Bridge Deck Protection Systems

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This article focuses on Washington State Department of Transportation (WSDOT) concrete deck protection systems and the challenges WSDOT has encountered in increasing the longevity of bridge decks.

Figure 1 shows a typical concrete bridge deck deterioration curve. WSDOT uses information like this to assess bridge deck condition for repair, rehabilitation, and protection systems. Bridge decks are assigned to condition categories as follows:

- Good: 0% deterioration of total deck surface.
- Fair: Between 1% and 2% total deck surface deterioration. Decks in this group are considered for monitoring.
- Poor: 2% to 5% total deck surface area has patching and spalling. Prioritization for an overlay is triggered.
- Excessive: Over 5% total surface deck deterioration. The deck is considered "past due" and requires either major deck rehabilitation or deck replacement.

Figure 2 presents the distribution of deck protection systems based on deck area for all bridges managed by WSDOT. About half of WSDOT's bridges have decks with bare concrete without any overlay. For new bridges, WSDOT uses epoxy-coated reinforcement for both the top and bottom layers of reinforcement to protect the bridge deck from corrosion-induced damage.

Prior to the use of epoxy-coated reinforcement, which began in the early 1980s, WSDOT bridge decks typically remained in good condition for the first 20 years of service, reached fair condition around 30 years, and fell to poor condition around 35 years.

WSDOT revamped the bridge deck concrete material specifications in an effort to ensure durability and eliminate or reduce early-age restraint cracking in bridge decks. Bridge decks constructed with this revised performance-based concrete mixture specification are commonly referred to as performance-based bridge decks. Based on the recommendations of WSDOT-funded research,[1] the most significant change in the revamped specifications was the removal of the prescriptive requirement for a

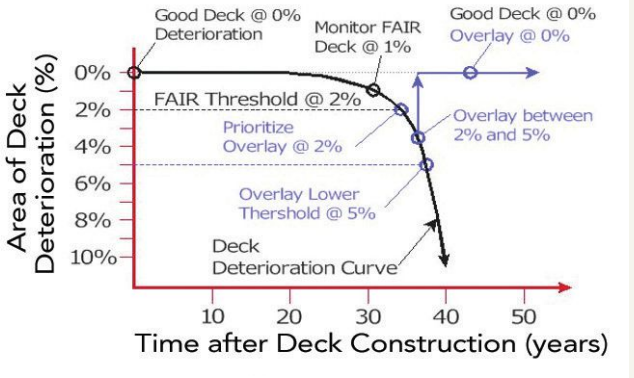

Figure 1. Typical concrete bridge deck deterioration curve. All Figures: Washington State Department of Transportation.

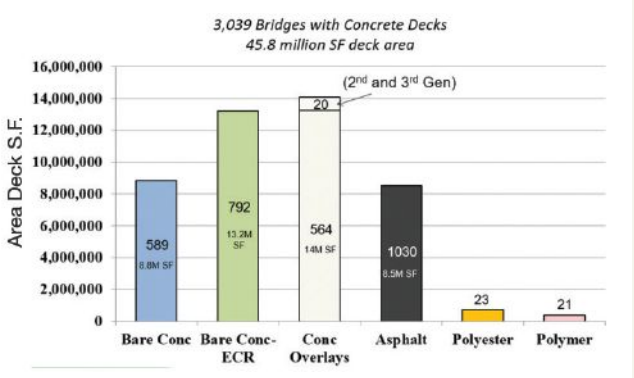

Figure 2. Total area of deck protection systems for bridges managed by Washington State Department of Transportation. Note: ECR = epoxy-coated reinforcement.

minimum cementitious content for bridge deck concrete, termed Class 4000D. Also, the specification includes a performance limit on drying shrinkage of 0.032% at 28 days based on American Association of State Highway and Transportation Officials requirements.[2] Another significant change was to increase the nominal maximum aggregate size from ¾ in. to 1½ in.

Deck Protection Systems

WSDOT uses five deck protection systems to improve the longevity of concrete decks.

Type 1

A Type 1 deck protection system is used for cast-in-place (CIP) concrete slab bridges, deck replacements, and the widening of existing decks. Notable features of this system are:

- A minimum of 2½ in. concrete cover over the top bars of deck reinforcement for CIP decks. The cover includes a ½ in. wearing surface and ¼ in. tolerance for the placement of the reinforcing steel. The concrete cover for the bottom layer of reinforcement is 1 in. minimum.
- Both the top and bottom mats of deck reinforcement are epoxy coated.
- Girder stirrups and horizontal shear reinforcement do not require epoxy-coated reinforcement.

Decks with epoxy-coated reinforcement (**Fig. 3**) are performing well compared with decks with uncoated (black) steel, which tend to exhibit corrosion-related damage.

Bridge decks using partial-depth precast, prestressed stay-in-place concrete deck panels are considered to have a Type 1 protection system; however, the reinforcement and prestressing strand in the partial-depth deck panels need not be epoxy-coated if they do not extend into the CIP portion of the deck.

Type 2

A Type 2 protection system consists of cementitious and polymer-based overlay on new or existing bridge decks. WSDOT requires new bridges to be designed for a 35 lb/ft^2 future wearing surface. Details of the three categories of overlays in this system follow.

Figure 3. Use of epoxy-coated reinforcement to protect the bridge deck from corrosion-induced damage.

1½ in. Modified Concrete Overlay

Concrete overlays are generally described as a 1.5-in.-minimum unreinforced layer of modified concrete. Overlay concrete is modified to provide a low permeability that slows or prevents the penetration of chlorides into the bridge deck and also has a high resistance to abrasion or rutting from snow tire studs. Ideally, the concrete cover to the top layer of reinforcement should be 2.5 in. For new structures, the deck reinforcement is epoxy coated.

These overlays were first used by WSDOT in 1979 and have an expected life between 20 and 40 years. As of 2010, there were more than 600 WSDOT bridges with concrete overlays. As the preferred overlay system for deck rehabilitation, these overlays provide long-term deck protection and a durable wearing surface. In construction, an existing bridge deck is hydromilled ½ in. prior to placing the 1.5-in. overlay (for more information on hydrodemolition, see the Concrete Bridge Preservation article in the Summer 2018 issue of *ASPIRE*®). This requires the finished grade to be raised 1 in.

The modified concrete overlay specifications allow a contractor to choose a latex, microsilica, or fly ash modified mixture design. Construction requires a deck temperature between 45°F and 75°F with a wind speed less than 10 mph. Traffic control can be a significant concern because the time required to cure these types of concrete overlays is 42 hours.

¾ in. Polyester Modified Concrete Overlay

These overlays were first used by WSDOT in 1989 and have an expected life between 20 and 40 years. As of 2010, there were more than 20 of these overlays in Washington. Currently, they are performing well, as expected.

The polyester modified concrete overlay uses specialized equipment and polyester materials to provide an overlay that normally cures in 4 hours. Construction requires dry weather with temperatures above 50°F. This overlay may be specified in special cases when rapid construction is needed.

3 in. Concrete Class 4000D Overlay

These overlays have a nominal 3-in. thickness and are placed after the existing bridge deck is scarified down to the top mat of bridge deck reinforcement. A minimum thickness of 2 in. is required to accommodate the larger aggregate in Concrete Class 4000D.

These overlays were first used in the mid 2010s on bridges that had previously received a modified concrete overlay. Second-generation modified concrete overlays were seen to suffer from debonding, which may have been due to microcracks in

the substrate concrete caused by rotary milling machines and other percussive equipment used to scarify bridge decks in the past. The increased depth of removal using hydromilling equipment ensures the removal of bruised or microcracked concrete in the existing bridge deck.

Type 3

A Type 3 protection system consists of a hot mix asphalt (HMA) overlay wearing surface and requires the use of a waterproofing membrane. HMA overlays provide a lower level of deck protection and introduce the risk of damage by planing equipment during resurfacing.

Asphalt overlays with a membrane were first used on a WSDOT bridge in 1971, and about one-third of WSDOT structures have HMA overlays. When properly constructed, bridge deck HMA has an expected life equal to the expected life of roadway HMA. However, unlike roadway surfaces, the HMA material collects and traps water carrying salts and oxygen at the concrete surface of the bridge deck. Given this additional stress to an epoxy protection system or a bare deck, a waterproof membrane is required to mitigate the penetration of salts and oxygen into the concrete. **Figure 4** shows the removal of a HMA overlay from a segmental bridge in Washington, and **Fig. 5** shows the completed bridge after application of waterproof membranes and the new HMA overlay.

HMA overlays may be used in addition to a Type 1 protection system for new bridges to match roadway pavement materials. New bridge designs using HMA wearing surfaces have an overlay depth of 3 in. to allow future resurfacing contracts to remove and replace 1¾ in. of HMA without damaging the concrete cover or the waterproof membrane.

WSDOT prohibits the use of a Type 3 (HMA overlay) protection system for prestressed concrete slab-girder (voided slabs) or deck-girder bridges managed by WSDOT, which have connections between the adjacent precast concrete members. Exceptions may be made for pedestrian bridges and for widening existing similar structures with an HMA overlay. The HMA overlay with membrane provides some protection to the connections between girders, but it can be prone to reflective cracking at the joints. Voided slabs may fill with water and aggressively corrode the reinforcement. Other prestressed concrete members with a Type 3 protection system have a minimum concrete cover of 2 in. over a top mat of epoxy-coated reinforcement.

Type 4

A Type 4 protection system is used for adjacent prestressed concrete members and requires a minimum 5 in. CIP topping with at least one mat of epoxy-coated reinforcement. This system eliminates wheel distribution problems on girders and provides both a quality protection system and a durable wearing surface. It is commonly used on prestressed concrete slab-girder systems that are connected with grouted keyways that only carry shear forces. For these systems, epoxy coating is not required for the top mat of reinforcement in the prestressed concrete member, but the reinforcement must have a minimum concrete cover of 1 in.

Type 5

A Type 5 protection system requires a 3 in. concrete cover that is constructed using a layer of monolithically cast concrete and a modified concrete overlay for double protection. This system is also used on all segmentally constructed bridges to protect construction joints and provide minor grade adjustments during construction. This system is also used for segmental bridges and bridge decks with transverse post-tensioning in the deck because deck rehabilitation due to premature deterioration is very costly. Details of the Type 5 protection system are:

- The deck is constructed with 1¾-in. concrete cover.
- Both the top and bottom mats of deck reinforcement are epoxy coated.
- Girder web stirrups and horizontal shear reinforcement are not required to be epoxy coated.
- The deck is scarified ¼ in. prior to the placement of a modified concrete overlay. Scarification with

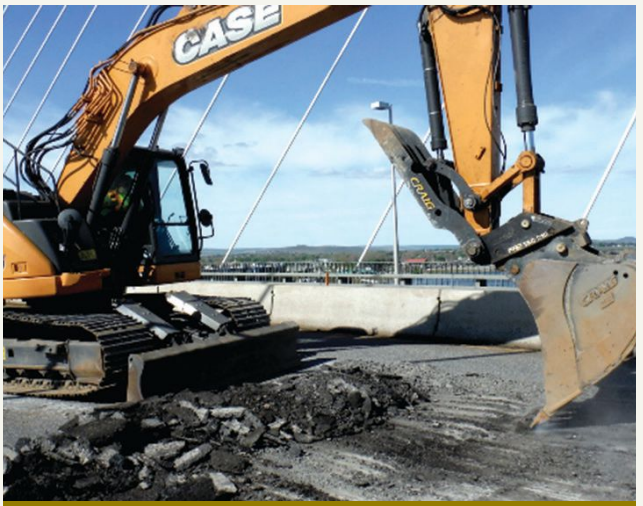

Figure 4. Removal of a hot mix asphalt overlay.

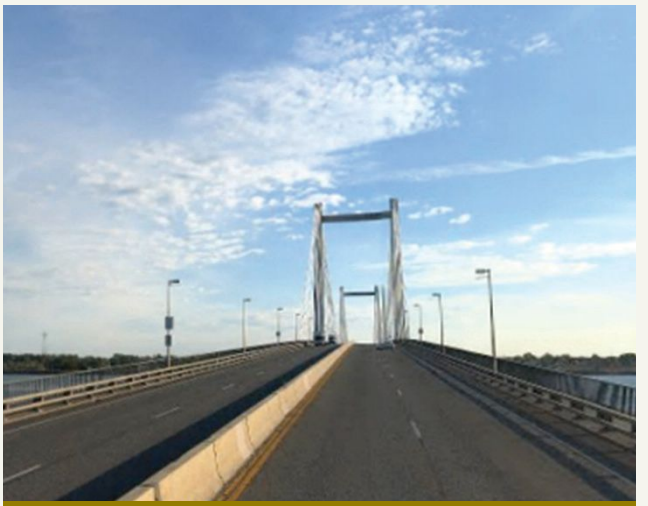
Figure 5. Completed bridge with a hot mix asphalt overlay.

diamond grinding to preserve the integrity of the segmental deck and joints is considered.
- A 1½-in. modified concrete overlay is placed as a wearing surface.

Discontinued Overlay Systems

A rapid-set latex-modified concrete (RSLMC) overlay uses special cement. RSLMC is mixed in a mobile mixing truck and applied like a regular concrete overlay. Like polyester, this overlay cures in 4 hours. WSDOT has discontinued the use of RSLMC due to its poor performance.

Thin polymer overlays are built-up layers of a polymer material with aggregate that is broadcast by hand. The first thin overlay was placed in 1986, and, after placing 25 overlays, they were discontinued in 1998 due to poor performance.

References

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Other Resources

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EDITOR'S NOTE

Overlay system performance can vary because of local conditions, material specifications, and installation requirements. Although WSDOT reports that the discontinued overlay systems have not performed well for its projects, they have been used successfully for projects in other states.