint Replacement						
Repair Concrete Curbs and Gutters						
Railing Paint						
Repair Approach Railing						
Repair Bridge Railings (Minor or Isolated Repairs of Bridge Railing Regardless of						
Shave Approach Shoulders						
Approach Slab Overlay						

Deck Fascia/Overhang Repair						
Repair Bridge Sidewalks						
Deck Repair - Half Sole (depth)						
Deck Repair - Full Depth						
Leveling/Lifting/Stabilization (Wedging, Mud						
Cut Relief Joints in Approach Pavement						
Replace Pavement Marking						
Overlay Approach Slab (Micro-Silica or Latex.						
Seal Cracks in Approach Slab						
Superstructure						
Pin & Hanger Replacement						
Steel Spot Painting						
Steel Zone Painting						
Superstructure (cont.)						
Steel Complete Painting						
Apply Acrylic Coatings to Concrete						
Collision Damage Repair(e.g., Heat						
Bearing Replacement						
Epoxy Inject Superstructure Cracks						
Drain/Scupper Repair/Replacement						
Temporary Support						
Structural Repair - Section Loss from						
Steel Paint- Overcoat						
Steel Paint - Recoat						
Bridge Paint Identification						
Minor Patching of Concrete Beams/Girders						
Paint Bearings						
Patch/Repair Superstructure Concrete						
Substructure						
Leveling/Lifting/Stabilization (e.g., Wedging,						
Patch/Repair Moderate Substructure						
Epoxy Inject Substructure Cracks						

Seal Abutments and Caps						
Structural Repair (e.g., pile replacement)						
Paint Structural Steel						
Maintain Seismic Retrofit (Paint or Repair						
Maintain Seismic Retrofit Components						
Clean and Paint Substructure Elements						
Patch / Repair Minor Substructure Concrete						
Other						
Mechanical/Electrical Replacement						
Bank Stabilization (e.g., Gabions, Rock						
Mechanical/Electrical Repairs						
Soil Stabilization (e.g., Polyurethane Grout						
False Decking						
Other						
Slope Paving Repair						
Repair Scour Monitoring System						
Install/Replace Bridge ID Marker						
Install Graffiti Deterrent Injection)						
Seal Cracks in Concrete Culvert						
Repoint Concrete Culvert						
Repair Washouts / Erosion						
Scour Countermeasures						
Repair/Replace Utilities & Signs						
Remove Drift						
Bank Stabilization (e.g., gabions, rock blanket)						
Remove Loose Concrete						
Tighten Loose Nuts and Bolts (Anywhere on Bridge)						
Remove Graffiti						

Rehabilitation

Activity	Uses/Year	Cost/Unit	Comments
Deck / Approach / Surface Items			
Railing Replacement Including Upgrading to Current Standards			
Shallow Rigid Concrete Overlay (ex. Latex Modified or Micro-Silica Concrete)			
Deep Rigid Concrete Overlay (ex. Latex Modified or Micro-Silica Concrete)			
Approach Slab Replacement			
Install or Upgrade Median Barrier			
Correct Deck Drainage (Cross Slope, Grade or Drainage Capacity)			
Replace Concrete Filler in Steel Grid Deck			
Rehabilitate Connectors in Steel Grid Deck			
Replace Deteriorated Steel Grid Sections			
Replace Deteriorated Boards in Timber Deck			
Superstructure			
Superstructure Rehabilitation			
Superstructure Replacement			
Bridge Widening			
Beam Repairs (e.g., Bolted, Welded, Heat-Straightening)			
Construct New Catwalks			
Replace Gates on Movable Bridges			
Raise Bridge to Increase clearance			
Rehabilitate Bearings (Major/Widespread Work Short of Replacement)			
Replace Diaphragm on Concrete Beams/Girders			
Substructure			
Partial/Full Substructure Replacement			
Substructure Repair (extensive)			
Seismic Retrofit			
Replace Navigation Protection (ex. Repair Damaged/Deteriorated Dolphins and Fenders)			

Slip lining (Culvert Type bridges)			
Debris Removal, Mud wall Patching, (Attenuator upgrade **)			
Large Culverts (4'-20' Spans) almost similar activities as for listed for bridges			
Small Culverts (<4' Spans) similar activities as for the Large Culverts			
Install Scour Monitoring System			
Activity	Uses/Year	Cost/Unit	Comments
Substructure			
Re-grade Channel under Bridge			
Construct Drainage Flume for Embankments			
Install Slope Paving			

Enhancements

Activity	Location of	Cost/unit	Date	Comments
Drain/Scupper Extension				
Splash guards for short deck drains				
Trough under closed joint				

Site Specific Preventive Maintenance

Activity	Product	Location of use	Date	Comments

APPENDIX B – DOT SURVEY SUMMARY

Q1 – Do you have dedicated bridge crews?

All agencies responding have dedicated bridge crews.

Q2 – Do these crews have specialized training?

Of responding agencies, 80% have crew have specialized training.

Michigan a Bridge Element Training Program for maintenance workers and has Region Structure Support Team that customizes training to bridge crews as needed.

Prior to 2008, MoDOT had both Central Office and district crews dedicated to bridge maintenance functions. In 2008 the Central Office bridge paint and repair crews were reassigned to the districts to supplement existing crews and to provide additional staffing to other district bridge maintenance crews. With the Department reorganization in 2011, the districts were directed to eliminate these special crews in favor of routine maintenance taking over all such functions. While a couple districts did so, more saw the benefit of having them and covertly kept the crews alive. Today, there is movement to reengage the special crews. The specialized training they have receive is primarily in the areas of equipment operation, occupational health, and safety. Work functions are typically learned on the job.

Kansas DOT has six Districts and only three have dedicated bridge crews. They are using a heavy equipment group that does all type of road and bridge repair that require bigger or more specialized operators.

West Virginia DOT has specific training for specialty products for concrete repair, expansion joints, sealers.

Q3 – Are these crews assigned to activities other than bridge maintenance?

Of responding agencies, 60% reassigned crews to tasks other than bridges.

Q4 – Do you have issues obtaining environmental permits when conducting bridge maintenance activities in and around streams?

1. All responding agencies require permitting for scour repair and one reports project delays due to problems obtaining the permit.
2. One agency required permits for bridge deck washing.
3. Two agencies require permits for bearing washing.
4. One agency requires permits for abutments and pier caps.

Comments:

1. Michigan DOT – Working in the river requires permitting, which are easily obtained unless there is an endangered species in the waterway. Bridges are not necessarily washed as part of routine maintenance; it is framed as a cleaning to facilitate proper

inspection using potable water.

2. Kansas DOT – We do some deck and bearing washing. We are not required currently to obtain a permit. We really don't do much substructure washing.
3. Ohio DOT – We are not doing a lot of bridge washing activities.
4. West Virginia DOT – Washing does not require permits since we have best practice agreement with our state DEP.

Q5 – Do you have purchasing issues for material or services?

Of the participating agencies 80% respond that they have purchasing issues.

Comments:

1. Michigan DOT - The ability to trial a new product is near impossible given purchasing limits and especially single sourcing rules. Single sourcing should be a much easier process in order to trial a new product.
2. Missouri DOT - Material and services are procured through our General Services division in the Central Office and districts.
3. Kansas - Street cleaners for urban decks and flush trucks for drain and joint washing.
4. Ohio DOT - Depending on the amount, needs to go through a bid process.
5. West Virginia DOT - Purchase of sole source products or services.

Q6 – What mechanisms do you use for purchasing services or material?

1. Michigan DOT - Agency wide master agreements
2. Missouri DOT - Agency wide master agreements and District/Regional agreements
3. Kansas DOT - District/Regional agreements
4. Ohio DOT - "P" Card if amount is not too large
5. West Virginia DOT - Agency wide master agreements and one time purchases through bid.

Comments:

1. Michigan DOT - We can purchase any material up to \$2,500 without bids. Up to \$10,000 with phone bids. Up to \$25,000 on Michigan's Buy4Michigan website. Above \$25,000 could take 3 to 18 months. We can also set up Indefinite Delivery Indefinite Quantity Contracts, As-Needed Contracts and Blanket Purchase Order Contracts.
2. Missouri DOT - We procure materials and services through the bid process. For materials, we typically cite the specifications and approved products list, if applicable. Some of the material contracts are open-ended, annual orders for users to purchase off of as they need it. Other material contracts and all service ones, are one-time purchases. Job Order Contract are often used in our urban areas for work they are not equipped, or do not have the resources, to perform.

Q7 - How is your bridge maintenance program funded?

All agencies reported being funding constrained and one agency reported funding was needs based.

Comments:

1. Michigan DOT - Future bridge conditions are modeled based on dividing the statewide capital improvement budget into Replacement, Rehabilitation and Preventive Maintenance. These percentages are optimized to forecast the best overall network condition. These projects are designed and sent to contractors. Additionally, each of the 7 regions in Michigan have 1 to 2 direct forces maintenance crews that do a variety of preventive maintenance repairs and emergency repairs.
2. Missouri DOT - Each district is allotted funds for operations based on a formula factoring things such as miles of road, number of bridges, ADT, etc. It is up to the district how they divide those funds up amongst the different maintenance functions.
3. Kansas DOT - We generally get about \$ 25 million a year for bridge maintenance but currently Kansas has had a serious tax short fall which the majority of this fund was pulled. Uncertain of what the future will bring.
4. West Virginia DOT - Annual budgets to districts.

Q8 – How do you select bridges for preventive maintenance activities?

Three agency's maintenance functions are condition based and one condition based as well as cyclical.

Comments:

1. Michigan DOT - When working in corridors we always try to work on every bridge regardless of condition.
2. Missouri DOT - Repair items are noted during the general inspection, entered into our BMS, and prioritized by district staff. Treatments, like washing/flushing and deck sealing, are set up on a rotation. The work items are then assigned and shared with responsible crews.
3. Kansas DOT - We had just started to go more to a preservation mode of project selection but now we will be in a very serious condition based reactivity maintenance program until we regain what we lost due to funds being reduced.

Q9 – Do you use preapproved contractors to perform bridge maintenance work?

1. Michigan DOT – Yes
http://mdotcf.state.mi.us/public/contractor_directories/index.cfm?show=preqwork
2. Missouri DOT – Yes - We do not have a list of preapproved bridge maintenance contractors; but, they are required to be registered with the State and in good standing with the Department.
3. Kansas DOT - Yes - For some actions we do.
4. Ohio DOT - No - Low bidder, but would like to have preapproved contractors

5. West Virginia DOT - No, but would like to have preapproved contractors.

Q10 – Does your agency use Standard Work Procedures for bridge maintenance activities?

1. Michigan DOT – Yes, each bridge maintenance activity has a performance guide. These are being transitioned into a MDOT Bridge Maintenance Manual.
2. Missouri DOT – Yes, please refer to MoDOT's "Maintenance of Bridges" (http://epg.modot.org/index.php?title=Category:770_Maintenance_of_Bridges) and "Bridge Preventative Maintenance Guidelines" (http://epg.modot.org/index.php?title=Category:771_Bridge_Preventative_Maintenance_Guidelines) EPG articles.
3. Kansas DOT - No, we do for a small list of items.
4. Ohio DOT – No
5. West Virginia DOT – No

Q11 – Does your Standard Work Procedures include approved materials?

1. Michigan DOT - Yes
2. Missouri DOT – Yes, approved products are noted by reference. The Department maintains a list of approved products for use on construction projects and one for maintenance work. There is a process for manufacturers/vendors to submit new products for consideration of placement on these lists.
3. Kansas DOT - Yes

Q12 - Do you track bridge maintenance activities?

1. Michigan DOT - Yes
2. Missouri DOT – Yes, field personnel are supposed to record their "performance actuals", time, equipment, and associated expenses in our Financial Management System. They also "close out" work items recorded in our BMS.
3. Kansas DOT - Yes, District tracks time, equipment & materials weekly with their sheet sheets under various bridge activities. Contract items generally require us to complete an inspection with updates.
4. Ohio DOT – Yes, our Maintenance Division tracks work activities done by ODOT forces.
5. West Virginia DOT - No

Q13 – Do you track cost of preventive maintenance activities?

1. Michigan DOT - Yes
2. Missouri DOT – Yes, for a good majority of this work, yes, as this is required to receive federal reimbursement per the Department's Preventive Maintenance Agreement with our FHWA division office.
3. Kansas DOT - Yes

4. Ohio DOT - No
5. West Virginia DOT - No

Q14 – Do you track service lives of preventive maintenance activities?

1. Michigan DOT - Yes
2. Missouri DOT - No
3. Kansas DOT - Yes, contract items we can with additional programming but not in-house activities.
4. Ohio DOT - No
5. West Virginia DOT - No

Q15 – Do you use in-house personnel for traffic control or do you use contract traffic control?

1. Michigan DOT - We use both. It depends on the complexity, and whether or not Temp Concrete Barrier is required. MDOT does not have a stock of Temp Concrete Barrier.
2. Missouri DOT – In-house
3. Kansas DOT – In-house
4. Ohio DOT – Both
5. West Virginia DOT – In-house

Q16 – Of the following bridge components what activities does your agency perform?

Michigan DOT	Bearing	Box Beams	Deck Joints	Abutments & Piers	Decks	Drains	Superstructure
Michigan DOT	Clean, Paint	Waterproofing membranes, asphalt wearing surface	Clean joints, Repair, Replace seals	Seal, Repair	Seal, repair	Clean	Clean, repair, paint
Missouri DOT	Clean	Sealing concrete, asphalt wearing surface	Clean joints, Repair, Replace seals	Clean, Seal, Repair	Clean, seal, repair	Clean	Clean, repair
Kansas DOT	Clean, Paint		Clean joints,	Clean, Repair	Clean, repair	Clean, repair	

			Repair seals				
Ohio DOT	Paint		Replace seals, joints, headers	Repair	Seal, repair		Repair, paint
West Virginia DOT	Clean, Paint	Waterproofing membranes, asphalt wearing surface	Repair, replace seals, joints, headers	Clean, paint, repair	Repair	Repair	paint

Comments for Q16:

Michigan DOT

1. Bearing - This is very limited and only on larger / higher asset bridges. Works quite well.
2. Box Beams - Side by side box beam bridges with waterproofing membranes have a very short life, and are quite ineffective.
3. Deck Joints - Each one of these is in the toolbox. Properly functioning deck joints are the most important maintenance item on the bridge.
4. Abutments/Piers - New substructures are sealed. Old substructures are always sealed after repair. Repair of substructure only works if you mitigate the cause of the damage. Leaky joints, frozen bearings, concrete pavement growth.
5. Decks - MDOT Direct Forces perform Thin Epoxy Overlays and Deck Patching routinely each year. These activities are also contracted. Additionally, MDOT has been performing thin epoxy overlays for so long that bridges are being re-applied. Thin epoxy overlays last 15 to 20 years and deck patching lasts 5 years, although preventing the halo effect of new delamination around patches has been difficult.
6. Drains - No Comment
7. Superstructure - Painting superstructures is exclusively performed by specialized contractors. Michigan has a statewide steel repair crew that exclusively installs temp supports and repairs beam ends year round. Cleaning is reserved for large asset superstructures prior to inspection, bridges with bird dropping problems, bridges with open metal grating decks.

Missouri DOT

1. Bearings - Our field crews try to clean/wash bearings annually. We find this activity effective as it minimizes the need to paint. We do not routinely grease or paint

bearings.

2. Box Beams - We do not typically design box beam bridges. Where we have, we include a concrete wearing surface that is sealed, like our concrete decks, with silane. We did have about 400 box beam bridges built under our Safe and Sound D/B program (circa 2010). These had waterproofing membranes and an asphalt wearing surface. We may have applied an additional asphalt wearing surface, or at least done some patching, on these; but, we have not touched the waterproofing membrane as of yet. We do not use waterproof membranes, as we don't put asphalt wearing surfaces down on good condition, much less new, decks. Asphalt overlays are typically reserved for poor decks to buy time. We do find sealing decks to be very effective at reducing deterioration and apply silanes and Pavon Indeck on regular cycles.
3. Deck Joints - Our field crews clean joints annually. Other joint preservation activities are performed as needed. All activities are effective at maintaining functionality of the joint and keeping water, road salts, etc. off the super and substructure.
4. Abutments/Piers - Our field crews clean these areas annually. Other preservation activities are performed as needed. We find cleaning and sealing are effective at minimizing repair. We do not paint concrete surfaces such as those found in these areas.
5. Decks - Our field crews try to clean/flush decks two times a year. Sealing is done on a cyclically. Whereas, repairs are done as needed. We find the preventive activities to be very effective at minimizing the reactive ones.
6. Drains - Our field crews clean/flush deck drains and drainage systems when they clean/flush the decks. We do not typically have a need to repair or paint them do their being galvanized metal or FRP.
7. Superstructures - Our field crews try to clean/wash superstructures annually. Repairs are done as needed. Painting is typically limited to spot painting as needed. All of these activities are effective at preserving the bridge.

Kansas DOT

1. Bearings - This is done very rarely anymore and we have to strongly request it.
2. Box Beams – no comment
3. Deck Joints - This is done very rarely anymore and we have to strongly request it.
4. Abutments/Piers - Some
5. Decks - Some, more patching when required.
6. Drains – Some, as needed.
7. Superstructures - No in-house.

Ohio DOT

1. Bearings - Painting is only done when the entire bridge is painted
2. Box Beams - Do not use box beams

3. Deck Joints – No comment
4. Abutments/Piers - As necessary when funds are available
5. Decks - Use silane sealers on decks first summer after construction
6. Drains – No Comment
7. Superstructures - As funds become available

West Virginia DOT

1. Bearings - These activities are done in conjunction with other repair activities.
2. Box Beams - No Comment
3. Deck Joints - No Comment
4. Abutments/Piers - No Comment
5. Decks - No Comment
6. Drains - No Comment
7. Superstructures - No Comment