PennDOT LTAP
technical
INFORMATION
SHEET #156
WINTER/2013

DAMAGE ASSESSMENT OF ADJACENT CONCRETE BOX BEAM BRIDGE SYSTEMS

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Concrete is a widely used construction material in bridge systems throughout the United States. Typically, concrete bridge systems are designed using reinforced, prestressed concrete, or post-tensioned concrete components. A common form of concrete bridge construction is adjacent noncomposite prestressed concrete box beam bridges.

These systems were first built in Pennsylvania in the 1950s and continue to be a common and cost-effective form of construction. According to the PennDOT Bridge Preservation Program, approximately 8 percent of the 25,000 state-owned bridges and 20 percent of the 6,400 locally owned bridges consist of adjacent box beam bridges. This tech sheet will provide information in evaluation of these bridges at a local level.

BRIDGE DETAILS

Adjacent noncomposite box beam bridges consist of pretensioned box beams that are laterally post-tensioned together. A common configuration is illustrated in Figure 1. The system is termed "noncomposite" because no concrete deck is attached to the top of the boxes. Instead, the boxes are arranged to provide the drainage cross-slope on the deck, and an asphaltic concrete deck is cast on top as a driving surface. In some cases, an impervious layer is used between the asphalt and the beams to prevent leakage; however, most systems do not have one in place.

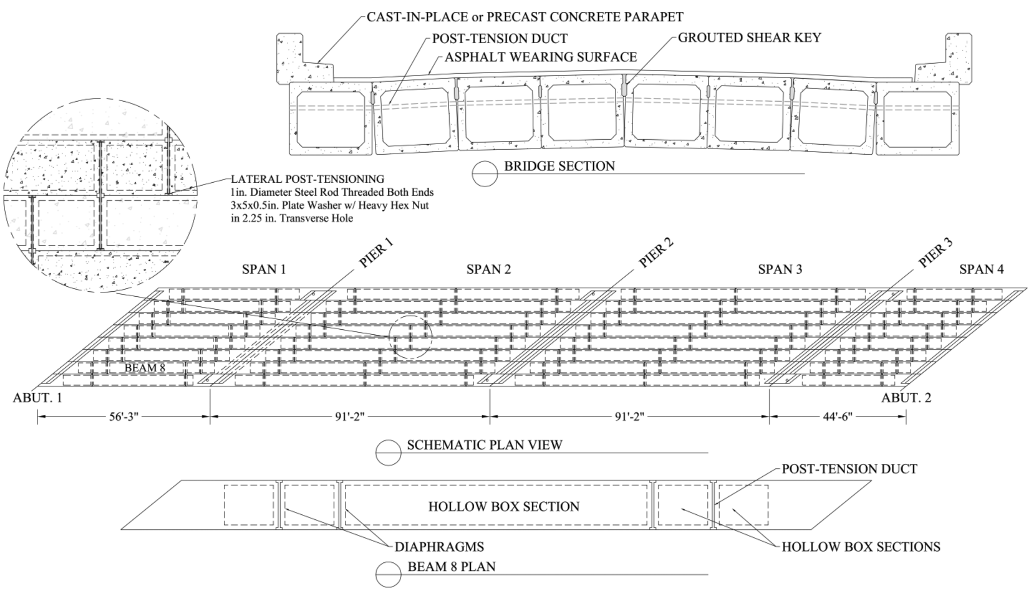

Figure 1: Adjacent noncomposite prestressed concrete box beam bridge

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CORROSION MECHANISMS AND LOCATIONS

The primary damage to these systems is associated with deterioration of the box beams due to corrosion. Corrosion of reinforcement occurs from a decrease in the acidity or basicity (pH) of the concrete typically generated by long-term exposure to chloride ions from deicing salts. The most common avenue of chloride exposure is from seepage through the pervious asphalt deck onto the beams. Because of the cross-slope of the bridge, this exposure is typically highest on the exterior beams as shown in Figure 2.

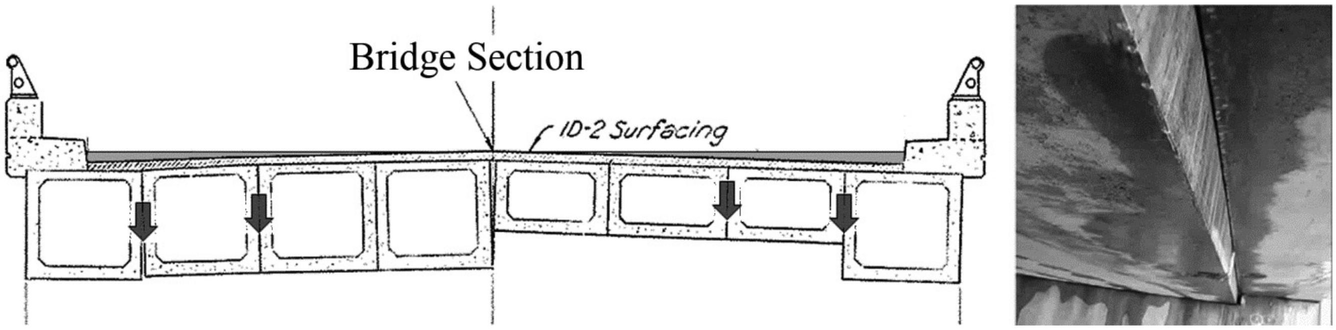

Figure 2: Seepage of chloride-laden water though deck onto box beams

When reinforcement bars or prestressing strands within the concrete corrode, the size of the reinforcement can increase up to seven times its original diameter. This increase in size places tensile forces on the surrounding concrete, causing it to crack. Cracking typically manifests as longitudinal splitting cracks, localized spalling around the reinforcement, or delamination of a section of the beam. In general, corrosion of one reinforcing bar or strand is associated with longitudinal cracking while corrosion of multiple adjacent reinforcing bars or strands can result in spalling or delamination of the concrete. Figures 3 and 4 illustrate examples of corrosion-induced deterioration.

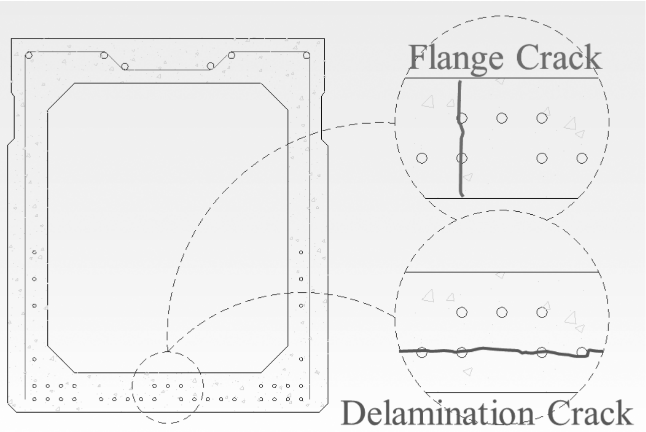

Figure 3: Schematic illustration of corrosion-induced damage on box beam

Figure 4: Longitudinal cracking (left) and spalling and delamination (right) induced by corrosion of the steel reinforcement

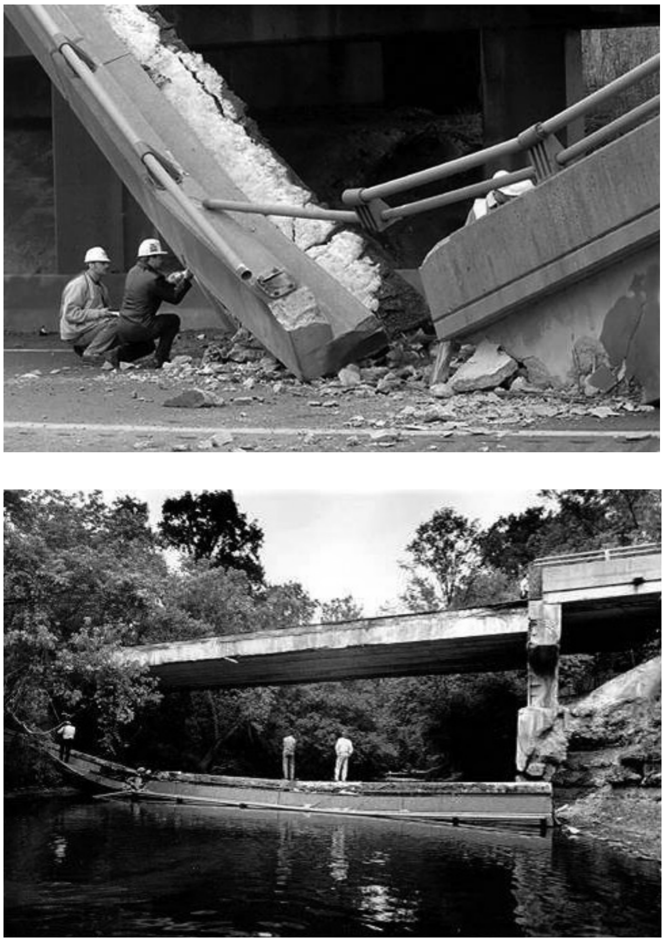

Figure 5: Prestressed bridge beam failures in Pennsylvania and Ohio

The reinforcement plays a vital role in the integrity of the bridge component. Corrosion or damage to the reinforcement can lead to catastrophic failure of the system. The bridge beam failures in Figure 5 show what can happen if strand corrosion and damage are left unchecked.

Visual inspection of corrosion damage of reinforced concrete members is the primary tool for improving the longevity of bridge systems. It is imperative to identify the presence of corrosion, repair the damage, and mitigate the source of corrosion at an early stage for the safety of the public. Local agencies should be proactive in identifying corrosion-induced damage to their bridges and involve a licensed bridge inspector whenever concerns arise.

CONDITION ASSESSMENT

The Federal Highway Association provides three condition rating numbers to a bridge ranging from zero to nine, where zero is given to a failed component and nine is given to a bridge with very minor or no signs of deterioration. One number is given to the bridge deck, one to the structure supporting the bridge deck (superstructure), and one to the part of the bridge that supports the superstructure and is directly in contact with the earth (substructure). A bridge is considered structurally deficient if the condition rating is four or less. Condition rating of the superstructure of adjacent prestressed bridge systems can be conducted in accordance with Table 1.

The condition rating is based on the amount of spalls and delaminations, the number of strands exposed, the type of cracks present, and the condition of the transverse tendons used to tie the box beams together. The bridge should be evaluated based on the most deteriorated beam on the bridge because failure of one beam can lead to injury or loss of life.

The condition assessment should also be conducted at the worse section of the beam, as opposed to the total surface area of the beam. For example, spall/delaminations of 15 to 25 percent refer to any one section of the bottom flange. If the box beam is 4 feet wide, the amount of spalling should only be present on 7 to 12 inches of the bottom flange width at any one section. Delamination often is not visually observable. To assist in identifying the extent of delamination, use a hammer to tap on the bottom flange to audibly check for soundness of the concrete.

A significant indicator of damage can be identified with a loss in camber. Most prestressed beams are designed such that the midspan is higher than the supports (i.e., camber). As deterioration occurs and significant strand corrosion becomes present, strands can fracture, resulting in loss of the initial camber of the beam. This can be assessed by comparison to adjacent beams. It is important to note that due to poor construction practices in the past, some bridges may contain variations in camber from initial construction. An associated damage is the presence of transverse cracks on the bottom flange of the beam. They should not be present in prestressed beams and are an indicator of significant deterioration or a past overloading of the bridge.

The number of strands exposed provides the main indicator used for assessment. The assumption is that if a strand is exposed to the air, corrosion will take place at an accelerated rate resulting in complete loss of the strand. All exposed strands are discounted from the remaining capacity of the beam member. This assessment should also be conducted on a cross-section level. For example, if three strands are exposed near the support but a different set of six strands are exposed 15 feet from the support, the two groups of strands should not be added. Instead the set of six should be counted. To determine the percentage of strands exposed requires the as-built details of the bridge. These drawings are not always available so appropriate conservatism should always be applied when determining the percentage of strands exposed.

This tech sheet provides a brief introduction to condition assessment of adjacent prestressed noncomposite box beam bridges. Municipalities should examine their local bridges on a regular schedule at least every two years. If a condition assessment of five or less is identified on the bridge or if any conditions of concern are identified, contact your regional PennDOT bridge office for further guidance.

Table 1: Condition Rating of Prestressed Box Beams

Condition Rating	Percent Strands Exposed in Single Beam	Other Deterioration of Beam	
9 – Excellent	0%	No cracks, stains or spalls	
8 – Very Good	0%	No cracks, stains or spalls	
7 – Good: Minor problems noted.	0%	Map cracks, miscellaneous hairline cracks	
6 – Satisfactory: minor deterioration of structural elements.	0%	Spalls	Minor Spalls/Delaminations, < 5%
		Cracks	Map cracks, miscellaneous hairline cracks
5 – Fair: Primary structural elements sound but showing deterioration.	1 to 5%	Spalls	Spalls/Delaminations, < 15%
		Transverse Cracks	None
		Longitudinal Cracks	Hairline longitudinal cracks in bottom flange
		Longitudinal Joints	Leakage at joints with light efflorescence
4 – Poor: Advanced deterioration of structural elements.	6 to 15%	Spalls	Spalls/Delaminations, 15-25%
		Transverse Cracks	Hairline flexural cracks in bottom flange
		Longitudinal Cracks	Minor efflorescence and or minor rust stains
		Longitudinal Joints	Heavy efflorescence and or minor rust stains
		Transverse Tendons	Loose or heavily rusted
		Web Cracks	Initiation of vertical or diagonal cracks in beam near open joints in barrier (< 3" length)
3 – Serious: Deterioration has seriously affected primary structural components.	15 to 20%	Spalls	Spalls/Delaminations > 25%
		Transverse Cracks	Open flexural cracks in bottom flange
		Web Cracks	Vertical or diagonal cracks in beam near open joints in barrier
		Camber	Sagging/Loss of camber
		Transverse Tendons	Broken or missing
2 – Critical: Advanced deterioration, close monitoring or closure needed.	> 20%	Any condition worse than detailed above	
1 – Imminent Failure: Major deterioration in critical structural components. Bridge is closed but corrective action may put the bridge back into light service.			
0 – Failed Condition: Bridge is out of service and beyond corrective action.			