Project Title
Sealing of Small Movement Bridge Expansion Joints
(Project Number: NETC 02-6)

Sponsored by
New England Transportation Consortium

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October 20, 2003
INTRODUCTION

Bridges are continually moving. The movements are produced by expansion and contraction caused by temperature variation, by concrete shrinkage and creep, by forces of vehicles on the structure, by wind and seismic loads and by structural settlements. In order for the structure to survive its service, it must be capable of accommodating all such movements.

The bridge expansion joints are the components designed to accommodate these cyclic movements. In addition to permitting the cyclic movement, the closed or sealed expansion joint systems provide barriers preventing runoff water and deicing chemicals from passing through the joint onto bearing and substructure elements below the bridge deck. Water and deicing chemicals have a detrimental impact on overall structural performance by accelerating degradation of bridge deck, bearing, and structural failure. In fulfilling their functions, expansion joints must provide a reasonably smooth ride for motorists.

RESEARCH PROBLEM

New England’s state highway agencies have recognized the on-going problems associated with bridge expansion joint leakage. The majority of New England’s bridges have short expansion lengths. Numerous types of joints have been experimented with and most reply on a seal compressed and placed in position. With time, most of these systems begin leaking at the interface of the joint seal and the sides of the joint. There is a real need to develop durable joint systems for movements up to 1.5 inches.

PROJECT OBJECTIVE

The main objective of this project is to conduct, based on analysis of relevant existing expansion joint sealing systems, research which will contribute to the development of most durable joint sealing material design for small movement bridge expansion joints in New England States. This project will look into selection of an appropriate sealing material (recently developed polymers) and ascertain its suitability by laboratory validation testing.

PROJECT TASKS

Task 1. Literature Search

A. TRIS and RIP Database

The Transportation Research Information Services (TRIS) and Research in Progress (RIP) Databases containing the information on completed and ongoing research on bridge deck joint sealing systems are visited and information relevant to our project has been collected and is being reviewed.
B. Literature on expansion joint systems in practice in New England

The information on the types expansion joint systems that are in use in New England States along with their experience with each type of system is collected and reviewed. The NETC Technical Committee members were contacted for the information. As of today, we have received information from four states (Maine, Massachusetts, Rhode Island and Vermont) out of six NE States. This information is presented below in the tabular form.

<table>
<thead>
<tr>
<th>State</th>
<th>Types of Joints employed</th>
<th>Experience With Each Type</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>Not available as of today (October 20, 2003)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maine</td>
<td>a. Compression Seal</td>
<td>Most Preferred</td>
<td>New Construction, Small movement, Versatile, Cheap Rehabilitation Project</td>
</tr>
<tr>
<td></td>
<td>b. Silicon -Pour-in-Place</td>
<td>Temporary (8-10 yrs.)</td>
<td>LargeM.R. (&gt;100mm)*</td>
</tr>
<tr>
<td></td>
<td>c. Gland Seal</td>
<td>Limited Success</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Evazote Seal</td>
<td>No Success, Failure in very short period</td>
<td></td>
</tr>
<tr>
<td></td>
<td>e. Asphaltic Plug Joint</td>
<td></td>
<td>Small M.R. (&lt;50mm)</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>Not available as of today (October 20, 2003)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Hampshire</td>
<td>a. Silicon based Sealant</td>
<td>Reasonable Success</td>
<td>Small M.R., 2-Part, Cold Applied Silicon Based Hot Applied, Petroleum Based</td>
</tr>
<tr>
<td></td>
<td>b. Roadway Crack Sealer</td>
<td>Preferred for shorter spans and on fixed ends</td>
<td>Short Spans (80’-140’) Blending Crack Seal Material and aggregates</td>
</tr>
<tr>
<td></td>
<td>c. Asphaltic Plug Joint</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Self-Made Type</td>
<td>Good Results</td>
<td></td>
</tr>
<tr>
<td>Rhode Island</td>
<td>a. Compression Seal</td>
<td>Poor</td>
<td>No more in use, Exists in Old Construction, Leakage, Loosening of angles</td>
</tr>
<tr>
<td></td>
<td>b. Strip Seal</td>
<td>Poor</td>
<td>For large thermal movement, leakage</td>
</tr>
<tr>
<td></td>
<td>c. Asphaltic Plug Joint</td>
<td>Most Preferred</td>
<td>Short Spans (30’-50’)</td>
</tr>
<tr>
<td></td>
<td>d. Open Joints, Sliding Plate Joint</td>
<td>Poor</td>
<td>May exist in Old Construction</td>
</tr>
<tr>
<td>Vermont</td>
<td>a. Asphaltic Plug Joint</td>
<td>Most Preferred for Short Spans (&lt;90’)</td>
<td>Small M.R. (&lt;50-75mm)</td>
</tr>
<tr>
<td></td>
<td>b. Vermont Joint</td>
<td>Preferred for Span &gt;90’</td>
<td>Small M.R. (&lt;75mm)</td>
</tr>
<tr>
<td></td>
<td>c. Finger Plate Joint</td>
<td></td>
<td>Large M.R. (&gt;75mm)</td>
</tr>
<tr>
<td></td>
<td>d. Modular Joints</td>
<td></td>
<td>Very Large M.R., Rarely Used</td>
</tr>
</tbody>
</table>
C. General Classification and Performance Evaluation of existing expansion joint sealing systems

Expansion joints fall into three broad categories depending upon the amount of movement accommodated.

a. Small movement joints encompass all systems capable of accommodating total motion ranges of up to about 45 mm.

b. Medium movement joints are the systems capable of accommodating total motion ranges between about 45 mm and about 130 mm.

c. Large movements joints include systems accommodating total motion ranges in excess of about 130 mm.

The critical factors influencing the successful performance of the various sealing systems in use are identified. The advantages and disadvantages of each type of sealing systems are also identified and documented below.

Small Movement Joints

1. Sliding Plate Joints

Steel sliding plates (Fig. 1) have been used extensively in the past for expansion joints in both concrete and timber bridge decks. Two overlapping steel plates are attached to the bridge deck, one on each side of the expansion joint opening. They are generally installed so that the top surfaces of the plates are flush with the top of the bridge deck. The plates are generally bolted to timber deck panels or embedded with steel anchorages in to a concrete deck. Steel plate widths are sized to accommodate anticipated total movements. Standard steel sliding plates do not generally provide an effective seal against intrusion of water and deicing chemicals into the joint and on to substructure elements. As a result of plate corrosion and debris collection, the steel sliding plates often bind up, impeding free movement of the superstructure.
Advantages

1. These types of joints are used to accommodate movement ranges of up to 4 in (100 mm) for short and medium span bridges.

2. These joints are structurally simple, reasonable in cost and have performed satisfactorily in some places where the trough was provided beneath the device to catch the drainage.

Disadvantages

1. The sliding plate joints are limited to horizontal movements, and therefore used only for bridges with static substructure and secure foundation to ensure that there would be no differential vertical movements.

2. It is difficult to have sliding plates in uniform contact. Since there is often a considerable variation in the fit of the contiguous sliding surfaces, these joints are not effective against water intrusion.

3. Where the differential vertical movements can occur at such joints or where the joints are not recessed slightly below the roadway surface, these joints can subject to significant distress and rapid deterioration.

4. Plates need to be adjusted periodically to reduce noise levels.

5. Improperly placed and exposed plates bend, warp and break off from their anchorages due to impact of heavy wheel loads. When the plate becomes bent from contact with plow blades, they create a very unsafe condition for traffic.

6. Finally, the corrosion of plates and debris collected may result in jamming of the joint checking the free movement of superstructure.
2. Compression Seal Joints

Compression seals, shown in Fig. 2, are continuous elastomeric sections (Generally the basic material is polychloroprene or otherwise known as Neoprene), typically with extruded internal web systems, installed within an expansion joint gap to seal the joint effectively against water and debris infiltration. Compression seals are held in place by mobilizing friction against adjacent vertical joint faces. The design philosophy requires that they be sized and installed to be always in a state of compression. To minimize slippage and maximum compression seal performance, a joint may be formed narrower than the design width, then sawcut immediately prior to compression seal installation.

Figure 2

Advantages

1. These joints are widely used to accommodate bridge movement ranges of up to 4 in (100 mm).

2. These seals are versatile, relatively inexpensive and easy to replace.

3. The performance of compression seals for joints with widths less than 3 in. has been found very good.

Disadvantages

1. High degree of debris collection atop may force the joint through the bottom of the joint.

2. Susceptible to snowplow equipments.

3. For the effective performance of the joint seal, the joints must be straight with sides parallel and suitably spaced to fit the compression seal of specified size.
4. For wider joints, it is difficult to ensure the adherence of the seal to the sides of the joint throughout the length of joint.

5. For bridges with large skew and curvature, the joint detail becomes more difficult and probability of achieving an effective seal becomes difficult.

3. Asphaltic Plug Joints

Asphaltic plug joints (Fig.3) comprise hot liquid polymer and graded aggregates compacted in modified asphalt (PMA). The Polymer modified asphalt PMA is installed continuously within a block out centered over the expansion joint opening with the top of the PMA flush with the roadway surface. A steel plate retains the PMA at the bottom of the block out during installation. The binder material is generally installed in heated form. Aggregate gradation, binder properties, and construction quality are critical to asphaltic plug joint performance.

Two critical material properties, namely, relaxation and glass-transition temperature, $T_g$, are required to qualify APJ material. It is found that APJs should not be installed in areas where the lowest anticipated temperature is below $T_g$. The relaxation of the APJ material should be sufficient to relieve the stress due to applied thermal displacement (Bramel et al., 2000).

![Figure 3: Asphaltic Plug Joints](image)

**Advantages**

1. They provide smooth, seamless roadway surface for traffic.
2. They provide watertight and snow plow proof expansion joints.
3. There is no debris collection at the top of the joint.
4. Properly qualified APJs are very effective in their performance.
Disadvantages

1. Polymer Modified Asphalt (PMA) material softens and creeps at warmer temperature, which results in wheel rutting and migration of PMA from block outs.

2. APJs are not suitable in cold areas where lowest anticipated temperature is below Transition temperature (T_g) for the APJ material.

3. APJs are not suitable in locations where the likelihood of slowly moving or stationary traffic exists. At such places, due to longer period of loading on joint, the flow of material under wheel occurs leading to rutting and track out conditions.

4. If the relaxation of the APJ material is not sufficient, the significant stresses are developed in the joint causing crack at joint-to-pavement interface.

5. Generally limited to the skew angle of below 30 degrees. Larger skew angle increases the rutting due to traffic.

6. These joints can not accommodate differential vertical displacements and should not be used at locations where such movements can occur.

4. Poured Sealant Joints

Durable low-modulus sealants (such as polyurethane, silicone, polysulfide, butyl and acrylic), poured cold to provide watertight expansion joint seals as shown in Fig. 4, have been used in new construction and in rehabilitation projects. Most silicone sealants possess good elastic performance over a wide range of temperatures while demonstrating high levels of resistance to UV and ozone degradation. Rapid curing sealants are ideal candidates for rehabilitation in situations where significant traffic disruption from extended traffic lane closure is unacceptable.
Advantages

1. It possesses good resistance against ozone and Ultraviolet degradation.

2. Easy to use and self-leveling, silicon sealants usually have high movement capability (+100/-50 percent of joint size for joints 1 - 3 inches).

3. Due to use of rapid curing sealants in rehabilitation project, there is very short time closure of lanes for traffic.

4. Many silicon sealants exhibit good elastic properties over a wide range of temperature variation.

Disadvantages

1. It’s a temporary type of joint system (8-10 years) and mainly used for bridge rehabilitation projects where it is difficult to replace existing seals.

2. Debonding with concrete or steel substrates yielding to leakage of water has been observed with previous poured sealed joints.

3. Very sensitive to field installation conditions, such as workmanship.

Medium Movement Joints

1. Strip Seals

An elastomeric strip seal expansion joint system, shown in fig. 5m, consists of a preformed elastomeric gland mechanically locked into metallic edge rails embedded into concrete on each side of the joint gap. Movement ranges of up to 4 in (100 mm) or less are accommodated by unfolding of the elastomeric gland.

![Figure 5](image-url)
Advantages

1. Properly installed strip seals have demonstrated relatively good performance.

2. Damaged or worn glands can be replaced with minimal traffic disruptions.

Disadvantages

1. The elastomeric glands exhibit a proclivity for accumulating debris. This debris can resist joint movement and result in a premature gland failure.

2. Faulty installations or unclean locking devices cause gland pullout from metallic rail edges.

2. Finger Plate Joints

Steel finger joints shown in fig. 6, have been used to accommodate medium and large movement ranges. These joints are generally fabricated from steel plate and are installed in cantilever or prop cantilever configurations. The steel fingers must be designed to support traffic loads with sufficient stiffness to preclude excessive vibration. These joints must also accommodate any rotation or differential vertical deflection across the joint. To minimize the damage from snowplow blade impact, steel fingers may be fabricated with a slight downward taper toward the joint centerline.

![Figure 6](image)

Advantages

They allow horizontal movement as well as differential vertical movement.

Disadvantages

1. Finger plate joints allow water and deicing chemicals to pass through them. Elastomeric or metallic troughs must be placed beneath them to intercept the deck water and debris away from the substructure members.
2. Where narrow bicycle tires are anticipated, floor plates should be used in the shoulder area.
3. The cantilevered fingers may be bent or broken down due to continuous pounding of heavy traffic.

Large Movement Joints

1. Bolt-Down Panel Joints

Bolt-down panel joints, also referred to as elastomeric expansion dam, consists of monolithically molded elastomeric panels reinforced with steel plates as shown in fig. They are bolted into the block outs formed in the concrete bridge deck n each side of an expansion joint gap.

Advantages

1. Bolt-down panels can be fabricated in varying widths proportional to the total allowable movement range. Normally used for movement ranges of from 2 to 13 in. (50 to 330 mm).

Disadvantages

1. Bolts and nuts connecting panel to bridge decks are prone to loosening and breaking under high-speed traffic. The loose panels and hardware in the roadway present hazards to vehicular traffic, particularly to motorcycles.

2. Modular Elastomeric Seal

The modular elastomeric seal is generally used for joints movement ranges greater than 4 in (100 mm). The standard devices are designed for movements of up to 24 in (600 mm). Because most of the bridge joint movements are within moderate ranges and these modular joints are structurally complex and relatively expensive compared to prefabricated elastomeric seals (Bolt- down, strip seal and etc.), only a limited number of these joints have been installed.
Advantages

1. These joints provide watertight vehicular load transfer across a wide expansion joint openings and performance of these joints installed at many locations have been found to be satisfactory.

Disadvantages

1. These devices are structurally complex and very expensive.

2. No general design or fatigue design provisions exist for these systems, which make them susceptible to fatigue failure.

Task 2. Laboratory Testing and Development Work

Currently, we are in the process of development of silicon foam sealant samples in the laboratory and also preparing for the initial tests which will determine the sealant’s adhesion characteristics, density, reaction characteristics and its tension/compression strengths. In order to proceed with development of silicon foam sealant and necessary laboratory tests, the following materials have been purchased and received.

a. DMS-S21 Silanol Terminated PolyDimethylsiloxane
b. SNB 1100 Bis (2-ethylhexanoate) tin
The normal method of foaming employs a two-part formulation with one ingredient containing a hydrosilane and the other an alcohol. When mixed, the reaction proceeds as follows:

\[ -(\text{CH}_3)_2\text{Si-H} + \text{ROH} \rightarrow -(\text{CH}_3)_2\text{Si-OR} + \text{H}_2 \]

The following tests are important, and hence, planned to be conducted on the silicon foam sealant in the lab.

1. Material Properties: Elasticity, Poisson’s Ratio, Shear Rigidity, Flow/Sag, Specific Gravity, and other related. Effects of the following factors on the mechanical properties of the material need to be determined: Curing Time, Tack Time, Skin over Time, Reaction Temperature, and other relevant parameters.
2. Bonding Strength/Adhesion Characteristics
3. Tensile/Compressive/Shear Strength
4. Impact, puncture resistant characteristics
5. Cyclic Loading (loading and unloading)
6. Temperature Sensitivity
7. Aging under water at an elevated temperature

**Task 3: Draft Final Report**

Preparation and submission of report of the results of the literature search and laboratory work to the NETC Technical Committee for review.
This task has been scheduled to commence on a future date.

**Task 4: Final Report**

Preparation and submission of final report, which shall contain the methodology for Demonstration and Monitoring Phase (Phase II) along with the estimated budget for Phase II.
This task has been scheduled to commence on a future date.
REFERENCES


