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176 Raymond Building, University of Kentucky
859.257.4513 www.ktc.uky.edu

Improved Bridge Joint Materials and Design Details

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Kentucky Transportation Center
176 Oliver H. Raymond Building
Lexington, KY 40506-0281
(859) 257-4513

www.ktc.uky.edu



Research Report
KTC-17-08/SPR14-492-1F

Improved Bridge Joint Materials and Design Details

Theodore Hopwood II, P.E.
Program Manager

Chris Van Dyke, Ph.D.
Research Scientist

and

Sudhir Palle, P.E.
Research Engineer

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

In Cooperation With
Kentucky Transportation Cabinet
Commonwealth of Kentucky

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16. Abstract Expansion joints accommodate bridge movements that result from factors such as thermal expansion and contraction, concrete shrinkage, creep effects, live loading, settlement of the foundation and substructure, and environmental stressors. Expansion joints fall into two categories — open joints and closed joints. Open joints contain gaps that facilitate the passage of water and debris runoff through bridge joints. Flexible or stiff troughs are generally installed beneath open joints to direct runoff away from bridge elements. Closed joints produce a watertight seal that inhibits water, debris, and deicing materials from passing through bridge joints and remaining in contact with underlying bridge components. This study investigated materials and design strategies to improve the performance of both open and closed joints. Wanting to improve the durability of compression and strip seals, which degrade over time or become detached from bridge decks, Kentucky Transportation Center (KTC) researchers approached several seal manufacturers about developing new seals reinforced with puncture-resistant fibers such as Aramid. Ultimately, researchers were unable to reach an agreement with any manufacturer, as it appears they have little interest in developing better-performing conventional joint types, preferring instead to focus on producing new proprietary joint types. As the Kentucky Transportation Cabinet (KYTC) increases its use of proprietary joints, it should implement a rigorous monitoring program to track their performance. With respect to open joints, KTC investigated the use of self-purging troughs. First implemented by the Kansas Department of Transportation, they leverage the power of air flow and vibrations produced by traffic to improve the routing of water and debris through troughs and away from underlying bridge elements. Conventional troughs receive infrequent maintenance and can become clogged with debris. Self-purging troughs eliminate this problem, which can potentially help extend the service lives of bridges on which they are installed. KYTC will benefit from experimenting more widely with self-purging troughs.			
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Table of Contents

Acknowledgements	3
Executive Summary	4
1. Introduction: Overview of Bridge Joints and Project Objectives	6
2. Need for Improved Seal Materials	11
3. State DOT Experiences and Common Joint Seals — Issues with Proprietary Narrow Gap Joint Seals	13
Service Experience of Common Joint Seals	13
Emerging Joint Types	14
Manufacturer Performance Expectations	14
Recommendations	15
4. Self-Purging Troughs	16
Recommendations	19
5. Conclusions and Recommendations	20
References	21
Appendix A: KYTC’s Forthcoming Approved Product List of Proprietary Deck Expansion Joints Seals for Specific Joint Movements	22

List of Figures

Figure 1 Detached Compression Seal Drooping Below a Deck Joint	11
Figure 2 Torn Strip Seal Gland	12
Figure 3 Joint Seal Life Expectancies for Pourable Seals, Strip Seals and Compressions from TSP2 Joint Survey (Graph Courtesy of D. Steiger, Watson, Bowman Acme)	13
Figure 4 Hybrid Finger Joint–Sliding Plate Joint and Debris and Vegetation Accumulation in Trough Below the Joint	16
Figure 5 Kansas DOT Self-Purging Trough Design	17
Figure 6 Collector for Self-Purging Trough	18
Figure 7 Sources of Poor Trough Performance	19
Figure 8 Unnecessary Bracket Attached to End of Self-Purging Trough Preventing It from Vibrating Properly	19

List of Tables

Table 1 Summary of Expansion Joint Characteristics	8
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Executive Summary

Expansion joints accommodate bridge movements that result from factors such as thermal expansion and contraction, concrete shrinkage, creep effects, live loading, settlement of the foundation and substructure, and environmental stressors. Expansion joints fall into two categories — open joints and closed joints. Open joints contain gaps that facilitate the passage of water and debris runoff through bridge joints. Flexible or stiff troughs are generally installed beneath open joints to direct runoff away from bridge elements. These troughs, however, can become clogged with sediment, debris, and even vegetation, which prevents them from serving their intended function. Many state transportation agencies lack the resources to perform routine maintenance on troughs, which can bring water and deicing materials into prolonged contact with underlying bridge elements, damaging them and reducing their service life. Conversely, closed joints produce a watertight seal that inhibits water, debris, and deicing materials from passing through bridge joints and from remaining in contact with underlying bridge components. The key feature of closed joints is the use of elastomeric seals (or asphalt for small joint movements) that span the gaps between deck segments or back walls making the joints watertight. Seals carry their own maintenance risks, as the use of improper installation methods can result in premature failure. Over time, seals may break down, become detached from the bridge deck, and suffer damage from repeated exposure to vehicle traffic and snowplows. Adhesive failure and pronounced temperature fluctuations also degrade the performance of seals and other closed joints. With the goal of improving bridge joint performance, Kentucky Transportation Center (KTC) researchers investigated the use of different materials to improve the durability and performance of seals and examined design strategies that enhance the operation of troughs located beneath open joints.

To improve the performance and longevity of seals, KTC researchers approached manufacturers about developing new conventional joint seals reinforced with puncture-resistant fibers such as Aramid. Researchers, based on the durability of puncture-resistant fibers in other applications, believed these fibers would significantly improve strength of seals. After making attempts for several years, KTC reached an agreement with one manufacturer in 2016 to develop a new seal. However, in January 2017 the manufacturer rescinded its offer. Given the feedback the company has received from manufacturers, it is evident they are not interested in developing conventional joint types that perform better, wanting instead to develop and promote the use of proprietary joint types. Currently, the Kentucky Transportation Cabinet (KYTC) is expanding its use of proprietary seals/joints. As they are used during maintenance projects, KTC recommends observing seal installations to ensure correct procedures are used. This should be followed up by the implementation of a comprehensive monitoring program that records the performance of seals at one- to two-year intervals. Given its history of performing joint evaluation work for the Cabinet, KTC is well-positioned to design and execute this monitoring program.

KTC researchers inspected open joints on KYTC-owned bridges, including an innovative design that combines two types of joints — part finger joint and part sliding plate. It uses fingers, but they are not cantilevered from both sides of the deck joint. Instead they are mounted on one side of the joint and are supported by a mating finger assembly and ride along a base plate like a sliding plate. While these joints are performing well, like many other open joints, researchers found debris and vegetation blocking troughs. Hoping to improve trough performance, KTC investigated self-purging troughs, which were pioneered by the Kansas Department of Transportation. Their unique designs harness the power of air flow and vehicle-induced vibrations to facilitate better routing of water and debris through troughs and away from underlying bridge elements. There are challenges associated with self-purging troughs — they cannot be used where pipes or other portions of the bridge structure could impinge on troughs, the neoprene material used in their construction can tear, and impediments near trough entrances can dampen vibrations (reducing their ability to efficiently convey water and debris). Despite these risks, their field performance has been excellent, and KYTC would benefit from installing them on a larger number of bridges.

The summary findings and recommendations of this project are as follows:

- KTC referenced a 2015 TSP2 Bridge Preservation Partnership Joint Committee Survey, which found that state DOTs have had the best performance in terms of durability using strip seals. Poured joint seals and compression seals have proven less durable, requiring agencies to replace them at more frequent intervals.
- As KYTC moves away from commodity seals and expands its use of proprietary seals, it will be helpful to undertake extensive field monitoring of proprietary seals to evaluate their performance. KTC recommends

developing a database to track the results of this monitoring. KTC has performed significant joint monitoring work for the Cabinet and can assist in that effort.

- Troughs are routinely placed beneath open joints to route water, debris, and deicing materials away from the bridge structure. Without maintenance, troughs frequently become clogged with debris, which can result in loss of trough function and damage to adjacent bridge components. To overcome this problem, the Kansas DOT has designed a self-purging trough design that harnesses the power of air flow and vehicle-induced vibrations to convey materials away from a bridge. KTC recommends that the Cabinet experiment with self-purging troughs to improve trough performance, reduce maintenance costs, and extend the life of bridges that have open joints.

1. Introduction: Overview of Bridge Joints and Project Objectives

Bridge movement results from a number of factors, including thermal expansion and contraction, concrete shrinkage, long-term creep effects from prestressing, post-tensioning shortening, live loading, foundation and substructure settlement, wind, and seismic events (Dexter et al., 2002; Purvis, 2003). Specifically, thermal expansion and contraction and concrete shrinkage and creep can instigate longitudinal and transverse motion. Bending induced by live loads results in deflection of the deck, which precipitates rotational movement. Concrete, the material conventionally used to fabricate bridge decks, is brittle and has low tensile strength. While steel reinforcement improves tensile strength and reduces brittleness, bridge decks nonetheless remain vulnerable to cracking and structural deterioration. To address these challenges, deck lengths are shortened by dividing a bridge into discrete sections, with open joints located between each section (Purvis, 2003). Thus, expansion joints accommodate bridge movements and structural deformation while improving deck resiliency, mitigating cracking, and reducing deterioration. Over the years, bridge joints have proved problematic by allowing moisture and deicing salts to spill onto superstructure and substructure elements, resulting in steel corrosion and spalling concrete. Preventing or repairing that damage has been a major expense to state departments of transportation (DOTs) over the past 40 years.

To address the joint-related problems, some DOTs have increased their use of jointless bridge designs incorporating semi- and fully integrated abutments (e.g., Hoppe et al., 2016). Through 2007, some 4,000 U.S. bridges had been built with semi-integral abutments and 9,000 more with fully integral abutments (White, 2007). Many bridges continue to be constructed with multiple spans using expansion joints. Some DOTs have sought to eliminate as many bridge joints as possible during rehabilitation work. However, most lack the financial resources to convert jointed bridges on a widespread basis.

There are two types of expansion joints used on bridge decks— open joints and closed joints. Open joints contain gaps or openings that permit water and debris runoff from bridge decks to pass through bridge joints onto underlying bridge components. Butt joints, sliding plate joints, and finger joints are the most common types of open joints. Closed joints are designed to provide a watertight seal that precludes water, debris, or deicing materials from passing through the deck joint. The key feature of those joints is the use of elastomeric seals (or asphalt for small joint movements) that span the gaps between deck segments or back walls, making the joints watertight. Among the most commonly used closed joints are poured seals, compression seals, strip seals, asphalt plug joints, cushion seals and modular expansion joints. Commonly, DOTs employ open joints to accommodate larger bridge movements. But open joints can introduce significant maintenance issues because of their potential to expose portions of the superstructure and substructure to corrosive agents (i.e., deicing materials). Flexible or rigid troughs are generally installed beneath open joints to collect water (typically contaminated with deicing chemicals) and debris and funnel them to drainage systems. Most trough designs are ineffective as they become filled with solid debris and block the passage of water runoff which spills onto underlying bridge elements. Troughs benefit from routine flushing to remove excess debris, however, most DOTs lack the resources to do so. Closed joints eliminate this problem, and while they provide a smoother ride, various maintenance problems are associated with their use as well. Improper installation methods can result in premature failure. Seals may break down over time, and repeated exposure to vehicle traffic and snowplows can damage them. Adhesive failure and pronounced temperature fluctuations also degrade the performance of seals and other closed joints. Table 1 summarizes the key characteristics of different open and closed expansion joints. For each joint type the table includes a brief description of its form, the amount of movement accommodated, design features for handling debris, and vulnerabilities that can undermine performance.

Most Kentucky Transportation Cabinet (KYTC) bridges have open or closed joints. Given the significant expense and time associated with installing and maintaining expansion joints, the Cabinet asked researchers at the Kentucky Transportation Center (KTC) to investigate different joints and identify strategies to improve their performance while reducing maintenance costs. Specifically, this project had four objectives:

- 1) Review materials commonly used to manufacture closed joints. Identify seals that use neoprene and seek substitute materials that offer better long-term flexibility. Identify seal reinforcing fibers to resist punctures.
- 2) Work with a joint/seal manufacturer and the Cabinet to introduce better performing joint types/seals and improved small deck movement joint seals (including both preformed and poured seals).

- 3) Evaluate trough designs used on recently completed large bridge projects and inspect existing troughs under open joints. From there, assess performance of existing systems and provide feedback to the Division of Structural Design along with recommendations for modifications (if necessary).
- 4) Investigate the performance of flexible self-purging troughs used by the Kansas DOT (including joint designs and trough material). Work with the Divisions of Structural Design and Maintenance to develop projects using experimental trough designs.
- 5) Work with the Divisions of Structural Design and Maintenance to deploy troughs/gutters on closed deck joints.

Table 1 Summary of Expansion Joint Characteristics

		Description	Movement Accommodated	Handling of Debris	Vulnerabilities
Open Joints					
Butt Joints	Opening through bridge deck; metal armoring often located on either side of the opening	<ul style="list-style-type: none"> • Rotational and minor thermal movements • Movements up to 1” (25 mm) 	<ul style="list-style-type: none"> • Passes through deck opening into neoprene trough • No trough present if water and debris will not affect substructure 	<ul style="list-style-type: none"> • Corrosion of metal armoring • Spalling or raveling of concrete if no armor is present • Buildup of debris in trough 	
Sliding Plate Joints	Plate is attached to one side of bridge deck and extends across the opening; unattached plate situated in slot on opposing span; anchored into concrete with welded steel bolts, bars, or studs	<ul style="list-style-type: none"> • Movements between 1” and 3” (25–75 mm) 	<ul style="list-style-type: none"> • Semi-open, it prevents the passage of most water and debris through the opening • May have neoprene trough to convey excess water and debris 	<ul style="list-style-type: none"> • Plates may loosen or detach • Accumulation of debris undermines plate stability • Anchor corrosion • Net equipped to deal high traffic volumes • Trough obstruction 	
Finger Joints	Interlocking cantilevered fingers span the joint opening	<ul style="list-style-type: none"> • Movements greater than 3” (75 mm) 	<ul style="list-style-type: none"> • Neoprene trough under opening catches and conveys excess debris and water 	<ul style="list-style-type: none"> • Anchorage issues • Upward protrusion of fingers creates rough riding surface • Concrete deterioration • Clogging of trough • Can jam, bend, or break if not installed correctly 	
Closed Joints					
Poured Seals	Viscous waterproof material (e.g., silicone) poured into the opening atop a polyethylene foam backer rod, which prevents material from flowing through	<ul style="list-style-type: none"> • Movements up to 0.25” (6 mm) 	<ul style="list-style-type: none"> • n/a 	<ul style="list-style-type: none"> • Improper installation may result in failure 	
Compression Seals	Continuous pre-formed neoprene elastomeric section that is compressed into the joint opening	<ul style="list-style-type: none"> • Movements less than 2.5” (63.5 mm) 	<ul style="list-style-type: none"> • n/a 	<ul style="list-style-type: none"> • Inconsistent performance • Damage from debris 	

	across the entire width of the bridge; may be open or closed cell			<ul style="list-style-type: none"> • Snowplow damage • Leakage • Loss of compression • Temperature extremes may cause loss of resiliency
Strip Seals	Neoprene membrane rigidly attached to a metal facing on both sides of joint; material is pre-molded into a V-shape that opens or closes as joint width fluctuates	<ul style="list-style-type: none"> • Movements up to 4" (100 mm) 	<ul style="list-style-type: none"> • n/a 	<ul style="list-style-type: none"> • Difficult to replace • Snowplow damage • Membrane may tear if non-compressible materials lodge in membrane crevices • Seals pull away from their groove in the metal facing • Breakdown if traffic moves over joint filled with debris
Plug Seals	Polymer-modified asphalt binder coats a blockout that is centered atop the joint; backer rod inserted into joint beneath blockout; steel plate centered over joint to bridge the opening	<ul style="list-style-type: none"> • Movements up to 2" (50 mm) 	<ul style="list-style-type: none"> • n/a 	<ul style="list-style-type: none"> • Softening in hot weather • Debonding of joint-pavement interface • Rutting and delamination • Rapid temperature changes may cause damage
Cushion Seals	Neoprene cushion recessed into the deck over the joint opening with steel rods	<ul style="list-style-type: none"> • Movements up to 4" (100 mm) 	<ul style="list-style-type: none"> • n/a 	<ul style="list-style-type: none"> • Snowplows can cut material • Damage often requires complete replacement • Adhesive failure and traffic may dislodge anchor nuts • Joint edge spalls

Modular Joint Sealing Systems	Combination of multiple elastomeric compression seals separated by one or more transverse center beams parallel to edge beams	<ul style="list-style-type: none"> • Movements between 4" and 24" (100–600 mm) 	<ul style="list-style-type: none"> • n/a 	<ul style="list-style-type: none"> • Fatigue cracking of welds • Damage to neoprene sealer, equalizer springs, and supports • Snowplow damage • High initial cost and maintenance costs • Leakage between compression seals and steel supports
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Sources: Dexter et al. (2003), Purvis (2003), Brown (2011)

2. Need for Improved Seal Materials

Most closed joints are manufactured out of synthetic rubbers. Three varieties of synthetic rubbers are typically used to produce these joints — neoprene, silicone, and ethylene propylene diene monomer (EPDM; also referred to as ethylene propylene rubber). The most commonly employed synthetic rubber in joint applications is neoprene, with several manufacturers using it to fabricate compression seals. Compared to natural rubbers, it has greater resistance to water, soils, and solvents. It remains durable in the face of wide temperature ranges and possesses moderate water resistance. Neoprene's tensile strength range is from 500 to 3,000 psi and has a durometer range of 20 to 95 (Shore A). The use of EPDM for joint seals is less common, although some V-seal expansion joint systems incorporate it as their primary material. EPDM has a high density and withstand temperatures up to 215 C. But compared to silicone, its resistance to extreme temperatures is noticeably lower. However, it should be kept in mind that all three rubbers can withstand the ambient temperatures encountered on most bridges. EPDM's chemical properties instill resistance against weathering, acids and alkalis, ultraviolet radiation, and ozone. Its tensile strength ranges from 500 to 2,500 psi, with a durometer range of 30 to 90 (Shore A). Compared to silicone, EPDM has greater tensile strength, which makes it less likely to tear. Silicone is a non-reactive flexible rubber frequently used for poured joints. Compared to common organic polymers, silicone has higher heat resistance and chemical stability. It is highly elastic and compressible, resistant along a wide temperature spectrum, water repellent, and possesses good release properties. It is generally resilient when exposed to wind, rain, and ultraviolet radiation; it undergoes no changes in its physical properties. Silicone's tensile strength range is 200 to 1,500 psi and a durometer range of 30 to 90 (Shore A). All three materials exhibit good compression set.

One problem with neoprene compression seals is that they sometimes lose their flexibility and detach from decks (Figure 1). Strip seals can be torn or punctured. While new joint types are being proposed and seeing wider use, KTC researchers believed that use of different seal materials or seal designs within the framework of the existing seal types might result in a more durable and longer-lasting seal.



Figure 1 Detached Compression Seal Drooping Below a Deck Joint



Figure 2 Torn Strip Seal Gland (Source: [Ohio DOT](#))

Aside from expansion joints, each synthetic rubber is used in a wide range of industrial applications. One salient point to note is that some products fabricated from synthetic rubbers incorporate fiber reinforcement to improve their resistance and durability. For example, some rubber tires integrate steel and polymers — including Aramid — to improve puncture resistance. Because fiber reinforcements have performed well in other applications, researchers at KTC reasoned that incorporating them into strip seals would result in improved performance and better long-term durability. Using better materials will bolster the long-term durability of compression and strip seals. That could help state DOTs significantly reduce maintenance costs.

As noted, a primary objective of this study was to forge a cooperative agreement with joint seal manufacturers that would result in the production of improved joint seals. Under such an agreement, manufacturers would have developed better performing compression seals and strip seals by making them out of different materials. In the case of strip seals, the goal was for manufacturers to reinforce them with puncture-resistant fibers such as Aramid. KTC attempted — for several years — to reach an agreement, without any success. However, in June 2016 the Center received a commitment from one manufacturer to work with the Center on improved seals. Based on the manufacturer’s promise, the study advisory committee extended the project by one year to achieve the project objective. In January 2017 the manufacturer rescinded its offer. Based on KTC’s experience and interactions with manufacturers, it appears they have little interest in developing the conventional joint types that perform better, preferring instead to promote the use proprietary joint types.

3. State DOT Experiences and Common Joint Seals — Issues with Proprietary Narrow Gap Joint Seals

In 2015, the TSP2 Bridge Preservation Partnership Joint Committee conducted a comprehensive national survey focused on the performance of different expansion joints. KTC assisted with this survey, which garnered responses from 46 state DOTs and 11 additional transportation agencies. The survey was presented to all DOTs within the TSP2 community. Based on the level of response, it is broadly representative of experiences among both DOTs and stakeholders in the joint industry. This section provides an overview of the survey’s findings and discusses potential issues with proprietary narrow gap joint seals, as a growing number of DOTs, including the Cabinet, are moving toward them.

Service Experience of Common Joint Seals

Figure 3 summarizes data on the durability of common types of deck seals (e.g., poured seals, compression seals, strip seals). The survey grouped the seal performance in five-year increments. DOTs reported that poured joint seals have been the least durable, with 49.6 % of the joints lasting from 0-5 years, 34.4 % lasting 5-10 years, and just 12.5% lasting 10-15 years. Compression seals have exhibited intermediate performance, with 22.6 % of the joints lasting from 0-5 years, 32.3 % lasting 5-10 years, and 45.2 % lasting 10-15 years. Strip seals have displayed the best performance according to the survey responses, with 12.5% of the joints lasting from 5-10 years, 25% lasting from 10-15 years, 37.5 % lasting 15-20 years and 25% exceeding 20 years. Those joint seal types have been in service for several decades and have been widely used by most DOTs.

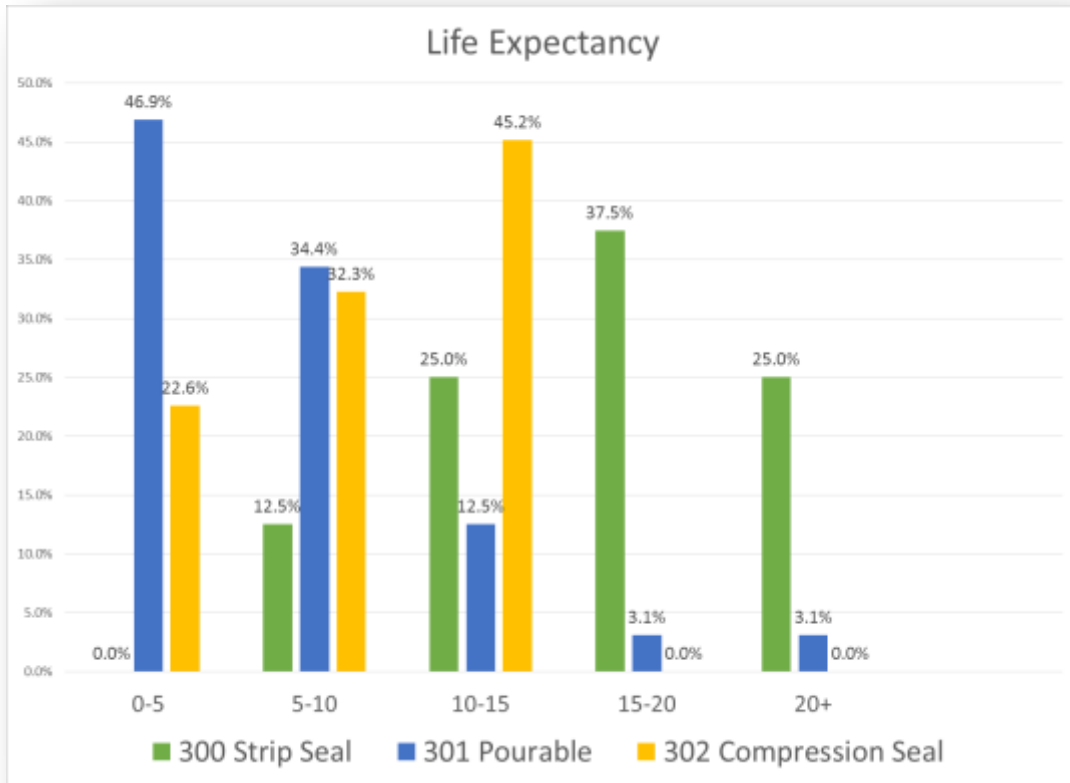


Figure 3 Joint Seal Life Expectancies for Pourable Seals, Strip Seals and Compressions from TSP2 Joint Survey (Graph Courtesy of D. Steiger, Watson, Bowman Acme)

Performance variance may reflect differences in material specifications/acceptance testing, joint preparation (e.g., sawed or poured deck nosings or use of blockouts), joint maintenance, bridge service environments, and installation

practices. These likely vary significantly among DOTs, and potentially within individual agencies themselves, as district or section offices may adhere to unique standards or practices based on local conditions.

Finger joints or modular joints are typically used when there are larger deck gaps depending on whether an agency prefers open or closed joints. Increasingly, DOTs are opting for jointless bridges on new construction and maintenance applications. For maintenance activities that convert a bridge to a jointless structure, extensive deck retrofitting is required; joint elimination is usually reserved for deck rehabilitation/replacement work.

Emerging Joint Types

DOTs have generally sought the most durable joint types where small joints (which typically accommodate 4" [10 cm] of movement or less) are used. For some DOTs, poured seals and compression seals have performed well in these situations, whereas others have been dissatisfied with their durability. DOTs satisfied with their performance are continuing to use them. DOTs moving away from these seal types have generally adopted what can be termed proprietary joint types (e.g., pre-compressed silicone and foam compressed covered foam hybrid and "V" types). The Virginia DOT (VDOT) has elected to replace narrow gap joint seals at five-year intervals regardless of their condition. VDOT no longer uses compression seals, preferring instead to use newer seal types. This paper refers to the three conventional seal types as *commodity seals* and the newer seal types as *proprietary seals*.

The 2015 survey established baseline data on the durability of joint seals, which can be used to determine whether proprietary joint seals offer benefits over commodity ones. For the most part, those joint types are new, and the Cabinet has little experience with them. The forthcoming KYTC Standard Specifications manual will include a list of approved proprietary seals (Appendix A). Two conclusions can be drawn from a review of the list: 1) the pre-compressed silicone and foam hybrid and V seals are considered interchangeable throughout the range of joint sizes, and 2) within certain joint sizes, different proprietary joints of the same type are specified.

For most joint seal replacement, installation work will be performed by contract. However, district personnel will replace or repair some poured joints. Moving forward, contractors will be allowed to replace joint seals using seals on the proprietary list provided in Appendix A. Their selection will be based on: 1) familiarity with a specific brand of joint or generic joint type, 2) cost, 3) availability and 4) any joint installation feature that might prove beneficial on a project.

The Cabinet's goal in moving away from commodity seals (Figure 1) is to utilize joints with greater durability and life expectancies. The Cabinet does not have the funds to adopt the VDOT practice of short-duration cyclic joint replacement. Therefore, the relative performance of the seals within each joint size category will be of importance to the Cabinet.

While strip seals may be most durable, they are also the costliest to install as part of a maintenance routine, as they require the placement of anchoring steel and extensive deck concrete work. This work can significantly disturb traffic while bridge repairs are completed. In some instances, they have been subject to snowplow damage, requiring costly repairs.

For the immediate future, the Cabinet's preferred options will be narrow-gap deck joints and proprietary seals. Because the purpose of switching from commodity to proprietary joint seals is to achieve greater seal durability, it is critical to determine which proprietary seal types (or products within a seal type) offer the greatest durability (taken as the measure of best performance). As noted, contractor selection of specific joint seals may be driven by other factors and it will be up to the Cabinet to utilize only the most durable proprietary joint seals in its approved products list to obtain the greatest benefit. Due to the relative newness of various proprietary joint seals, their performance remains unknown, both relative to the commodity joint seals and to one other.

Manufacturer Performance Expectations

There is reason to question the performance of the proprietary joint seals, including differences in the same generic types. One manufacturer has its V-seal on the Cabinet's forthcoming approved product list for 3" and 4" joint sizes (D.S. Brown Company, 2016). Its maintenance guide for bridge expansion joint seals compares the life expectancy of a V-seal to a poured seal (5-10 years). The compression seal has a stated life expectancy of 10-15 years, although it is not available in sizes over 2-1/2". D.S. Brown has another proprietary preformed joint seal (the J Seal) that costs more than either the compression seal or the V-seal, and has a stated life expectancy of 10-15 years, the same as its

compression seal. Another product that competes with the V-seal, the RJ Watson Silicoflex, is supposed to be very durable. According to RJ Watson, “Silicoflex applications installed in the mid-1990s are still performing effectively to this day.” That would place performance on par with strip seals, which DOTs generally regard as the most durable type of joint seal, with a median life expectancy of 15-20 years. The D.S. Brown guide states that the life expectancy of its strip seal is 20-25 years. There are significant differences in the V-seal designs and materials between the various V-seal manufacturers including seal materials, adhesives and the use (or non-use) of backer rods. Watson Bowman Acme V-seals are closer to the Silicoflex, but do not have an extensive history of service.

Any potential differences between the proprietary pre-compressed silicone and foam hybrid seals has not been established. This type of joint is recognized as being easy to install, but life expectancies have not been established to permit comparisons with other proprietary (or commodity) joint types, or with other proprietary products in the same class.

For V-seals, there are clear differences in manufacturer expectations for their products. However, those seals are considered equivalent in the forthcoming KYTC Standard Specification approved products list. In addition to hybrid silicone and foam and V-seals, the Cabinet should investigate the use of a joint-type known variously as cushion, plank, or segmental seals. These seals can be used for joint gaps/movements 5” (≈13 cm) or greater. They were initially used in the 1980s with embedded anchors, but they eventually failed, which prompted the Cabinet to discontinue their use. The industry has since developed chemical anchoring involving the use of adhesive to bond the anchors to decks, which successfully addressed the joint failure problem. Use of this seal/joint type would provide the Cabinet with another viable option in addressing larger joint gaps/movements.

Recommendations

It is not known whether all the potential proprietary seals/joints have gone through the KyPEL new product approval process. As this list begins to be used for maintenance projects, it would be beneficial to monitor proprietary seal/joints, beginning with installation and moving forward. Monitoring installation to determine if contractors comply with the manufacturer instructions would be of value in assessing future performance. If installation is not monitored, the seals should be inspected within a few months of installation, followed by periodic monitoring at one- or two-year intervals. KTC recommends developing a spreadsheet or database that contains the following information derived from inspections and deterioration plots:

- Bridge name
- Routes and locations (GPS)
- Number and type of joint seals
- Joint sizes (measured at deck temperatures)
- Installation date (month/year)
- ADT (average daily traffic)
- Installation quality/comments
- Debris accumulation
- Joint condition (with pictures)

It will probably take 3-5 years to obtain meaningful data. At that point, the performance of each seal can be evaluated, and the Cabinet can keep better performing seals on its approved product list while removing those that do not perform well.

The Cabinet likely lacks manpower to prepare and feed data into the proposed joint seal spreadsheet/database. KTC has performed significant joint evaluation work for the Cabinet and would be able to create the spreadsheet/database and maintain it by performing periodic joint inspections on bridges throughout the state. Inspections of joint seals could be incorporated in the KYSPR Long-Term Monitoring project.

4. Self-Purging Troughs

State DOTs generally install inclined troughs beneath open joints to channel water, debris, and deicing materials from the joints and bridge structure. The retention of debris around bridge joints is problematic because it can expose structural elements of a bridge to materials that can undermine their performance. While troughs should theoretically prevent long-term exposure to water, debris, and deicing materials, many state DOTs do not routinely clean them out. Failure to flush out troughs leads to the gradual accumulation of debris. As part of this study KTC researchers inspected joints on several bridges owned by the Cabinet, including an innovative design that combines two types of joints — part finger joint and part sliding plate (Figure 4a). The design uses fingers, but they are not cantilevered from both sides of the deck joint. Instead they are mounted on one side of the joint and are supported by a mating finger assembly and ride along a base plate like a sliding plate. The advantage of this design is that the fingers do not have to be as thick as those used on conventional finger joints. The fingers are more amenable to construction alignment problems than the monolithic sliding plates and should prove more durable under traffic. KTC inspected several bridges that use this type of joint and all were found to be in good condition — firmly attached to the deck with no bent fingers.

Although this unique joint design has performed well, the troughs located beneath the joints have clogged with debris such as twigs, leaves, sediment, and other litter. Due to the buildup of sufficient organic material in the trough, vegetation recruitment has begun (Figure 4b). Many state DOTs encounter this problem because they lack the personnel to make regular field visits to clean out troughs. Clogged troughs can lead to problems elsewhere on a bridge. For example, a trough on the I-65 John F. Kennedy bridge in Louisville continuously overflowed due to the presence of excess debris and clogged drain pipes. The overflow of salt-laden runoff collected in the gap between an uplift bearing base plate and an anchor bolt, causing the anchor bolt to corrode and fail. Because of the costly maintenance issues occluded troughs present, DOTs are looking for solutions such as innovative trough designs that would keep troughs free of debris without regular maintenance. To that end, the Kansas DOT (KDOT) has developed a self-purging trough that takes advantage of air flow and the vibrations produced by bridge traffic to divert materials away from the bridge.



Figure 4 (a) Hybrid Finger Joint–Sliding Plate Joint; (b) Debris and Vegetation Accumulation in Trough Below the Joint

KDOT's self-purging trough consists of a looped neoprene sheet that is positioned below an open joint to catch falling debris and convey it away from bridge elements. There should be a minimum trough gap of three inches, and there should be space provided on each side of the trough to allow for its transverse movement. KDOT recommends

installing the trough to achieve the maximum possible slope. To achieve that on wider bridges KDOT employs double troughs (Figure 5).

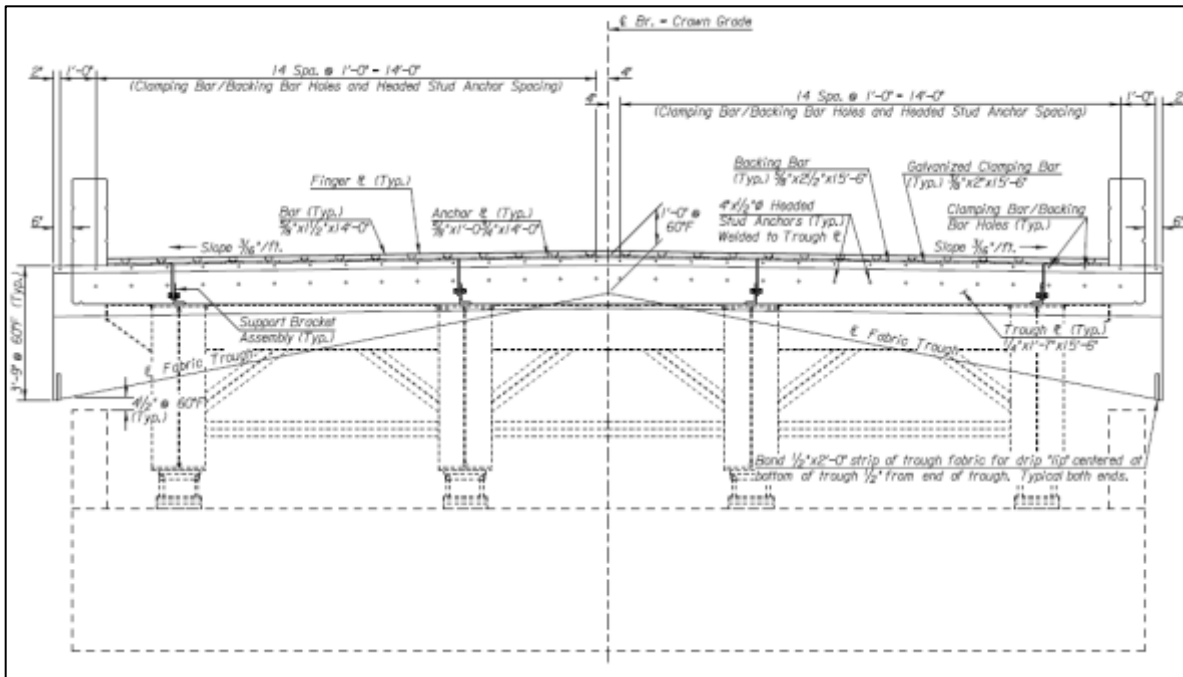


Figure 5 Kansas DOT Self-Purging Trough Design using Double Troughs to Increase Slopes and Promote Debris Removal

The trough works by being agitated by traffic over the joint. The trough material is very flexible (1/8-inch thick fiber-reinforced neoprene). The Cabinet’s specification for that material, as used on the recent Greenup Dam Bridge, is nearly identical to that specified by KDOT:

Neoprene Trough. Fabric reinforced drainage trough shall be polychloroprene (Neoprene) of 1/8-inch thickness. Trough shall be reinforced with one or two plies of tightly woven polyester or nylon fabric. The inside surfaces of the trough shall be smooth to promote self-removal of foreign material during normal joint operation.

Neoprene fabric composite material shall comply with the following:

<i>PHYSICAL PROPERTY</i>	<i>ASTM TEST</i>	<i>Value</i>
<i>Density</i>		<i>75 pcf minimum</i>
<i>Hardness (Type A Durometer)</i>	<i>D2240</i>	<i>50 to 75</i>
<i>Tensile Strength, both directions</i>	<i>D378</i>	<i>800 lb. minimum</i>
<i>Elongation at ultimate tensile strength</i>	<i>D412</i>	<i>35% minimum</i>
<i>Tear (Die C)</i>	<i>D624</i>	<i>120 lb./in minimum</i>
<i>Low Temperature Brittleness (22 hrs. at -20°F. then wrapped around a 3-inch mandrel)</i>	<i>D2137</i>	<i>No Cracks</i>
<i>Ozone Resistance (20% strain) 100 pphm in air (100 hrs. at 100° F)</i>		<i>No Cracks</i>

KDOT places a drain box and/or collector at the end of a trough and requires that there be no choke points or obstructions along the trough which could impede either the transverse movement of the trough or block debris flow (Figure 6). The trough should also avoid contact with beam ends. Drain boxes are connected to large-diameter drains (approximately 9” [23 cm]). Their wide diameters let drains can accommodate significant quantities of debris and water without any risk of plugging.



Figure 6 Collector for Self-Purging Trough

KDOT maintenance officials have reported good performance of self-cleaning troughs. Nonetheless, they are not invulnerable to potential problems, as documented in Figure 7. The installation will not work where pipes or other elements of a bridge structure can sometimes impinge on troughs, which introduces a slope discontinuity that prevents the passage of debris and water to the drains. The troughs must allow free movement along their entire length to promote the self-cleaning feature. Troughs may also be susceptible to damage. The neoprene sheet used for the trough is susceptible to tearing if it repeatedly rubs up against a hard object such as a beam end. Choke points may also develop if the sides of the trough are constricted and cause debris to become lodged. If there are impediments near the entry point of the trough that dampen vibration, the trough may be unable to transport debris and water toward the drain (Figure 8).

There are a few simple guidelines for designing the self-purging troughs:

- Minimum 3-inch trough gap
- Provide space for transverse motion of trough
- Maximum possible slope on trough
- Drain box/collector at end of trough
- No choke points or impediments to trough movement or debris flow
- Avoid contact with beam ends to prevent trough damage
- Use large-diameter drain pipes (9 inches or greater)



Figure 7 Sources of Poor Trough Performance: (a) Conduct Obstructing Material Flow; (b) Tear in Neoprene Trough; (c) Choke Point Caused by Debris



Figure 8 Unnecessary Bracket Attached to End of Self-Purging Trough Preventing It from Vibrating Properly

Recommendations

Despite the possible complications associated with self-purging troughs, their overall performance record indicates that problems are rare and can be mostly avoided by adhering to proper design and installation procedures. Their principal benefits — being able to move water, debris, and deicing materials safely away from bridges with little maintenance requirements — far outweigh any downsides. As such, KTC recommends employing self-purging troughs on several bridges and monitoring their long-term performance.

5. Conclusions and Recommendations

This report has briefly reviewed strategies and techniques to improve the design and performance of open and closed joints. Originally, KTC researchers had hoped to work with seal manufacturers to develop improved joint seals. Unfortunately, no manufacturers were willing to produce better functioning commodity joints strengthened with puncture-resistant fibers. Despite this setback, this project generated useful outcomes and recommendations:

- KTC referenced the 2015 TSP2 Bridge Preservation Partnership Joint Committee Survey, which found that state DOTs have had the best durability performance using strip seals. Poured joint seals and compression seals have proven less durable, requiring agencies to replace them at more frequent intervals.
- As KYTC moves away from commodity seals and expands its use of proprietary seals, it will be helpful to undertake extensive field monitoring of proprietary seals to evaluate their performance. KTC recommends developing a database to track the results of this monitoring. KTC has performed significant joint monitoring work for the Cabinet and can assist in that effort.
- Troughs are routinely placed beneath open joints to route water, debris, and deicing materials away from the bridge structure. Without maintenance, troughs frequently become clogged with debris, which can result in loss of trough function and damage to adjacent bridge components. To overcome this problem, the Kansas DOT has designed a self-purging trough design that harnesses the power of air flow and vehicle-induced vibrations to convey materials away from a bridge. KTC recommends that the Cabinet experiment with self-purging troughs to improve trough performance, reduce maintenance costs, and extend the life of bridges that have open joints.

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**Appendix A: KYTC's Forthcoming Approved Product List of Proprietary Deck
Expansion Joints Seals for Specific Joint Movements**

The following is a list of expansion joint seals approved for use in Kentucky. This list includes all expansion joint seals with the exception of neoprene strip seals. The Joint size is defined by the range of movement for each seal, not the field measured width at 60 degrees Fahrenheit. All joints are "V Seal" type or pre-compressed silicone and foam hybrid type.

<u>Joint Size (Nominal width)</u>	<u>Seal Model no.</u>	<u>Company</u>
½ inch	SES-012	SSI
	BEJS-ON-A-Reel	BEJS
1 inch	SES-100	SSI
	25EH	Watson Bowman Acme
	BEJS-ON-A-Reel	BEJS
1 ½ inch	SF 150	RJ Watson
	SES-112	SSI
	40EH	Watson Bowman Acme
	EMSEAL (1 ½")	BEJS
2 inch	SES-200	SSI
	50EH	Watson Bowman Acme
	EMSEAL (2")	BEJS
2 ¼ inch	SPS 225	Watson Bowman Acme
	SF 225	RJ Watson
	SES-214	SSI
2 ½ inch	SES-212	SSI
	65EH	Watson Bowman Acme
	EMSEAL (2 ½")	BEJS
3 inch	V-300	DS Brown
	SES-300	SSI
	75EH	Watson Bowman Acme
	EMSEAL (3")	BEJS
4 inch	SPS 400	Watson Bowman Acme
	SF 400	RJ Watson
	V-400	DS Brown
	SES-400	SSI
	100EH	Watson Bowman Acme
	EMSEAL (4")	BEJS
5 inch	SF 500	RJ Watson