Bridge Views

Issue 79 November/December 2015

Inside This Issue...

VDOT's Use of Concrete Closure Pours to Eliminate Bridge Deck Expansion Joints

Adam Matteo, Virginia Department of Transportation

Fig. 1. Typical Bridge Deck Expansion Joint.

General

Expansion joints in bridge decks have long been recognized as the one of the leading factors in bridge deterioration. Expansion joints, placed at the ends of bridge decks to allow for thermal expansion and contraction and live-load deflection, inevitably leak, allowing water to seep below the bridge deck. The water often carries chloride-laden road salts, which rapidly accelerate the corrosion rate of superstructure and substructure elements. A typical expansion joint is shown in Figure 1. Figures 2 and 3 show areas under leaking joints that exhibit accelerated corrosion due to the intrusion of water, salt, grit and oil.

Fig. 2 and 3. Corrosion, Deterioration and Sediment Buildup Under Leaking Joints

Difficulty in Maintaining Expansion Joints

Ideally a bridge owner should be able to maintain joints in a satisfactory condition to prohibit the inflow of water through the seal. However, the durability of commonly used seals has proven to be highly problematic. In high traffic environments seals may last less than 1 year, and the cost of traffic control to re-seal joints continues to increase. Figure 1 shows three common problems affecting the durability of joint seals:

- Localized failure of the concrete adjacent to the joint
- Accumulation of grit and debris above the joint seal, causing failure of the seal
- Debonding of the seal from the adjacent concrete

VDOT collects data on the performance of its bridge joints during each regular bridge inspection. VDOT has approximately 1 million linear feet of expansion joints in it inventory, 900,000 linear feet of which are pourable seals or compression seals. Of these joints, the following percentages are in Condition State 1 (no leakage).

- Pourable Seals: 68%
- Compression Seals: 61%

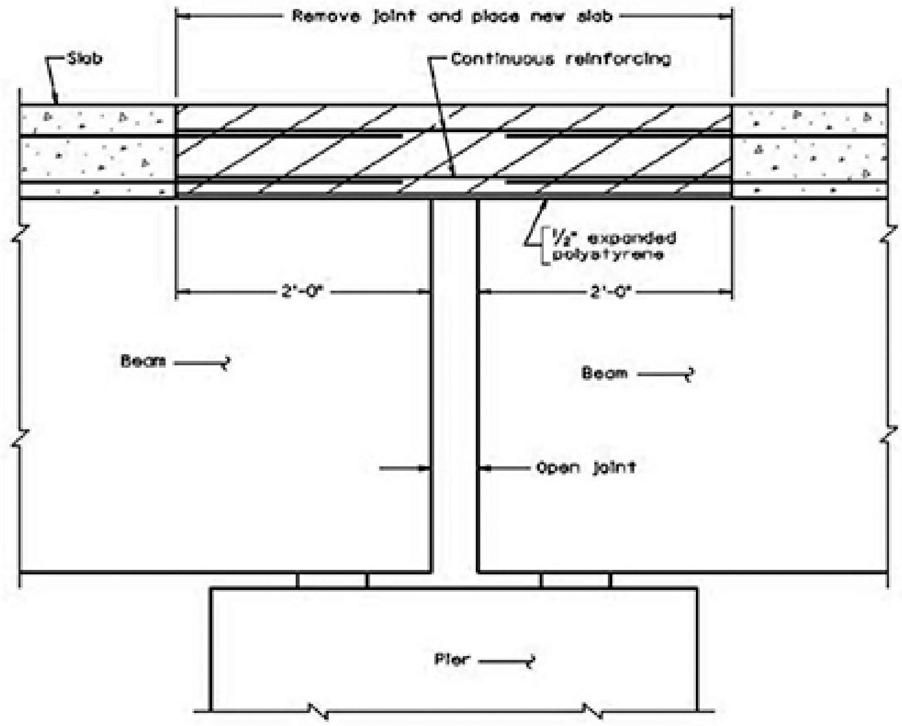

Fig. 4. Detail for "Link Slab" Eliminating Joint over Pier

Taken together, only 2/3 of the total length of pourable and compression seals are functional. However, because of the way that joint condition is measured, the problem is actually more severe. If a particular joint is 50' long and has 2' of unsatisfactory seal, the joint is reported as having 48' in Condition State 1 and 2' in Condition State 2 or 3 (deteriorated or failed). However, that 2' of compromised joint seal is enough to allow the flow of chloride-laden water below the deck surface. An analogy may be made to the gutters on a home. If a house has 50' of rain gutter, 48' of which is functional and 2' of which is not, the entire gutter is non-functional.

Addressing the Problem

In the early 1990s VDOT acknowledged the difficulty of maintaining expansion joints and began to experiment with the concept of eliminating the joints entirely. VDOT began to place closure pours in the locations of existing joints, essentially eliminating the joint entirely. These closure pours were initially placed over pier supports and called "link slabs". Later, VDOT began to install closure pours

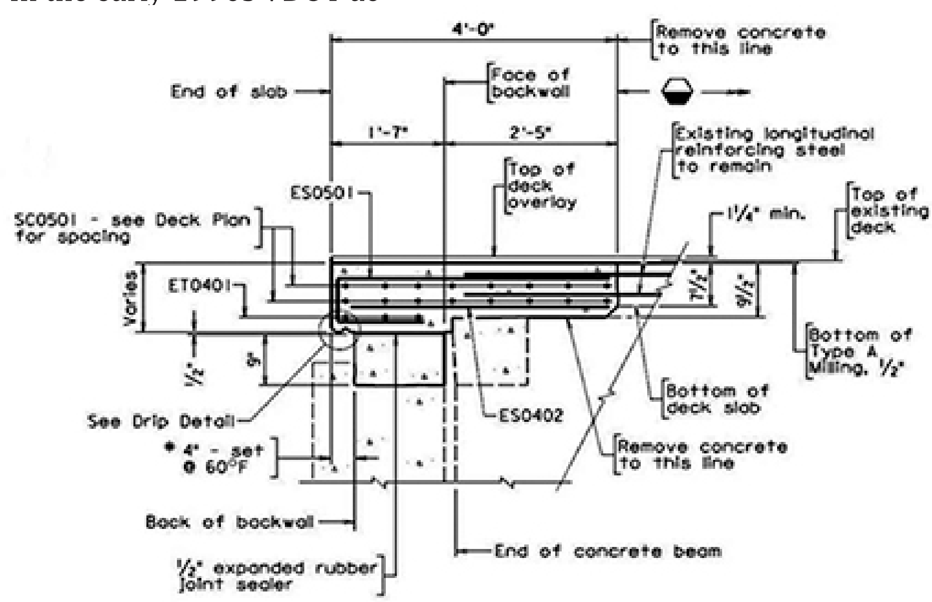

Fig. 5. Detail for "Deck Extension" Eliminating Joint at Abutment

Fig. 6. Step 1 - Jacking Beam Ends to Free Bearings

Fig. 7 and 8. Remove Concrete in Deck for 2' on Either Side of Joint; Form Between Girders; Place Bondbreaker (foam) over Girders; Place Reinforcement; Cast Concrete

called "deck extensions" at the ends of bridges over the abutments. Since that time we have successfully eliminated over 700 joints on more than 300 bridges. Figures 4 and 5 provide typical engineering details for link slabs and deck extensions. Figures 6 – 10 show photographs of the joint elimination process.

The performance of the link slabs has been excellent. While small cracks often appear at the interface between the closure pour and the existing deck, these cracks don't allow significant moisture to reach the bearings. Link slabs have been used on highly skewed and heavily travelled (interstate) bridges with good results.

Considerations Affecting Decision to Eliminate Joints

VDOT has established that joint elimination is the most cost-effective maintenance option when viewed from the perspective of life-cycle investment. Typical costs to eliminate joints are about $700 per linear foot, which is an investment that pays strong dividends in the overall durability of bridges. VDOT's current guidance requires that joint elimination be evaluated as the primary joint treatment on all rehabilitation projects. Each of VDOT's 9 districts has a target to eliminate 1% of its joints per year. While our standard 4,000 psi low-permeability concrete has provided good results, VDOT has also begun to deploy flexible concrete mixes utilizing fiber reinforcement.

The two greatest impediments to joint elimination are traffic control and apprehension about the effects on the piers. In high traffic environments it is difficult to obtain approval for lane closures of adequate duration for joint eliminations. In order to address this concern, VDOT is developing generic details for temporary driving surfaces that will span the opening required for joint elimination. This will allow contractors to perform the work over multiple shifts.

To address concern about pier loads we are developing standard calculation templates to allow for quick analysis of pier loads after joint elimination. Because joint elimination changes the articulation of a bridge, certain piers will receive additional lateral loads after project completion. These lateral loads are rarely enough of a concern to preclude the elimination of a joint, but example calculations currently under development will provide an additional level of security for designers in the future.

For more information, please contact Adam Matteo at Adam.Matteo@vdot.virginia.gov

Fig. 9 and 10. Joints Eliminated Over Pier and at Abutment

Improving Durability of Bridge Decks using High Performance Concrete

John Staton, Michigan Department of Transportation and Dave Juntunen, Michigan Department of Transportation

The Michigan Department of Transportation (MDOT) recently completed the "Fix on 96", which was a $148 Million project that reconstructed 7 miles of urban freeway and rehabilitated 37 bridges from Newburgh Road to Telegraph Road on I-96 in metropolitan Detroit.

Michigan's strategic goal is to be an "Innovation Hub" where engineers work to achieve greater efficiencies and value added outcomes. A cornerstone for innovation includes efforts to continually strive to incorporate more durable products into our transportation infrastructure. One of these innovations used on the "Fix on 96" was to implement the use of High Performance Concrete (HPC) for bridge deck application. The HPC mixture, specified by MDOT as Grade DM Concrete, is a concept which had its inception in the HPC pavement arena over 15 years by MDOT material engineers.

Fig. 1. Celebration of the completion of the Fix on 96.

In addition to the concrete's ability to sustain long-term repetitive loading of Michigan's heavy trucks, the primary criterion for high performance hinges on the concrete's ability to resist Michigan's harsh wet-freeze environment where a substantial amount of deicer salts are applied to the roadway surface in efforts to facilitate safe travel. Hence, it was established that the Michigan HPC must represent the following durability characteristics:

- the entrained air-void system within the concrete mortar must be well distributed and of sufficient quality to provide frost resistance.

- the concrete must be of low permeability in efforts to minimize the ingress of water and deicer chemicals, and
- the amount of cementitious paste must be reduced and optimized in efforts to reduce the overall shrinkage, thus reducing the risk of shrinkage-related cracking.

A well-established entrained air void system is critical toward protecting the mortar fraction of the concrete against freeze-thaw damage. The quality of this air-void system depends greatly on the chemical interaction between each of the components of the concrete mixture, as well as other outside influences (handling and placement, temperature of the concrete mixture). In efforts to ensure the overall quality and stability of an air-void system, smart selection of compatible materials is crucial, as well as employment of a strategy for process control which encompasses the need for periodic air content checks at set points in the process as the concrete moves from batching through transport to final placement into the forms. Short of the use of advanced testing devices and test methods developed to actually quantify the air bubble size distribution in the field, it can be expected that if the fresh concrete can be handled with minimal loss of total air content, the "locked-in" air-void system of the hardened in-situ concrete will be of sufficient quality to protect the concrete from freeze-thaw damage for many years to come.


Fig. 2. Completed bridge Deck on the Fix of 96.

Keeping the water and aggressive deicing salts from getting in to the concrete is a premiere aspect of MDOT's HPC bridge decks in Michigan's wet-freeze environment. Moderate replacement of the Portland cement (25 to 40 percent) with a Supplemental Cementitious Material (SCM - fly ash and slag cement) cement will work in harmony with the Portland cement to produce a secondary chemical hydration reaction during hydration that, in turn, contributes toward further densification of the cementitious paste. The result is a significant reduction in the overall permeability of the hardened concrete. This keeps the salt and water from getting into the concrete, reducing the potential for freeze-thaw and deicer-related damage as well as corrosion of the reinforcing steel. SCM's have also proven to successfully mitigate the potential for Alkali-Silica Reaction (ASR).

Since the cement paste is the weakest component of a normal concrete matrix, it makes sense to strive to minimize its presence in the mixture. Additionally, since the vast majority of mass loss (shrinkage) in the hardened concrete occur in the paste component of the matrix, it makes sense to, again, keep the paste volume toward a minimum. Granted, sufficient paste volume is still necessary to ensure ease of placing and finishing, however, adopting a well-graded distribution of aggregates in the matrix will greatly enhance the concrete's ability to be placed and finished, while shaving 100 pounds per cubic yard of cementitious material from the mixture. To add a synergistic flavor to the mix, incorporating well-graded aggregates in conjunction with an SCM further enhances the ability of the concrete mixture to be placed and finished while accommodating the overall reduction in cementitious material content.

Finally, since over 70 percent of the volume of the concrete is comprised of coarse aggregates, there should be an emphasis toward ensuring that high quality freeze-thaw resistant aggregates are specified for the HPC.

To date, MDOT has demonstrated that it can be both innovative and cost effective to produce HPC for highway applications using current materials and methods. With approximately 11,300 cubic yards of HPC bridge deck mixture placed on this project, there is now compelling testimony that it can easily be done. The feedback from this project was encouraging in the sense that the local concrete producers and material suppliers were heavily vested in making sure that all aspects of the Grade DM concrete were successfully accomplished. Initially, there were concerns about the level of efficiency that would be gained when attempting to optimize standard bin aggregates. However, to the satisfaction of all, the combined effects of the final aggregate gradation blend and the SCM produced a fresh concrete that was easily pumped, could be placed and finished with less hand work, was much more able to maintain a stable entrained air-void system, and ultimately contributed to a reduction in deck cracking.

For more information, the authors can be contacted at statonj@michigan.gov and JuntunenD@michigan.gov

Selecting a Bridge Joint System

Joseph Becker, RJ Watson, Inc

When beginning any discussion on bridge joint systems one must consider the purpose and function of the bridge joint in today's modern highway system. A bridge joint can be likened to the roof on your house. They protect very expensive components underneath. Damaged and leaky bridge joints are the cause of millions of dollars of substructure damage per year due the damaged joint allowing the passage of liquid and debris from the deck of the bridge to the girder and bearing assembly's below. This damage usually extends to concrete pier caps as well and its typically exacerbated by the application of deicing salts and liquids in certain climates.

Fig. 1. A close up of a preformed silicone bridge joint system.

When selecting a bridge joint system one must consider several factors. The bridge joint system must eliminate the passage of liquid and debris, it must be accurately sized, the material properties must be contusive to the application. In order to offer guidance its best to consult directly with a manufacturer of bridge joint systems such as R.J Watson, Inc who has decades of experience in the design, manufacture, and installation of bridge joint systems.

Many systems on the market today can be considered legacy systems. These systems have been in use for a very long time and do not have a excellent track record of success. Neoprene based compression seals, poured silicone joints and strip seals are all very common fixtures on the roadway today. Fortunately over the years extensive studies have been done to try and determine the main causes of failures in these bridge joint systems. While no study is completely conclusive due to the different climatic conditions across the country it has been noted that neoprene based systems have a inherent tendency to become brittle and take what's known as a compression set over years of being installed on a structure. This is due to their organic material properties breaking down under U.V. exposure. These systems also rely completely on compression to stay in place. It can be difficult to accurately size these types of joints because one must know the exact openings of the structure and the exact movement range of the bridge to the ¼". Strip seal systems are in wide use throughout the country. The steel extrusions typically last a very long time however they are susceptible to corrosion, plow hits, and rocking loose after years of heavy traffic passing over them. The gland in this system is typically made fof neoprene and is susceptible to the failure modes as compression seals, especially since strip seal systems tend to collect the most debris. This gland is replaceable however it has been studied and shown that this replacement process can be very time consuming and difficult to accomplish out in the field.

Recently a new generation of bridge joint systems has come to market bring with them improved technologies and features that prolong the life of the system and allow easy reparability down the road. One such system is the preformed silicone system Silicoflex offered by R.J. Watson. This system is completely inorganic and is finished in carbon black to make it extremely resistant to U.V. light and greatly decreases the possibility of the gland breaking down over time. The Silicoflex system is bonded to the joint face using a 100% single part silicone adhesive that forms a tenacious bond with concrete, steel, or elastomeric concrete headers. The system is fairly universal in that it can be bonded to just about any existing joint opening. There are only three standard sizes of this system so it is very easy for an end user to determine what size they need. Silicoflex can span ½" to 6.5" openings within the four individual sizes R.J. Watson offers. Because this system is so universal its quickly become a favorite of state DOT maintenance forces who must quickly repair all manner of joint systems in the field on a moment's notice. Silicoflex has also been called upon frequently in Accelerated Bridge Construction projects due to its ease and speed of installation. The Silicoflex system is now used in rehab and new highway construction and on rail bridges both in the US and abroad. This system, when coupled with a modified improved steel armoring system has also been approved by several states as an equal to the strip seal design featuring the cumbersome extrusions. When it comes to reparability Silicoflex is ahead of the other systems on the market. A small tear or puncture in the gland can be "healed" simply by applying more of the included Silicoflex Locking adhesive extending the life of these systems for years and years.

Always remember when choosing your joint system to request testing data and be sure the supplier your working with has the ability to connect you with the right system for your project and for your budget. When you consult with the industry experts at R.J. Watson, Inc you can be sure that they will work with you to ensure you have a system that will last and preform as promised.