February
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Better Bridge Joint Technology

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16. Abstract
Research was conducted to determine best practices for bridge expansion joints and headers in the Northeastern States. This research included understanding how joints and headers are used and maintained in Massachusetts and several states in and around New England, and what factors and practices have affected joint and header performance both positively and negatively. Information on joints, headers and practices collected from meetings with Massachusetts District offices is presented. A survey was sent to states around the northeast and results are summarized for each of the nine states. There were 26 respondents as some states provided multiple responses used to compare variation of practices within individual states. Bridge joint use and performance varies between states and within states. Information is presented for joint types and headers in use in the northeast including their performance, installation and maintenance practices.

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Better Bridge Joint Technology

Final Report

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Executive Summary

The University of Massachusetts Amherst conducted a research project to determine best practices for bridge expansion joints and headers in the Northeastern states of the United States (US). This research included understanding how joints and headers are used and maintained in Massachusetts and several states in and around New England, and what factors and practices have affected joint and header performance.

All bridges experience thermal expansion and contraction as temperatures fluctuate, and require some way to allow these movements to occur. In conventional jointed bridges, expansion joints are provided in the superstructure to allow these thermal movements. There are two categories of joint types: open joints and closed joints. Open joints are designed to allow water to flow through the joint into a drainage system and carry the water away from the bridge. In closed joints, the joint is designed to prevent any water from passing through the joint. There have been many issues with closed expansion joints becoming damaged or failing and allowing water and debris to reach superstructure and substructure elements. Similar results occur if the drainage systems fail in open joints. In New England and other states that experience harsh winters, the water reaching these components also carries road salts which accelerates corrosion of bridge components. Consequently, the costs of joint failures extend far beyond repairing or replacing a damaged joint and include damage to superstructure and substructure components. Most states are moving toward jointless bridges to avoid the problems and cost associated with expansion joints; however, jointless bridge construction is not always an option (due to skew and length limitations). Additionally, switching to jointless construction is a long process and in the meantime bridges with expansion joints need to remain functioning properly. Therefore, understanding best practices, as well as common sources leading to failure, is an important step towards extending the life and enhancing the performance of expansion joints.

The first part of this research includes a literature review of previous joint research and compiling information on existing bridge joint inventory in Massachusetts. Next, information was collected on bridge joints, headers, and practices throughout Massachusetts by meeting and interviewing personnel from each of the six district offices of MassDOT. A survey was created and distributed to representatives from the Departments of Transportation of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Vermont. The responses from these states were compiled and an overall summary of the states' responses was created.

The joint performance reported by states differed according to their definition of a successful joint. Installation procedures were reported to have the biggest impact on joint performance. Many states reported similar construction issues that have negatively impacted performance and the importance of proper training and inspection. While all states would like to perform preventive maintenance, the majority are not able to perform the level of maintenance they would like due to lack of funds. If preventive maintenance could be performed adequately, it is expected that service lives and performance of joints would benefit from the practice.

Overall there is no perfect expansion joint, but information is provided on many factors that should be considered when determining a joint type to use.

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1.0 Introduction

Expansion joints play an important role in bridges, allowing the superstructure to expand and contract as it undergoes cyclic thermal changes. Bridge joints notoriously suffer wear and tear as a result of being subjected to thermal movements, traffic impacts, freeze thaw cycles and various weather conditions. In the Northeast, the winters can bring months of heavy snow which also means the expansion joints are subjected to road salts and other anti-icing materials. Corrosion of steel superstructure and substructure elements including reinforcement within concrete elements is greatly accelerated when exposed to salts. If expansion joints stop performing properly the elements below are exposed to water and salts. Both the superstructure and the substructure can subsequently be damaged leading to costly repairs and replacements. Therefore, it is important to determine best practices in Massachusetts as well as surrounding states to better understand not only the causes of joint failure, but measures that can be taken to prevent failure and extend the service life of joints.

Chapter 1.0 will present a summarized literature review, including information on joint types and previous research. Chapter 1.0 will also include current bridge inventory and a description of the PONTIS database, followed by a description of the six Massachusetts Department of Transportation (MassDOT) districts. Chapter 2.0 will focus on the MassDOT information collected from interviews at each of the six District Offices. A description of joint types (past and present) used in Massachusetts will be detailed, including performance of joints, causes of failure and success, best practices (when applicable) and other information specific to the joint types. Joint headers are also included together with types used (past and present), experience with the header types, and any recommendations from the districts on best practices. An overview of information collected from district meetings and survey responses are presented in Chapter 3.0, including detailing practices during installation and maintenance, as well as other general practices.

Chapter 4.0 will present results of a regional survey on Better Bridge Joint Technology that was sent out to State Departments of Transportation, including: Massachusetts, New Hampshire, Connecticut, Rhode Island, Vermont, Maine, New York State, New Jersey, and Pennsylvania. A summary of the highlights of responses from each state will be presented, followed by a summary of responses from all states that includes information on joints, headers, maintenance, installation, and other practices to compare between states. Chapter 5.0 will provide a summary, conclusions and recommendations.

1.1 Literature Review

There have been many studies on bridge joints in the past. Two comprehensive studies that were examined as part of this research were the NCHRP *Synthesis of Highway Practice 319*, published in 2003 (*1*), and a more recent report *Survey of Past Experience and State-of-the-*

Practice in the Design and Maintenance of Small Movement Expansion Joints in the Northeast, published in 2014 (*2*).

Purvis (*1*) includes an extensive description of joint types and classifications, common issues of maintenance, and the instances where various bridge joints are used. Furthermore, the report presents results from a survey with data collected from 34 respondents from state Departments of Transportation and other similar agencies in 10 Canadian provinces.

The report by Milner and Shenton III (*2*) contains a comprehensive literature review of multiple prior studies and reports with summaries, key findings and conclusions from each source. This report is a great resource of past research done on bridge joints. This report also contains information on small movement bridge joints and survey results with data that are specific to small movement bridge joints (defined as less than two inches in the report).

Both resources are recommended for thorough information on bridge joint types, general performance issues and details, as well as fairly complete literature review of available resources. This information is therefore not repeated in this report. This report differs from previous reports in that it focuses on all bridge joint types (small and large movement), focuses on New England and surrounding states that experience similar weather and collects survey data from a wider group than previous surveys. The last point is important as it was found that responses vary widely between districts within state Departments of Transportation. Regional states' joints are subject to the typical problems experienced with bridge joints everywhere, but have the added element of issues involved with road salts/anti-icing materials and plow damage. The data and survey presented in this report address performance of joints types accommodating all ranges of expansion, and the issues of deterioration and maintenance with headers and joints specific to weather conditions experienced in and around New England.

1.2 Importance of Expansion Joints

Bridges are subject to thermal fluctuations that cause them to expand and contract with changing temperatures. In recent years, there has been a move towards constructing integral abutment bridges, or eliminating bridge joints in retrofits wherever possible. This shift in preferred design is in large part due to problems experienced with expansion joints, including damage from leaking/failed joints and the fact that joints require frequent maintenance to keep them functioning. While jointless bridges are a desirable alternative to conventional expansion joints, they are not always an option. Jointless bridges generally have skew limitations as well as expansion limitations; when these limitations are exceeded, expansion joints are needed. In addition, there are a large number of joints currently in use across the country and even if state Departments of Transportation decide to eliminate joints where possible, this process will take a long time, during which existing bridge joints need to function and perform as well as possible.

In conventional jointed bridges, as the superstructure expands and contracts, the movement is accommodated by expansion joints that allow these movements to occur without causing damage to the bridge. While the joints open and close with fluctuating temperatures, they also play a critical role of keeping water and salt from flowing onto the superstructure and channel it away from the bridge while also protecting the substructure components. An ideal joint would be able to perform these tasks seamlessly while causing minimal disturbance to drivers (i.e. sitting flush with the roadway and remaining quiet under vehicle traffic). However, when bridge joints are damaged they can lead to numerous problems including causing damage to other bridge elements, often leading to costly and time consuming repairs.

Keeping drains maintained and cleaned is important to prevent them from filling up with debris which inhibits them from performing the task for which they were designed. Similarly, washing out and cleaning joints is important to prevent the build-up of debris. When joints continuously fill up with debris, road salts/sands, and other materials, it not only prevents the joints from expanding/contracting correctly, but can result in tearing the joint material and/or corrosion which can both cause leakage. The leakage can prevent the joint from performing correctly and cause serious damage to the substructure which, if left un-treated, could threaten the integrity of the bridge itself.

1.2.1 Deterioration Resulting from Damaged Joints

When joints stop performing correctly and allow salt water and anti-icing products to pass through to the substructure, they can cause expensive and extensive damage to the steel and concrete below. Joint failure can be costly in regards to repairing or replacing the joint, but the cost can extend far beyond the joint itself if it fails to protect the superstructure and substructure elements. The images shown in this section come from MassDOT inspection reports. Figure 1 shows substructure damage under a leaking deck joint where there has been section loss and web crippling.

Figure 1: Section Loss and Web Crippling at Deck Joint

An example of superstructure damage is shown in Figure 2 where a leaking joint resulted in corrosion and other damage to the beam ends. A way to prevent leakage is to continue the deck over the backwall so that the joint does not leak here; beam end corrosion is a major issue from leaking joints. Figure 3 shows substructure damage where leaking joints lead to concrete damage beneath the bridge.

Figure 2: Section Loss, Rust Holes and Corrosion Cracks at Deck Joint

Figure 3: Substructure Damage to Concrete from Leaking Joint

A report compiling cost of corrosion to the United States in 1998 gives insight into direct and indirect costs of corrosion in infrastructure. At the time the information was compiled, over 87,000 (15%) of the 583,000 highway bridges in the United States were classified as structurally deficient as a result of corrosion. The annual direct cost of this damage was estimated to be $8.3 billion. Indirect costs, such as traffic delays and lost productivity, were estimated to be up to ten times greater than the direct costs (*3*). In 2012, further research was done demonstrating the extent of corrosion damage increasing with time; this research noted that not only the degree of damage increases with time, but the rate at which the damage occurs increases with time as well (*4*, p.3). Hence, the annual cost of corrosion from highway bridges has increased significantly since the data was collected in 1998. Proper installation and systematic maintenance of joints could dramatically reduce future bridge expenses.

1.3 Categories of Joint Types

There are two main classifications of bridge joints: open joints and closed joints. Open joints allow water to pass through them into a drainage system, typically a trough, that diverts the water away from the bridge. Closed joints are watertight joints that are designed to prevent any water from getting into the joint. Both joint types have associated issues. In open joints, the drainage troughs are known to fill with debris and become clogged, which can then allow salt water and anti-icing chemicals to overflow, reach substructure components of the bridge and cause damage. In closed joints, salt accelerates the corrosion of reinforced concrete and steel while anti-icing chemicals and debris deteriorate the joint. Traffic issues can also lead to rutting of joints and tearing of seals which then cause leakage to substructure components. When joints are damaged or have failed, they can either be repaired or replaced. In a joint repair, the existing joint remains in place and only the damaged component is fixed. In a joint replacement, the entire existing joint is removed, and may be replaced by a new joint of the same type or by a different type of joint.

The following sections will present a description of joint types that will be addressed in this report, including schematic images and examples of damaged or failing joints where applicable. The organization of joint descriptions will include all closed joints, followed by all open joints, and finally a separate category of a "jointless option" as an alternative to expansion joints that could replace the joints in a retrofit or be used in new construction. Joints in each category will be presented in order of increasing expansion accommodations.

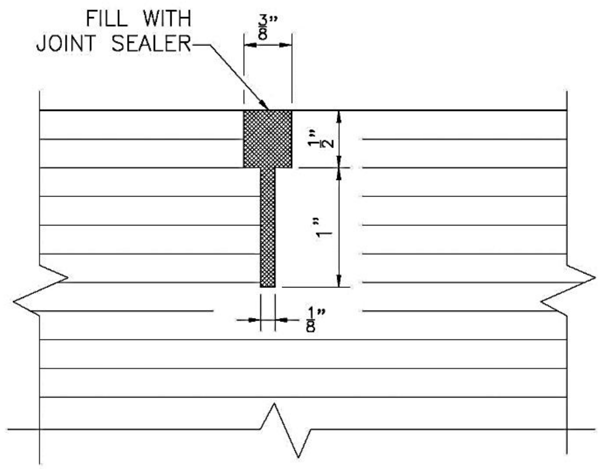
1.4 Description of Closed Joints

The following joint types are classified as closed joints. These joints are designed to prevent any water from getting through the joint.

1.4.1 Saw and Seal

Saw and seal joints are intended to accommodate small movements of up to ½". The joint details are fairly simple; a saw cut is created in the riding surface, and sealant is poured into the opening and allowed to cure. A schematic of the saw and seal joint is shown in Figure 4. They are designed using the saw cut detail for minimum to no movement from the bridge manual (*5*). The saw cut generally goes 2" into the deck/wearing surface. While saw and seal joints are low maintenance, the most important step during construction is to properly locate where the saw cut needs to be made. Otherwise, cracking occurs adjacent to the joint. One possible remedy is to mark the curb where the deck ends prior to putting down wearing surface so the installer knows where the joint should be. While specifically marking the curb is not in the item for sawing and sealing joints (*5*), the special provisions for this item emphasize that the contractor must accurately locate joints by referencing the existing joints before they are covered with hot mix asphalt overlay.

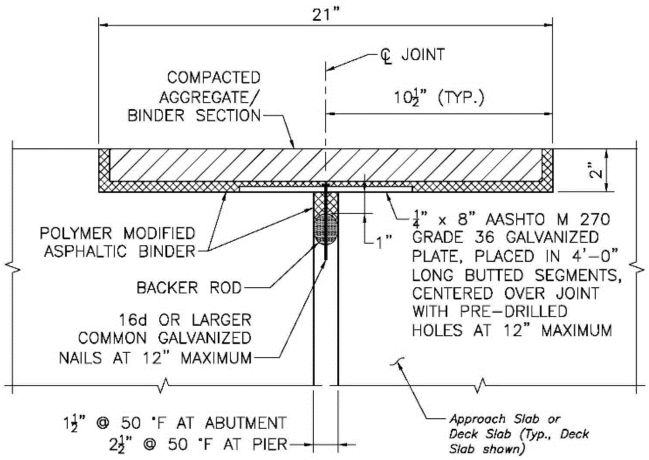
Figure 4: Schematic of Saw and Seal (5, Ch.4)



1.4.2 Asphalt Plug Joints

Asphalt plug joints are generally used for expansion 2” or less and for skew angles less than 30°. Manufacturers do not recommend asphalt plug joints for use under high traffic volume. The general details of asphalt plug joints include a backer rod under a block out connected to a steel gap plate that sits over the block-out (typically by galvanized nails 16d (3.5 inches) or larger). The block-out is then covered in binder and filled with the asphalt plug joint mix. The benefits of these joints include the ease of installation, low cost of installation, low cost of repair and low instance of snow plow damage. They can be installed segmentally so they are not as disruptive to traffic flow as other joint types that require entire installation at one time. There are also multiple problems associated with asphalt plug joints. They do not perform well where they meet curbs, barriers, or parapets because the backer rod is not easily maneuvered at up-turns and they end up with leakage at these locations. When used in heavy traffic, they experience rutting. Plow damage occurs when they heave and rise above grade. If installed in hot weather, the material can soften. There has been debonding at the interface of joint and pavement, and cracking in cold weather. An alternative to a conventional asphalt plug joint (referred to as a “modified asphalt plug joint”) has recently been used in some states. The modified asphalt plug joint uses EM-SEAL (which will be discussed in another section) underneath the asphalt to help create a more watertight joint. A typical asphalt plug joint is shown in Figure 5.

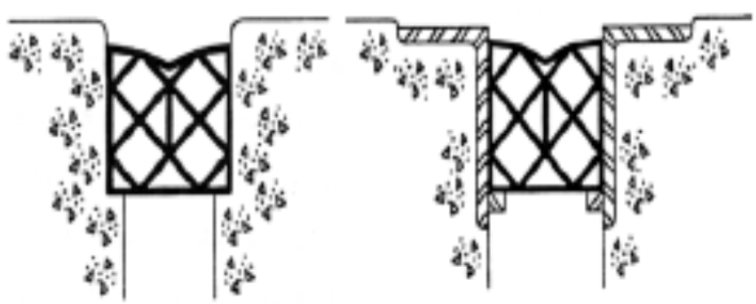
Figure 5: Asphalt Plug Joint Details (*5*, Ch.10)



1.4.3 Compression Seals

Compression seals can accommodate movement from 0.25” to 2.5”. They rely on continuous pre-formed neoprene elastomeric rectangular section that is installed by squeezing and inserting seal into joint opening. An illustration of a cross-section of an open cell compression seal is shown in Figure 6 which demonstrates that compression seals can be installed with or without metal facing. The seal must always stay in compression in order to remain in place and stay watertight.

Figure 6: Schematic of Compression Seal with and without Facing (*1*, p.11)



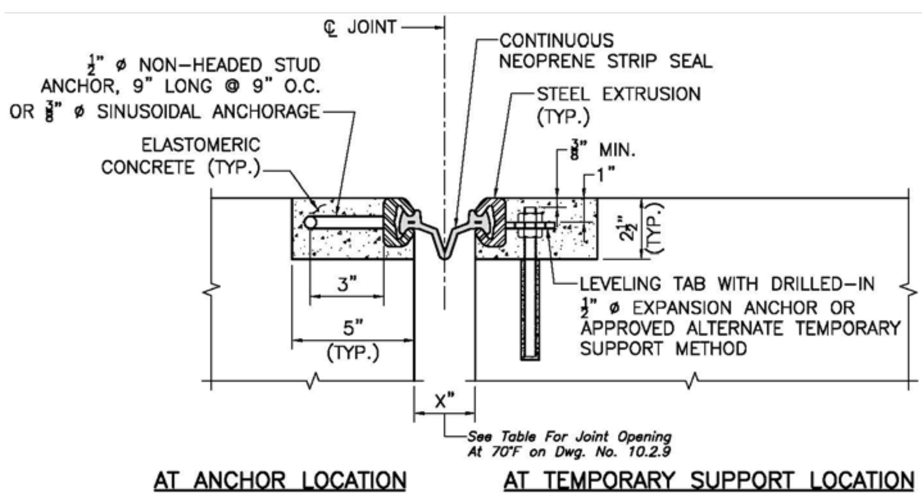
If the seal is improperly sized, or if the joint opening is not a uniform width, early failure can occur. Over time, compression seals have been reported to have decreased ability to stay in compression as a result of loss of resilience. This is even more prevalent if the movement is large. Compression seals should not be spliced. Compression seals can be made of closed cell foam or open cell foam. Figure 7 shows a failed compression seal from a MassDOT inspection report where 90% of the seal is displaced. The right side of the figure shows the picture of the same joint from below where the seal has fallen through and heavy debris build-up surrounds it.

Figure 7: Damaged Compression Seal

1.4.4 Strip Seals

Strip seals can accommodate up to 4” of movement, and can be used on skew angles greater than 30° as opposed to asphalt plug joints. The material of a typical neoprene strip seal is pre-molded into a V-shape that opens and closes with expansion and contraction of the joint. The neoprene is attached to metal facing on either side of the joint and anchored into the edges of the deck slabs. While strip seals are watertight when properly installed, can be used under high traffic volume, and can achieve service lives longer than other joint seals under ideal conditions, they are also subject to a number of issues. They are difficult to replace, as the seal should be completely replaced and not spliced. These joints also have issues where there are sharp changes in geometry. Strip seals experience plow damage often, and have occasionally pulled out of the metal facing. One of the most common problems is that non-compressible debris builds up in the expanded V-shape, and then under joint contraction the debris can tear the seal causing rupture and leakage to the substructure. Typical strip seal details are shown in Figure 8.

Figure 8: Strip Seal Details (*5*, Ch.10)



New installation of strip seals specifies the use with elastomeric concrete headers. A picture of the failure of a strip seal from a MassDOT inspection report is shown in Figure 9. The figure shows where debris has built up and the seal has torn through in some locations allowing water to leak through.

Figure 9: Damaged Strip Seal

1.4.5 EM-SEAL

EM-SEAL is a pre-compressed, watertight, tensionless silicone seal. EM-SEAL can be used in new joint construction, as a replacement for failed strip seals, as part of "modified asphalt joints", or in other instances where a typical seal joint is used. One of the main benefits of EM-SEAL is that it comes with pre-fabricated corner and transition pieces that can be easily maneuvered up and over curbs and parapets. This results in a continuous watertight seal that is nearly impossible to achieve with a typical backer rod. EM-SEAL comes supplied on a reel for sizes ½" to 1 ¼" and as a straight run stick for sizes 1 ½" to 4". In Figure 10, an EM-SEAL schematic is shown in typical concrete substrates (new or retrofit). Figure 11 shows the EM-SEAL being installed by MassDOT. The image also shows the vertical pieces that come for ease of maneuvering over changes in geometry.

Figure 10: Schematic of EM-SEAL(*6*)

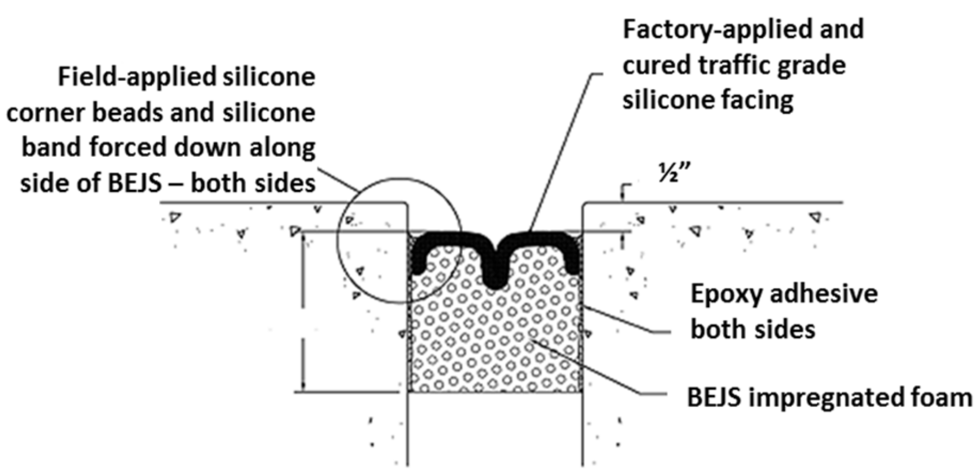
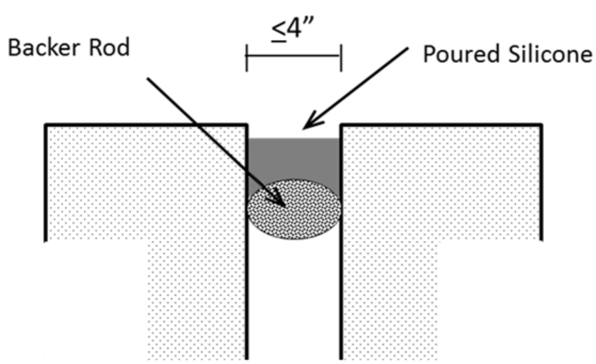


Figure 11: Installation of EM-SEAL on MassDOT Bridge

1.4.6 Pourable Seals

Pourable seals accommodate movement up to 4”. A simplified cross-section of a pourable seal is shown in Figure 12. Generally, silicone is used as a pourable sealant over a backer rod which prevents the sealant from flowing through the joint. Once the sealant molds to the joint opening, and bonds to the sides, it remains flexible and is able to expand and contract. Pourable seals are typically used with elastomeric headers. The joint edges should be clean and sound to ensure proper, tight, bonding.

Figure 12: Simplified Schematic of a Pourable Seal



One benefit of pourable seals is that the performance is not affected if the joint walls are not perfectly parallel since it will mold into the shape of the irregular opening. The joint is generally easy to repair since just a portion of the seal can be repaired if needed which also minimizes traffic impact. Problems include: de-bonding, splitting, and damage from debris build-up. A picture of a damaged pourable seal from a MassDOT inspection report is presented in Figure 13. The seal has debonded and is missing from many areas of the joint, and is now filled up with debris.

Figure 13: Damaged Pourable Seal

1.4.7 Modular Joints

Modular joints, like finger joints, are large movement expansion joints that can accommodate movements greater than 4”. Generally, modular joints are made up of multiple strip seals. The system consists of three main components: sealers, separator beams and support bars. The separator beams allow joining of strip seals in series, while the separator beams and sealers create a watertight joint (*1*, p.15). Modular joints are expensive to install, and can have multiple issues. They can experience fatigue cracking of welds, damage to seals, damage from plows, and once the seals are damaged they leak and cause damage to the substructure.

A schematic of a modular joint is presented in Figure 14. An image of a damaged modular joint from a MassDOT inspection report is presented in Figure 15. The inspection report noted that several support beams were cracked, loose, deflected upward (up to ½”) and the joints were excessively moving under live load. Some steel beams were also missing, and others were broken.

Figure 14: Schematic of Modular Joint (1, p.15)

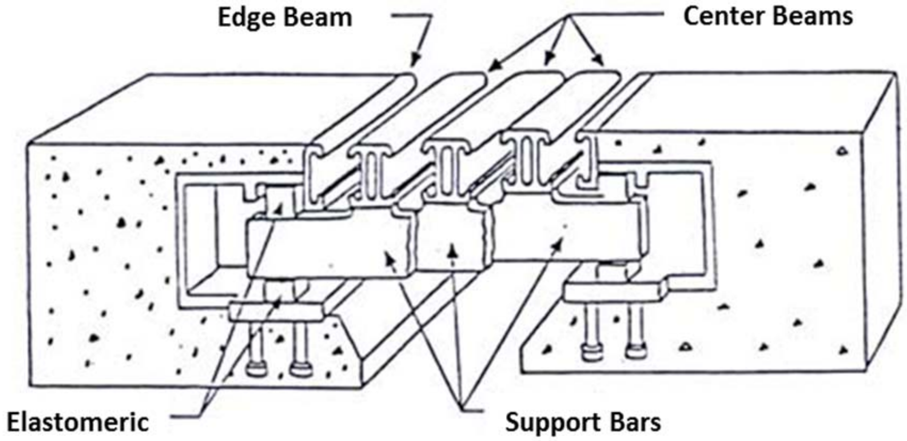


Figure 15: Damaged Modular Joint

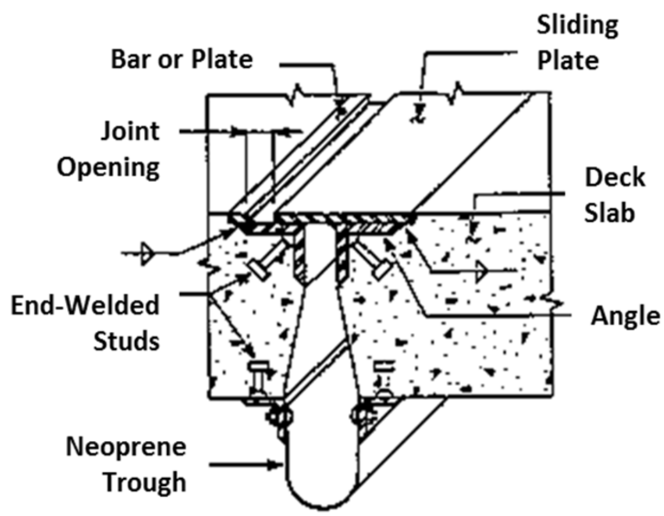
1.5 Description of Open Joints

The following joint types are classified as open joints; these joints allow water to pass through the joint into a drainage system beneath it that is designed to channel the water away from the bridge. While "open joints" are defined categorically, this term will be used in the following chapters to define a basic joint type. Open joints are simply headers with no seal or a joint where instead of replacing a seal that has fallen through it is left as an "open joint" over a backer-rod. The joints described in the following sections, which are categorically open joints, will be referred to by their joint name in proceeding chapters.

1.5.1 Sliding Plate Joints

Sliding plate joints are used to accommodate movement of 1-3". A simplified schematic is presented in Figure 16. In this joint, a steel plate is attached to one side of the joint and extends over the joint opening. The side of the plate that is unattached rests in a slot opposite the attached plate. The joint is anchored into the concrete with welded steel bolts or studs. Common failures include the plates loosening over time and becoming noisy under traffic. There can be loss of support and poor anchorage of the plates. At the slot end of the plate, build-up of debris can occur and pry the plate up over time. Plates and anchors are subject to plow damage. Anchors can corrode and fail from fatigue under traffic.

Figure 16: Simplified Schematic of Sliding Plate Joint (*1*, p.7)



1.5.2 Finger Joint

Finger joints accommodate movements greater than 4". They are classified as an open joint since the steel plate fingers that mesh together also move apart and allow water to pass through the joint, typically into a drainage trough. While finger joints typically have longer service lives than most joints, they also have numerous associated problems. Concrete around the joint tends to deteriorate, there can also be anchorage issues and fingers can bend upward when impacted by a plow. These issues can result in increased noise and a rough riding surface. Plows can also catch them and cause damage. The most problematic area of finger joints tends to be the drainage troughs. These troughs are the only barrier between water and the substructure and they are very difficult to maintain which leads to them building up with debris and failing, resulting in corrosion damage to substructure elements. A schematic of a finger joint is presented in Figure 17. An example of a finger joint that is not functioning correctly is presented in Figure 18. This picture was taken on a Massachusetts bridge where the joint is completely closed at 75°F (well below the maximum temperature in Massachusetts).

Figure 17: Schematic of Finger Joint (*1*, p.7)

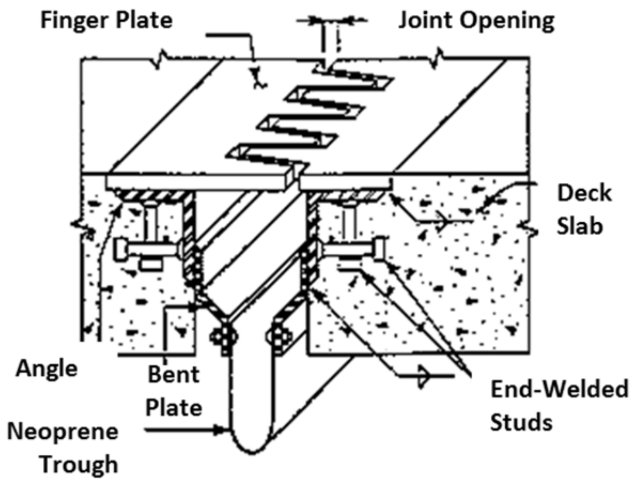


Figure 18: Finger Joint Completely Closed at 75°F

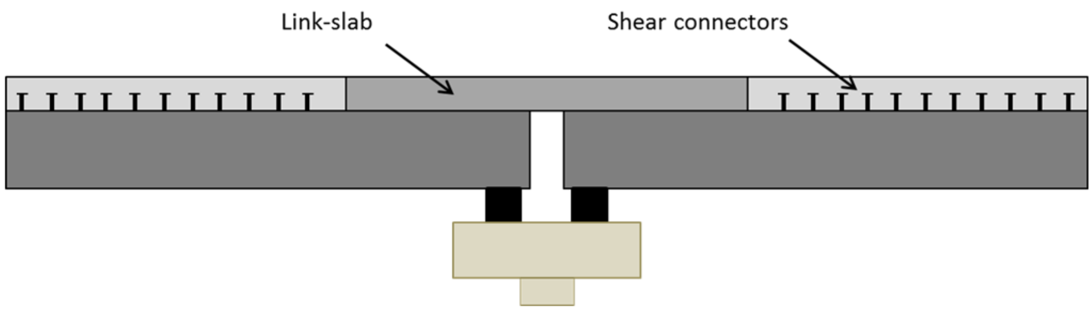
1.6 Description of a Jointless Option

A preference in new bridge construction is to minimize expansion joints wherever possible. There are varying options for jointless bridges. One option is to create an integral abutment bridge, where the girders are cast monolithically with the abutment and thermal movement is accommodated by the substructure. Most jointless options require complete bridge replacement. The following section details a straightforward method that can be used on existing jointed bridges to make them jointless.

1.6.1 Link-Slabs

Link slabs are generally created to connect simply supported spans over piers where each span is supported on elastomeric bearing without anchor bolts. While link-slabs are not necessarily an expansion “joint”, they are a good alternative to joints and can be used to replace joints in retrofits, and during deck replacement. The process of connecting the spans in a retrofit would include cutting back concrete to a specified distance to either side of where the girders are supported on their corresponding bearings. In most cases, the concrete decks are connected to the supporting girders by shear studs to make the superstructure composite. Conversely, where the link slab is installed the shear studs are ground down to allow for more freedom of movement over the connecting region. The concrete is cast between the two adjoining decks with reinforcing bars. It is ideal to spray a waterproof membrane on top to prevent water from getting through the small cracks that may occur. The reinforcement is designed to resist bending moment induced by end rotations under service live loads. A simplified schematic of a link-slab is shown in Figure 19.

Figure 19: Simplified Schematic of Link-Slab



1.7 Bridge Inventory and PONTIS Database

The first part of this research is focused on bridges in Massachusetts that use expansion joints to accommodate thermal movement, which will be referred to as “jointed bridges.” Some of the information presented in this report comes from the PONTIS database. MassDOT uses PONTIS to catalog bridge inventory which includes basic information about the bridges, inspection reports, condition ratings, and joint types. Massachusetts has a total of 5,062 bridges, over half of which are classified as jointed bridges. It is important to note that these jointed bridges are classified by PONTIS, which only classifies bridge joints in bridges greater than 20 ft. in length. Therefore, expansion joints for minimal movement such as saw and seal joints are not included in the PONTIS data presented in this report. These joint types will be addressed in other sections of the report as these joints are used on many bridges in Massachusetts.

Of the 5,062 bridges in Massachusetts, 2,814 bridges have joints categorized as element number 300-305. The rest of the bridge inventory is either saw and seal, jointless, or culvert with fill. The five joint classifications in PONTIS are as follows:

- **300:** Strip seals: This element defines only joints which utilize a neoprene waterproof gland with steel extrusion to anchor the gland
- **301:** Pourable seals: This element defines only joints filled with a pourable seal

- **302:** Compression seals: This element defines only joints filled with a pre-formed compression type seal
- **303:** Assembly (modular) joint/seal: This element defines only joints filled with an assembly mechanism that may or may not have a seal. This includes modular assemblies
- **304:** Open: This element defines only joints that are open and not sealed
- **305:** Other joint/seal: This element is used for sliding plate joints and asphalt plug joints

The PONTIS database was used to create spreadsheets containing information for a straightforward comparison of many bridge factors to joint types. These factors include the structure main type, the maximum span length, the structure length, the condition rating (of joint elements), and the bridge age. In order to obtain all data needed for these comparisons, some of the data (structure main type, maximum span length, structure length, and bridge age) were not included in the PONTIS inventory file. However, through the National Bridge Inventory (NBI) this information was obtained for the jointed bridges in the PONTIS database, and was added to the spreadsheet by cross-referencing the bridge structure numbers. For bridge age, the year built (or reconstructed) was subtracted from the year 2015. This information was compiled in spreadsheets with bridges specific to each of the six districts, as well as a summary sheet with all of Massachusetts information, and was provided to MassDOT personnel.

1.8 Overview of Districts

MassDOT is divided into six districts. Each district number and their corresponding territory are presented in Figure 20. The headquarters of the district offices are located in Lenox (District 1), Northampton (District 2), Worcester (District 3), Arlington (District 4), Taunton (District 5), and Boston (District 6). Table 1 shows the distribution of bridges in each district, which includes the total number of bridges and the number of those bridges that have bridge joints classified in PONTIS. This table also shows how many of the total bridges are owned by MassDOT (as opposed to municipal bridges). In November, 2009 ownership of all bridges owned by the Department of Conservation and Recreation (except for pedestrian bridges) was transferred to MassDOT; therefore, these bridges are included in the total.

Figure 20: Districts of MassDOT

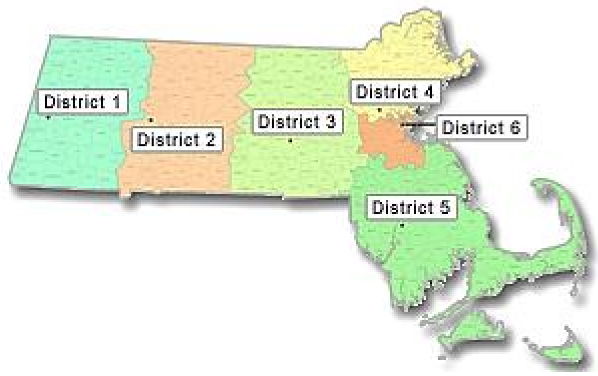


Table 1: Distribution of Bridges in MassDOT Districts

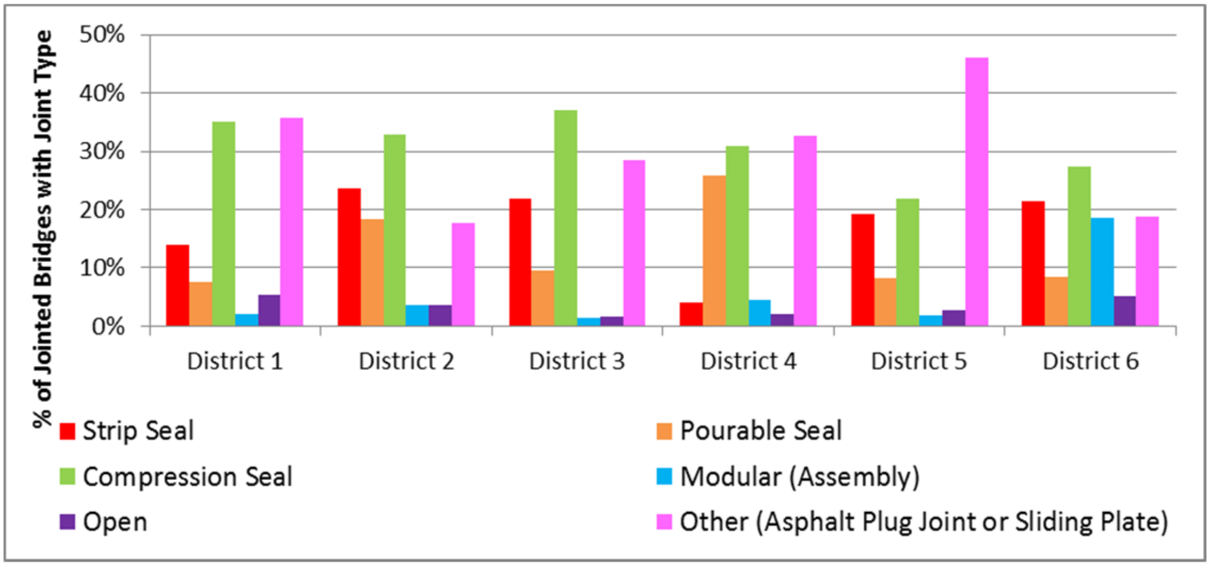
No. of Bridges	District Number						TOTAL	TOTAL OWNED BY MASSDOT
	1	2	3	4	5	6		
Total	703	834	1158	827	858	682	5062	3474
"Jointed Bridges"	185	413	624	558	455	579	2814	2557

When there is new construction, bridge joints are restricted to those in the Bridge Design Manual (*5*). For joint repair, the individual districts handle repair choices internally; and are not held to the same restrictions as joint options for new construction. When re-decking is performed, the design decisions could be done in-house or by consultants, depending on the district. At least one district has a designated "bridge group." The source documents of special provisions originate from the Boston headquarters, but districts can add their own unique specifications to supplement these.

There is no maintenance manual for Massachusetts, and maintenance decisions are left to the individual districts. While each district receives a portion of the allotted federal money to be used towards bridges, the districts choose where this money would be spent in their district. Additionally, using the federal money requires specifying each job that the money will be used for and therefore the districts noted that it would not be feasible to use the money on general "maintenance." Any maintenance practices employed by a district would come out of the districts funds; given limited resources, none of the districts have an existing maintenance policy. There are no preservation specifications in Massachusetts. One district pointed out that this is the biggest issue affecting joint performance.

Each of the individual districts has unique needs based on many factors in their district. Districts have different construction time restraints, traffic volume, types of roads, etc. which dictate what joint types they use and what construction methods are available. As a result, joint preferences, as well as joint performance, vary from district to district. A breakdown of the joint types, per PONTIS classification, per district is presented in Figure 21.

Figure 21: Percent of Jointed Bridges with Each PONTIS Joint Type



A map of the major roadways in Massachusetts is presented in Figure 22. Table 2 shows the distribution of turnpike bridges as well as other major interstate bridges for each of the districts in Massachusetts.

Figure 22: Major Roadways in Massachusetts (MassDOT)

Table 2: Distribution of Turnpike and Interstate Bridges in Districts

<table>
<tr><th colspan="2" rowspan="2">No. of Bridges</th><th colspan="6">District Number</th><th rowspan="2">TOTAL</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><td rowspan="2">I-90 (Turnpike)</td><td>All Bridges</td><td>39</td><td>73</td><td>93</td><td>0</td><td>0</td><td>51</td><td>256</td></tr>
<tr><td>"Jointed Bridges"</td><td>35</td><td>65</td><td>77</td><td>0</td><td>0</td><td>36</td><td>213</td></tr>
<tr><td rowspan="3">Major Interstates</td><td>All Bridges</td><td>0</td><td>131</td><td>240</td><td>198</td><td>136</td><td>187</td><td>892</td></tr>
<tr><td>"Jointed Bridges"</td><td>0</td><td>131</td><td>227</td><td>183</td><td>123</td><td>187</td><td rowspan="2">851</td></tr>
<tr><td>Interstate #</td><td>N/A</td><td>91, 291, 391</td><td>84, 190, 290, 395, 495</td><td>93, 95, 495</td><td>95, 195, 295, 495</td><td>93, 95</td></tr>
</table>

District 1 is located at the western end of Massachusetts. This area has the most short-span bridges of any district, of which many use saw and seal joints but are not in PONTIS because of their short spans. This is why the 185 “jointed bridges” for District 1 appears to be far less than any other district. District 1 also has significantly lower traffic volume than the other districts. This lower traffic volume allows them to do lane closures for repairs, have extra time for installations, and they do not face the same time constraints as other districts. This district has some of the Massachusetts Turnpike (Turnpike) bridges, as shown in Table 2.

District 2 is also located in western Massachusetts, with 413 jointed bridges within the district. This district has many medium to shorter span bridges, with the majority of bridges being less than 200 ft. in total length. This district also has some turnpike bridges, as well as some bridges on Interstates 91, 291 and 391.

District 3 has many Turnpike bridges, with 624 total jointed bridges. The majority of bridges in this district have a total length ranging from 60 ft to 200 ft. District 3 has some bridges on Interstates 84, 190, 290, 395, and 495.

District 4 has 558 jointed bridges, the majority of which (similarly to District 3) range from 60 ft to 200 ft. District 4 does not have Turnpike bridges, but has some on Interstates 93, 95, and 495.

District 5 has 455 jointed bridges. However, many of the bridges in this district are on limited access highways (including Rt.3) with high traffic volumes. District 5 does not have Turnpike bridges, but has some on Interstates 95, 195, 295. and 495. The high traffic volumes result in shortened construction time availability, which in turn limits the joint types and materials they are generally able to use. Unless the bridge work is classified as “new construction”, any repairs or replacements on any bridges in these high traffic volume areas must be completed between 8pm and 5am Monday through Friday. Additionally, there are seasonal restrictions for Cape Cod where no work can be done between Memorial Day and Labor Day.

District 6 is the Boston district which has turnpike bridges, some on Interstates 95 and 93 and city bridges, with a total of 579 jointed bridges. Essentially all bridges in this district are subject to extremely high traffic volumes and strict time constraints for completing bridge work. Any bridge joint repairs or replacements must be completed in the 8pm-5am time period, which limits joint options.

For all districts except for District 5, part of the districts responsibility is the Massachusetts Turnpike bridges. The Turnpike is unique in that the wearing surface is significantly thinner than any other roadways in Massachusetts. This thin wearing surface limits joint options because many call for a wearing surface thicker than that of the Turnpike. Furthermore, bridge joints tend to deteriorate and fail sooner as a result of both the thin wearing surface and high traffic volume.

All districts inspect town-owned bridges as well as the state-owned bridges, with the majority of inspections being done in-house. Large or complex bridges that take multiple days to inspect are contracted out to consultants. For town-owned bridges, the condition tends to be slightly better due to the lower traffic volume. Although the districts inspect the town bridges, they are not in charge of maintaining them or repairing them.

2.0 Massachusetts Joints and Headers

Information was collected from Massachusetts by attending meetings with each of the six districts and discussing their joint and header practices. After each of these meetings, the districts also completed the survey that was created and sent to other state Departments of Transportation. This chapter will present all of the information collected from Massachusetts from both the individual meetings and survey responses.

2.1 Joints

2.1.1 Saw and Seal

Five of the six districts have saw and seal joints currently in service, and four districts report using them in new construction. The majority of districts also use this joint type as a replacement joint both for overnight construction and when there is no time constraint. Saw and seal joints are believed to perform adequately with routine repair and maintenance, and the reported service life ranges between districts with some reporting 5-12 years, and one reporting more than 16 years. No districts plan on phasing these joints out. It was noted that these have been used to replace existing joints that were oversized for the actual movement experienced by the bridge.

Saw and seal joints are used for very short span bridges, accommodating movement of ¼” to ½”, and they are not designated as a joint in the PONTIS database. While there is not a joint classification for saw and seal joints, it is unclear as to whether some inspectors would put them in the “305: Other” category if the saw and seal replaces another joint type. Many districts use them over fixed joints at the abutments or over piers with fixed bearings on both sides.

The benefits of saw and seal joints are that they are easy to maintain and provide a smooth driving experience. The majority of districts classify the performance of these joints as very successful when used as deck over backwall detail, and slightly less successful when used over existing joints.

Some problems with the saw and seal joint can come from the contractor inaccurately locating the joint location, such as the ends of beams on a skew. This may be due to the contractor and field engineer perception that location on these small joints is not critical. However, incorrect location of the joint leads to leakage when a secondary crack occurs at the location of rigidity where the saw should have been placed. Using saw and seal joints on the Massachusetts Turnpike has been a problem, as with other joints which require 2-3” of overlay; the Massachusetts Turnpike only has 1 ½” wearing surface and this thin surface leads to early failure.

Some steps that could be taken to improve the performance of saw and seal joints are to mark the curb where the deck ends before placing the wearing surface so that the joint location can still be clearly seen (District 1). While this is not stated in the item for “sawing and sealing joints in asphalt at bridges,” it is the contractor’s responsibility to install the proposed joint at the proper location. Typically, when these joints are installed everything is excavated and exposed and locating the deck end is a straightforward task with no additional cost. However, sometimes this task is so simple that it is overlooked and the contractor ends up guessing where the deck end is after the paving is done (District 1).

Another critical piece of the saw and seal joint that is often not perceived as important is placement of the bond breaker tape; this detail is often skipped on site during installation. Bond breaker tape allows free expansion and contraction of the joint sealant with fluctuating temperatures. When the bond breaker tape is skipped the sealant can bond to the wrong areas of the joint, which can result in tearing or stretching to the point of failure.

Overall, saw and seal joints have been successful for very small movements, and with close attention to specifications and construction details can provide very good performance.

2.1.2 Asphalt Plug Joints

Asphalt plug joints are currently in use in all districts, and are being used for new construction. They are also being used as replacement joints with the majority of districts using them as an option in all situations. The asphalt plug material can set quickly enough to use in overnight construction. While almost all districts agree that asphalt plug joints could perform well if routine maintenance and repair was performed, the service life reported for them varies throughout Massachusetts. Three of the seven respondents (43%) believed asphalt plug joints have a typical service life of five to eight years, followed by two respondents (29%) noting the service life to be zero to four years, one respondent (14%) choosing nine to 12 years, and one choosing 13-16 years. This wide range of typical service life is likely due in part to what the individual defines as failure of the joint. Satisfaction or lack thereof, with asphalt plug joints tends to depend heavily on the expectation of service life for joints and perceptions of acceptable levels of deterioration before replacement. Both of these factors also rely heavily on traffic volume and detailing.

Asphalt plug joints are generally used to accommodate movement of ½” to 1 ½” (District 4 will use them for up to 2”), with bridge skews less than 30°. Three districts provided a typical thickness of asphalt plug joints. District 2 and District 3 reported a minimum thickness of 2”, while District 1 reported using a thickness of at least 2 ½” to 3”. A few of the districts have started using “modified asphalt plug joints” by incorporating EM-SEAL into the joint and then covering the EM-SEAL with asphalt to create the asphalt plug joint. Asphalt plug joint details at parapet or barrier can be difficult due to vertical projection over curb. EM-SEAL comes with vertical pieces to help solve this problem and create a watertight seal (better than typical backer rod detail which is difficult to maneuver up and over curb). So far, the districts that have tried using the modified asphalt plug joints have been happy with the performance and have not had problems, though this is still a fairly new practice.

District 5 is currently trying to phase out asphalt plug joints due to the poor performance with the asphalt surface course above the joint, and instead use strip seals with elastomeric headers. In this district, asphalt plug joints will no longer be used as replacement joints and moving forward they will be replaced with other joint types. District 6 is also unhappy with the performance of asphalt plug joints saying that they are not a preferable joint. This district did note that the poor performance may be, in part, due to the use of Duracel quick-set concrete headers with the joint. These districts have both noted that they are limited in time for joint work and almost all work needs to be done between 8 pm and 5 am, which limits the ability to use normal setting concrete and the amount of preparation time. These districts also have a significant amount of high traffic volume, a condition under which asphalt plug joints are reported to perform poorly.

The majority of districts state that asphalt plug joints do not perform well in high traffic volume roads, and note that the manufacturers often state that they are not recommended for use with high traffic volume. Asphalt plug joints also don't perform well with skewed bridges. They are not used for skews greater than 30° but can also experience problems with lower skew angles. On the Massachusetts Turnpike, the wearing surface is thinner than other roadways which limits the thickness of joints that can be used; while asphalt plug joints should have a minimum thickness of 2", asphalt plug joints have to be installed with 1 ¾" thickness which has been noted to result in early failure (along with the high traffic volume). Mix type has also been noted to impact asphalt plug joints; it was suggested that change in mix compositing causes poor performance.

Typical failure modes of asphalt plug joints include rutting, heaving, tire damage where the tires shove the joint out over time, cracking, and dislodged sections coming out of the joint. If there is too much movement, cohesion induced cracks can form through the middle of the joint. Districts noted different definitions of "failure" of the joint; some reporting failure at the onset of rutting, while others state that the joint is only considered failed once binder is lost and water begins leaking through the joint.

The majority of districts agree that when asphalt plug joints are first installed, they have great ride-ability and a smooth transition over joint. They are also generally easy to repair since they can be repaired segmentally. The general consensus of the districts is that quality control of asphalt plug joints during preparation and installation is critical to their success, and this is an area that needs improvement. This includes proper preparation before joint installation, including sandblasting and cleaning of the cut prior to joint placement. Neglecting this step can significantly decrease the service life and overall performance of the joint. Some districts have noted variability in the materials used in asphalt plug joints and suspect that specific materials or mixing practices affect performance. District 3 has added specifications that eliminate contractor interaction with the component materials by requiring pre-mixed bagged materials and use a qualified installer; since these specifications have been implemented the quality of the joints has improved.

Overall, the majority of districts agree that asphaltic plug joints require routine maintenance due to their shorter design life and that current funding levels make this difficult. Additionally, District 5 states that a lack of preservation specifications is a major problem. It was noted by several districts that quality control would improve performance, as well as research to develop a more resilient/flexible material. Improper installation is thought to be a leading source of failure in asphalt plug joints which could be improved with better training of inspectors and whoever the district sends to oversee the installation. Problems with installation, reported by the districts, include: improper setting of plate, backer rod not being installed over curb correctly, lack of proper cleaning after cut is made and wrong box-out dimensions. Successes in preventing leakage, especially at the detail over the curb and parapet, have been seen with modified asphalt plug joints using EM-SEAL. Asphalt plug joints are not recommended to be used with high traffic volume, or high skew angles (maximum 30°).

2.1.3 Compression Seals

Compression seals are currently in service in all districts, but only two districts reported using compression seals in new construction. They are also being used by a few districts as replacement joints for existing compression seals, both for overnight construction and when there are no time constraints. Five of the six districts reported that if routine repair and maintenance were performed, compression seals would perform adequately. The typical service life varies between districts with District 1 reporting five to eight years, District 4 reporting nine to twelve years, and Districts 2, 5 and 6 reporting thirteen to sixteen years. Almost all districts have started phasing out the use of compression joints, or would like to phase them out moving forward.

Compression seals generally perform decently when they are first installed. District 6 noted that the steel armoring with compression seals usually gets damaged by plows and since the armored headers are difficult to repair, they usually remove the entire compression seal joint resulting in an open joint until a full repair can be completed. One of the problems with compression seals is that the neoprene seals suffer from compression set (the loss of ability to self-expand after cyclic loading) and tear/fall out as a result. Districts have reported compression seals failing at attachment with bonding noted as the main problem with this joint type. One district stated that a new type of foam compression seal bonds to sidewall well, and has had good performance so far.

Overall, districts are choosing to replace compression seals with other joint types. Some districts have replaced compression seals with EM-SEAL, noting that if the steel armor is in good shape it is straightforward to install EM-SEAL and can be done quickly. Another retrofit method is to take out steel armor, replace with new concrete headers and a poured silicone seal with bituminous overlay. Some districts noted using saw and seal joints to replace failed compression joints, where District 6 noted that they replace the compression joint then do a saw cut overlay. It was also stated that Closed Cell Foam is not suitable and is likely to fall out, so compression seals should be made of neoprene. The wide range of materials that have been classified as compression seals over the years makes it difficult to distinguish performance problems specific to the joint type versus material used.

2.1.4 Strip Seals

Strip seals are currently in service in all districts, and five of the six districts are using them in new construction. All districts are using them as replacement joints when there are no time constraints on construction and four of the six districts use them as replacement joints when overnight construction is needed. Of all the joint types, the strip seal is the only joint type that all six districts listed as performing well when routine repair and maintenance is performed. The service life reported for strip seals range from five to eight years to greater than sixteen years, with the majority of districts reporting between nine and sixteen years. The performance of strip seals is rated as fairly successful by all districts. Only District 4 reported that they would like to phase out strip seals moving forward.

Strip seals are used to accommodate movement of up to 4”, and can be used for 1½” to 4” if skew is greater than 30°. Strip seals, unlike asphalt plug joints, are approved for high skew angles. Therefore, strip seals may be used for smaller expansion needs in a place where an asphalt plug joint would typically be used if the skew exceeds the 30° limitation that asphalt plug joints are limited to. Strip seal joints have broad application, being used for longer spans, skewed bridges and high traffic volume areas.

Strip seals have been used to replace compression seals and pourable seals in some districts. One district stated that while strip seals are a little more expensive than pourable seals (approximately $350/linear ft. for strip seal installation, everything included, while pourable seals are approximately $300/linear ft.), the strip seals are more durable so they tend to be worth the extra cost and time to install. If an existing strip seal joint is being replaced and the headers are still in good condition, the strip seal can be installed within the existing headers.

Strip seals can be used with armored headers, elastomeric headers, or normal setting concrete headers. The headers of strip seals have impacted the performance, with districts noting problems with the various types of headers and how they affect the joints. District 2 noted that elastomeric headers have issues when used with joint replacements if the substrate is in poor condition and unsound concrete is not completely removed, but these headers can work well in new construction. District 1 stated that they have had numerous issues with elastomeric headers performing poorly and falling apart shortly after installation, so they have switched to 4000 psi concrete headers. District 6 has experimented with using open cell foam with the strip seal and so far it has been a success. Some districts noted that anchorage is not great for elastomeric headers; they rely heavily on bonding and when substrate is in poor condition or if improperly installed then the headers debond.

There are some problems associated with strip seals. Replacing strip seals is not a quick process because the seal cannot be spliced, which requires the whole seal to be replaced at once. Failure of seals and missing seals were reported. Debris and sand can build up on seal, tearing the seal and causing damage over time if not cleaned.

Overall, the consensus from all districts is that strip seals perform very well even with minimal maintenance. The details for strip seal installation are simple, and districts stated that the current specifications are sufficient, but that implementation of the specifications could be improved. One of the areas that needs improvement is preparation before installing the joint; this is true for many joint types, where improper cleaning prior to installation and not following all manufacturer specifications leads to problems. If strip seals were properly maintained and construction followed the specifications closely it is believed that the joint could last approximately 20 years.

2.1.5 EM-SEAL

EM-SEAL is currently being used in four districts, while no districts are using them as an option for new construction (EM-SEAL is not a joint option in the bridge design manual for Massachusetts). Two districts report using them for joint replacements. Another use of EM-SEAL is being applied in tandem with other joint types such as the Modified Asphalt Plug Joint. The service life is still not known since these are fairly new joints. The consensus of the performance of EM-SEAL is that with routine repair and maintenance, this joint type is close to an absolute success. This product is still fairly new in comparison to the other joint types in Massachusetts, so time will be the ultimate test for its performance, but so far the feedback of its performance has been positive.

There are many benefits of EM-SEAL. The joint is watertight and although it is still a fairly new joint type, districts report that EM-SEAL in service for four years still shows no leaking. EM-SEAL has been used to replace many joint types such as silicone seals, compression seals, and plug joints. When armored headers are in good condition, they can be left in place with EM-SEAL replacing the damaged joint. Perhaps the biggest benefit of EM-SEAL is that it comes with transition pieces, which allows for easily constructing the joint up and over curbs and parapets while maintaining a watertight seal, something that has proven difficult when using backer-rods in joint construction.

EM-SEAL is described as a simplified method to keep joints watertight, especially around the curb. It has had successful performance on limited access highways, demonstrating that it can stand up to high traffic volume. Across the districts it is described as a preferable joint. While still being a fairly new joint, EM-SEAL's performance has been promising.

2.1.6 Pourable Seals

Pourable seals are currently in service in four of the six districts; however, they are not used in new construction. District 1 uses pourable seals as a replacement when overnight construction is required, District 2 uses them as a replacement when there is no time constraint, and District 5 uses them in both instances. Half of the districts report that if routine repair and maintenance are performed then pourable seals would perform adequately. Only three districts reported a typical service life of pourable seals, with all of them selecting the shortest service life of zero to four.

Pourable seals are economical and quick to install and therefore good for short term fixes. However, the problems seem to outweigh the benefits. Some problems with pourable seals include adherence issues, holes and tears in the joint seal, low durability and problems with backer rods. Many of these problems appear to be related to installation and inspection issues so performance may be significantly improved with proper training. Problems noted during construction include use of improper backer rod diameter, inconsistent depth of backer rod along the joint and material being installed too thinly. Once installed, debris can build up and push the sealant and backer rod through the joint creating an open joint. Districts are moving away from pourable seals, noting that they are perceived to be more vulnerable than other joint types.

2.1.7 Modular Joints

Modular joints are currently in service in five of the six districts, and half of the districts are using them in new construction. District 1 does not have any modular joints, and they are also a district with many short-span bridges where there is not a high demand for joints that can accommodate large expansions. District 2 reported that they would like to phase modular joints out in the future, however they have not been able to do this yet because there is not currently a better alternative to accommodate the large movement demands. Finger joints are the alternative for large movement demands, but they are unhappy with the performance of these joints as well.

The majority of districts state that when routine repair and maintenance is performed, these joints perform adequately, with the expected service life ranging from thirteen years to greater than sixteen years. There is a modular joint in District 4 that has been in service since the late 1970's and is still performing well. The overall performance of modular joints varies between districts from average to highly successful.

There are a few problems described with modular joints. One district states that support bars can be a problem with support pins eventually falling out and leading to failure. If the joints are not regularly cleaned, debris builds up and causes problems. In some cases, where the salt builds up in the joint, it can thicken into a cake-like substance and would need to be brushed to loosen debris before washing.

While modular joints have some problems, it is difficult for districts to stop using them at this time. Districts report that modular joints and finger joints are typically the only options for large expansion needs, so with no alternatives they have to use one or the other.

2.1.8 Sliding Plate Joints

Sliding plate joints are currently in use in all districts, but only one district uses them in new construction. Half of the districts state that sliding plate joints would perform adequately if routine repair and maintenance were performed. Of the districts that reported an average service life of these joints, most stated thirteen to sixteen years, while one district stated greater than sixteen years.

Four districts would like to phase out or have phased out sliding plate joints. Districts generally believe that sliding plate joints are difficult to repair and are very susceptible to plow damage. Accordingly, over the years they are being phased out rather than repaired. The reported performance of these joints is highly variable throughout the state, with three districts reporting that they are close to an absolute failure, and two districts reporting that they are an absolute success. When these districts defined success of a joint, the three that rated the sliding plate joint close to an absolute failure all defined success as including watertightness. The two districts rating the joint an absolute success put the emphasis of a successful joint in a long service life, while one of the two also mentioned preventing water from passing through but only as a secondary factor of success. These ratings show that joint preferences vary throughout the state based on what each district wants in a successful joint.

2.1.9 Finger Joints

Finger joints are currently in service in five of the six districts. District 4 and District 2 report using them in new construction; however, District 2 did state that they would like to phase them out and are only using them because they do not have a better option to accommodate large movements. Finger joints could be used as replacement joints if there were no time constraints, however, they would be difficult to replace in the short term. Four of the districts report that finger joints perform well if routine repair and maintenance were performed; all districts state that the expected service life of these joints range from thirteen years to greater than sixteen years. The consensus of the performance of finger joints varies, with two districts reporting they are highly successful and two districts rating their performance on the lower end of the spectrum.

Finger joints are used to accommodate large expansion movements. One district reported that these used to be the large expansion joint of choice, but they have since moved to modular joints. Some finger joints that were installed in the 1960's are still holding up. However, the main problem with these joints seems to stem from the lack of maintenance. These are expensive joints to replace, so proper maintenance would be cost effective in the long term.

When the troughs under the finger joints are not regularly cleaned they can get clogged, which can lead to failure. In one case, a failed trough caused leakage to the girder underneath and resulted in an extremely costly repair of the girder. One district has started using fiber reinforced polymer (FRP) troughs in place of metal troughs, which they say will last a lot longer but are also more expensive. These FRP troughs could also be used to replace traditional neoprene troughs. Most districts try to get the troughs cleaned out at least every two years to keep them maintained, and some districts say if the inspector notes that they are in bad condition they will try to get them cleaned sooner. District 6 noted that the lower levels of multi-level bridges do not see much rainfall. Therefore, the troughs don't get cleaned out by rainwater flowing through them and tend to build up debris. For this reason, cleaning the troughs on lower decks should be done much more often.

Overall, finger joints can be expected to have a long service life compared to most other joint types, but they need to be maintained in order to keep them in service and functioning correctly. Removing these joints for replacement takes a lot of money and time, and damage to troughs can lead to damage of other elements of the superstructure. It is therefore important to routinely clean the debris from them and maintain the joint to avoid other expenses.

2.1.10 Open Joints

Basic open joints (either headers with no joint or headers where the joint has come through and only a backer rod or something similar remains) are currently in service in three of the six districts. No districts are using open joints in new construction, and no districts are using them as a repair joint. Districts report unfavorable performance of these joints, even with routine maintenance and repair. Most districts have already phased them out, or would like to phase them out in the future. When ranking the performance of open joints on a scale of absolute failure to absolute success, three districts ranked them an absolute failure while two districts ranked them neutral. District 6 did note that a go-to repair, in the past, has been to create an open joint, which was a quick fix in a district that requires extremely timely repairs. Nevertheless, it does appear that all districts have decided that the performance of open joints is not worthy of keeping them in their inventory, even if they provide a quick fix.

2.1.11 Link-Slabs

Link-slabs are currently in service in all districts. The majority of districts are using them in new construction, and all districts use them as an option for replacing existing joints with this jointless alternative where possible. Five of the six districts report that link-slabs perform well if routine repair and maintenance is performed. The average service life of link-slabs ranges from 13 to greater than 16 years, with the majority of districts reporting greater than 16 years. In ranking the performance of link-slabs, the consensus is that the performance of this joint type is highly successful.

Link-slabs have typically been used in fixed-fixed locations (between bearings that allow rotation but do not allow lateral or transverse translation), but can also be used with neoprene bearings. They have been used for retrofit of deck sections or complete re-decking. If there is an open joint and a fixed-fixed bearing (or neoprene), a link-slab can be created by putting in a continuous deck with rebar. The design manual has a simplified design for link-slabs, with design tables provided.

One factor preventing districts from using link-slabs is the cost. District 1 stated that they would prefer to use them wherever possible if they had the money to do it; they also noted that they used a link-slab in a retrofit in 1999 to eliminate a pier joint and it has been performing well with no issues. Another problem is that in districts where construction has to be done extremely quickly to avoid lane closures, link-slabs are not a practical option. When link-slabs can be used as an option, districts agree that they are a desirable choice to accommodate expansion needs and have been extremely successful from a maintenance point of view.

2.2 Headers

Armored headers, normal set concrete headers, and elastomeric concrete headers are types of joint headers that have been used in all districts. Five of the six districts have also used quick setting concrete. The only district that does not use quick setting concrete is District 1, which does not have high traffic volume and time constraints that the other districts face. Currently, three districts still use armored headers in some cases, all districts use normal set concrete and elastomeric concrete, and quick setting concrete is still used by the five districts with high traffic volume. Elastomeric concrete is specified as the standard to be used with strip seals (5). Header type for other joints can vary slightly between districts where the decision can be based on both district preference as well as time and weather factors.

Construction issues (including improper preparation work), weather at time of installation, snow plows, and quality control are all factors that can impact header performance. One example of improper preparation was referenced when discussing elastomeric headers installed in replacement projects; if substrate is saturated in chloride it can corrode reinforcing bars and result in spalling and joint failure. When replacing headers, a saw cut is recommended to be made two feet to either side of the joint and then remove the concrete until sound concrete is reached. However, the definition of "sound" concrete is subjective, with districts noting that concrete removal is often insufficient, resulting in poor substrate conditions. Improper preparation can also lead to bond issues. When debond occurs, debris can build up and tear at the joint. Another construction issue noted by District 4 is that it is very difficult to get good concrete consolidation and to completely fill the voids, especially under the horizontal leg of the embedded steel angles. Weather conditions can affect bonding of header and setting of concrete; manufacturers typically provide specific weather conditions for installation and if these are not met then early failure can occur. Plows hitting headers is an issue especially with armored headers, where the plow can hit the steel plate and pull it out. Finally, quality control can impact header performance. The quality of headers mixed on site can be affected if specifications are not followed closely.

Armored headers that currently exist in districts are generally left in place if in good condition and just the seal of the joint will be replaced (with EM-SEAL, compression seal, etc.). However, armored joints have had many issues resulting from plow damage, which rips them out and/or causes them to protrude from the surface of the road. The risk of plow damage is increased where armored headers are used on skewed bridges; as the skew of the bridge gets closer to the angle of the plow, there is more surface area of the joint that is likely to be caught by the plow. When armored headers start becoming dislodged from impact of plows and traffic, they become noisy for drivers as they move up and down as cars drive over. Due to the plow damage, difficulty to repair quickly, and banging of these headers (when anchorage gets pulled out or failed and plates move loudly under traffic), they are not a preferred header type. Armored headers are not typically repaired because repairs tend to not remain watertight and leakage occurs where welds break; districts will tend to wait until there are funds to completely replace the armored headers with another joint type.

Normal set concrete is a header option for all six districts when there are no time constraints for construction. District 1 reported having bad experiences with elastomeric headers and therefore has changed to using 4000 psi (3/8" thick) concrete for headers instead. This district does not have high traffic volume so they are able to use normal set concrete with more flexibility in time and lane closures and they do not use quick setting concrete. These normal setting concrete headers have only been in place one to two years but are still holding up well, although minor cracking can occur. District 5 noted that their standard is to use normal set concrete headers for exposed concrete decks with deck over backwall, as well as with plug joints. District 6 stated that they would consider using normal set concrete with any joint type, however this is a district with strict traffic demands and allowing for the curing time is not typically an option unless it is on new construction.

While elastomeric headers are generally the header of choice among districts, two districts note that the use of elastomeric concrete as a replacement header can be compromised by the condition of the substrate. Elastomeric concrete header performance relies heavily on proper installation. Multiple districts point out that elastomeric concrete requires understanding of the material and mixing requirements, noting that failure to adhere to these requirements will result in premature failure. Furthermore, elastomeric concrete is highly weather sensitive and the conditions need to be perfect (based on the Watson Bowman Acme instructions) for proper adherence to the substrate. Other weather conditions can lead to premature failure. One district pointed out that some states stay away from elastomeric headers because high strength concrete becomes brittle and needs proper curing time. It was also noted that varying temperature extremes in other states may impact choice of header type. Elastomeric headers have the potential to perform well, but care should be taken to understand how to properly install them in both new construction and header replacement projects, taking special care to clean the substrate, reach sound concrete, and prepare the surface well for bonding. Some elastomeric concrete brands being used are WaboCrete (with strip seals) and Delcrete (D.S. Brown), with Delcrete being more common among the districts but both being reported as high quality when installed properly.

Quick-setting concrete is used in many districts, and is good for timely repairs that need to be done in one night. While the convenience of being able to install headers overnight is a benefit, quick setting concrete headers were reported to fail within two to three years due to the limitation of the materials and direct exposure to traffic. For districts with high traffic volume, such as District 5 on the limited access highways, they are forced to use quick-setting concrete in order to meet the public demands for speedy road work and minimize impact on traffic flow, even if this is not the ideal header material in terms of long-term durability. Duracel is one brand that has been used for quick overnight fixes, however it has had mixed reviews. District 6 reported problems with freeze-thaw performance when using Duracel and has switched to Thoroc1060 BASF as their quick-set concrete of choice. Meanwhile, District 5 was using Thoroc1060 and reports that this, too, failed freeze-thaw testing and they have now switched to CTS Low Permeability Cement which, when mixed on site with water and aggregates, can be ready to open to traffic in 1 to 3 hours from pouring.

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3.0 Massachusetts Practices

3.1 Installation

Installation workmanship is ranked by all districts as the most important factor influencing success of joint performance. Issues during construction and installation are cited as being a likely leading cause of decreased service life of joints. For new joint installation, joint type and general specifications are provided through the MassDOT Load and Resistance Factor Design (LRFD) Bridge Manual (*5*). While the majority of districts agree that the specifications for installation of joints are likely adequate, they often noted that inadequate implementation of the specifications often decreases the service life and overall performance of joints.

Districts all have an engineer on site during installation. The on-site engineer could be a maintenance engineer, bridge engineer, or construction engineer depending on the district. While manufacturer specifications often state that a manufacturer representative should be on-site during installation, this does not happen for the majority of cases unless it is an early implementation of a product or material. Most districts agree that unless they are trying a new joint type, the manufacturer representative is not on-site. One district did note that they will typically have a manufacturer on site for large expansion joints, such as modular joints and finger joints, since these are more complex to install. Another district stated that company representatives have come out to projects when there have been problems with a specific joint type. It is generally the contractor's responsibility to bring a company representative to the site, but this was noted to rarely occur unless specifically required by the field engineer.

Discussions with manufacturer representatives emphasized the importance of a manufacturer representative on site in order to ensure proper preparation work prior to installation, especially with regard to cleaning and sandblasting of the opening after the cut has been made. However, they stated that time and financial restrictions on projects often preclude them from being called to the site. Alternatively, to increase service life and joint performance it may be beneficial for manufacturer representatives to hold training sessions with each of the districts and contractors to teach the proper techniques for ensuring adequate installation practices. District 1 specifically noted that they have had manufacturers' representatives to their district office in the past, and this is a practice that appears to be worthwhile for the other districts.

The temperature at installation of joints is considered by all districts by adjusting the opening width of the joint gap. In other cases, standard tables may be provided by the manufacturer for installation, tabulating joint gaps that correspond to applicable temperature (at installation). For small expansion joints, adjusting for temperature isn't as important. Saw and seal joints and others designed for minimal movement do not need any special accommodations for installation temperatures. Most specifications for joint openings assume an installation temperature of 50°F and these are then adjusted for different temperatures.

Only emergency repairs are done in the winter months, with most joint installations being performed during the summer and fall.

All districts agree that most water leakage starts where the joint meets the face of the barrier because it is difficult to ensure continuity of the seal at the sharp change of plane and direction. This construction detail can be difficult to perform with a backer rod, however care should be taken to ensure this step of installation is performed correctly to prevent this common area of leakage.

After new joint installation, MassDOT contract specifications require a “Watertight Integrity Test” for strip seals but this is called out in special specifications for other joints too according to most districts. The watertight integrity test states that at least five workdays after the joint system has been fully installed the contractor shall test the full length of the system for watertight integrity to the satisfaction of the engineer on site. The entire joint system shall be covered with water (either ponded or flowing) for a minimum of fifteen minutes. During these fifteen minutes, and for a minimum of forty-five minutes after the water supply has stopped, the concrete surface under the joint shall be inspected for any evidence of penetrating water or moisture. Water tightness shall be defined as no dripping water on any surface on or outside the joint. If there is any evidence of leaking, the contractor must determine the location(s) of leaking and take all measures necessary (which must be approved by the engineer) to stop the leak. This work shall be done at the contractor’s expense and a subsequent test must be performed to the same conditions as the original test, with the same steps taken if there is still leakage, until the joint is fully water tight.

While the watertight integrity test is outlined in the specifications, one of the districts noted that it is not always done. Furthermore, this is generally only required for new construction of strip seals with no requirements for repaired or replaced joints.

For joint repair there is no warranty on the work, while for joint replacement there is a warranty of 2 years. Districts report that getting a contractor to come back out to do the work under warranty is generally difficult so they are rarely able to enforce it. There is typically no recourse once construction ends.

Districts provided information on installation practices that they believe positively influence overall joint performance. The majority of districts noted that proper workmanship during installation greatly benefits joint performance.

One district noted that in skewed bridges, concrete is poured continuously but can only be rake finished by machine over the straight portion of the bridge. Therefore, the parts of the bridge near the skew need to be hand-raked, which can lead to problems if done poorly. This is something contractors, inspectors, and resident engineers should be aware of to look out for during skewed bridge construction.

Surface and substrate preparation and cleanliness is another influencing factor; sandblasting is in the specifications for most joint installations and yet it is rarely done due to either time or money constraints. This step can make a major difference in the success of a joint, as noted by districts and manufacturers alike.

3.2 Maintenance

Maintenance is critical to joint performance, but all districts noted a lack of funding to adequately perform preventive maintenance. District 1 used to have a maintenance crew (until 1995) that cleaned bridges annually. The cleaning included blowing out or washing out joints in the spring, cleaning decks, and cleaning the bridge substructure and underneath bridges in the summer. The district noted significant improvement in the joint performance and overall bridge condition when this maintenance was routinely performed. The majority of districts pointed out that routine cleaning of joints would be very worthwhile and would have a positive impact on joint performance.

District 5 came up with a “Bridge Maintenance Policy” a few years ago that received very positive feedback from the Federal Highway Administration (FHWA). Unfortunately, funds were not forthcoming to implement the proposed program. The ideal maintenance routine for the district would be systematic maintenance through a corridor style contract where a contractor would work their way down the highways systematically cleaning joints. A contract to power wash bridges was expected to cost approximately $300,000 in its entirety.

While preventive maintenance is not routinely done, inspectors do typically flag bad joints to prioritize work according to safety and traffic volume concerns.

District 2 reports that bridge deck and joint washing/cleaning, re-sealing of joints, and cleaning of bins/troughs under finger joints is currently being performed. District 6 does do some cleaning with maintenance crews, which focuses on blowing out/scratching out debris from joints then running a sweeper through. In general, the funds are not available in any of the districts to do the level of routine, systematic, or preventive maintenance that they would like. Life cycle costing that includes the cost of repairing and replacing joints, as well as the damage that can occur as a result of failing joint systems, was noted to show clear benefits of a full maintenance program. However, the maintenance and construction budgets are separated such that maintenance budgets do not benefit from savings in construction costs. Additionally, substructure repair resulting from joint failure is handled separately from joint maintenance personnel and within separate budgets. An overall perspective that considers the cause and effect of failing joints and looks at overall life-cycle costs would be worth implementing. This would need to include budgetary reward between construction, repair and maintenance budgets, including both superstructure components and elements such as joints.

3.3 General

3.3.1 Design, Provisions, Specifications

Districts agree that existing general specifications are generally very good, but the implementation in the field by the contractor or inspector needs improvement. One suggestion of a possible approach to fixing this is to have statewide training for inspectors of all districts, as well as resident engineers that will be on-site. The training should have everyone go through the steps of what is expected during construction per the specifications.

While there are special provisions that source from Boston headquarters, at least one district noted that they have provisions unique to the district now where they have added onto the original specifications with practices they have had success with.

When it comes to new joint installation, the districts are limited to joint types in the MassDOT LRFD Bridge Manual (*5*). Joint replacements also have guidelines in the Bridge Manual. There are no standard repair details through the Bridge Manual; this is generally left up to the individual districts to decide on the best approach for repair. District 5 noted that joint performance could likely be improved if preservation specifications were detailed. These would include steps to take after construction to keep the joints functioning properly instead of relying on reactive maintenance once problems have already occurred.

3.3.2 Joint Repairs

District 3 noted that the range of expansion is sometimes overestimated in existing bridges. Therefore, they re-evaluate and replace with the most relevant joint type, not necessarily one similar to the existing one. When replacing joints (not the entire deck) the district can decide on the replacement joint; although there are replacement guidelines in the Bridge Manual, they have the ability to determine the best method they want to use within the individual district.

Repairs are more difficult in the districts with high traffic volume, often requiring an 8pm to 5am (Monday through Friday) time period, which leads to restrictions on what methods, materials and joint types are applicable.

Field splicing is only allowed on certain joint types. In general, all districts agree on the materials that can be field spliced. Neoprene seals (both strip seals and compression seals) shall be continuous and may not be spliced under any circumstance. EM-SEAL type seals (silicone) are the only seals that can be field spliced. Asphalt plug joints may be spliced in the field. For non-seal materials, field splicing is allowed by welding of steel strip seal rails and in some cases steel headers.

Deck replacements vary by district. While some districts reported typical deck life of 25 years, this does not necessarily mean that re-decking is done this often. District 6 reports that re-decking is done every 25-35 years maximum (this district is the Boston area district with extremely high traffic volume which likely wears down surfaces more quickly). Decks can be in service over 40 years in other districts, and District 4 reports decks are still in service from the 1960’s (50+ years). District 5 reported that re-decking is rare, and it generally turns into full structure or superstructure replacement. When deck replacement is done, the design choice could be done in-house or by consultants, depending on the district. Joints are replaced during re-decking, but this does not necessarily mean changing joint types. When deck is replaced it is classified as new construction, therefore joint types need to come from MassDOT LRFD Bridge Manual (*5*).

4.0 Survey on “Better Bridge Joint Technology”

4.1 Overview of Survey and State Responses

A survey was created using “Survey Monkey” and sent to state Departments of Transportation (DOTs) in and around New England in order to collect responses regarding other state’s bridge joints, construction, repair, and maintenance practices. The results from this survey were used to determine best practices with joints and headers and understand how joints are used and maintained beyond Massachusetts. The survey was sent to DOTs in Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York State, Pennsylvania, Rhode Island, and Vermont. The survey was also sent to and completed by the MassDOT Districts in order to have direct comparisons to other states’ responses. The survey was sent to 58 people (district engineers and chief engineers); two weeks after the survey was emailed, follow-up emails and/or phone calls were sent to gather as many responses as possible. There were a total of 26 responses to the survey (45% response rate); the respondents and their corresponding state are presented in Appendix A: Survey Respondents. For DOTs in Maine and Rhode Island, the survey was sent to the Chief Engineer’s assistant to distribute.

The survey was organized into five topics: joints, headers, new installation and repair, maintenance, and overall practice, with a total of 44 questions. All survey questions are presented in Appendix B: Questions from Survey. Due to the large number of responses, all tables and figures were not included in this report, but they have instead been summarized in the following sections of individual state responses, with an overall summary of all state responses at the end of this chapter.

For some states, there were multiple respondents to the survey. However, not all respondents provided answers to all questions (or for all joint types). Therefore, some of the tables and figures will show multiple responses to some questions, and no responses or one response to another. The results presented show all answers provided. In the plots where an average value is shown, the average may not be the midpoint of the maximum and minimum rating because in many cases multiple respondents selected a single point or selected a value between the maximum and minimum, so the average shown is weighted.

4.1.1 Connecticut

Connecticut currently has six joint types in use: asphalt plug joints, compression seals, sliding plate joints, finger joints, modular joints, and saw and seal: deck over backwall. For new construction and joint replacement, however, only asphalt plug joints and modular joints are being used (both for overnight construction and construction without time constraints).

Asphalt plug joints and modular joints are the only joints that they believe perform adequately if routine repair and maintenance are performed. The typical service life experienced with these, however, is quite short: for asphalt plug joints (zero to four years), while modular joints have a longer service life of thirteen to sixteen years. These service lives are presented in Table 3.

Table 3: Typical Service Life of Joints (Connecticut Survey Respondent Answers)

Connecticut: Typical Service Life of Joints		
Years	**Asphalt Plug Joint**	**Modular Joint**
0-4	1	
5-8		
9-12		
13-16		1
>16		

In Connecticut, a successful joint is defined as one that provides good ride-ability and water tightness. Failure of a joint is defined as one that leaks or has poor ride-ability. Connecticut rated the performance of both asphalt plug joints and modular joints as neutral. These ratings are shown in Figure 23. The importance of multiple factors to joint performance was rated and is shown in Figure 24 (note that maintenance practices were not rated).

Figure 23: Performance Rating of Joints (Connecticut Survey Respondent Answers)

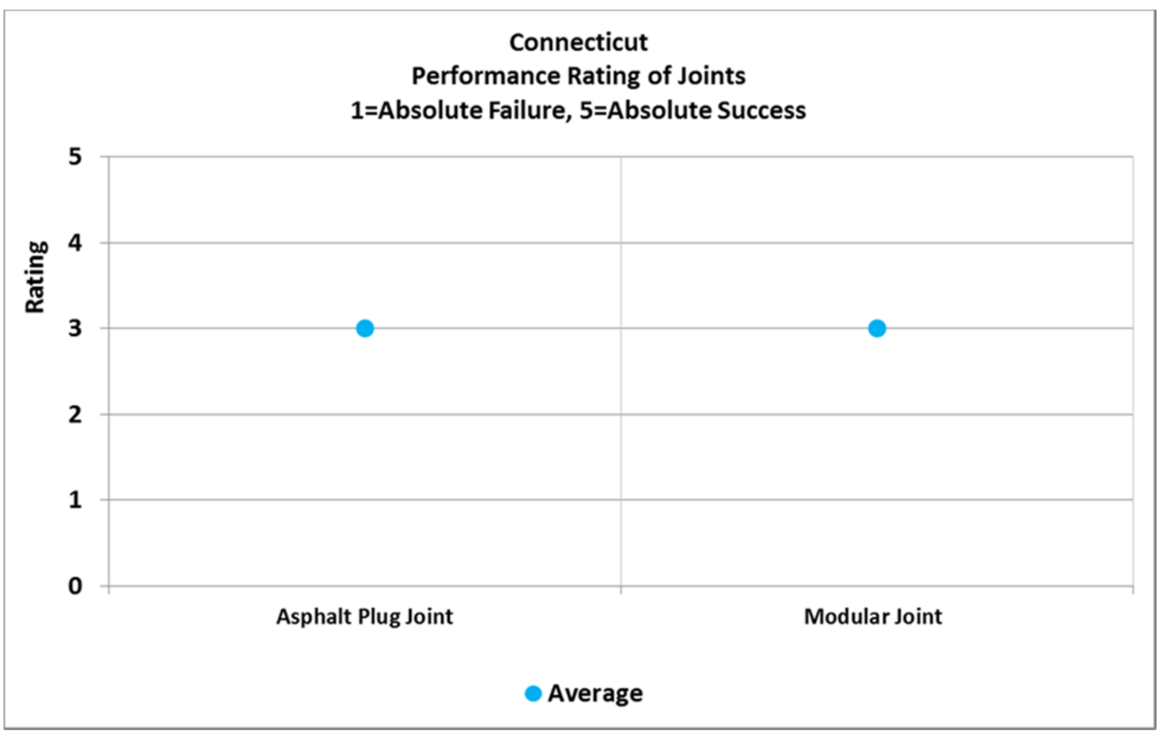
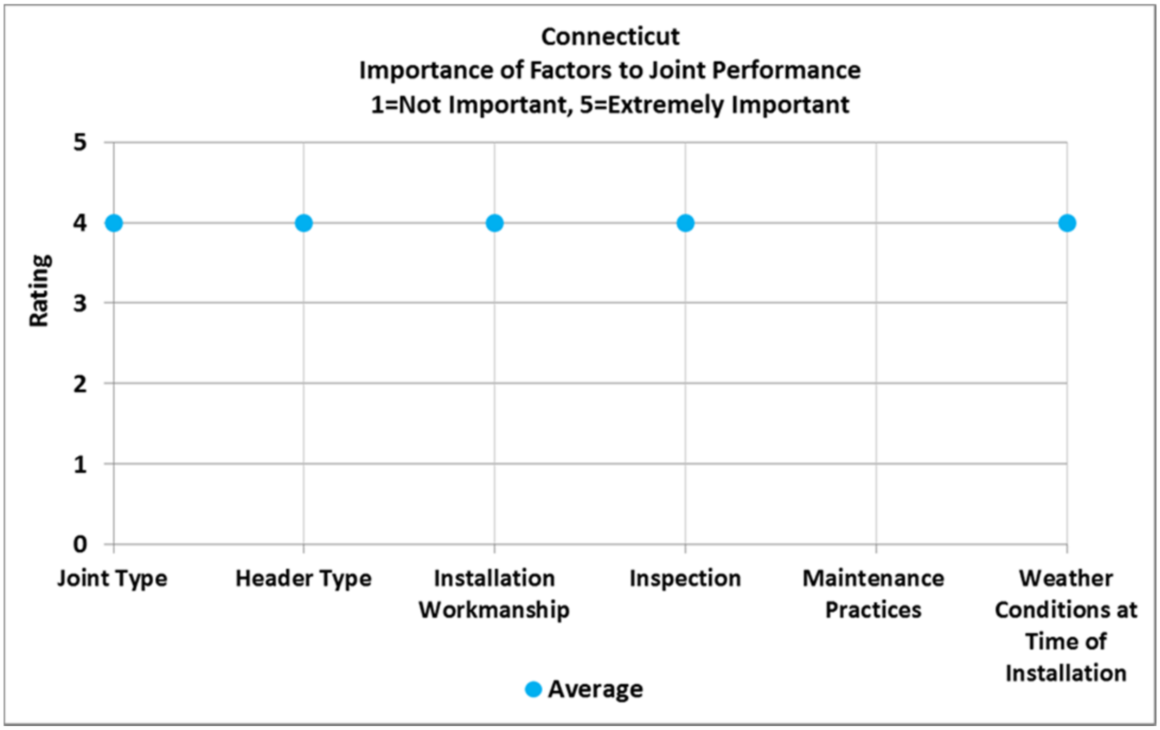


Figure 24: Importance of Factors to Joint Performance (Connecticut Survey Respondent Answers)



For headers, currently either normal setting concrete or elastomeric concrete are used when there are no time constraints, and quick setting concrete is used when overnight construction is required. Armored headers are not currently used, and were not used in the past according to the respondent.

Temperature is considered for joint installation. No testing is done (such as watertight testing) to verify proper installation or repair. There are also no required weather conditions for installation of joints or headers. It was noted that lack of attention to proper surface preparation prior to joint installation or dampness of the base concrete can both negatively impact the performance of joints. Field splicing is not allowed on repairs of any joint type. The manufacturer’s representatives are sometimes on site to oversee joint work at time of construction. There are standard joint and header replacement details for Connecticut, but no standard repair details. The respondent did not comment on anti-icing chemicals, preventive maintenance, or whether there is a bridge maintenance manual separate from the design manual.

4.1.2 Maine

Maine is one of the states with the broadest range of joint types in use. The current joints in service in Maine include asphalt plug joints, strip seals, compression seals, pourable seals, EM-SEAL, sliding plate joints, finger joints, modular joints, link-slabs, open joints, saw and seal: deck over backwall, and Silicoflex. In new construction, asphalt plug joints, strip seals, compression seals, EM-SEAL, finger joints, modular joints and saw and seal: deck over backwall are used. For replacement projects, asphalt plug joints, strip seals, compression seals, EM-SEAL, finger joints and saw and seal: deck over backwall are used when there are no time constraints. If overnight replacement is required, asphalt plug joints, strip seals, compression seals, EM-SEAL or finger joints are used.

With routine repair and maintenance, all respondents stated that the joints that perform adequately are asphalt plug joints, compression seals, EM-SEAL, and finger joints. Half of the respondents also added strip seals, sliding plate joints and saw and seal: deck over backwall to this list. The typical service life of joints was rated, and the joint with the shortest service life is the pourable seal, followed by asphalt plug joints. The greatest variability in responses was for the service life of modular joints. Many of the joints have typical service lives greater than sixteen years. All responses are presented in Table 4.

Table 4: Typical Service Life of Joints (Maine Survey Respondent Answers)

Maine: Typical Service Life of Joints										
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Pourable Seal**	**EM-SEAL**	**Sliding Plate Joint**	**Finger Joint**	**Modular Joint**	**Open Joint**	**Saw and Seal: Deck Over Backwall**
0-4				1						
5-8	1							1		
9-12		1	1		1					
13-16										
>16			1		1	1	2	1	1	1

All respondents from Maine stated that they would like to phase out modular joints, while half of the respondents would like to phase out all joints. It was noted that joints leak, which leads to multiple problems when not properly maintained, including issues with bearings, beams, abutment/pier concrete, etc. Joints are difficult to install properly to provide a smooth ride, particularly when being replaced as part of rehabilitation efforts.

In Maine, success of a joint is defined as one that does not leak and can remain in place for 20 years without having to do any major work on it. Failure of a joint is defined as one that leaks, falls apart shortly after it is installed requiring emergency measures to repair, or one that leads to other issues when not properly maintained. Joint performance was rated and is shown in Figure 25. None of the joints were rated an absolute success, however the joints rated close to an absolute success are EM-SEAL, sliding plate joints, finger joints, and saw and seal: deck over backwall. Open joints, modular joints, and pourable seal joints have the lowest performance rating. When rating the importance of multiple factors to joint performance, the most important factors were installation workmanship and inspection. These ratings are all shown in Figure 26. The most promising new products are Silicoflex and EM-SEAL. MaineDOT is also looking at/using on a trial basis joints using heavy steel angles for joint armor and steel plates/rebar hoops for anchorages. They are very heavy duty joints but use readily available materials and the welding details are relatively simple.

Figure 25: Performance Rating of Joints (Maine Survey Respondent Answers)

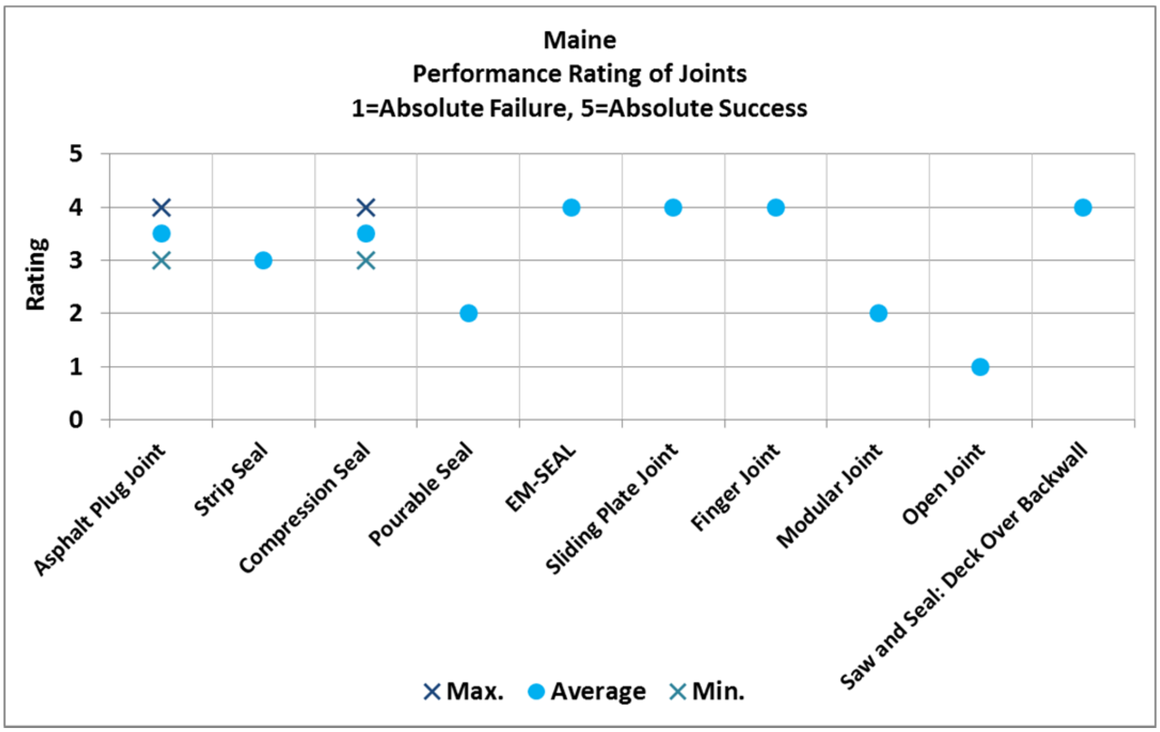
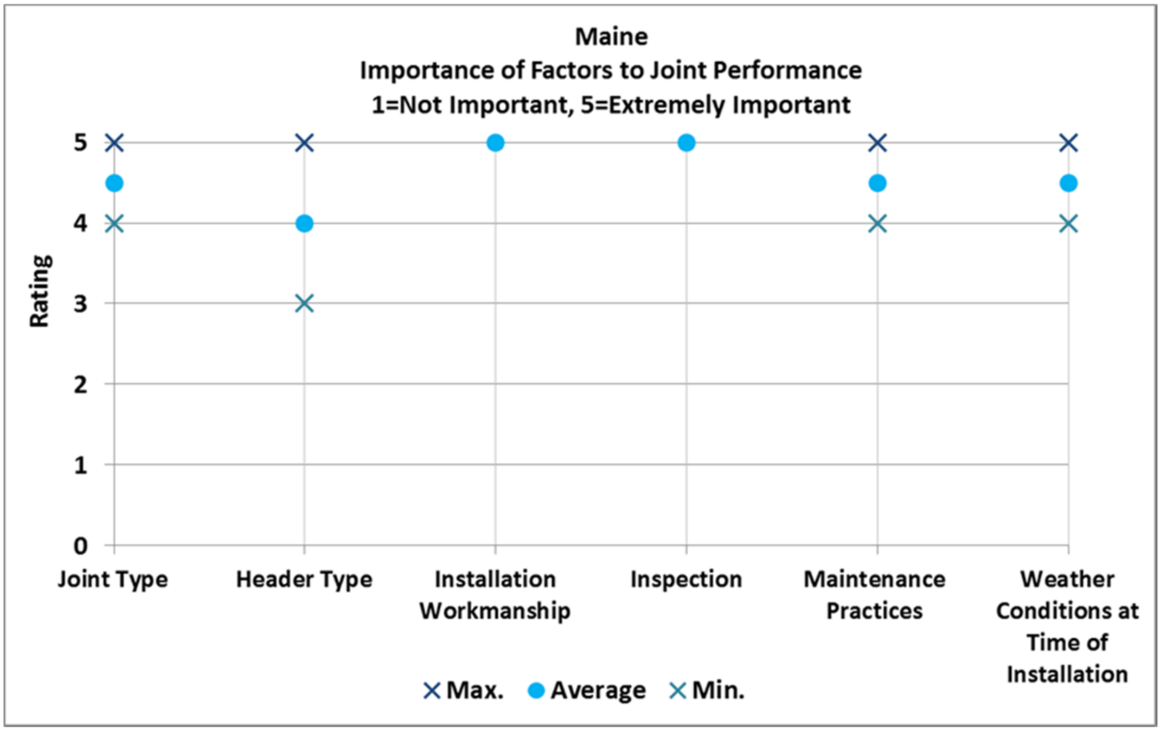


Figure 26: Importance of Factors to Joint Performance (Maine Survey Respondent Answers)



Headers currently in use in Maine are elastomeric concrete and quick setting concrete (for both overnight construction and when there are no time constraints), and normal setting concrete and armored headers when there are no time constraints. There is not a specific material used for extreme cold weather, but according to one respondent any material used must meet the requirements of the specifications for maintaining temperature, or must be installed per manufacturer requirements. Elastomeric headers have had some problems in Maine. They can have poor adhesion to substrate, difficulty in providing proper grade, expansion of material once placed, and some material failures after it is in place for a short time. While the reasons for these issues are not known, respondents stated that it may be due to improper mixing of components, moisture on substrate, or environmental conditions.

Temperature is considered during installation of joints by adjusting the opening. However, one practice that has negatively impacted joint performance is installing them when the temperature is too warm. Another factor with a negative influence is inadequate cleaning prior to installation. There is no testing done to ensure proper installation of joints. One respondent noted that joints should be set in the fall, and this has been found to positively influence joint performance. Field splicing is allowed on some joints, although joint types were not specified. The manufacturer's representative is sometimes on site to oversee joint installation. Some practices that negatively impact joint performance include inadequate cleaning prior to installation. Furthermore, some standard joint details show use of steel studs to anchor joint armor into concrete where the studs can be installed with a stud welding machine or by "stick" welding. Preventive maintenance is performed by doing annual cleaning. For anti-icing of roads, Maine is a salt priority state.

In Maine, they have found that the use of studs may not be the most reliable means of anchoring the steel, due to the quality of the weld. They suggest using other options such as steel straps or rebar welded to the joint armor. In addition, they found that their standard details had not been changed or been reviewed for many years so there have not been design checks for the number/spacing of studs for some time. When this was reviewed, they found that in some cases the number and spacing of studs was inadequate for the loads being applied. There are no standard replacement details or repair details for joints and headers. There is a bridge maintenance manual for Maine.

4.1.3 Massachusetts

Massachusetts currently has asphalt plug joints, strip seals, compression seals, pourable seals, EM-SEAL, sliding plate joints, finger joints, modular joints, link-slabs, open joints, saw and seal: deck over backwall, and saw and seal: over existing joint. In new construction, all but pourable seals, EM-SEAL, and open joints are currently used. Not all districts use the same joint types for new construction, however. All but open joints would be used in replacement projects if there is no time constraint, while for overnight construction the majority of districts would use asphalt plug joints and strip seals, with fewer districts also noting they would use saw and seal: deck over backwall and over existing joint, compression seals, pourable seals, EM-SEAL, and link-slabs.

With routine repair and maintenance, all respondents believe strip seals perform adequately while the majority of respondents also believe link-slabs, saw and seal: deck over backwall, compression seals and asphalt plug joints also perform adequately under these conditions. The typical service life of joints is presented in Table 5. Asphalt plug joints had the most variability in responses, ranging from zero to sixteen years. The shortest service life was assigned to pourable seals and EM-SEAL. Joints to which the most respondents assigned a service life of over sixteen years include finger joints and link-slabs.

Table 5: Typical Service Life of Joints (Massachusetts Survey Respondent Answers)

Massachusetts: Typical Service Life of Joints											
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Pourable Seal**	**EM-SEAL**	**Sliding Plate Joint**	**Finger Joint**	**Modular Joint**	**Link-Slab**	**Saw and Seal: Deck Over Backwall**	**Saw and Seal: Over Existing Joint**
0-4	2			3	1						
5-8	3		1							1	
9-12	1	2	1							2	1
13-16	1	3	3			3	2	2	2		
>16		1				1	3	1	3	1	

Joints that have been phased out by at least one district include: asphalt plug joints, compression seals, pourable seals, sliding plate joints, finger joints, and open joints. Compression seals had the most respondents that have or want to phase them out. Other joints that at least one respondent would like to phase out moving forward include: asphalt plug joints, strip seals, pourable seals, sliding plate joints, finger joints, modular joints, and open joints. Reasons for wanting to phase out joints types include difficulty to maintain, expensive to repair, rutting of material, or leaking issues.

The definition of success ranges slightly between respondents, with some emphasizing that a long service life is important and others emphasizing that the joint has to be watertight. Other attributes of a successful joint would include smooth ride-ability and requiring minimal maintenance. Failure definitions include a joint that leaks and one that becomes damaged to the point it does not provide a smooth riding surface. Performance of joint types is presented in Figure 27. The highest success ratings were assigned to link-slabs, saw and seal: deck over backwall, strip seal, EM-SEAL, finger joints and modular joints. The lowest rated joints were open joints and pourable seals. The importance of multiple factors to joint performance is presented in Figure 28. The most important factor, unanimously, is joint installation.

Figure 27: Performance Rating of Joints (Massachusetts Survey Respondent Answers)

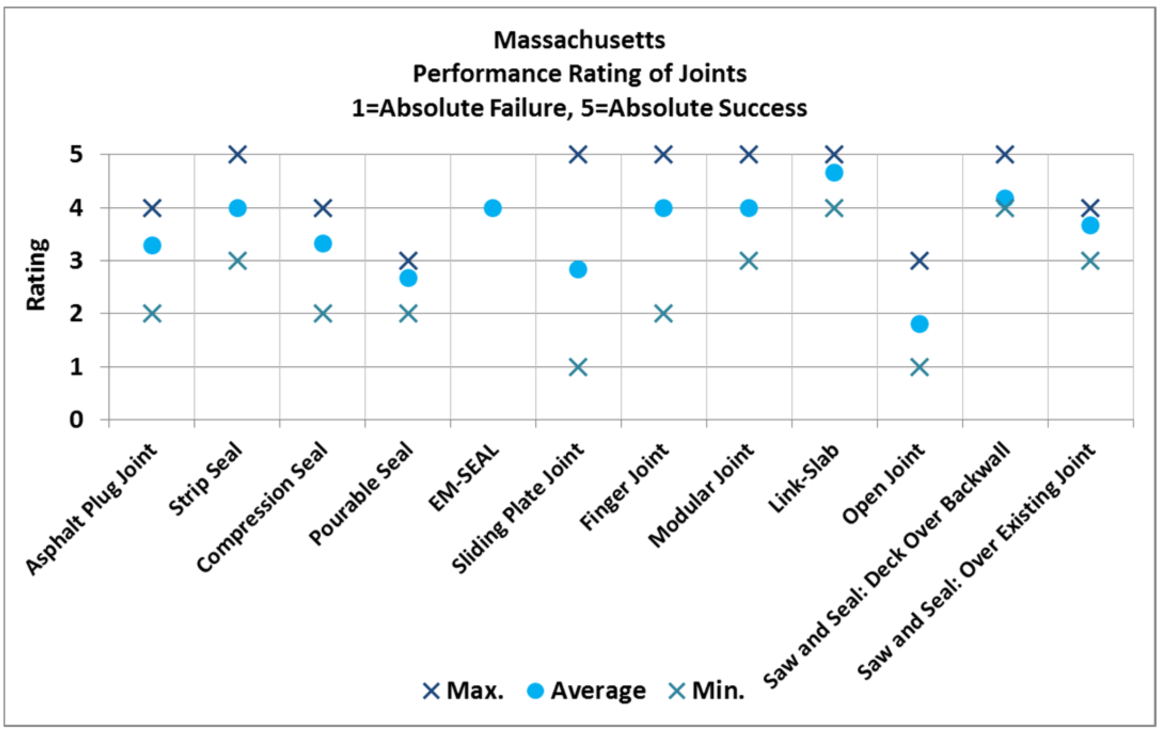
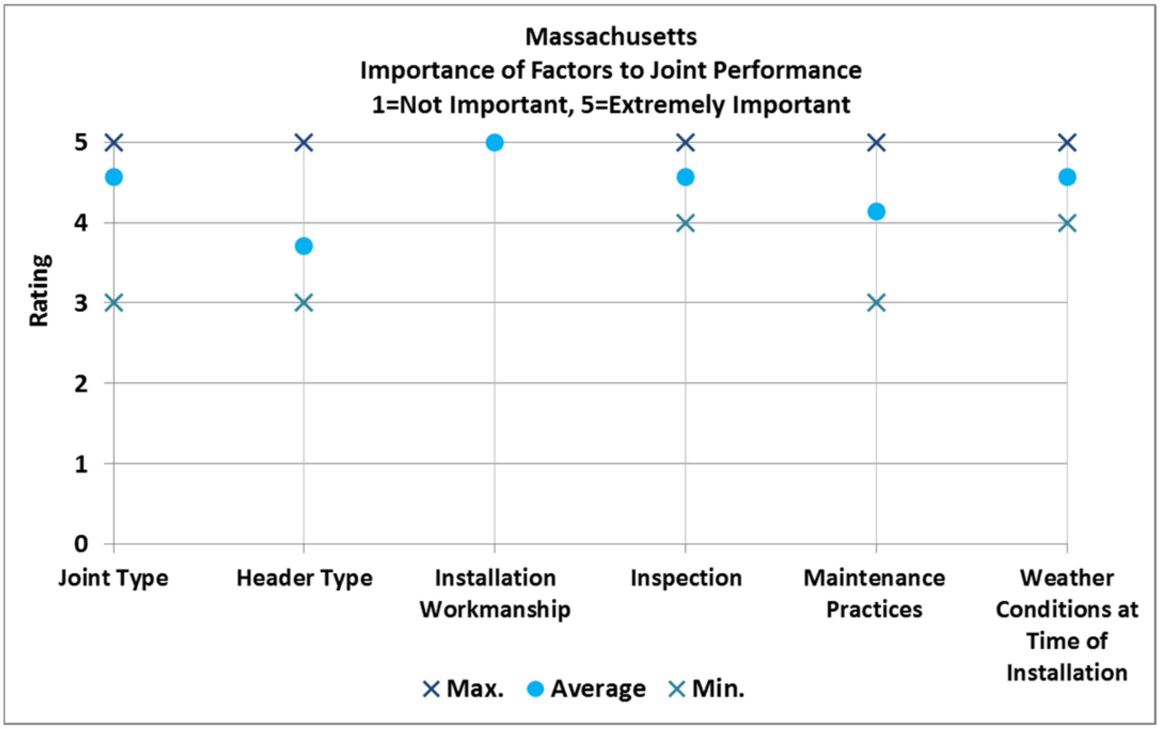


Figure 28: Importance of Factors to Joint Performance (Massachusetts Survey Respondent Answers)



Installation practices that have negatively impacted joint performance include lack of inspection at time of construction, not adhering to stated requirements for joint installation, and poor workmanship. All districts and manufacturers agree that lack of surface/substrate preparation and not taking measures to properly clean prior to joint installation are leading causes of early failure of joints. This lack of proper preparation and cleaning leads to many problems (including debonding, corrosion of joint from chloride in substrate, lack of adherence of joint materials, etc.).

Strict quality control is another factor influencing joint success; one district has noted that they have implemented quality control standards in their district and states that it has had a very positive affect on joint performance so far. Using high quality materials is important to the success of joints.

Consideration of weather conditions at time of installation is another important factor, ranked highly in the level of importance by all districts.

Headers currently in use are armored headers, normal set concrete, and elastomeric headers. Quick setting concrete is only used if overnight work is needed, while elastomeric headers may also be used in this case. Armored headers have had issues with plow damage and are not easily repaired, so most districts prefer not to use them anymore. With strip seals, elastomeric concrete is specified in the standard details. Other joint types have headers based on the district's preference.

Officially, there are no standard repair details for joints and headers. However, some districts responded that there are standard details of replacement joints and headers available. Temperature is considered at the time of installation. Recommendations from manufacturer specifications should be followed, as well as making proper adjustments. It is not only important to adhere to temperature recommendations and make proper adjustments, but also not to install the joint in any extreme temperatures (hot or cold), as this affects materials and the opening size for the joint. Watertight testing is typically done after a new strip seal joint installation. There is no watertight testing done on an asphalt plug joint at any time during or after construction. Field splicing is allowed on some joints; these joints vary by district. There is no bridge maintenance manual currently in Massachusetts. Some districts perform bridge deck and joint washing/cleaning as well as cleaning of troughs, but most districts do not have the funds to perform the preventive maintenance that would prolong joint life. For anti-icing, sodium chloride (rock salt) is used, and one district noted sand may also be used.

4.1.4 New Hampshire

New Hampshire has five joint types that are currently in service as well as used for new construction: asphalt plug joints, strip seals, compression seals, finger joints, and modular joints. While all of these are used as replacement joints when there are no time constraints, only asphalt plug joints are used for overnight replacements. All of the joint types used are believed to perform adequately if routine repair and maintenance are performed. Sliding plate joints have been phased out of use in New Hampshire due to issues with leaking.

The average service lives of joints are presented in Table 6. Asphalt plug joints and pourable seals have the shortest service life of zero to four years, while compression seals, finger joints, and modular joints have the longest service lives at more than sixteen years.

Table 6: Typical Service Life of Joints (New Hampshire Survey Respondent Answers)

New Hampshire: Typical Service Life of Joint Types						
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Pourable Seal**	**Finger Joint**	**Modular Joint**
0-4	1			1		
5-8						
9-12						
13-16		1				
>16			1		1	1

A successful joint in New Hampshire is defined as one that does not leak, requires low maintenance, is repairable, is durable and lasts longer than twenty years. A failed joint would be defined as a joint that leaks, has seals that have fallen out, or has cracks (specifically in asphalt plug joints). Considering these definitions, joint types were rated on their performance. The highest rated joint in New Hampshire is the compression seal, and the lowest rated joints are the pourable seal, sliding plate joint, and saw and seal joints. All ratings are shown in Figure 29. The importance of multiple factors to joint performance is presented in Figure 30. They rate all factors as highly to extremely important.

Figure 29: Performance Rating of Joints (New Hampshire Survey Respondent Answers)

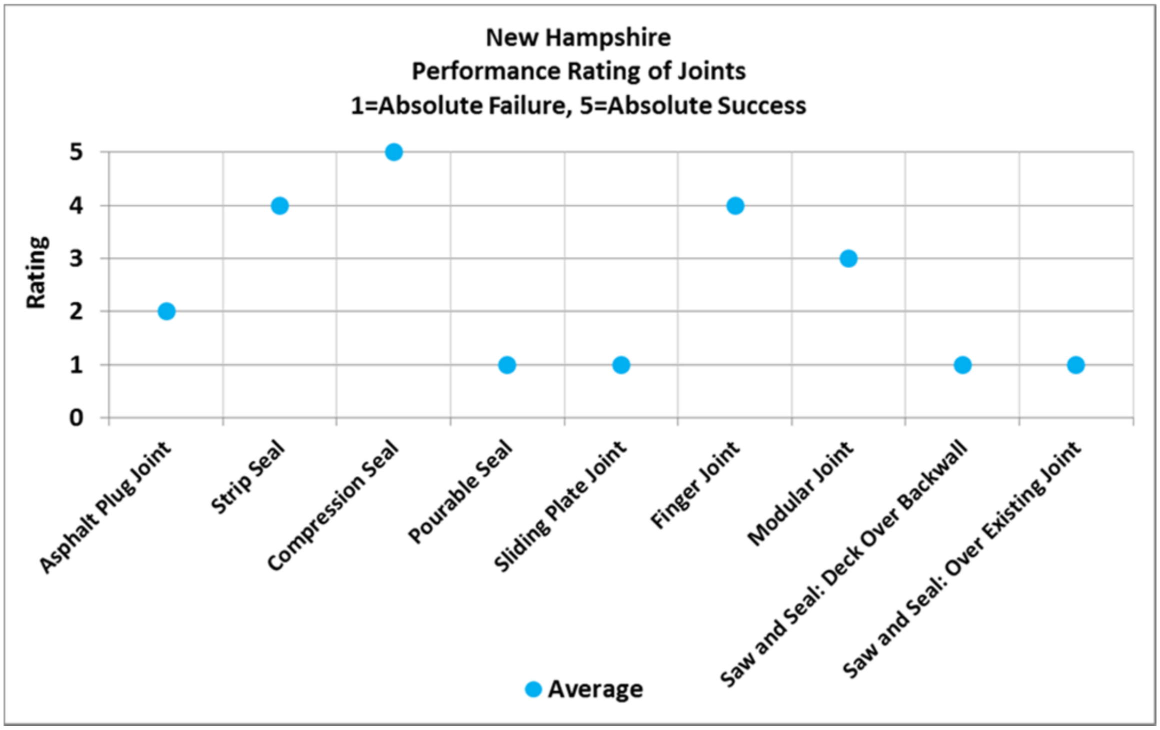
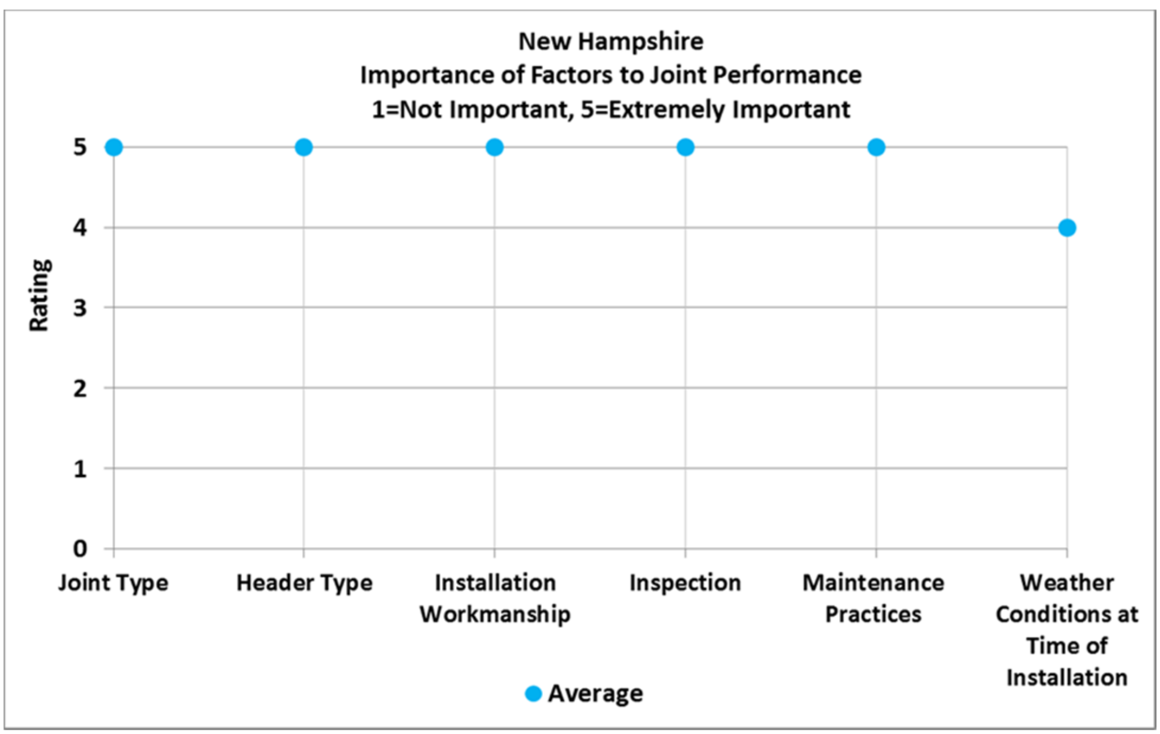


Figure 30: Importance of Factors to Joint Performance (New Hampshire Survey Respondent Answers)



Headers currently being used in New Hampshire are armored headers and normal setting concrete when there are no time constraints. Quick setting concrete and elastomeric concrete are used in overnight construction. It was noted that using steel angles and large anchorage is working well, while elastomeric headers have been noted to de-bond and then require replacement.

There are standard new design and replacement details for the state, but no standard repair details. Temperature is considered at the installation of the joint; the joint is sized assuming 150°F temperature change and approximately 65°F at installation. The joint is then installed and set for the current temperature prior to pouring the concrete headers. There are no specific weather condition requirements for installation of joints or headers. Field splicing is permitted on compression seals, strip seals, finger joints and modular joints. It was noted that installation practices that negatively impact joint performance include material and installation not installed according to specification, or not according to design plans. New Hampshire has a preventive maintenance program in which joints are cleaned of debris annually. For anti-icing chemicals, New Hampshire uses rock salt and pre-wetting treatment of calcium chloride.

The State Contract Administrator oversees installation and testing of joints. The watertight integrity test is performed five work days after the joint system has been fully installed. The contractor tests the entire length of the joint system for watertight integrity by employing a method agreed upon by the engineer. After either ponding or pouring flowing water over joints for a minimum of 15 minutes, the concrete surfaces under the joint are inspected. The concrete surfaces are also checked for a minimum of 45 minutes after the water supply has stopped for evidence of dripping water or moisture. Free dripping water on any surface on the underside of the joint is not accepted, while patches of moisture are not cause for non-acceptance.

4.1.5 New Jersey

In New Jersey, the joints currently in service are: asphalt plug joints, strip seals, compression seals, pourable seals, EM-SEAL, and finger joints. For new construction, only strip seals and compression seals are used. These are also the two joint types used for replacements when there are no time constraints. When overnight replacement is required, pourable seals or EM-SEAL are used. Joints that typically perform well with routine repair and maintenance are compression seals and EM-SEAL.

The typical service life of joint types is presented in Table 7. Finger joints and open joints have the longest service life of more than 16 years. The shortest service life was assigned to asphalt plug joints and pourable seals with a service life of zero to four years. These are the two joint types that have been or currently are being phased out. Pourable seals exhibit adhesion issues during the winter months when bridges contract, while asphalt plug joints are not able to hold up to truck traffic.

Table 7: Typical Service Life of Joints (New Jersey Survey Respondent Answers)

New Jersey: Typical Service Life of Joints							
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Pourable Seal**	**EM-SEAL**	**Finger Joint**	**Open Joint**
0-4	1			1			
5-8					1		
9-12		1					
13-16			1				
>16						1	1

Success of a joint in New Jersey is defined as a joint that can form a water-tight seal and expand and contract with the bridge. Failure of a joint is one that does not meet these standards. EM-SEAL and compression seals have the highest rating of an absolute success, while asphalt plug joints received the lowest rating of an absolute failure with pourable seals not performing much better. All ratings are presented in Figure 31. In rating the importance of various factors to joint performance, the installation workmanship, inspection, and maintenance practices were rated as the most important. The joint type and header type are not believed to have as significant an impact as these other factors. These ratings are presented in Figure 32. Note that "weather conditions at time of installation" was not rated by the respondent, so no data is presented for this factor.

Figure 31: Performance Rating of Joints (New Jersey Survey Respondent Answers)

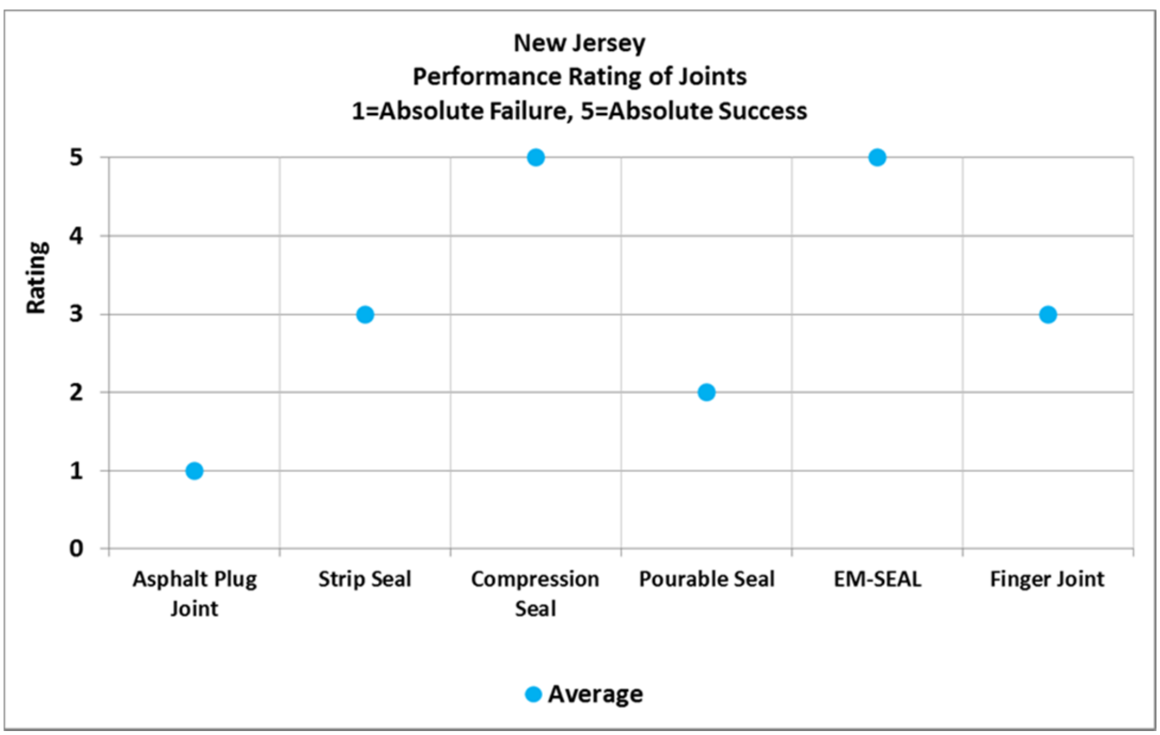
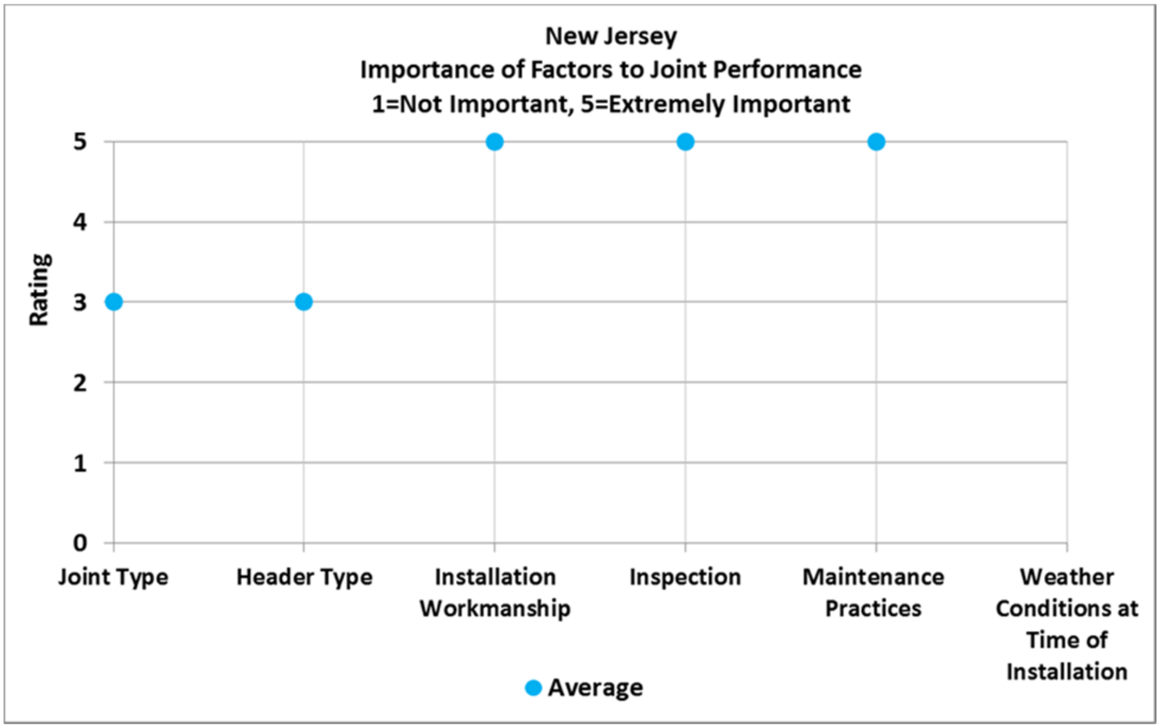


Figure 32: Importance of Factors to Joint Performance (New Jersey Survey Respondent Answers)



Headers that are currently being used in New Jersey are armored headers and normal setting concrete when there are no time constraints, while quick setting concrete and elastomeric concrete are used when overnight construction is required. Armored headers were noted to fail over time and potentially create hazardous situations with metal protruding into the roadway.

There are standard joint and header replacement and repair details in New Jersey. Temperature is considered during joint installation by using manufacturer's recommended install temperatures. While watertight testing is not typically done, one respondent noted that the deck is power washed after joint installation on FHWA maintenance projects and joints are inspected at that time for any failures.

Field splicing is allowed on EM-SEAL and pourable seal. However, splicing pourable joints during winter months has led to failures. Partial replacement of joints has not been found to provide as tight of a seal as complete replacement of joints. A construction practice that positively influences joint behavior is to, where possible, completely remove and reconstruct adjacent concrete then replace joints to provide a new, clean, water-tight seal. Pourable seals do not perform well on vertical re-seals and they tend to pool at the base. EM-SEAL performs best as a vertical joint re-seal.

There are bridge maintenance guidelines in place for FHWA bridge maintenance contracts. There is also a complete NJDOT/FHWA Bridge Preventive Maintenance Program in place. For anti-icing, New Jersey uses sodium chloride (rock salt), liquid calcium chloride, and salt brine. The manufacturer's representative is sometimes on site for installation of joints. The representatives are usually requested to be on site by the resident engineer during the first installation of any given product by a contractor.

4.1.6 New York State

New York State currently has every joint type in service (based on survey results) as well as armor-less joints with foam seals. The majority of responses stated that for new construction, modular joints, compression seals, link-slabs and pourable seals are used. Some other responses included using asphalt plug joints, strip seals, EM-SEAL, finger joints, saw and seal: deck over backwall, and armor-less joints with foam seals in new construction.

For joint replacement projects, when there are no time constraints, asphalt plug joints, strip seals, compression seals, pourable seals, EM-SEAL, finger joints, modular joints, link-slabs, and saw and seal: deck over backwall are used. When overnight replacement is required, asphalt plug joints, strip seals, compression seals, pourable seals, and EM-SEAL are used.

Strip seals, compression seals, and pourable seals are the joints that 100% of respondents believe perform well with routine repair and maintenance. Other joints that were selected as having good performance with these conditions are asphalt plug joints, EM-SEAL, finger joints, modular joints, open joints, and saw and seal: deck over backwall. Typical service life of joints ranged between respondents. However, all respondents agreed that pourable seals have the shortest service life of zero to four years, and asphalt plug joints and strip seals also have shorter service lives. It was noted that pourable seals and foam compression seals generally last five years or less, sometimes only a couple of years, but they are easy to replace. All responses are presented in Table 8.

Table 8: Typical Service Life of Joints (New York State Survey Respondent Answers)

New York: Typical Service Life of Joints								
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Pourable Seal**	**Finger Joint**	**Modular Joint**	**Open Joint**	**Saw and Seal: Deck Over Backwall**
0-4	1	1	1	3				
5-8	1	1	1					
9-12			1		1	2		1
13-16								
>16		1			2	1	1	1

Strip seals, sliding plate joints, and open joints are currently being phased out. Respondents are phasing out or would like to phase out finger joints. New York would also like to phase out compression seals. It was noted that finger joints last more than 10 years, but that the troughs are difficult/impossible to maintain. For strip seals, it is difficult to replace the seals. The current NYSDOT standard sheets specify closed cell foam joint seals or pourable seals only. Reasons preventing joints from being phased out include difficulty finding a type of joint that will always work. They also noted they would like to use link-slabs more often, but maintaining traffic is problematic and also adds significant cost to the project. Typically, the joints need to be replaced during nightly lane closures so that rush hour traffic can use the lanes daily.

Foam seals are easy to install or replace, but they have had problems with larger sizes (>3") tearing or being punctured under traffic. For reconstructed joints on existing bridges, the header durability appears to be the limiting factor in joint life. They added that installing new headers over old concrete decks is not a good idea. Many joints were noted to suffer from snow plow damage.

A successful joint in New York is one that prevents water penetration for more than 10 years with little to no maintenance, does not cause traffic problems, and does not get damaged by snow plows. Failure of a joint is defined as one that leaks and causes chloride damage to parts of superstructure and substructure, causes traffic problems, a joint that is susceptible to snowplow damage, needs seal replacement before 10 years, and joints that are not continuous at the ends of superstructure and substructure. When joint performance was rated, the highest rating was given to link- slabs and saw and seal: deck over backwall. The lowest rating was given to sliding plate joints and open joints. All ratings are presented in Figure 33. The most important factor affecting joint performance in New York is installation workmanship, followed closely by inspection and weather conditions at time of installation. All ratings are presented in Figure 34. The most promising joint types are EM-SEAL and link-slabs.

Figure 33: Performance Rating of Joints (New York State Survey Respondent Answers)

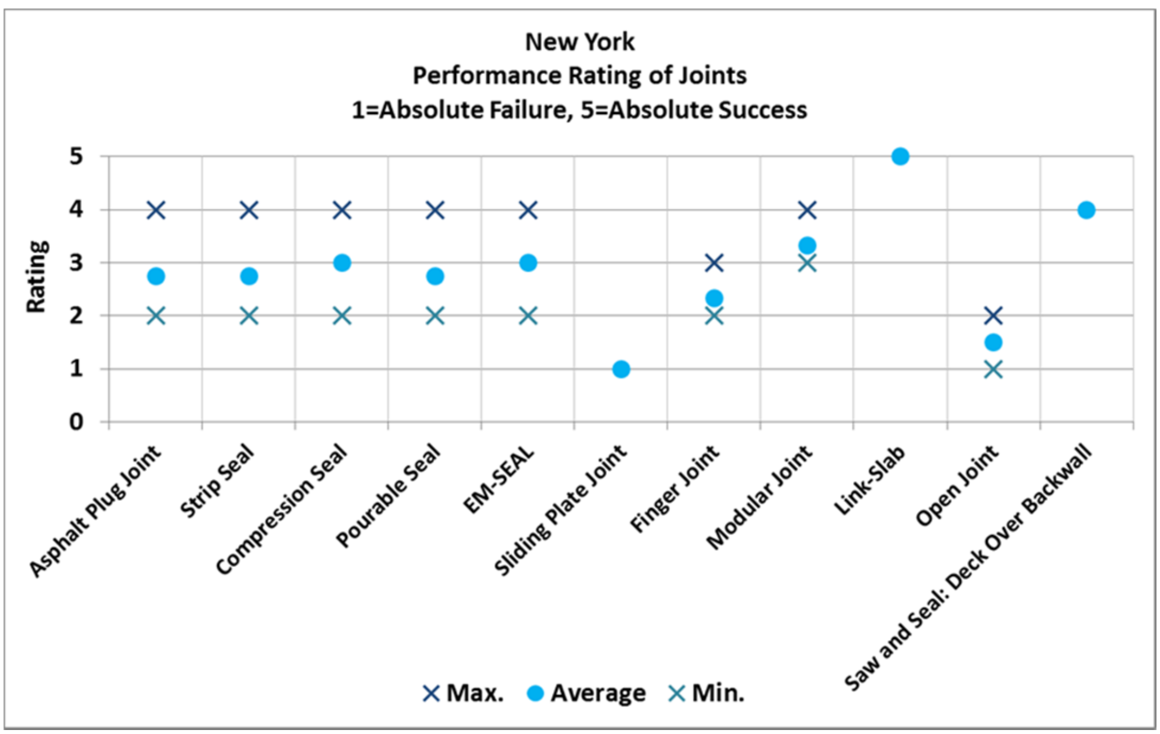
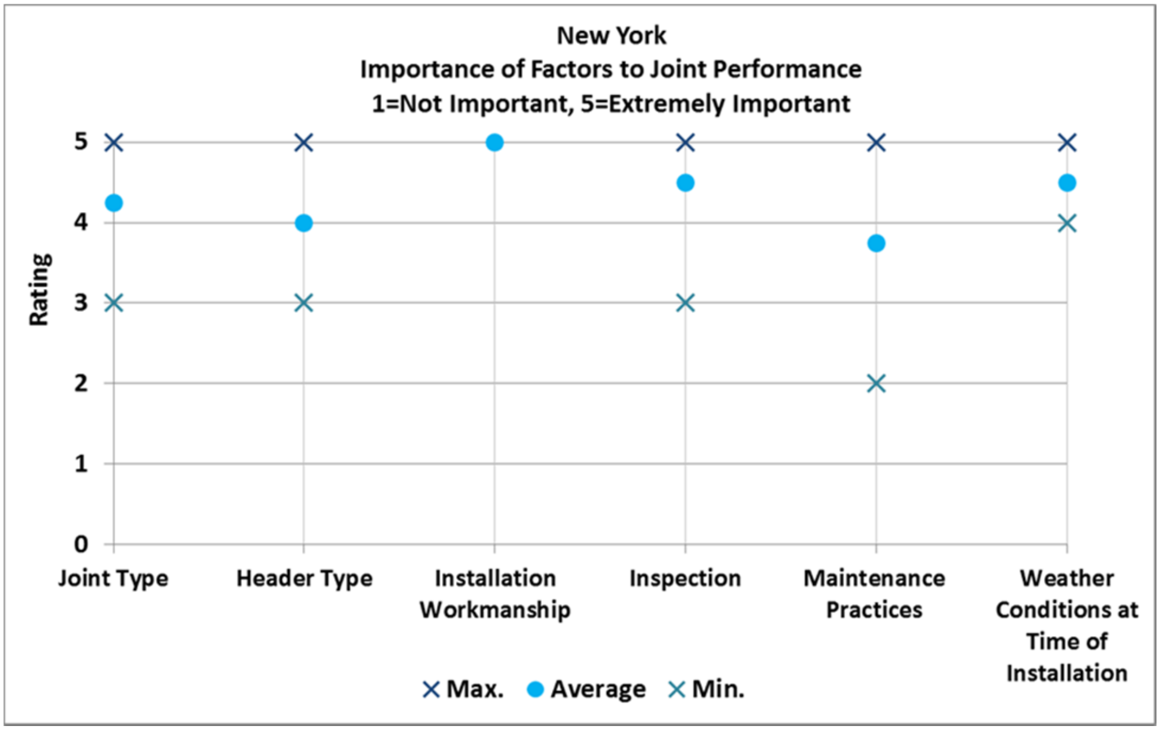


Figure 34: Importance of Factors to Joint Performance (New York State Survey Respondent Answers)



Current headers used in New York are normal setting concrete, elastomeric concrete, and quick setting concrete. For overnight construction, only quick setting concrete and elastomeric concrete are used. For new headers, NYSDOT standard details only specify elastomeric concrete. In the past, armored headers were used with joints such as compression seals for decades, but they were very difficult to repair and continuously subject to plow damage. Elastomeric concrete is used for compression seals and pourable seals, while quick setting and normal setting concrete are used for modular joints.

New elastomeric headers placed on old concrete decks can fail prematurely due to deteriorated deck concrete. Elastomeric concrete can also have tire friction issues, issues with rutting, and in some cases sections of the header of broken out. Some elastomeric concretes are low strength or exhibit creep so they cannot overhang the end of a deck. They are also sensitive to damp concrete installations.

Temperature is considered during joint installation. There is a table of joint opening adjustments due to temperature difference from the standard 68°F. Fabricator’s charts are used to properly size the seals. Watertight integrity tests are performed after new installation and witnessed by the engineer in charge; no testing is done on repairs. Concrete deck must be dry before elastomeric concrete is placed. There is also a specified temperature range given in the NYSDOT specifications. Field splicing is generally allowed for closed cell foam seals which can be field welded to splice or extend the seal. One respondent noted that most other joint types are not allowed to be spliced.

There are installation practices that were described to positively influence joint performance: removal of all unsound concrete requiring removal of at least 2 ft. of deck on each side of joint centerline, proper cleaning of surfaces, ensuring dry surface prior to placing elastomeric concrete, waiting after the header is placed until it is completely dry to the touch before installing seal, and casting fine aggregate to surface of elastomeric concrete to provide some initial tire friction.

Installation practices that negatively impact joint performance include: installing headers and seals in short windows of time, improperly specifying joint seals (sometimes seal is not properly sized and is placed in tension when the temperature drops, resulting in bond failure between seal and header), replacing armored headers with elastomeric headers resulting in an increase in the seal width which can lead to seal failures as a result of debris build up, and placing elastomeric concrete on concrete that has not cured for at least 10 days.

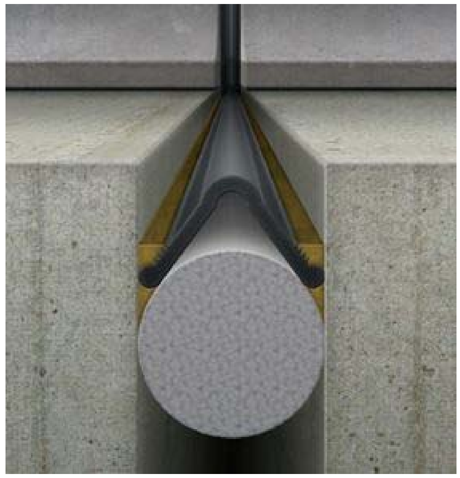
The majority of respondents stated that there are standard joint and header replacement details utilized in the state, and all respondents noted that there are no standard repair details for joints and headers. The majority of respondents also noted that there is a bridge maintenance manual for the state that is separate from the design manual; this document is referred to as "Fundamentals". Routine deck washing is performed. They would like to perform more preventive maintenance, but the maintenance group is understaffed. For anti-icing, New York predominantly uses just salt, but sometimes it is mixed with calcium chloride or magnesium chloride.

4.1.7 Pennsylvania

In Pennsylvania, current joints in service are asphalt plug joints, strip seals, compression seals, pourable seals, sliding plate joints, finger joints, modular joints, open joints, saw and seal: deck over backwall, saw and seal: over existing joints, inverted V-joints, and a combination of strip seal with an asphalt plug joint over the top of the strip seal. In new construction, the joints used are: strip seals, compression seals, pourable seals, finger joints, modular joints, saw and seal: deck over backwall and inverted V-joints. There are also finger joints being constructed off the bridge with a concrete trough detail behind the backwall.

In joint replacement projects, asphalt plug joints, strip seals, compression seals, pourable seals, inverted V-joint, and saw and seal: deck over backwall are used for both overnight replacements as well as replacements with no time constraints. Replacement joints used strictly when there are no time constraints are modular joints and saw and seal: over existing joint, while finger joints and open joints are also choices for overnight construction. Inverted-V joints were added in the "other" category of joints. This is a newer joint type that was not included in the survey. An inverted-V joint is a rubber strip seal joint with an upside-down "V" shape. The benefits of this seal shape, according to manufacturer D.S. Brown's website, is that seal is weather, UV, ozone and tear resistant, is quickly installed, and can be used for easy rehabilitation of existing expansion joints (*9*). An example of the V-Seal Expansion System is shown in Figure 35.

Figure 35: D.S. Brown V-Seal Expansion Joint System (*9*)



Joints that typically were reported to perform well with routine repair and maintenance varied throughout Pennsylvania. All respondents agree that strip seals are on this list, while the majority also chose asphalt plug joints, finger joints, and modular joints. Other responses included pourable seals, compression seals, and saw and seal: deck over backwall. Typical service life of joints is presented in Table 9. The shortest service life was assigned to strip seals, compression seals, pourable seals, open joints and saw and seal: over existing joint. At least one respondent selected a typical service life of zero to four years for these joints. For the strip seal, many other districts selected this joint as having one of the longest service lives, showing the variability in performance throughout the state. The longest service life was assigned to finger joints, sliding plate joints and modular joints. As previously stated, some respondents also selected strip seals. These joints were all said to have a service life over sixteen years by at least some respondents. Pennsylvania has just started using EM-SEAL for seal replacements, so its service life is not yet known.

Table 9: Typical Service Life of Joints (Pennsylvania Survey Respondent Answers)

Pennsylvania: Typical Service Life of Joints											
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Pourable Seal**	**Sliding Plate Joint**	**Finger Joint**	**Modular Joint**	**Link-Slab**	**Open Joint**	**Saw and Seal: Deck Over Backwall**	**Saw and Seal: Over Existing Joint**
0-4		1	1	2					1		1
5-8	5										
9-12			1	1				1			
13-16		2					1			1	
>16		2			1	4	2				

Joints that have been, or are currently being, phased out include: asphalt plug joints, compression seals, pourable seals, sliding plate joints, finger joints, and open joints. Joints that Pennsylvania would like to phase out include: modular joints and saw and seal: deck over backwall. Some respondents chose that they would like to phase out compression seals, sliding plate joints, and finger joints but have not yet started to. Compression joints weaken over time and fall through open joints. Finger joints are very difficult to maintain and replace drainage troughs. The circumstances (if any) preventing the phasing out of joints include project development and funding as well as the expense of removing the entire joint system. In general, Pennsylvania is eliminating joints when possible and/or designing semi-integral approaches.

In Pennsylvania, the definition of a successful joint varies slightly throughout the state: service life of a successful joint would range from 5 to over 15 years, and water-tightness should be maintained over this service life. The joint should be maintenance free or be easy to maintain, be durable, allow for easy movement, be cost-effective, and be able to be replaced in a short time. One respondent stated, with regards to finger joints, the joint should last as long as the deck and the troughs should last at least 20 years without leaking.

Failure of a joint includes joints that allow water to leak through and damage the substructure, short life span, joint leakage in between maintenance cycles for the wearable components (neoprene seal, trough), and the steel extrusion requiring repair before the life expectancy of the seal.

In rating the performance of joints, the highest rated joints were strip seals and saw and seal: deck over backwall, while the lowest rated joints were open joints and sliding plate joints. All ratings are presented in Figure 36. The importance of factors on joint performance is presented in Figure 37. The most important factor is installation workmanship, while the least important factor is weather conditions at time of construction. The most promising new products in Pennsylvania are EM-SEAL and using elastomeric concrete for header repairs. Another respondent noted that although they are not using new products, they believe using a specialized tool for neoprene seal installation in strip seals may reduce damage to the seal during installation. This has not been implemented as of yet, but will be specifying the use of this tool for future installations. Information on this specialized tool is available from D.S. Brown (*9*).

Figure 36: Performance Rating of Joints (Pennsylvania Survey Respondent Answers)

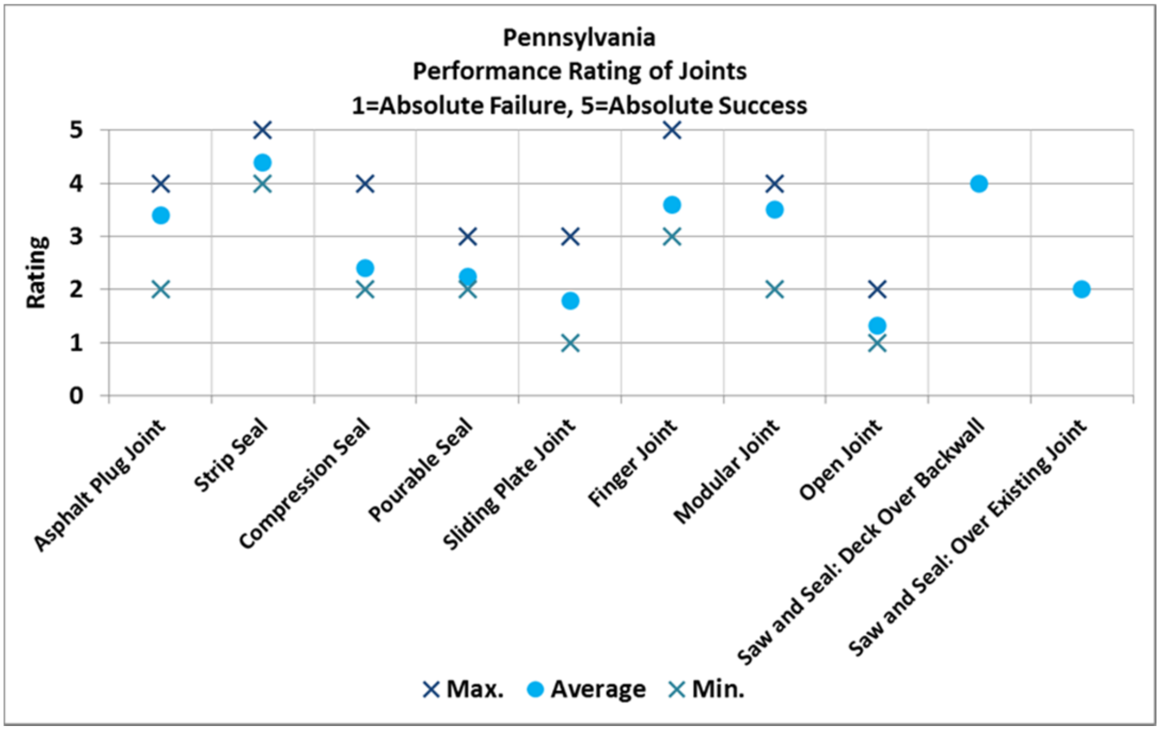
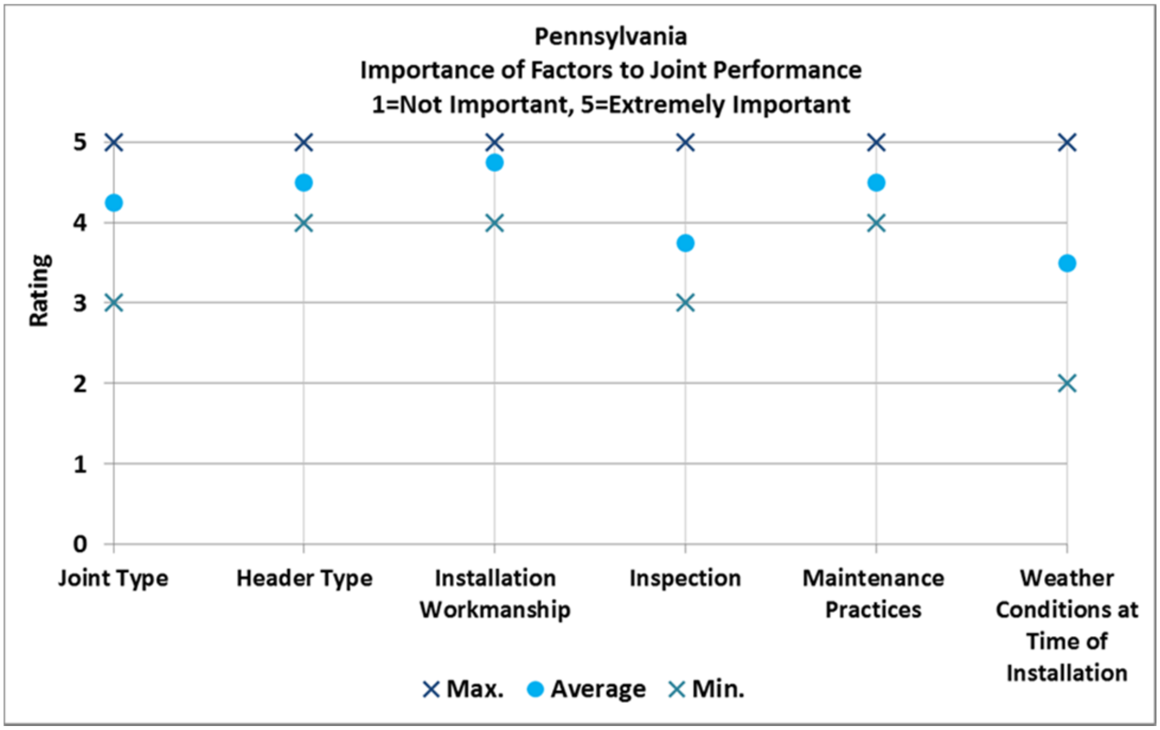


Figure 37: Importance of Factors to Joint Performance (Pennsylvania Survey Respondent Answers)



Headers currently in use when there are no time constraints include: armored headers, normal setting concrete, and elastomeric concrete. Headers used when overnight construction is required include quick setting concrete and elastomeric concrete, while one respondent also reported using armored header. Steel armor is used for strip seals, modular joints and finger joints. Armored headers can rust and deteriorate, get damaged by snow plows, and can experience some spalling of concrete around steel headers. In other cases, armored headers have performed well. Elastomeric concrete headers are specified for repairs of deteriorated headers according to one respondent.

There are standard joint and header replacement details in Pennsylvania, but there are not standard repair details. Temperature is accounted for during joint installation. If there is a total depth joint replacement, then the distance between the joint will be adjusted to temperature prevailing at time of installation prior to pouring concrete. A temperature table is placed on bridge plans for setting the joint opening based on the installation temperature. Standard watertight testing is done after new joint installation, but is not done on repairs. Repair jobs are generally done during the summer. Any concrete work (for joint installation) would require cold weather curing measures to be used during cold weather. Field splicing of joints is allowed and is typically done for strip seals or inverted V-joints.

Having a field representative on site to provide technical assistance and following manufacturer's specifications are both felt to have positively influenced joint performance. However, it was noted that the representative is only sometimes/rarely on site for joint installation. Inverted-V (strip seal) joints are preferred joints. Many of the issues that are reported to negatively influence joint performance relate to strip seals. Steel extrusions have to be clean before joint installation. Installation of bonding compound cannot be done too far in advance of setting the seal. Pennsylvania may start requiring a specialized tool to install the neoprene gland since there have been issues in the past where use of normal hand tools ended up damaging the seal. They also recommend constructing semi-integral approach with joint located off the bridge when possible. Finger joints with concrete troughs behind the abutment have performed very well in Pennsylvania.

There is a bridge maintenance manual in Pennsylvania. Preventive maintenance is performed with annual pressure washing and cleaning of debris, deck and joints. Strip seal neoprene glands are replaced on a 10 to 15-year cycle on interstates, sometimes longer on other roadway classifications due to funding restraints. For anti-icing, salt and salt brine pretreatment are used.

4.1.8 Rhode Island

There are currently a wide range of joint types in Rhode Island, including: asphalt plug joints, strip seals, compression seals, pourable seals, sliding plate joints, finger joints, modular joints, link-slabs, saw and seal: deck over backwall, and saw and seal: over existing joint. Of those joint types, all are being used in new construction except for sliding plate joints and saw and seal: over existing joints. For replacement joints, asphalt plug joints, compression seals, link-slabs and saw and seal: deck over backwall are joint choices when there are no time constraints, as well as when overnight replacement is required. Strip seals, finger joints and modular joints are also used for replacement joints, but only when there are no time constraints. Sliding plate joints and open joints have been (or are currently being) phased out. The reasons for discontinuing them include their susceptibility to plow damage.

Of the many joint types in use in Rhode Island, the joints that typically perform adequately if routine repair and maintenance are performed are asphalt plug joints, compression seals, pourable seals, and saw and seal: deck over backwall. The typical service life of the joint types are presented in Table 10. The joints with the longest service life are strip seals, compression seals, and finger joints, while the shortest service lives are for the asphalt plug joint and saw and seal: over existing joint.

Table 10: Typical Service Life of Joints (Rhode Island Survey Respondent Answers)

Rhode Island: Typical Service Life of Joints								
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Pourable Seal**	**Finger Joint**	**Modular Joint**	**Saw and Seal: Deck Over Backwall**	**Saw and Seal: Over Existing Joint**
0-4								
5-8	1							1
9-12				1		1	1	
13-16			1					
>16		1			1			

In Rhode Island, a successful joint is defined as one that is water tight and provides a smooth riding surface, with the opposite being defined as failure. Rhode Island rated the performance of joint types with results shown in Figure 38. None of the joints were rated an absolute success, however asphalt plug joints, pourable seal, link-slab, and saw and seal: deck over backwall were all rated as successful with a rating of 4. The joints with poor performance ratings were strip seals and modular joints (with a rating of 2) and open joints (absolute failure). Multiple factors were rated for their importance to joint performance. The single most important factor affecting joint performance, according to Rhode Island, is installation workmanship. The factor with the least importance is header type. These results are presented in Figure 39.

Figure 38: Performance Rating of Joints (Rhode Island Survey Respondent Answers)

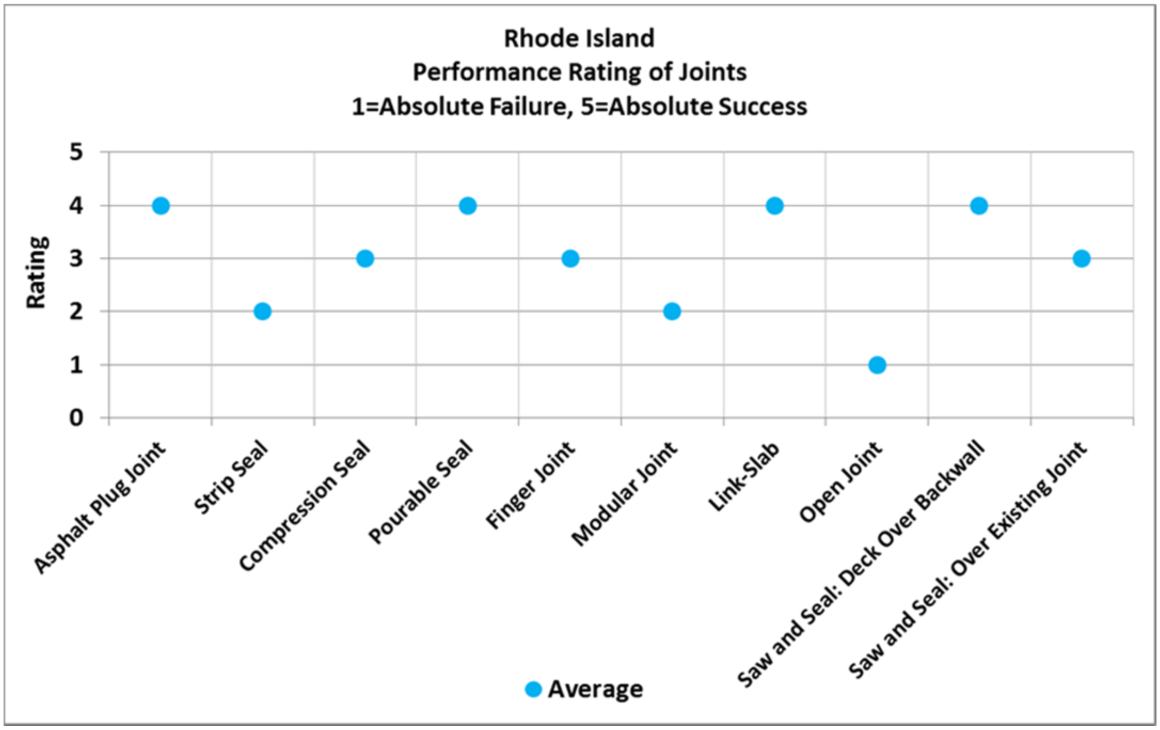
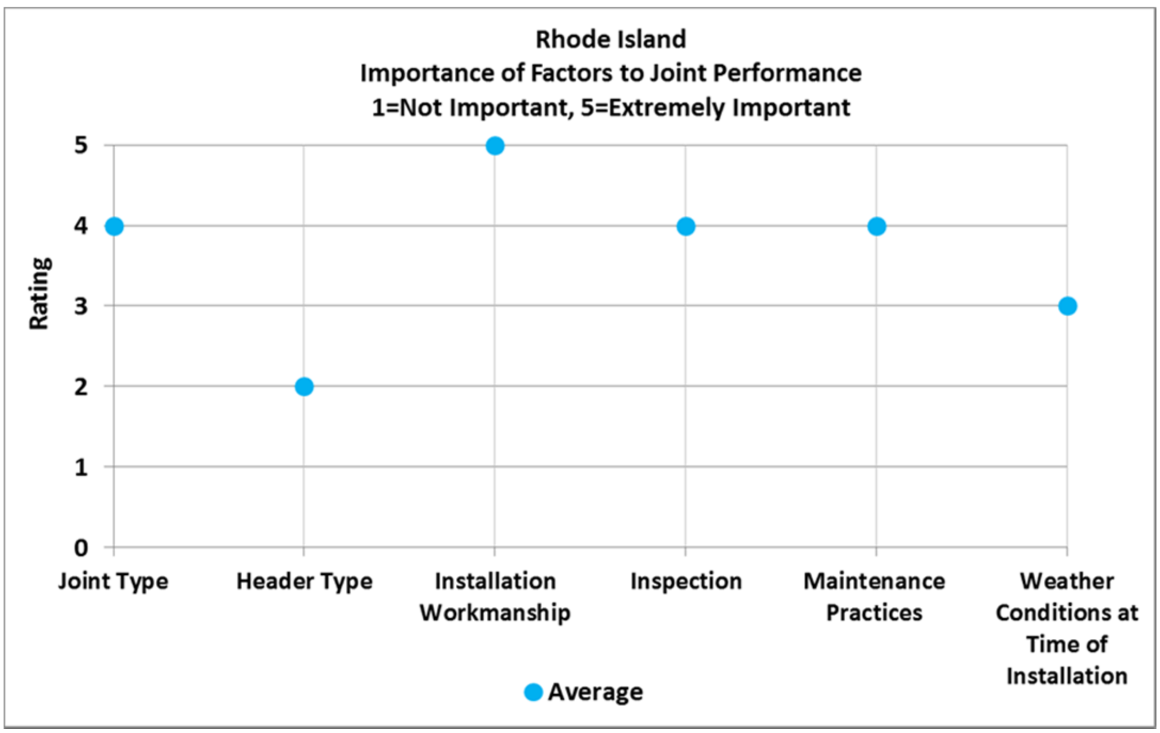


Figure 39: Importance of Factors to Joint Performance (Rhode Island Survey Respondent Answers)



Armored headers, normal setting concrete, and elastomeric concrete are all used in Rhode Island when there are no time constraints, and quick setting concrete is used when overnight construction is needed. Elastomeric concrete is used with strip seals, while quick setting concrete is used with poured sealant and deck over backwall (saw and seal). In high traffic volume bridges there have been issues with anchorage pulling out of elastomeric headers.

There are no standard joint or header replacement or repair details in Rhode Island. The temperature is considered when joints are installed by adjusting the opening for temperature increase or decrease from 60°F. The only weather requirement for joint installation is that the temperature must be 45°F or higher. There is no testing (such as watertight test) done to verify proper installation or repair. Field splicing is allowed on all repairs unless restricted per manufacturer recommendations. Although there is no solid evidence, it is believed that construction phasing has a negative influence on joint performance, and complete installation without phasing improves joint performance. The manufacturer's representatives are sometimes present to oversee joint work at time of construction. Rhode Island uses salt as their de-icing treatment.

4.1.9 Vermont

Vermont has a range of joint types currently in use which include: asphalt plug joints, strip seals, compression seals, sliding plate joints, finger joints, modular joints, link-slabs, open joints, and saw and seal joints. The two joint types not currently in service are pourable seal and EM-SEAL. For new construction, the joint types being used are asphalt plug joints and compression seals for small movement, and finger joints and modular joints for larger movement. For replacement projects, the only joint used for overnight construction would be the asphalt plug joint. When there are no time constraints, Vermont uses asphalt plug joints, compression seals, sliding plate joints, finger joints, link-slabs, or saw and seal: deck over backwall.

Of the joints used in Vermont, the ones that typically perform adequately if routine repair and maintenance are performed are asphalt plug joints and saw and seal: deck over backwall, while half of the respondents also added compression seals, finger joints, and link-slabs. Typical service lives of joints in Vermont are presented in Table 11. The joints that were unanimously assigned the longest service lives are finger joints and modular joints. The joint with the shortest service life is the asphalt plug joint. Vermont is currently phasing out, or would like to phase out, strip seals, sliding plate joints, modular joints, open joints, and saw and seal: over existing joints.

Table 11: Typical Service Life of Joints (Vermont Survey Respondent Answers)

Vermont: Typical Service Life of Joints									
Years	**Asphalt Plug Joint**	**Strip Seal**	**Compression Seal**	**Finger Joint**	**Modular Joint**	**Link-Slab**	**Open Joint**	**Saw and Seal: Deck Over Backwall**	**Saw and Seal: Over Existing Joint**
0-4									
5-8	2								
9-12		1	2				1	1	
13-16									
>16				2	2	1		1	

In Vermont, success of a joint is defined as one that meets or exceeds the predicted service life without failing, and one that allows movement while also being easily maintained. Failure of a joint occurs when it allows water to reach the bearings, bridge seats or ends of the beam. It was noted that any type of mechanical joints are harder to maintain and typically much more costly.

When rating the success of joints, the only joint type rated an absolute success was the link-slab, with asphalt plug joint and finger joint highly rated as well. All ratings are presented in Figure 40. The importance of various factors to joint performance was rated. The most important factors were joint type, header type, installation workmanship, and maintenance practices. The ratings are shown in Figure 41. Manufacturer's representatives are sometimes on site for joint installation. Vermont stated that a promising new product they are using is 501 Matrix (asphalt plug joints). This system is a pre-measured, pre-packaged joint system composed of uniquely formulated polymer modified asphalt binder combined in one box with the exact ratio of select aggregate (*7*). The product eliminates field measuring, proportioning and mixing typically required with asphalt plug joints.

Figure 40: Performance Rating of Joints (Vermont Survey Respondent Answers)

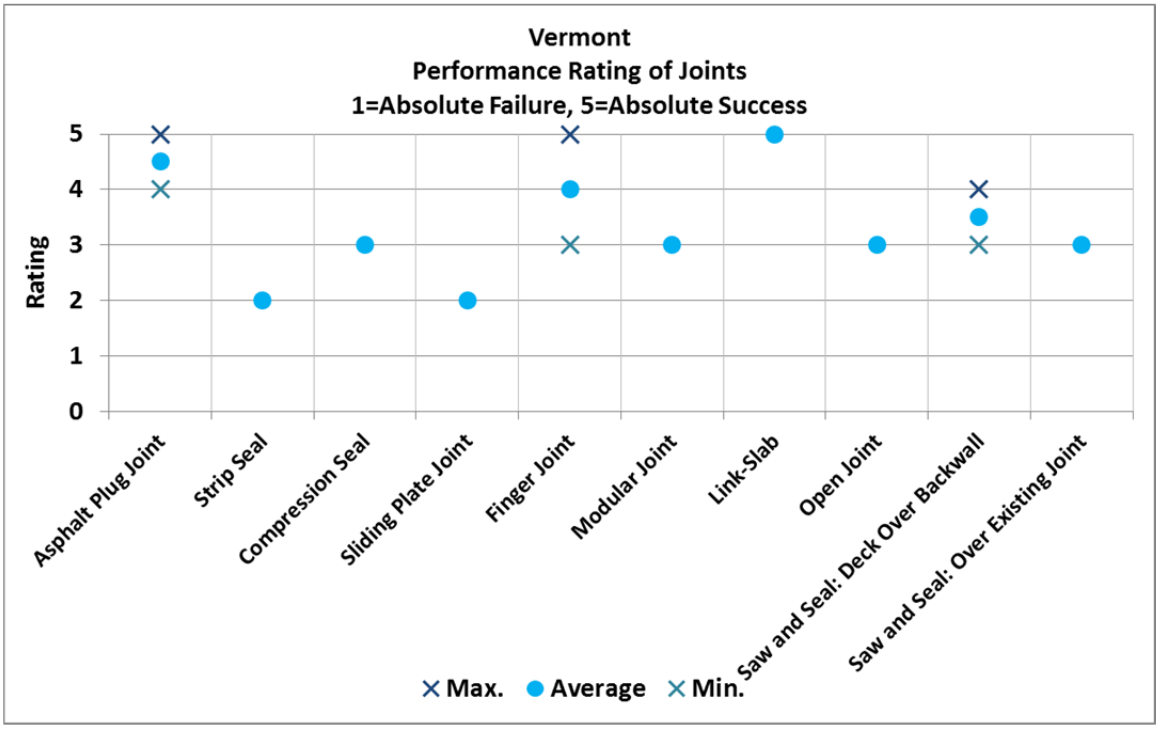
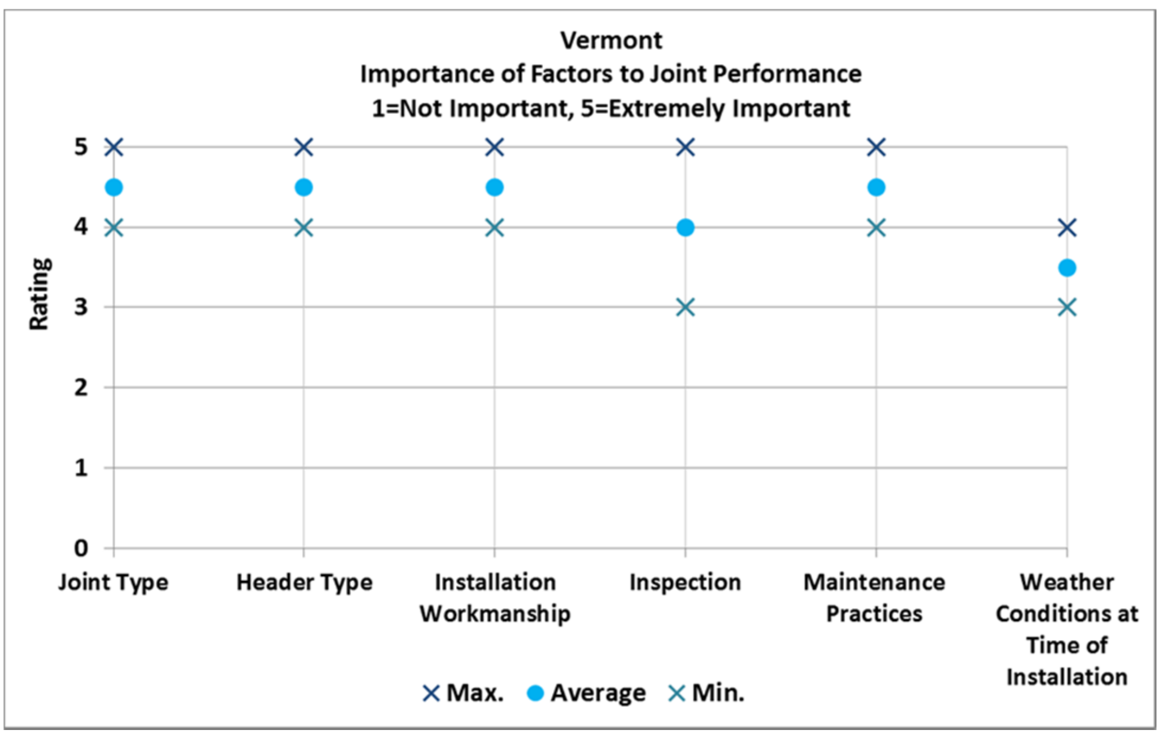


Figure 41: Importance of Factors to Joint Performance (Vermont Survey Respondent Answers)



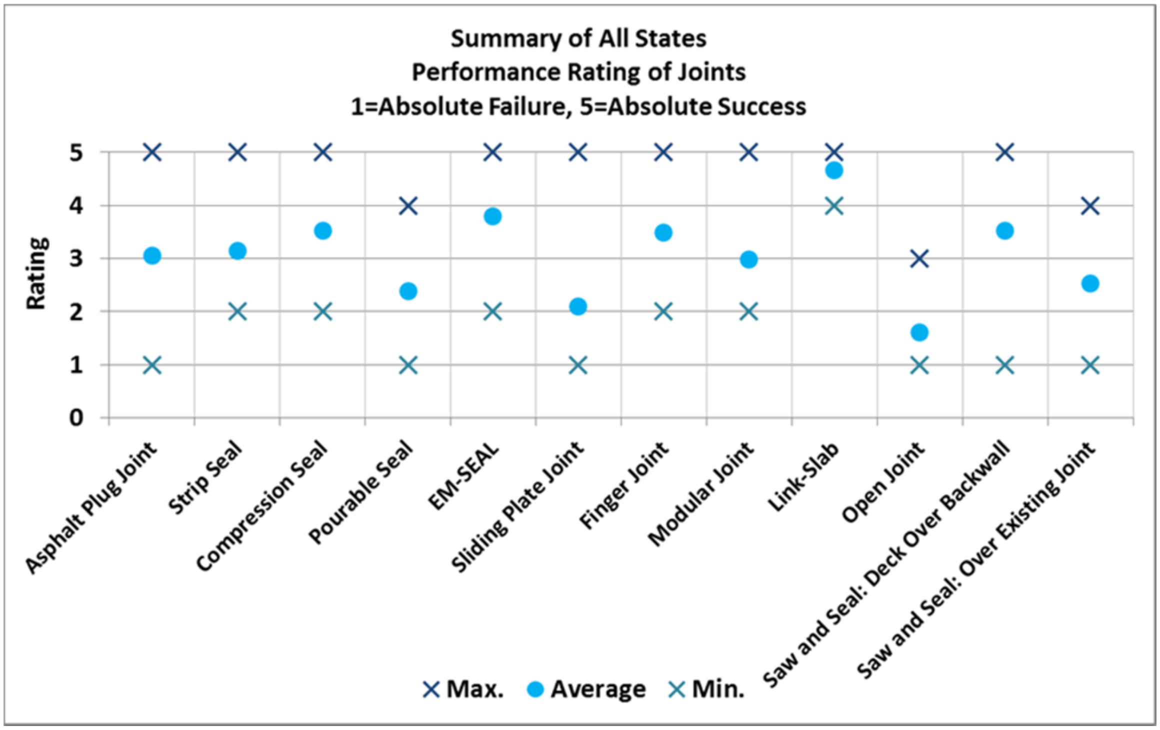
Only normal setting concrete and quick setting concrete are used for headers in Vermont; quick setting being used only when overnight construction is required. For extreme cold temperatures, Vermont has approved Tech Crete as a header material. Quick setting concrete headers do not seem to last as long as normal setting concrete headers. It was also noted that most concrete headers react differently than the bituminous material surrounding them, which makes them more likely to be damaged by heavy truck traffic. For anti-icing treatments, Vermont uses salt, salt brine (includes calcium chloride and magnesium chloride) and Ice-B-Gone.

Temperature is considered for joint installation. For longer bridges, joints with troughs are adjusted to neutral temperature condition. This applies to finger joints and some modular joints. Other weather specifications include asphalt plug joints being repaired, replaced, or installed during spring, summer or fall construction. There is no testing done to verify proper installation. Field splicing is done on some repairs. Vermont performs preventive maintenance. They have a sweeping/washing program where 100% of bridges are swept each year and 50% of washable bridges are washed, including deck, joints, troughs, drains, and superstructure components. Asphalt plug joints are on a 5 to 6 year repair or replacement cycle. Joint headers are repaired as necessary. Bridge joint troughs are washed when bridges are washed.

4.2 Summary of All State Responses

The average rating of joint performance from all states is presented in Figure 42. These ratings present the average of each state's average ratings. The figure shows the maximum and minimum rating assigned to each joint type in the survey (considering all individual responses). According to the survey results, the joints with the best performance are link-slabs, EM-SEAL, compression seal, and saw and seal: deck over backwall. The joints with the worst performance are open joints, sliding plate joints, and pourable seals. However, these results show that the majority of joint types have a large range of performance ratings. Link-slabs have the overall best performance rating with the highest average rating as well as the least variability in performance ratings.

Figure 42: Summary of States Performance Rating of Joints



As a result of differing expectations on joint performance, success of a joint is not a direct correlation with its typical service life, and failure of a joint does not necessarily mean it has a short service life. For example, sliding plate joints and open joints have typical service lives greater than nine years, and in many cases greater than sixteen years, despite having “poor” performance compared to other joints. Those pleased with asphalt plug joint performance have an expectation of a short service life for these joints. For some of the more successful joints, such as EM-SEAL and compression seals, many states rate their service life below nine years. These examples are shown in Figure 43 and Figure 44.

Figure 43: Variation in Typical Service Life of Two of the Highest Rated Joints

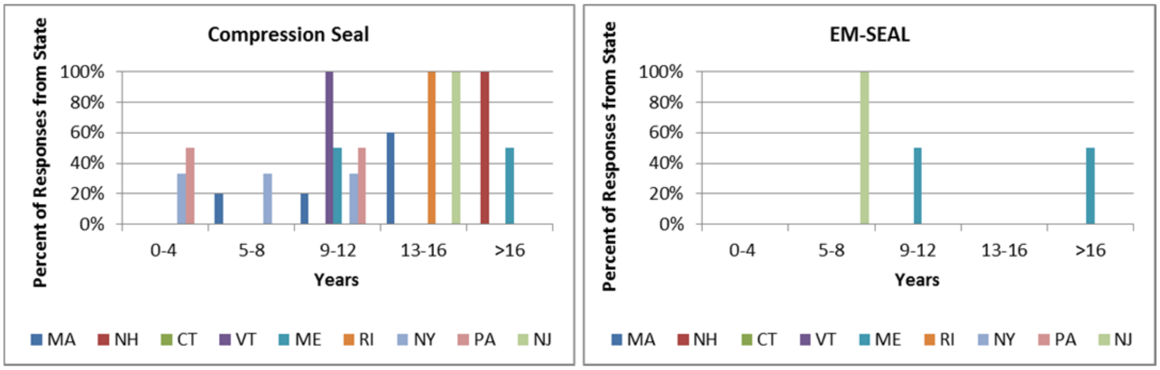


Figure 44: Variation in Typical Service Life of Two of the Lowest Rated Joints

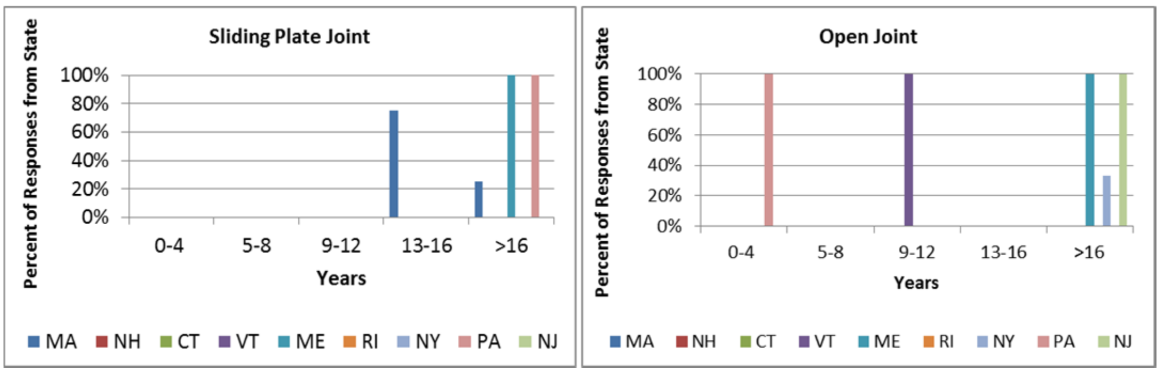


Table 12 presents a complete list of typical service life ratings from all states. In order to fit all data in the table, the following acronyms were used to denote joint types: saw and seal: deck over backwall (SS:D), saw and seal: over existing joint (SS:O), asphalt plug joint (APJ), compression seal (CS), strip seal (SS), EM-SEAL (EM), pourable seal (PS), modular joint (MJ), sliding plate joint (SPJ), finger joint (FJ), open joint (OJ), and link-slab (LS).

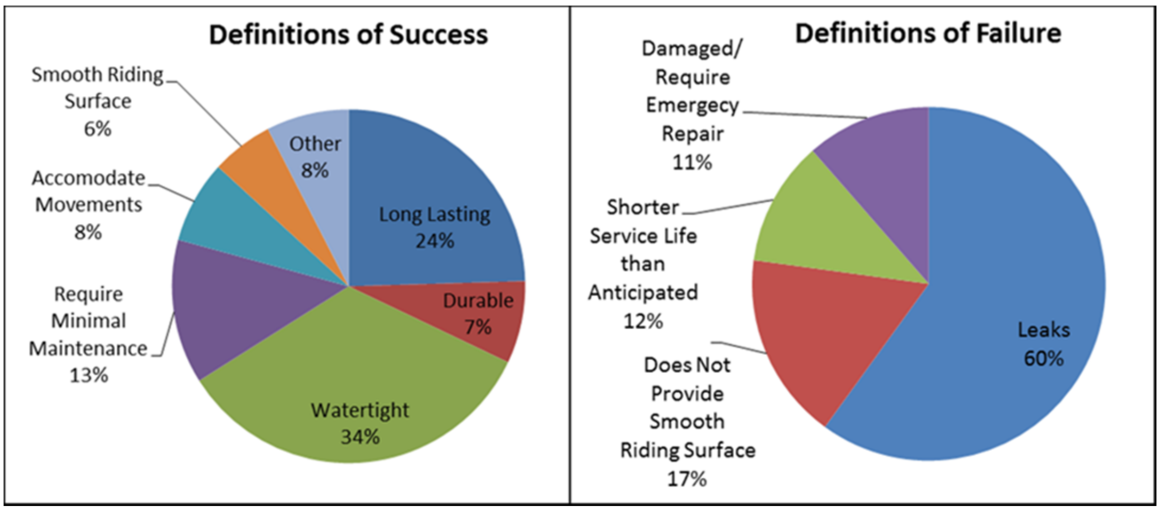
Table 12: Typical Service Life of Joints Assigned by All Respondents

All States: Typical Service Life of Joints												
Years	**SS:D**	**SS:O**	**APJ**	**CS**	**SS**	**EM**	**PS**	**MJ**	**SPJ**	**FJ**	**OJ**	**LS**
0-4	0	1	6	2	2	1	11	0	0	0	1	0
5-8	1	1	13	2	1	1	0	1	0	0	0	0
9-12	5	1	1	6	5	1	2	3	0	1	1	1
13-16	1	0	1	5	7	0	0	4	3	2	0	2
>16	4	0	0	2	4	1	0	8	3	16	3	4

Finger joints have the longest typical service life, and also the most consistent, with 16 of the 19 respondents reporting a service life of greater than sixteen years. The common consensus on finger joints is that they could perform well, but plow damage and drainage troughs lead to many issues. All states reporting problems with finger joints noted that they are nearly impossible to maintain and often build up with debris, fail, leak, and experience other similar issues.

Definitions of success and failure were categorized and presented in Figure 45. Of the 26 survey respondents, 24 provided definitions for success and failure. These were compiled and quantified based on each factor noted by respondents. Therefore, the total number of factors noted by respondents is referenced rather than the total number of respondents (18 of the 26 respondents noted that joints that are watertight are critical to success, but this was 34% of the 53 total factors mentioned by the respondents).

Figure 45: All States Definitions of Success and Failure of a Joint

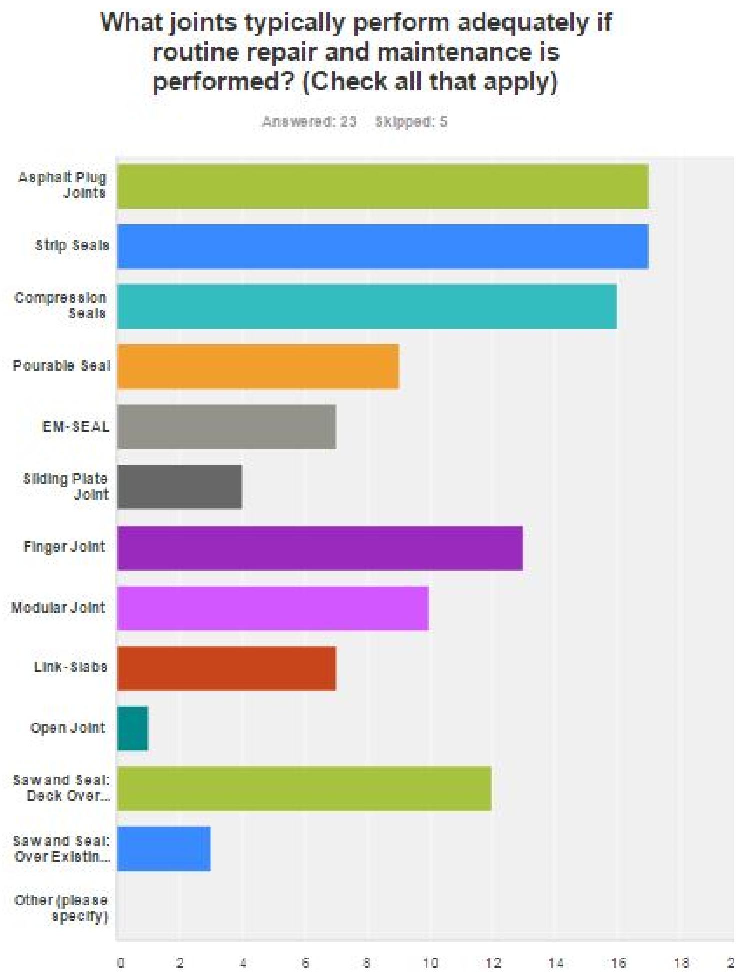


The definition of a successful joint varies slightly for each state, and can also vary from respondents within a state. However, there are many similarities in what states would use to define a successful joint: joints that do not leak, that provide a smooth riding surface, require minimal to no maintenance, and do not get damaged by snow plows. In many cases, the large variation in a joint's performance rating came from the individual respondent's definition of a success and failure. For example, within Massachusetts the sliding plate joint was rated an absolute success by two respondents and a failure by another two. The difference in their definitions of success were that the two respondents rating the joint a success put the most value in a long service life, while the two rating it a failure put value in the joint being watertight.

The definitions of failure of joints included joints that leak, have seals that fall out, do not provide a smooth riding surface, and cause other issues when not properly maintained (including damage to beam ends and bearings). In Figure 45, the category of "damaged/requires emergency repair" includes joints damaged from plows and joints that are difficult to maintain and result in costly damage when maintenance is not performed.

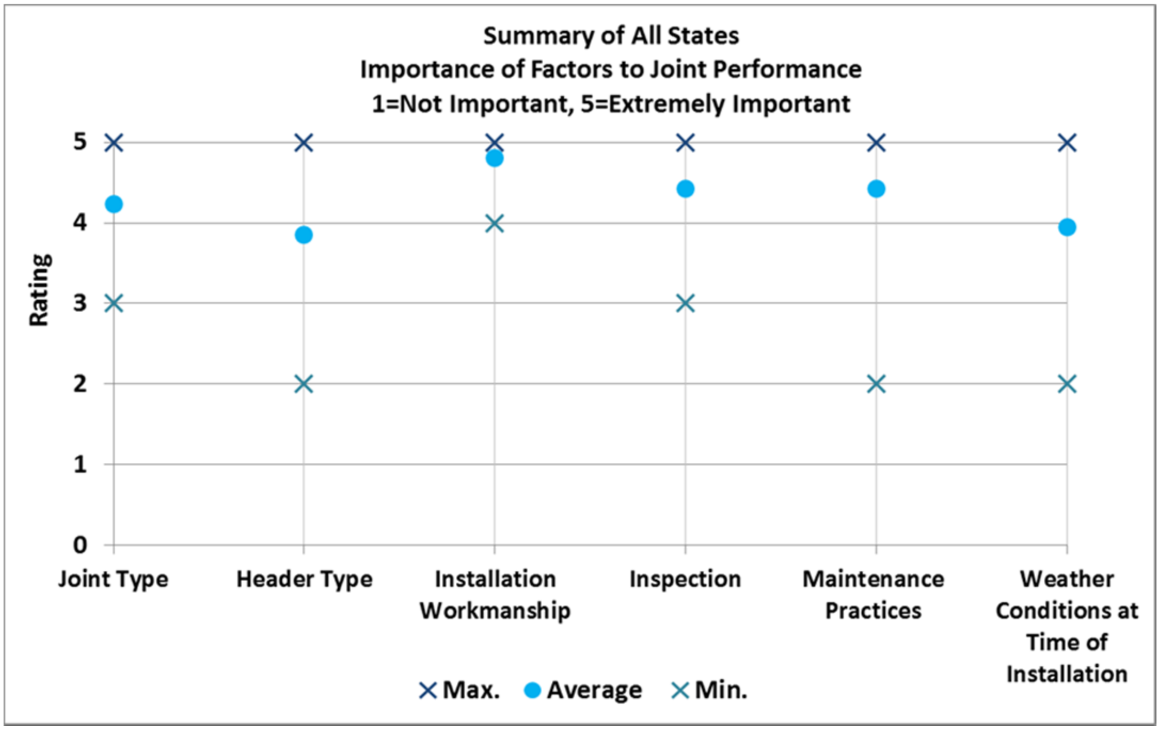
The joints selected by the most respondents as ones that perform adequately with routine repair and maintenance are asphalt plug joints, strip seals and compression seals. All results are shown in Figure 46. Open joints, saw and seal: over existing joints, and sliding plate joints received the lowest rating. Open joints and sliding plate joints also received the lowest success rating, being rated close to an absolute failure. While some joints may perform poorly without routine repair and maintenance, the respondents believe they have the ability to be a successful joint. Open joints and sliding plate joints are not successful and are not believed to have the potential to be successful by most respondents.

Figure 46: Joints that Perform Adequately with Routine Repair and Maintenance



The most important factor in influencing joint performance is installation workmanship; this factor was the highest rated when all states' ratings were averaged as shown in Figure 47. Furthermore, installation workmanship has the least variation in state responses, with all respondents rating the importance highly. The second most important factor is equally assigned to inspection and maintenance practices. This shows that the joint type itself is not as important as proper installation, ensuring proper installation (inspection), and maintaining the joints. However, only three states report doing watertight testing upon new installation and watertight testing is almost never done after repairs.

Figure 47: Summary of States Rating of Factors Affecting Joint Performance



Installation practices have a significant impact on joint performance, and many states gave suggestions of practices that positively and negatively impacted performance, as well as experiences where certain joints or headers perform poorly. Multiple states noted that installation of joints or elastomeric headers should not be done when the deck is damp, as this leads to early failure and adhesion issues. One of the most consistent installation practices that lead to failure is improper cleaning of surface prior to installation. Many states noted that cleaning after initial cut is made, including sandblasting, is generally included in the specifications but is often skipped due to time constraints or other issues.

Joint seals are sometimes improperly sized, according to one state, and the seal ends up being placed in tension when the temperature drops, which results in bond failure between the seal and header. Bond failure is something many states have experienced and noted as a problem. Installation of bond cannot be done too far in advance of placing the seal or this will likely result in inadequate bond.

State DOTs selected joints that perform adequately if routine repair and maintenance were performed. These answers differed from the joints rated an absolute success or an absolute failure. The joints selected for this question are ones that may have one or more issues with them if they are not maintained or repaired, but would be adequate joint choices with routine repair and maintenance.

The most popular choices were asphalt plug joints and strip seals, with 17 of the 28 respondents (61%). Compression seals were the next joint choice with 16 of 28 respondents (57%). Most states thought that these joint types were easier to replace when there were issues and less expensive than some other options (including less time consuming for installation and therefore less costly). The joint that does not perform adequately, even with routine repair and maintenance, is an open joint. Only 1 of 28 respondents chose an open joint for this question, with the other low scoring joint being a sliding plate joint (4 of 28 respondents). These two joints are also the ones rated closest to an absolute failure.

While maintenance is an important component of joint performance, many respondents stated that their state or district did not have the funds to perform as much maintenance as is needed or as they would like. Similarly, many respondents noted that maintenance groups are understaffed. 57% of respondents reported doing some type of preventive maintenance including bridge sweeping/washing (where 50% of washable bridges are washed to include deck joints, troughs, drains, and superstructure components), and annual cleaning of debris from joints. Among these respondents, it was also noted that the cleaning is not always done well, and that maintenance programs are inconsistent. While there are not enough funds available to do the level of preventive maintenance most states would like, the lack of incorporating a program for this results in significant costs to the state as time progresses. If joints are not maintained and troughs/drainage systems are not cleaned out, leaking often occurs.

There are two broad categories of maintenance: preventive maintenance and reactive maintenance. While reactive maintenance is more common among the states (repairing a failed joint when it is reported from inspection or citizens calling to report damaged joints), this approach to maintaining joints is not cost-effective. AASHTO Bridge Maintenance suggests that for maximum effectiveness of joint performance as well as the highest return on resources expended, preventive maintenance of joints should begin when the bridge is new and continue throughout its life (*8*). Documenting joint performance starting when they are new would bring attention to any early failure issues; these could stem from improper design or construction, improper forming of joint opening (or wrong size of opening), improper seal size or placement, inadequate bonding of seal to adjacent concrete, or failure to install bond breaker (*8*, p.151). These issues were noted by multiple states as causes of early failure of joints. If they are realized early, then the problem can be addressed and potentially prevented from happening again.

If these issues go undocumented, over time they will more than likely lead to many other problems; not only does the severity of damage from a leaking joint increase over time, but the rate of damage also increases (*4*). By the time the joint is considered completely failed (which varies depending on the state's definition of failure) and reactive maintenance is implemented, the damage from the failed joint will more than likely be significantly more costly than if the problem was realized and repaired quickly. Many joint failures result from debris build up and failure of drainage troughs which could be avoided (or at the least, the trough could perform successfully for a longer period of time), with a preventive maintenance program. Investing money into these types of programs would likely extend the service lives and performance of joints as well as minimize repairs, replacements, and costly repairs to elements damaged by failing joints.

Having a field representative on site to provide technical assistance and ensure that the contractor closely follows the manufacturer's specifications, is believed to have a positive impact on joint performance. The presence of a representative or inspector, regardless of specific interactions, gives an indication that workmanship is important to the success of the project and can result in an improved joint. There should be quality control and materials should be exactly those specified by the manufacturer. The majority of states also have problems when concrete is not removed all the way to sound concrete. It is suggested that concrete should be removed over at least 2 ft. of deck on each side of the joint centerline ensuring all unsound concrete is removed. When the substrate is in bad condition prior to installation of the header, it can result in many problems; substrate can be saturated in chloride, corroding bars and popping them up which pushes out the joint. There have been some reported anchorage issues in elastomeric headers when they are under high traffic volume, but this is not a prevalent problem.

There were many similarities in header behavior, problems, and possible solutions throughout the responses. One state noted that for reconstructed joints on existing bridges, the header durability appears to be the limiting factor in joint life; they continue stating that installing new headers over old concrete decks is not a good idea. When armored headers are replaced with elastomeric headers, the width of the seal is increased which can result in debris build up and lead to seal failure. Elastomeric concrete should not be placed on concrete that has not cured for at least 10 days. Where possible, it is suggested to completely remove and reconstruct adjacent concrete then replace joints to provide a new, clean, watertight seal. Furthermore, a successful practice has been to, after cleaning surfaces and ensuring a dry surface, wait until the header is completely dry to the touch before installing seals. Another suggestion was to cast fine aggregate to the surface of elastomeric concrete to provide some initial tire friction.

Partial replacement of joints does not provide as tight of a seal as complete replacement of joints, and replacements are generally not checked for watertightness after installation. When joints are being installed, it was noted that construction phasing is believed to have a negative impact on performance and complete installation should be performed without phasing.

Traffic volume should be a consideration in joint types. Asphalt plug joints have not performed well under high traffic volume and are not recommended for this use by manufacturers. Strip seals have performed better in high traffic volume, and EM-SEAL has proven durable in these conditions so far. These conditions also limit options for header materials since the amount of time for repairs is very limited. Quick setting concrete generally needs to be used, which does not perform as well as other header materials but meets the short time constraints. Some respondents noted that Thorac1060 BASF and CTS Cement (low permeability) perform decently as quick setting concrete options.

Cost data was collected for any joints on which the states had information. The approximate costs are given in price per linear foot, including installation and materials, but not including cost of traffic control/police. This data is presented in Table 13. The most expensive joint types are modular joints and finger joints, which also tend to last longer than other joint types. Saw and seal joints are the least expensive, followed by EM-SEAL and asphalt plug joints. Strip seals are slightly more expensive when installed, but to just replace the seal they are among the least expensive. However, the cost of these joints is not the only consideration. Traffic impacts are often a top priority for state DOTs. There was no information available for the cost of link-slabs, however many respondents noted that the reduced maintenance demands in these joint types, and lack of associated issues, makes them a desirable option. Even if the upfront cost is greater than other joints, they should still be considered for the many benefits they offer over other joint types.

Table 13: Approximate Cost Data for Joint Types Provided by Survey Respondents

Joint Type	Cost per Linear ft.
Finger Joints	$1375-$1750
Pourable Seal	$300 (including header)
Compression Seal	$450
Strip Seal	$300-$800, $75 to replace seal
Saw and Seal Deck over Backwall	$15-$25
Saw and Seal over EM-SEAL	$60
Asphalt Plug Joint	$120-$200
Modular Joint	$1750-$4600
EM-SEAL	$90

As far as successful new products, EM-SEAL was at the top of many states' list. This seal has not been in use for very long but has already shown promise in its performance. One of the benefits of EM-SEAL is that it comes with vertical pieces making it easy to maneuver up and over parapets and curbs, a detail that is difficult and generally leaks when done with other joint types. EM-SEAL has also demonstrated success when incorporated with other joint types, such as the modified asphalt plug joint which uses EM-SEAL underneath the asphalt plug. While time will tell how well these joints hold up, they have initially been successful.

Vermont commented that they use 501 Matrix asphalt plug joints that have been very promising. The Crafco 501 Matrix Asphaltic Plug Joint System comes pre-measured and pre-packaged and is hot-applied. It is composed of a unique polymer modified asphalt binder combined in a box with the exact ratio of select aggregate (*7*). Using a product like this eliminates contractor interaction with material and ensures high quality control. One Massachusetts District (District 3) has switched to using pre-mixed asphalt plug joints as well and has reported that the success of these joints is higher than previous asphalt plug joints that were mixed on site, noting an increase in overall quality of the joints.

Other states have had success with Inverted-V strip seals and Silicoflex joints. Many states noted that link-slabs have been highly successful; generally, the only issue is finding the time and money to install these types of joints. These joint types have performed very well without needing much maintenance and do not have the same leakage problems as many other joint types. Other states have tried “modified asphalt plug joints” by combining the plug joint with strip seals, EM-SEAL, or other seal types. Pennsylvania noted that they have been using finger joints with concrete troughs behind the abutments and that these have performed very well. Another two states have started using heavy steel angles for joint armor and steel plates/rebar hoops for anchorages; they note that they are heavy duty joints but use readily available materials and welding details which are relatively simple. Finally, another state suggests using a specialized tool for neoprene seal installation in strip seals, stating that normal hand tools tend to lead to damage/tears.

When it comes to choosing the best joint type, there is no right answer. Many factors need to be considered and while no option may be perfect, the information collected from these states should give insight into which joints perform well in various conditions and meet various needs. Some joints, such as asphalt plug joints and strip seals, do not have a long service life if they are not maintained, but they provide relatively quick installation at comparatively low costs and can be repaired more quickly than other joint types. If time is not an issue, considering an option like link-slabs or saw and seal: deck over backwall would be worthwhile to take the time installing since they require minimal maintenance and can remain in service for longer periods of time without issues. For joint types accommodating large movement, most states agree that finger joints are the better option if they can figure out a solution to the trough problems. Pennsylvania suggested that putting the finger joints with concrete troughs behind the abutments would be a viable option. Overall, the joint type should be chosen based on a number of factors it can accommodate.

Attention also needs to be placed first and foremost on the installation practices, as was pointed out by all states. Without proper installation, the service life will not be as long as expected and other issues could present themselves before failure, such as leaking of joints which affects many other potentially costly areas of the bridge. All states reported that installation practice is the single most important factor affecting joint performance. Other factors rated highly important as well, including inspection, maintenance and weather at time of installation.

Some of the most important factors that need to be addressed during installation include proper cleaning of joint opening prior to installation, proper sizing of joint opening and proper timing of placing bond to ensure adequate adhesion. To ensure proper installation, inspectors should be aware of all specifications the manufacturer provides and ensure that they are completed. Most states report that the manufacturer’s representative is rarely on site during joint installation, so it is critical that whoever is overseeing the project understands the proper steps and ensures their completion.

When it comes to choosing the best joint type, many factors should be considered. Beyond expansion needs, states need to consider factors such as traffic demands, cost, and time. With most joints, the ability to perform adequately stems from their installation, inspection, quality control of the product, and maintenance practices. No joint is perfect, but could have improved performance throughout their service life if these measures were taken.

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5.0 Conclusions and Recommendations

5.1 Conclusions

This report presented a literature review of previous joint research, organized information on the existing bridge joint inventory in Massachusetts, compiled joint information and practices from meetings with the six MassDOT district offices, compiled information from survey responses by Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Vermont, and summarized all survey responses.

The purpose of this research was to determine best practices with bridge expansion joints and headers from Massachusetts and states in and around New England. Joints that are damaged and not functioning properly lead to costly issues that extend far beyond the joint itself; superstructure and substructure elements can be damaged by corrosive materials carried by water leaking through joints. While preventative maintenance would be an ideal way to prolong joint life, as well as enhance joint performance over its service life, none of the states are able to incorporate the level of maintenance they would like to due to a lack of funding. Lack of maintenance is a main cause of joint failure which leads to much greater repair and maintenance costs for the superstructure and substructure elements. An evaluation of overall life-cycle bridge costs would be worthwhile and DOTs that are practicing regular maintenance attribute this to better joint life and performance.

An ideal joint would be one that remained in service and performed without issue for a long period of time without needing maintenance. However, there is no perfect joint. Individual joint types have advantages and disadvantages associated with them that should be considered when selecting a joint type for a project. The definition of a successful joint varies between states and between individuals within states. Some respondents define a successful joint as one that could remain in service for a long period of time, while others define that a successful joint should also remain watertight through its service life. Others noted that each joint type has its own expected durability and this should be considered in defining success. Others indicated that some leakage is acceptable as the joint ages.

The highest rated bridge joints from all states were link-slabs, EM-SEAL, compression seals, saw and seal: deck over backwall and finger joints. However, only link-slabs had consistent high ratings, while all other joints had a wide range of success ratings based on individual respondents' definitions. Open joints and sliding plate joints received the lowest performance ratings, with respondents noting problems including leaking (as expected) and difficulty to repair. The majority of respondents would like to phase these out, or have phased them out already. This was also mentioned by individuals of some joints which were rated highly by others.

Typical service lives of joints varied between respondents as well. Pourable seals have the shortest reported service life of zero to four years, but some states still use these joints because they can be quickly installed, are less expensive than many other joints, and can be repaired quickly. Similarly, asphalt plug joints have a short reported service life, with the majority of respondents stating they are in service five to eight years. However, these joints are also quick to install and relatively inexpensive, resulting in their continued use in the majority of states.

With asphalt plug joints, some states reported that quality control of the product is a big contributor to the joint performance. Vermont and one district in Massachusetts have started using pre-mixed, pre-bagged asphalt plug joint products that eliminate contractor interaction with the material and have reported that these have been successful so far and perform better than asphalt plug joints mixed on site. Another new technique with this joint type reported by some respondents is using a "modified asphalt plug joint" where EM-SEAL is used beneath the plug joint in an effort to increase watertightness of the joint. So far, these have performed well but are still a new practice.

All states reported that installation practice is the single most important factor affecting joint performance. Other factors rated highly important as well, including joint and header types, inspection, maintenance practices, and weather at time of installation. The majority of practices reported that negatively impact joint performance were issues during the installation of the joint.
Some of the most important factors that need to be addressed during installation include proper cleaning of joint opening prior to installation, proper sizing of joint opening and proper timing of placing bond to ensure adequate adhesion. To ensure proper installation, inspectors should be aware of all specifications the manufacturer provides and ensure that they are followed. Most states report that the manufacturer's representative is rarely on site during joint installation, so it is critical that whoever is overseeing the project understands the proper steps and ensures their completion. Training of contractors, installers, and site engineers would be beneficial to ensuring proper installation and maintenance. Currently, the on-site engineers have different levels of experience and knowledge; therefore, a statewide training could ensure uniform standards are being upheld during installation.

Overall, in order for there to be consistent practices throughout a state, decision making would have to be heavily centralized. This research has shown that within a state each district has various constraints, inventories, traffic demands, and local contractor and inspector experience/training. Therefore, there is benefit to allowing localized decision making, but this is not consistent between new installation and repair or replacement of joints. While variability in practice throughout a state is not an issue in itself, it does make it difficult to determine any statewide conclusions.

When it comes to choosing the best joint type, many factors should be considered. Beyond expansion needs, states need to consider other factors such as traffic demands, cost, and time. With most joints, the ability to perform adequately stems from their installation, inspection, quality control of the product, and maintenance practices. No joint is perfect, but all could have improved performance throughout their service life if these measures were taken.

5.2 Recommendations for Implementation

Based on the research conducted for this report through district meetings and survey responses, the authors propose the following recommendations be considered for future bridge joint practice in Massachusetts to improve joint and header performance, save cost on frequent repairs and replacements, minimize costly damage to other structural components, and extend the service life of joints:

- Address joint installation and expected performance during pre-construction meetings
- Initiate statewide joint/header installation training of contractors, installers, inspectors and on-site engineers
- Develop a consistent program for preventive maintenance, including routine cleaning of joints and drainage troughs along with designated funding for these activities
- Require watertight testing on all closed joint types for both replacement and repair of joints
- Have manufacturer representative on-site for installations when possible
- Determine a way to warranty joint performance for a period of time post-construction
- Streamline process for adding new products to approved product list for new construction
- Include information specific to joint performance in a searchable database, such as PONTIS, and on inspection reports

5.3 Recommended Future Research

The report highlighted multiple areas that would benefit from further research. Overall, a method of tracking quantifiable data would be needed to draw conclusions on best practices and life-cycle benefits of practices such as preventive maintenance. The authors propose the following research topics for further insight into better bridge joint technology:

- Evaluate differences in district repair and replacement methods and contracts to determine best practices
- Collect direct measurement of installation tolerances in MassDOT joint installation projects
- Perform experimental tests on joint and header alignments to quantify resulting damage
- Perform experimental tests on header materials subject to a range of forces, including impact, cyclic load, and freeze-thaw
- Develop test methods for approval of joint and header materials
- Track life-cycle comparison of joints in similar bridges with and without preventive maintenance

- Perform an overall analysis that considers cause and effect of failing joints while also analyzing overall life-cycle costs (pending initiation of long-term collection of relevant data by MassDOT)

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7.0 Appendices

7.1 APPENDIX A: Survey Respondents

Table 14: Survey Respondents from All States

State	Name	Position
Connecticut	Carl Nelson	District Engineer
Maine*	Ben Foster	Assistant Bridge Maintenance Engineer
Maine*	Eric Shepherd	Assistant Bridge Program Manager
Massachusetts	Prem Kapoor	District Bridge Engineer
Massachusetts	Pellegrino Vona	Bridge Design Team Leader
Massachusetts	Kuok Chiang	Senior Structural Engineer
Massachusetts	Mark Banasieski	District Two Bridge Engineer
Massachusetts	Mohamemd Nabulsi	District Bridge Engineer
Massachusetts	Rich Madsen	Design/Review Engineer-Project Development
Massachusetts	Shane Sousa	Acting District Bridge Engineer
New Hampshire	Angela Hubbard	Project Engineer
New Jersey	Gerald Oliveto	Principal Engineer
New Jersey	Greg Renman	Manager Structural Evaluation
New York State	Peter McCowan	Civil Engineer III (Structures)
New York State	Ron Kudia	Regional Structures Engineer
New York State	David Laistner	Civil Engineer 2
New York State	Robert H. Curtis	Region 7 Design Engineer
Pennsylvania	Pinakin Chokshi	Civil Engineer Transportation
Pennsylvania	Peter H. Berg	Assistant District Bridge Engineer
Pennsylvania	Tom Macioce	Chief Bridge Engineer
Pennsylvania	Ralph DeStefano	District 9 Bridge Engineer
Pennsylvania	Lloyd Ayres	District 3 Bridge Engineer
Rhode Island*	David Fish	Managing Engineer
Vermont	Tammy Ellis	District Transportation Administrator
Vermont	Wayne Symonds	Structures Program Manager
Vermont	William P. Sargent	Bridge Maintenance Manager

***In Maine and Rhode Island, the survey was sent to the assistant to the chief engineer (by request) to be distributed**

7.2 APPENDIX B: Questions from Survey

MassDOT Better Bridge Joint Technology Research

Information about you

* 1. Select the Department of Transportation that you work for:

- ◯ Massachusetts
- ◯ New Hampshire
- ◯ Connecticut
- ◯ Rhode Island
- ◯ Maine
- ◯ Vermont
- ◯ New York State
- ◯ New York City
- ◯ Pennsylvania
- ◯ New Jersey

* 2. Your name:

____

* 3. Your job title:

____

* 4. I am knowledgeable about the following practices (check all that apply):

- ☐ New design
- ☐ Maintenance
- ☐ Inspection

5. Years of experience:

- ◯ 0-5
- ◯ 5-10
- ◯ 10-20
- ◯ >20

MassDOT Better Bridge Joint Technology Research

General Joint Information

6. What joints are currently in service in your state? (Check all that apply)

- [ ] Asphalt Plug Joints
- [ ] Strip Seals
- [ ] Compression Seals
- [ ] Pourable Seal
- [ ] EM-SEAL
- [ ] Sliding Plate Joint
- [ ] Finger Joint
- [ ] Modular Joint
- [ ] Link-Slabs
- [ ] Open Joint
- [ ] Saw and Seal: Deck Over Backwall
- [ ] Saw and Seal: Over Existing Joint
- [ ] Other (please specify)

7. What joints are being used in new construction in your state? (Check all that apply)

- [ ] Asphalt Plug Joints
- [ ] Strip Seals
- [ ] Compression Seals
- [ ] Pourable Seal
- [ ] EM-SEAL
- [ ] Sliding Plate Joint
- [ ] Finger Joint
- [ ] Modular Joint
- [ ] Link-Slabs
- [ ] Open Joint
- [ ] Saw and Seal: Deck Over Backwall
- [ ] Saw and Seal: Over Existing Joint
- [ ] Other (please specify)

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8. What joint types are being used in joint<u>replacement projects</u>? (Check all that apply)

	When there are **no time constraints**	When **overnight replacement is required**
Asphalt Plug Joints	☐	☐
Strip Seals	☐	☐
Compression Seals	☐	☐
Pourable Seals	☐	☐
EM-SEAL	☐	☐
Sliding Plate Joint	☐	☐
Finger Joint	☐	☐
Modular Joint	☐	☐
Link-Slab	☐	☐
Open Joint	☐	☐
Saw and Seal: Deck Over Backwall	☐	☐
Saw and Seal: Over Existing Joint	☐	☐

Other (please specify joint type and one/both instances when it's used)

9. What joints typically perform adequately if routine repair and maintenance is performed? (Check all that apply)

- ☐ Asphalt Plug Joints
- ☐ Strip Seals
- ☐ Compression Seals
- ☐ Pourable Seal
- ☐ EM-SEAL
- ☐ Sliding Plate Joint
- ☐ Finger Joint
- ☐ Modular Joint
- ☐ Link-Slabs
- ☐ Open Joint
- ☐ Saw and Seal: Deck Over Backwall
- ☐ Saw and Seal: Over Existing Joint
- ☐ Other (please specify)

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MassDOT Better Bridge Joint Technology Research

General Joint Information (Continued)

10. What is the typical service life you are achieving with your current joint systems?

	0-4 years	5-8 years	9-12 years	13-16 years	>16 years	I don't know	Not applicable
Asphalt Plug Joint	○	○	○	○	○	○	○
Strip Seal	○	○	○	○	○	○	○
Compression Seal	○	○	○	○	○	○	○
Pourable Seal	○	○	○	○	○	○	○
EM-SEAL	○	○	○	○	○	○	○
Sliding Plate Joint	○	○	○	○	○	○	○
Finger Joint	○	○	○	○	○	○	○
Modular Joint	○	○	○	○	○	○	○
Link-Slab	○	○	○	○	○	○	○
Open Joint	○	○	○	○	○	○	○
Saw and Seal: Deck Over Backwall	○	○	○	○	○	○	○
Saw and Seal: Over Existing Joint	○	○	○	○	○	○	○

11. What joint types have been/currently are being phased out, and which would you like to phase out?

	Have been/currently are being phased out	Would like to phase out
Asphalt Plug Joints	○	○
Strip Seals	○	○
Compression Seals	○	○
Pourable Seals	○	○
EM-SEAL	○	○
Sliding Plate Joint	○	○
Finger Joint	○	○
Modular Joint	○	○
Link-Slab	○	○
Open Joint	○	○
Saw and Seal: Deck Over Backwall	○	○
Saw and Seal: Over Existing Joint	○	○

Other (please specify joint type and whether it has been/is being phased out or you would like to phase it out)

12. For any joints that have been, or are currently being, phased out of your inventory – Specify problems encountered with that joint type/reason(s) for discontinuing.

13. Please describe any circumstances preventing you from phasing out specific joint types.

14. Describe problems related to specific joint types not addressed in previous questions.

MassDOT Better Bridge Joint Technology Research

General Joint Information (Continued)

15. How do you define success of a joint?

16. How do you define failure of a joint? (Answer can be general or specific to joint types)

17.

Rank the performance of each joint type:

1= Absolute Failure, 5= Absolute Success

	1	2	3	4	5	N/A
Asphalt Plug Joint						
Strip Seals						
Compression Seal						
Pourable Seal						
EM-SEAL						
Sliding Plate Joint						
Finger Joint						
Modular Joint						
Link-Slabs						
Open Joint						
Saw and Seal: Deck Over Backwall						
Saw and Seal: Over Existing Joint						

MassDOT Better Bridge Joint Technology Research

General Joint Information (Continued)

The final questions of this section are regarding the total cost per linear foot for different joint types. If your state has the cost information for any of the joint types you will be asked (on the next page) to fill in the cost for any joints applicable. If you have no cost information for any joints, select "no" and this part of the the survey is complete.

18. Could you provide cost information for any of the joint types (past or present) in your state?

- ○ Yes
- ○ No
- ○ Have data and would like to follow up rather than answer at this time

MassDOT Better Bridge Joint Technology Research

General Joint Information (Continued)

19. For any joint that you have the information for, please provide the total cost per linear foot (all inclusive). For the joints that you do not have cost information for, you may leave them blank.

Asphalt Plug Joint	
Strip Seal	
Compression Seal	
Pourable Seal	
EM-SEAL	
Sliding Plate Joint	
Finger Joint	
Modular Joint	
Link-Slab	
Open Joint	
Saw and Seal: Deck Over Backwall	
Saw and Seal: Over Existing Joint	
Other	

20. For any joints that you were able to provide cost information for, please list what the cost included for each applicable joint (if different joints include different costs) and add any other comments regarding the cost of these joints.

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HEADER INFORMATION

The following questions refer to headers.

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Header Information

21. What types of headers are currently being used in your state? (Check either or both instances where applicable, leave blank if not used)

	When there are no time constraints	When overnight construction is required
Armored Headers	☐	☐
Normal Setting Concrete	☐	☐
Quick Setting Concrete	☐	☐
Elastomeric Concrete	☐	☐

Other (please specify header type and one/both instances when it is used)

22. What types of headers have been used in the past in your state? (Check all that apply)

- ☐ Armored Headers
- ☐ Normal Setting Concrete
- ☐ Quick Setting Concrete
- ☐ Elastomeric Concrete

Other (please specify) or provide comments

23. If the headers selected above are specific to certain joint types, please describe which joint types correspond to the headers used.

24. What are approved header materials for extreme cold temperatures in your state (if any)?

25. Provide any positive or negative experiences with each header type:

MassDOT Better Bridge Joint Technology Research

NEW INSTALLATION AND REPAIR

The following questions refer to new installation and repair.

MassDOT Better Bridge Joint Technology Research

New Installation and Repair Information

26. Are there standard joint and header replacement details utilized throughout the state? (Complete replacement of joint)

- Yes
- No
- I don't know

If "yes", please provide web page or contact information to obtain a copy of these

27. Are there standard joint and header repair details utilized throughout the state? (Patch or partial replacement of joint)

- Yes
- No
- I don't know

If "yes", please provide web page or contact information to obtain a copy of these

28. Do you consider the temperature at the time of joint installation for any or all joint types?

- Yes
- No
- I don't know

If "yes", how is temperature accounted for?

29. Are any tests (such as watertight testing) done to verify proper installation and/or repair in your state?

	Yes	No	I don't know
New Installation	○	○	○
Repair	○	○	○

If "yes", please describe the tests performed and who oversees them

30. Does your state require any specific weather conditions for installation of joints or headers?

- ○ Yes
- ○ No
- ○ I don't know

If "yes", please provide web page or contact information to obtain a copy of these

MassDOT Better Bridge Joint Technology Research

New Installation and Repair Information (Continued)

31. Is field splicing allowed on any repairs?

- Yes
- No
- I don't know

If "yes", what types of joints can be field spliced?

32. Are there any installation practices that your state has found to positively influence the performance, durability, or service life of joints?

- Yes
- No
- I don't know

If "yes", please explain.

33. Are there any installation practices that your state has found to negatively influence the performance, durability, or service life of joints?

- Yes
- No
- I don't know

If "yes", please explain.

34. Please comment on the most effective and most problematic details for joint continuity at deck ends, curbs and parapet walls.

17

MAINTENANCE

The following questions refer to maintenance.

MassDOT Better Bridge Joint Technology Research

Maintenance Information

35. Is there a Bridge Maintenance Manual separate from the Design Manual for your state?

- Yes
- No
- I don't know

If "yes", please provide web page or contact information to obtain a copy of these

36. Does your state perform preventative maintenance to prolong the life of bridge joints?

- Yes
- No
- I don't know

If "yes", describe the preventative maintenance program

37. What type of deicing chemicals/treatments does your state use?

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OVERALL PRACTICE

The following questions refer to overall practice.

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Overall Practice

38. Please rate the following for their importance to joint performance.
1=not important, 5=extremely important

	1	2	3	4	5
Joint type	○	○	○	○	○
Header type	○	○	○	○	○
Installation workmanship	○	○	○	○	○
Inspection	○	○	○	○	○
Maintenance Practices	○	○	○	○	○
Weather conditions at time of construction	○	○	○	○	○

39. What is your state's approval process for using new products for joint systems in new construction?

40. What is your state's approval process for using new products for joint systems in maintenance?

41. Are there any new products your state is using that appear promising?

42. Are manufacturer's representatives present to oversee joint work at time of construction?

- ○ Often
- ○ Sometimes
- ○ Rarely
- ○ Never

Comments:

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43. How does your state catalog joints for tracking purposes (i.e. inspection reports, element level detail, etc.)

44. If your state has an electronic method for cataloging joint performance, is it searchable by joint type?

- Yes
- No
- I Don't Know
- Not Applicable