Eliminating Bridge Joints with Link Slabs

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A functional expansion joint is paramount to the longevity of a bridge. When adequately designed, correctly installed, and maintained, it allows the bridge to expand and contract as temperature changes, accommodates rotation of the beam ends, and contains surface runoff. However, bridge owners have struggled in the past to maintain expansion joints. Joint failure can cause leakage that leads to premature deterioration and failure of beam ends, bearings, and underlying substructure elements (**Fig. 1**, **2**).

The Federal Highway Administration (FHWA) published the downloadable *Bridge Preservation Guide*[1] in the spring of 2018. This guide defines bridge preservation terms and identifies commonly practiced bridge preservation activities. It provides examples of cyclical and condition-based maintenance activities that extend the service life of a bridge and its components. Bridge owners may use these activities to keep their bridge inventory in a state of good repair, and these activities are eligible for federal funds. Joint elimination is one of the eligible condition-based activities.

Developing strategies to eliminate bridge joints is not new: integral abutments were developed in the 1970s specifically to eliminate joints at the bridge ends.[2] Historically, for existing structures, a strategy to eliminate an existing joint has been to eliminate the joint and make the superstructure continuous. However, this method tends to be challenging for simply supported spans, as the continuous superstructure needs to handle the negative moment at the pier and requires strengthening both the girders and deck.

To mitigate leaking joints and to avoid strengthening the superstructure, some bridge owners have eliminated existing joints by replacing them with link slabs; a few owners are also conducting studies on material types, design, and impacts of link slabs on the overall behavior of the structure. Currently, the common understanding is that, although fine cracks may develop in a link slab installed to eliminate a joint, the presence of fine cracks is preferable to a deck with a leaking joint.

A link slab is constructed between two noncontinuous superstructure elements and is designed to support traffic wheel loads and the bending moment due to girder rotations. There are two types of link slabs: full depth (**Fig. 3**) and partial depth (**Fig. 4**). The link slabs are not intended to transmit live-load effects from one span to another, which would create girder continuity. Because span movement is restricted, a global analysis of the entire bridge must be conducted; this analysis must take into consideration substructure flexibility and bearing types that allow proper load distribution. Link slabs are not a panacea, but a tool to prevent surface runoff laden with harmful chemicals from attacking bridge beam ends, bearings, and substructures.

Recently, FHWA published *A Case Study: Eliminating Bridge Joints with Link Slabs—An Overview of State Practices.*[3] This case study presents an overview of the use of link slabs by four state agencies. The four agencies represented are the Virginia Department of Transportation (DOT), because it has installed more link slabs than any other owner in the country; the Massachusetts DOT, because it has used link slabs for accelerated bridge construction; New York State DOT (NYSDOT), because it has recently developed standard details and example calculations; and the Maryland Transportation Authority, because it has very recent research regarding

Figure 1. Leakage from failed or deteriorated bridge deck expansion joints can cause deterioration of beam ends, bearings, and substructure elements. All Photos and Figures: Federal Highway Administration.

Figure 2. Chemical-laden surface runoff can accelerate substructure deterioration beneath an expansion joint.

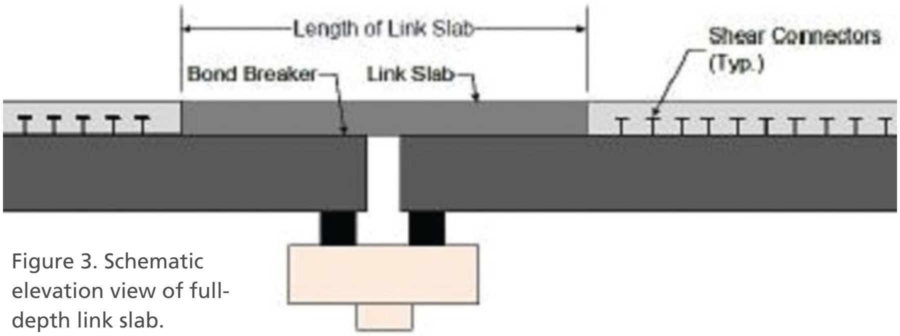

Figure 3. Schematic elevation view of full-depth link slab.

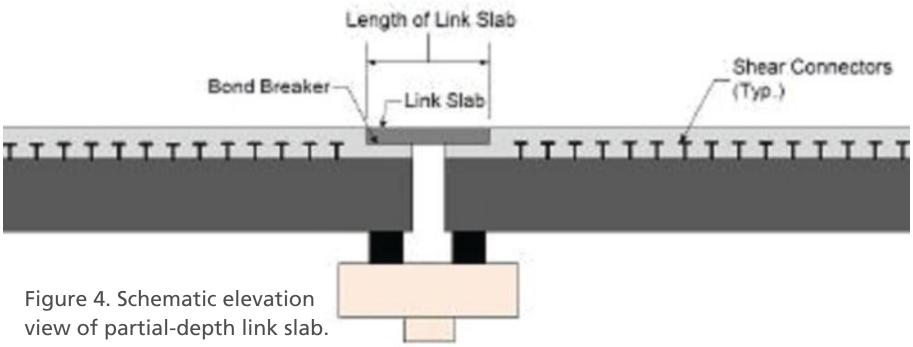

Figure 4. Schematic elevation view of partial-depth link slab.

link slabs. The case study presents the agencies' design approaches to evaluating the impact of installing a link slab on existing bearing types and mitigating concrete cracking, as well as design methodologies and materials used.

As one example, the NYSDOT uses the strain compatibility design method to evaluate the cracking potential of link slab concrete. Their material of choice is ultra-high-performance concrete (UHPC) due to its high tensile strength, high compressive strength, strong bonding to adjacent deck concrete, and low permeability. UHPC is a fiber-reinforced, cementitious composite material with mechanical and durability properties that far exceed those of conventional concrete materials (UHPC has been the topic of several recent articles in *ASPIRE*®—a general introduction appeared in the Spring 2017 issue).

NYSDOT designs link slabs for a maximum concrete strain of 0.0035 in tension and a maximum compressive stress of 14 ksi. The ability of UHPC to develop ultimate tensile strains up to 0.007 by development of microcracks allows the link slab to accommodate girder end rotations. A maximum design strain of 0.0035 (50% of the ultimate value) at the extreme tensile fiber is chosen to control crack width. Limiting the tensile strain increases the service life of the link slab by preventing cracking that would allow penetration of moisture and chemical-laden surface runoff.

The case study provides an example that illustrates the difference in bridge mechanics before and after installation of a partial-depth link slab. The initial condition (**Fig. 5**) has a joint at the simply supported ends of two adjacent spans at a bridge pier with one "fixed" bearing, allowing rotation but not translation, and one "expansion" bearing, allowing both translation and rotation. After installation of the partial-depth link slab and replacement of the existing bearings with elastomeric bearings (**Fig. 6**), the bearings are no longer required to rotate; instead, they only translate. The beam end rotation is accommodated by the link slab, which is designed to resist the flexure due to live-load girder end rotations. The use of a bond breaker between the link slab and the top of the girder prevents any continuity between spans. Reinforcement in the link slab is typically spliced to existing deck reinforcement. Bridge mechanics will differ if both the bearings are "fixed" or "expansion," which is why a full analysis of forces is warranted.

Through the Every Day Counts innovation initiative, FHWA will be promoting the use of UHPC in the preservation and repair of bridges by encouraging its use in link slabs, beam end repairs, and deck overlays. The implementation team will publish design guidance documents that describe UHPC, outline bridge preservation and repair applications, and include specific design and construction recommendations for link slabs, beam end repairs, and bridge deck overlays. Additional information on the use of UHPC for bridge preservation and repair can be found at https://www.fhwa.dot.gov/innovation/everydaycounts/edc_6/uhpc_bridge_preservation.cfm.

Joint elimination, where feasible by design and appropriate for structure behavior, is a condition-based preservation activity, and is eligible for federal funding. State DOTs, local agencies, and other bridge owners are facing significant challenges in addressing the needs of our aging infrastructure. Due to age, the number of bridges moving from good to fair condition is on the rise. The replacement of deck joints with link slabs as a bridge preservation activity is one of the few ways we can slow this trend and extend our bridges' service lives.

References

1. Federal Highway Administration (FHWA). 2018. *Bridge Preservation Guide—Maintaining a Resilient Infrastructure to Preserve Mobility.* FHWA-HIF-18-022. Washington, DC: FHWA. https://www.fhwa.dot.gov/bridge/preservation/guide/guide.pdf.
2. FHWA. 1980 (January 28). *Technical Advisory T 5140.13: Integral, No-Joint Structures and Required Provisions for Movement.* Canceled October 1, 1989.
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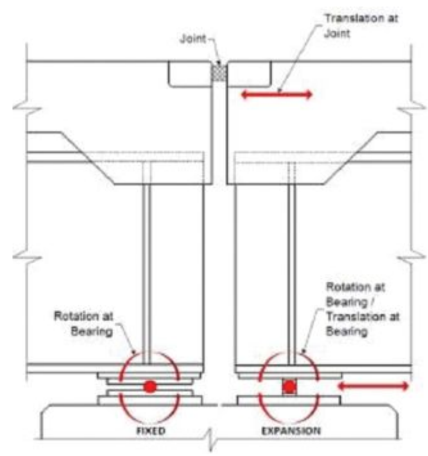

Figure 5. Typical deck joint at pier with movements indicated at deck and bearings.

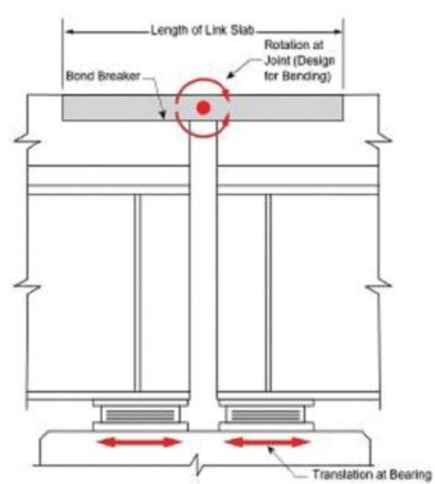

Figure 6. Typical partial-depth link slab at pier accommodating translation and rotation at deck and bearings.