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Eliminating Bridge Joints – A Preservation Strategy

Houston Walker, P.E., Tennessee Department of Transportation

SR-50 over Happy Hollow Creek: Tennessee's Longest Jointless Concrete Bridge at 1175' Long

It has long been recognized by many bridge engineers that the best expansion joint is no expansion joint at all. *The AASHTO LRFD Bridge Design Specifications, 6th Edition*, recognizes this opinion about joints in section C2.5.2.1.1 of the commentary: "*Other than the deterioration of the concrete deck itself, the single most prevalent bridge maintenance problem is the disintegration of beam ends, bearings, pedestals, piers and abutments due to percolation of waterborne road salts though the deck joints. Experience appears to indicate that a structurally continuous deck provides the best protection for components below the deck*." Thus, the elimination of joints is one of the best ways to preserve the condition of bearings, beam ends and substructure components.

The first step in eliminating bridge joints is to utilize continuous spans, thus eliminating joints at piers. The second step is to build the girder and deck system integrally with the abutments. The Tennessee Department of Transportation (TDOT) has been utilizing this method of constructing bridges since 1964. Although other states, notably Ohio, used this method as early as the late 1920's, TDOT has pushed the limits. TDOT has extended the use to longer and longer spans and currently is considered a national leader in applying this design concept. TDOT routinely builds jointless, integral abutment bridges up to 400 feet long in steel and up to 800 feet long in concrete. TDOT's longest entirely jointless and integral bridges are 1175 feet long in concrete and 536 feet long in steel. TDOT has also constructed a concrete bridge 2,695 feet long with joints only at the abutments.

The benefits of jointless, integral bridges are many. The most obvious is the elimination of the initial cost of joints and expansion bearings, which can be quite expensive. The biggest benefit from the standpoint of bridge preservation is the reduction in the amount of water, which may be salt laden, that can leak through the joint and be deposited on the girders, bearings and substructures below. Water leakage can cause accelerated deterioration of both concrete and steel girders and rusting of metal bearings. Why do joints leak? Elastomeric glands can become filled with road debris, eventually causing tears, and mechanical parts can break under the pounding of truck wheel loadings. Some common problems which can be caused by expansion joints are:

- Bearings can seize due to corrosion
- Bearings can tip over or ratchet out of position
- Joints can be difficult to install and may need to be raised for future paving
- Lubricated bearings often lose their effectiveness due to the buildup of grime and the loss of lubrication
- Malfunctioning bearings can cause structural damage
- Joints can be damaged by snowplows
- Loose or damaged joints in traffic lanes may be a hazard to traveling public

All of these conditions may be cause for future expensive repairs or replacement of expansion joints and bearings.

There are also inherent advantages to jointless, integral bridge construction. Some of those are listed here, but a detailed explanation is beyond the scope of this article:

- Substructure design is more efficient, since there is an increase in the number of supports over which longitudinal and transverse forces may be distributed
- Adds redundancy for catastrophic events
- Eliminates loss of seat support in seismic events
- Increases damping capacity by absorbing seismic energy
- Enhances live load distribution to girders at bridge ends
- Promotes rapid construction of abutments
- Minimizes construction tolerance problems
- Enhances flexibility for end span ratios (less uplift concerns)
- Reduces seat width requirements
- Lessens expense of bearings

Joints in bridges can be compared to a cut in the skin, with the expansion joint as a bandage. Over time, the bandage can become damaged, allowing foreign materials (salt and water) to enter the underlying tissue (beams and bearings), allowing infection (corrosion) to cause damage to the body (bridge). Eventually, medical treatment (bridge repair) is needed to correct the problem. If left untreated, severe illness can occur and perhaps debilitation (bridge closure) would result. This analogy might be a little "clinical", but it illustrates the circumstances. The best remedy would be to avoid the cut in the first place.

There are of course limits on the amount of thermal movement that can be accommodated by jointless bridges either at piers or at integral abutments. Large thermal deflections and forces on stiff pier columns can be reduced by using expansion bearings. Integral abutments can accommodate movements of 2 inches or more. The use of jointless bridges with integral abutments has proven over many years to be an excellent strategy to help preserve bridges from the ravages of salt induced corrosion damage. Not only are jointless bridges effective, they are more economical and provide several inherent design advantages.

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Fully Precast Bridge System used in Washington State Highways for Life Project, Part 2—Bridge Design and Construction

Joseph G. Sweet and Roger H. L. Chen, West Virginia University

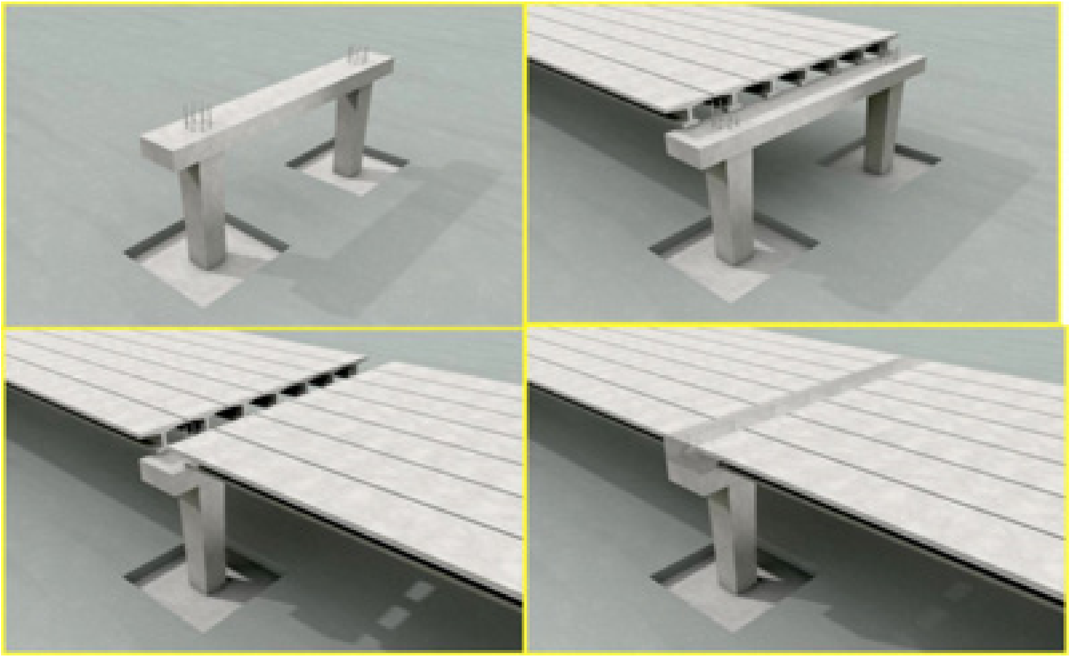

Figure 1. A typical Washington State Department of Transportation prestressed girder bridge with lower bent cap and integral joint.

The Washington State Department of Transportation (WSDOT) Highways for Life (HFL) project offers a precast concrete bridge system that is simple, rapid to construct, with excellent seismic performance. The WSDOT HFL(1) project includes precast segmental columns, precast bent cap, and precast superstructure. The project is also known as the US 12 Bridge over I-5, Grand Mound to Maytown Interchange Phase 2 Bridge 12/118 Replacement. This article is the second in a two-part series on the bridge project, and it covers the bridge design and construction.

The precast columns are composed of three segments with the lower column segments erected on concrete leveling pads into a cast-in-place (CIP) concrete spread footing. The column-to-cap beam connection is made with a small number of large bars grouted into ducts in the cap beam. The large size bar-ducts lead to a connection that can be assembled easily on site. The precast bent cap beam is built in two pieces that are integrated with a closure pour near its mid-span. The precast bent cap and precast superstructure are then connected together at the intermediate pier with a cast-in-place concrete diaphragm meeting the requirement of the AASHTO Guide Specifications for LRFD Bridge Seismic Design(2) for integral joint, and WSDOT Bridge Design Manual3 (BDM) requirements. Figure 1 shows schematic of a typical WSDOT prestressed girder bridge with lower bent cap and integral diaphragm.

WSDOT HFL Project

The objective of WSDOT HFL project was to demonstrate the constructability of the fully precast bent system on an actual bridge project of US-12 crossing Interstate 5 (I-5) in Washington State. The demonstration project is a replacement bridge that will be built on an alignment parallel to an existing bridge. It is a two-span bridge, with tall abutments on the end and a center bent that is located in the median strip. The HFL bridge features included: unique connection to footing, precast columns in segments, column segment grouted joints, precast bent cap segments, cast-in-place precast bent cap closure, precast superstructure with CIP closure at intermediate pier, and precast end and intermediate diaphragms.

The top of footing reinforcement are not continuous through the precast column segment as is usually done with the cast-in-place applications. To achieve proper interface shear transfer between the precast column and

Figure 2: Construction sequences for placement of precast column segment into footing.

the cast-in-place concrete footing, the exterior of the column is roughened near the bottom to improve the transfer of shear stress. The construction sequences for placement of precast column segments into the cast-in-place footing as shown in Figure 2 includes: excavate for footing and install forms, place leveling pad and set first segment of column, place footing reinforcing and cast footing concrete, and remove forms and backfill.

The columns used in this project are spliced to permit erection in segments. While the columns of the demonstration project are small enough to be handled in a single pick with a crane, the segmental concept will demonstrate the technology for use on projects where the columns are-longer and cannot be lifted with a single pick. The precast first-stage cap beam for the demonstration bridge will be built in two pieces that are integrated with a closure pour near its mid-span. This is required because the bridge is 84 feet wide, including sidewalks. Ideally, the precast first-stage cap would be built as a single piece element to avoid the time required for splicing segments, but pick and shipping weight restrictions led to the two-piece solution. The construction sequences for placement of precast column segments and precast bent as shown in Figure 3 are: 1) place and shim middle column segments, 2) place and shim top column segments, 3) install column bracing, 4) place and shim precast bent cap segments, 5) install grout forms and seal and, and 5) pump grout and close grout tubes.

The superstructure of the bridge consisted of WSDOT W35DG Standard precast pretensioned deck bulb tee girders that span 88 feet. These are supported by the center bent connected to the precast bent cap with a cast-in-place diaphragm and a 5-inch cast-in-place slab over the deck bulb tees. The intermediate and end diaphragm were precast with the girders at the fabrication plant. The construction sequences for placement of precast superstructure are: 1) place precast girders on oak blocks, 2) install girder bracing, 3) complete welded ties between girders, 4) place slab reinforcement and cast concrete, 5) cast pier diaphragm concrete 10 days after slab casting, and 6) cast traffic barrier and sidewalk.

LESSONS LEARNED FROM THE DEMONSTRATION PROJECT

Lessons learned from the construction of first WSDOT HFL project included those for precast bent system, and those for precast segmental columns. It is preferable that the columns be in a single precast piece with the grout connection at the precast bent cap and socket into CIP footing. The HFL project consisted of 96 grouted bar-duct connections and a CIP connection in the precast bent cap. Tolerance of precast pieces and erection tolerances were of extreme importance. Grout form quality and ability to seal with column is the key to successful grouting. The contractor preferred the joints that had the ducts in the lower section. They indicated that all the joints where the ducts were below the joint were grouted without any leaking. Shim locations and grout lifting pressures need to be included in erection plan calculations.

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Figure 3: Column Segment and Precast Bent Cap Erection.

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Further Information

For further information, readers are encouraged to contact the author at khalegb@wsdot.wa.gov.

Crystalline Silica Rule Under Review at the Office of Management and Budget

Thomas Harman, Portland Cement Association, and Tony Kojundic, Elkem Materials Inc.

A worker sandblasts a concrete surface.

In February 2011, the Occupational Safety and Health Administration (OSHA) sent its proposal to manage occupational exposure to respirable crystalline silica (RCS) in the workplace to the Office of Management and Budget (OMB) for review prior to publication. After an initial ninety-day period, OMB extended its review, and the proposal has remained at OMB since. Worker exposure to RCS has been on OSHA's agenda for some time. The report from the Small Business Administration, which is referred to as the SBREFA Panel report (Small Business Regulatory Enforcement Fairness Act of 1996), published findings about the effects on small businesses in December 2003. The peer review report to assess health effects of RCS on humans was initiated in May 2009 and completed in January 2010.

OMB has met with several stakeholders, including trade associations, labor organizations, and individual companies during the review process in order to gather information about how a RCS rule would affect the groups. For example, the Portland Cement Association (PCA) led a coalition of trade associations that represented concrete product manufacturers, including the National Ready Mixed Concrete Association, the Precast/Prestressed Concrete Institute, the National Concrete Masonry Association, and the American Concrete Pipe Association, to communicate to OMB their collective interests in the proposal. The meeting took place in May 2011.

OSHA is believed to be considering three permissible exposure limits (PEL) for exposure to crystalline silica in the proposal* : 0.1mg/m^3, 0.05 mg/m^3, and 0.025 mg/m^3. The currently enforceable limit from OSHA is 0.1mg/m^3. In addition to revising the PEL and in consideration of other comprehensively managed health standards like those found in Title 29 Code of Federal Regulations Part 1910 Subpart Z (29 CFR 1910), the agency may also promulgate requirements for ancillary provisions. The elements contained in ancillary provisions may include:

- Personal monitoring (in addition to area monitoring) for exposure to crystalline silica;

- The establishment of regulated areas;
- The designation of a competent person to conduct exposure assessments;
- Banning certain practices in the workplace;
- Specific provisions related to abrasive blasting work;
- Respiratory protection and other personal protective equipment, such as coveralls;
- Personal hygiene and shower facilities;
- Meal rooms where materials contaminated with RCS may not be present;
- Special housekeeping practices and requirements;
- Individual health screening and employee health monitoring;
- Special provisions for hazard communication; and
- Requirements for individual recordkeeping

Companies must take a most cautious approach in protecting their employees' health if employees are potentially exposed to crystalline silica at work. Various federal, state and sometimes local standards mandate RCS exposure testing to determine the level of the material in the workplace. Industrial hygienists are trained professionals who test the work atmosphere to detect the presence of harmful or noxious contaminants, such as respirable crystalline silica, to which individuals are exposed. Testing for the presence of RCS involves the use of an air sampling pump over a designated period of time. The pump collects air from the individual's breathing zone, and deposits the respirable portion of CS dust onto a filter which has been pre-weighed. The difference between the pre-sample and post-sample weight allows an analytical laboratory to determine the amount of RCS to which the employee is exposed. If an overexposure to RCS is detected, then companies must determine the appropriate method to reduce the overexposure. Controlling the exposure risk to RCS may include:

- Eliminating the hazard by substituting another material for respirable crystalline silica, or
- Revising the process that uses RCS by introducing a high-efficiency particulate air (HEPA) filter, or
- Reducing the amount of time that the employee is exposed to RCS, or
- Requiring the employee to wear a personal air respirator

Eliminating the respiratory hazard is always preferable to requiring the use of personal protective equipment.

At this time, only the officials at OMB know if/when the agency plans to send the proposal back to OSHA, either allowing publication to go forward without revision, or requiring OSHA to revise the standard before the agency can formally issue a Notice of Proposed Rulemaking (NPRM). In the Unified Agenda from the Department of Labor, OSHA shows an NPRM on crystalline silica will be released in May 2013. The rule is "economically significant," which means that the rule could have an annual effect of $100 million or more on the economy, or that the rule could "adversely affect the economy, productivity, competition, jobs, the environment, public health and safety, or tribal governments or communities."†

Associations like the Silica Fume Association, (www.silicafume.org)‡ the Portland Cement Association, (www.cement.org) and those previously noted in the article provide excellent guidance and resources for managing respirable crystalline silica in the workplace. Regardless of the administrative status of the rule, employee exposures to RCS must still be controlled.

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(article continues on next page)

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[*] The PEL for crystalline silica is based on a formula, where the

$$\text{PEL} = \frac{10 \text{ milligrams/meter}^3}{(\% \text{ silica} + 2)}$$

[†] Executive Order 12866 was signed by President William Jefferson Clinton in September, 1993, and the order set guidelines for determining when rules are economically significant as well as additional considerations.

[‡] Silica fume is an ultrafine form of amorphous (non-crystalline) silica which is collected as a by-product from the production of silicon and ferrosilicon alloys. Due to its non-crystalline character, silica fume is a non-hazardous alternative to quartz flour and is used as valuable pozzolan in concrete.