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Evaluation of Silicone Sealants on Bridge Deck Expansion Joints

R. Taylor Robertson, W. Micah Hale

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ABSTRACT

Expansion joints in bridge decks must be sealed to prevent surface water and contaminant runoff from deteriorating the load carrying steel and concrete members beneath the structure. Within the past few years the Arkansas State Highway and Transportation Department (AHTD) has specified poured silicone joint sealers on new bridges via Special Provision. The success of these type joints has been variable, including several premature joint failures. The object of this research was to monitor five installations of poured silicone joint sealers on bridges and watch them for one year. Also, fifteen existing joints were to be looked at over the course of the project.

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Chapter 1

Introduction

1.1. Expansion Joint Importance for Bridge Decks

Bridge deck expansion joints are important to the performance of bridge decks, because they allow for movement of the bridge deck through expansion and contraction while keeping water and debris from getting through to the bridge understructure and causing corrosion. Without these joints, bridge decks would not have any means to expand and contract during the temperature changes that occur during the winter and summer months. Also, expansion joints allow other bridge movements to occur. Designing expansion joints has become of particular importance due to the wide range of expansion joints available for bridge decks.

In particular, silicone sealants, specifically the Dow Corning 902 RCS sealant, are the focus of this research project since this joint sealer is used throughout Arkansas. Silicone sealants have been determined to be a cheap and effective way to quickly seal joints while having a manufacturer's recommended life that matches many other available methods of sealing expansion joints.

1.2. Background on Expansion Joints

Silicone sealants have been used to seal expansion joints for nearly 40 years (7, 9). These first types of silicone sealants were much more costly than they are today due to the extensive development of silicone sealants. Also, the first generation of silicone sealants would develop acid while curing which would react with concrete and diminish the bond between the concrete and the sealant (7). Today's silicone sealants have evolved and no longer develop acid. Additionally, their cost is much less than the previous generations (7).

If properly installed, silicone sealants are very good at resisting many different types of environmental conditions while not losing its initial properties (7). Also, silicone sealants are not affected by ultraviolet radiation which helps them to last much longer than other types of sealants (24).

1.3. Research Objectives

The goal of the research is to develop a comprehensive installation procedure that can be used by the Arkansas State Highway and Transportation Department (AHTD) when installing the Dow Corning 902 RCS Joint Sealant in bridge deck expansion joints. Another goal of the research is to determine if this silicone material is worthwhile to use on joints in the state of Arkansas. To complete these tasks, the research team visited 20 different bridge decks throughout Arkansas to observe the joint. Of these 20 bridge deck joints, 5 joints were monitored from installation and monitoring continued for one year. The other 15 bridge decks contained joints that were classified as either in good, very good, or poor condition. These sites were visited only once and notes and photos were taken to compare them to other joints throughout the state. All of these joints were located throughout the state and were examined during a range of times so as to get differences in temperature and climate for each of the various joints.

Some of the many factors that may affect the joints were installation procedures, what time of year they were installed, temperature and moisture at time of placement, temperature and moisture at time of visit, width of joint, depth to joint sealant, and backer rod diameter to name just a few.

Other tasks that are to be completed with this research project include a literature review, AHTD specification review, and interviews with resident engineers and representatives from Dow Corning about their product to determine appropriate uses for the silicone joint sealant.

Chapter 2

Background, Literature Review, and Specifications

2.1. Types of Joints

Two broad categories of expansion joints exist today and they are open and closed joints. Each type of joint has specific properties, and each bridge should be evaluated to correctly identify the type of expansion joint needed for the bridge depending on movement, environmental factors, loading, amount of traffic, etc. Cost and location of the bridge deck are also very crucial in choosing between an open and closed joint (8). One final note to mention is that many bridge decks today are designed without joints (1).

2.1.1. Open Joints

Open joints are expansion joints that allow water to flow through the roadway to a drainage trough underneath the bridge (1, 3). This drainage trough is used to move the water and debris away from the abutments of the bridge and keep corrosion from occurring (1, 3). Drainage troughs need to be correctly designed so as to keep debris from building up and causing the trough not to drain properly (3). Some of these open joints can allow for a great deal of movement of the bridge deck (1). Three different types of open joints will be discussed which include butt joints, sliding plate joints, and finger joints.

2.1.1.1. Butt Joints

Butt joints usually consist of a pair of metal angles which are embedded into the concrete bridge deck at the expansion joint and are suitable for bridges with movement consisting mostly of rotation (3). This joint does not prevent water and debris from getting through to the under structure (3). For this reason, little or no thermal movement should be present when using these joints (3). Also, the width of the joint should be minimal so cars are not driving across a wide gap (3). Drainage troughs must be used on these joints to prevent water and debris from causing corrosion to the major substructures of the bridge. A typical butt joint with trough can be seen in Figure 1 below (3).

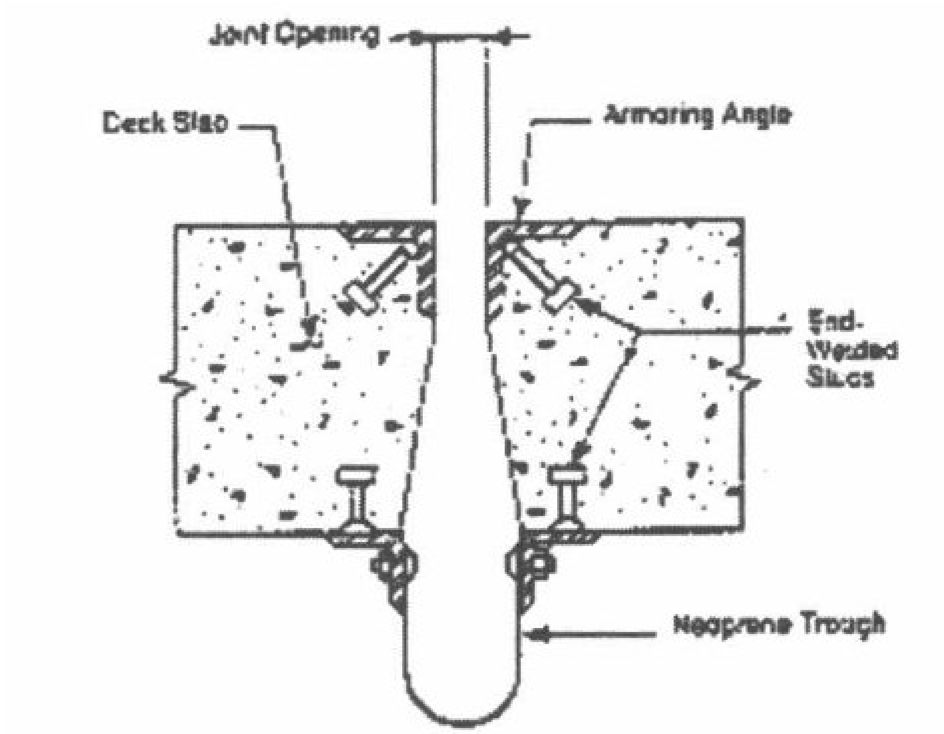


Figure 1: Typical Butt Joint with Trough (3)

Problems with this type of joint consist of corrosion of the metal angles, debris build-up in the trough, displacing of an angle through support failure, and “spalling or raveling” of the concrete on the deck whenever the butt joint does not contain armoring (3). For this reason, most butt joints have armor on the top edge at the surface of the deck to protect the concrete and prevent the edges of the joint from being damaged. Butt joints are seldom used today and many are being replaced with expansion joints that last longer and have fewer problems (3).

2.1.1.2. Sliding Plate Joints

Sliding plate joints are very similar to butt joints that are armored except they also contain a plate that slides across the entire joint to keep debris from getting through the joint (3). These joints are very good for bridges that have movements from 1 to 3 inches (3). Drainage troughs are normally placed underneath these joints to keep water and very small debris from getting through to the abutments and causing damage (3). A typical sliding plate joint with a trough can be seen in Figure 2 below (3).

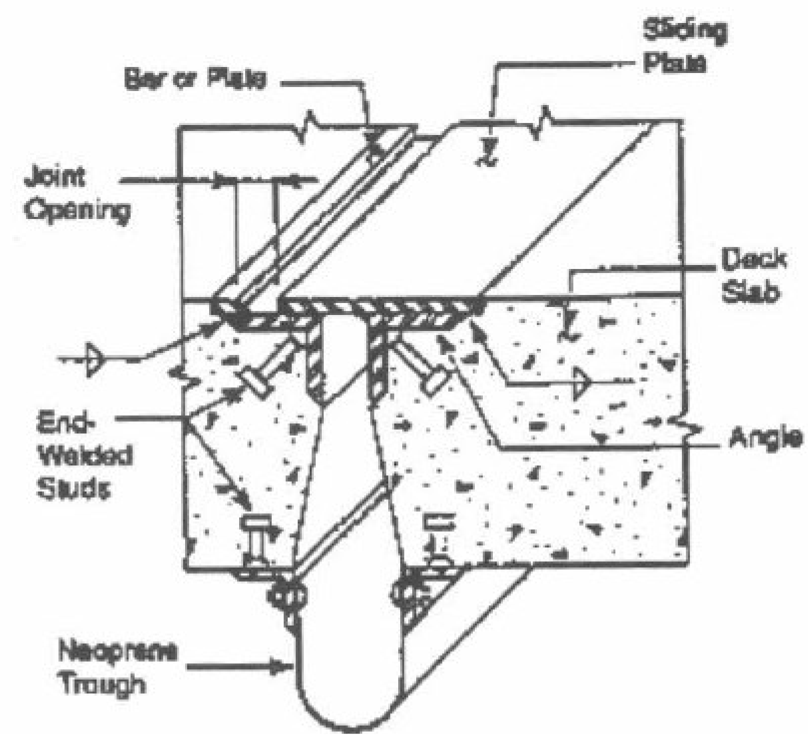


Figure 2: Typical Sliding Plate Joint with Trough (3)

Problems associated with sliding plate joints include the plates loosening over time and becoming noisy under traffic, debris detaching the plates and causing traffic hazards, snowplow blades damaging the joint, and corrosion and deterioration of the joint pieces (3). Today, sliding plate joints are seldom used due to many of these problems. Sliding plate joints are a poor choice for major highways containing truck traffic (3).

2.1.1.3. Finger Joints

Finger joints resemble metal fingers that interlock and are used on bridges with movements greater than 3 inches (3). Drainage troughs are once again used on these joints to keep water and debris from corroding any major part of the bridge substructure (3). Figure 3 below shows a typical finger joint with trough (3).

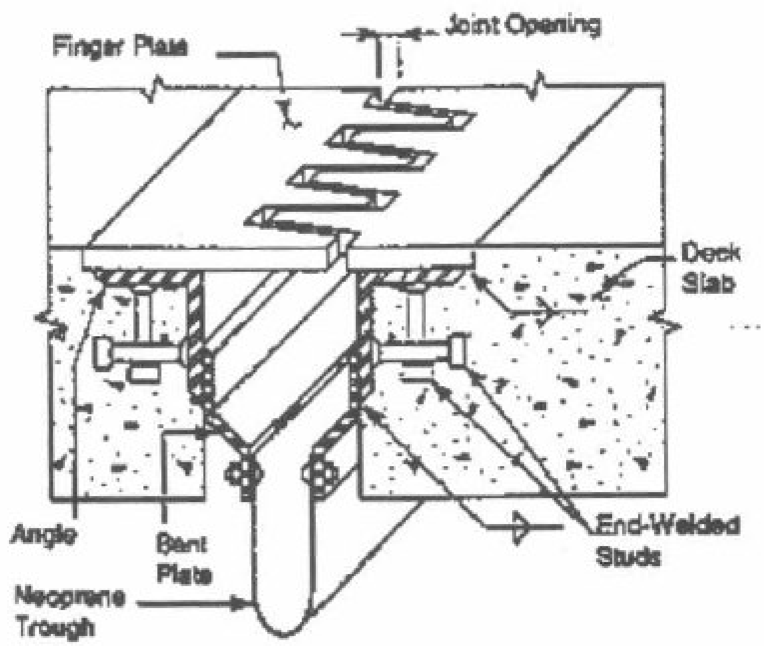


Figure 3: Typical Finger Joint with Trough (3)

Very few problems are known to occur with finger joints and they are often specified to be used on longer bridge spans due to lower initial and maintenance costs when compared to other types of expansion joints that are used for large movements (3).[2]

[2] AHTD has had numerous problems with the neoprene troughs underneath these joints including filling up with debris, tearing, and breaking away from their supports.

Failures include broken fingers, concrete deterioration around the joint, and anchorage problems (3).

2.1.2. Closed Joints

Closed joints are joints that do not allow water or debris to penetrate the joint in any way (3). Many different types of closed joints are in continual development to produce joints that can resist traffic loads, resist penetrating objects, resist forces from bridge movement, and remain watertight while being cost effective (3).

Closed joints were developed in large part due to the increased use of deicing salts on the roadway (3). These deicing salts can lead to corrosion of reinforced concrete and steel. Some of the closed joints that will be discussed include field molded sealers, strip seals, plug seals, inflatable neoprene seals, cushion seals, and modular joint sealing systems (3).

2.1.2.1. Field Molded Sealers (Silicone Sealants)

Field molded sealers which include silicone sealants are pourable sealers that were originally used for joint movements less than 3/16 of an inch (3). Silicone sealers were among the first type of closed joints to function properly and many manufacturers have developed better products that allow for more movement (3). Field molded sealers are poured in place in the joint and many are slightly recessed into the joint so as not to come in contact with traffic (3). Typically backer rods are placed into the joint first to provide something for the sealant to be poured on top of and to bond the joint to the edges of the deck (3). Backer rods do not bond to the sealant (3). These sealers will bond to the sides of the joint to create a watertight joint (3). Silicone joints have become by far the most used of the sealants today (3). Figure 4 below shows a typical layout for a poured-in-place sealant (3).

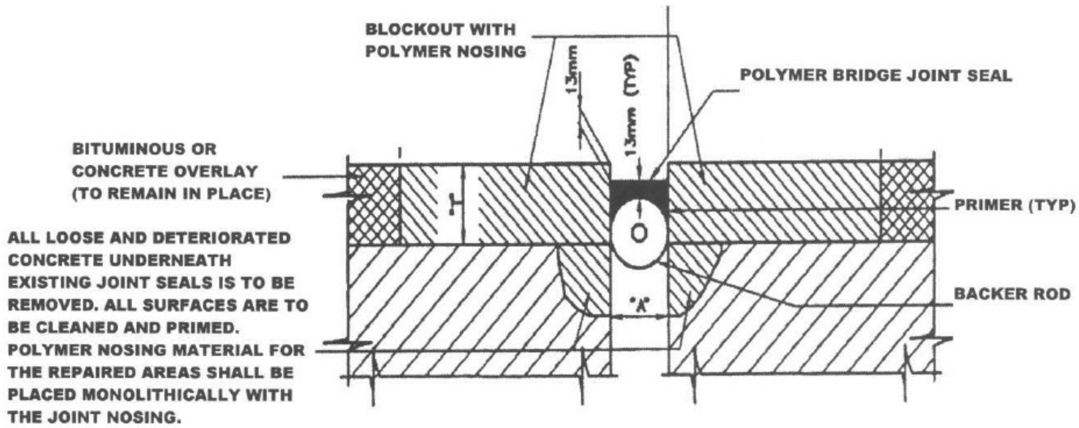


Figure 4: Typical Poured Sealant Joint (3)

Problems that can occur with these sealants include poor bonds between the sealant and deck, tears in the sealant, and damage from incompressible debris (3). Many of the first sealants such as heated asphalt or coal tar products had many of these problems and their use did not continue (3). Today's sealant products are much improved and fairly inexpensive leading to a more widespread use (3).

Some of the advantages of field molded sealants are the ability to bond to joint walls, maintaining properties during bridge movements, and quick repair of the seal to minimize traffic problems (3). One of the more important things to note with field molded sealants is that proper installation of these joints is necessary (3). Cleaning the sides of the joint, placing the backer rod correctly, and placing the sealant at the correct depth are all very important to the lifespan of sealants and will be discussed in more detail later in the chapter.

2.1.2.2. Compression Seals

Compression seals are a "continuous preformed neoprene elastomeric rectangular-shaped section" that is placed into the joint opening over the entire joint length (3). These seals can accommodate movements from 0.25 to 2.5 inches (3). This seal is inserted by being compressed and slid into the joint with a lubricant that helps bond the seal to the joint walls (3). A closed compression seal picture can be seen below in Figure 5 (3).

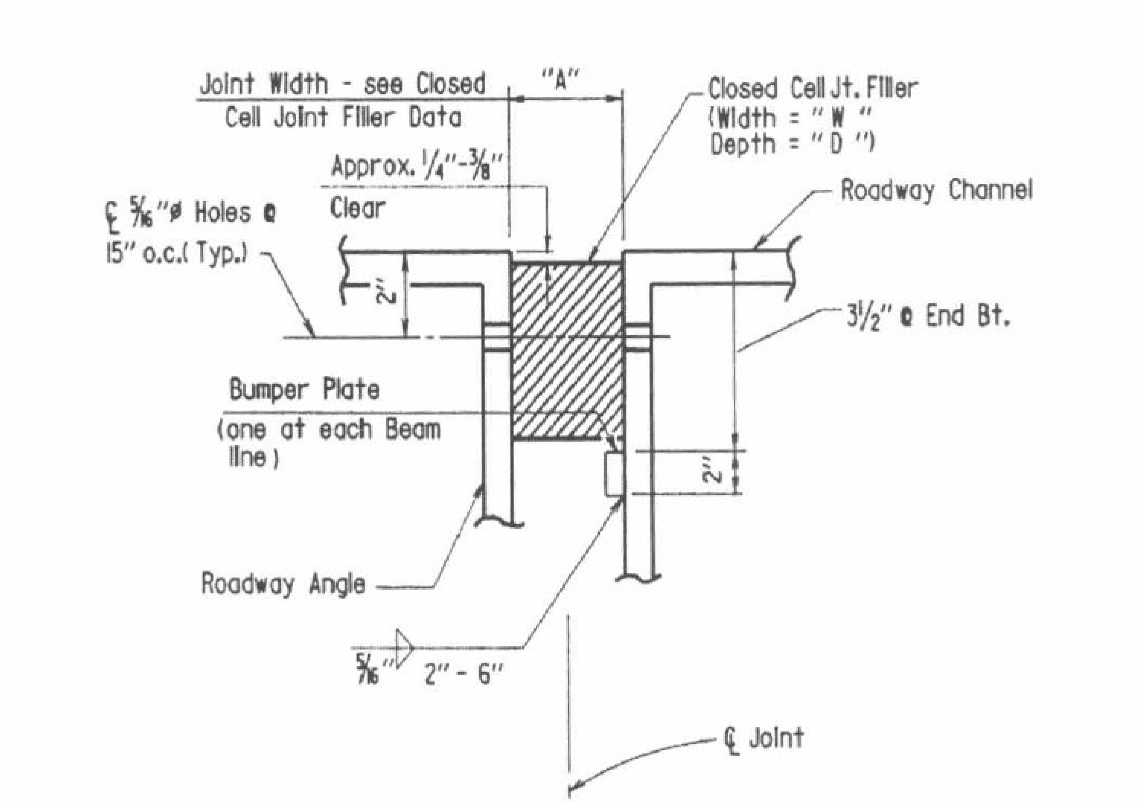


Figure 5: Typical Closed Compression Seal Joint (3)

When using a compression seal, many installation issues should be addressed which include not splicing the seal, sizing the seal properly, placing the seal at the correct depth, and constructing the joint openings properly (3). Without doing these, one may decrease the lifespan of compression seals (3). Compression seals have been shown to lose much of their initial compressive state over time and using these joints in places with major temperature differences has been shown to decrease their lifespan (3).

2.1.2.3. Strip Seals

Strip seals are made up of a neoprene membrane that attaches to the metal facing on both sides of the joint (3). These seals are pre-molded in a "V" shape that opens and closes with the joint and can withstand movements up to 4 inches (3). Strip seals have also been shown to have longer lifespan than other joints and are extremely watertight (3). A typical strip seal can be seen in Figure 6 below (3).

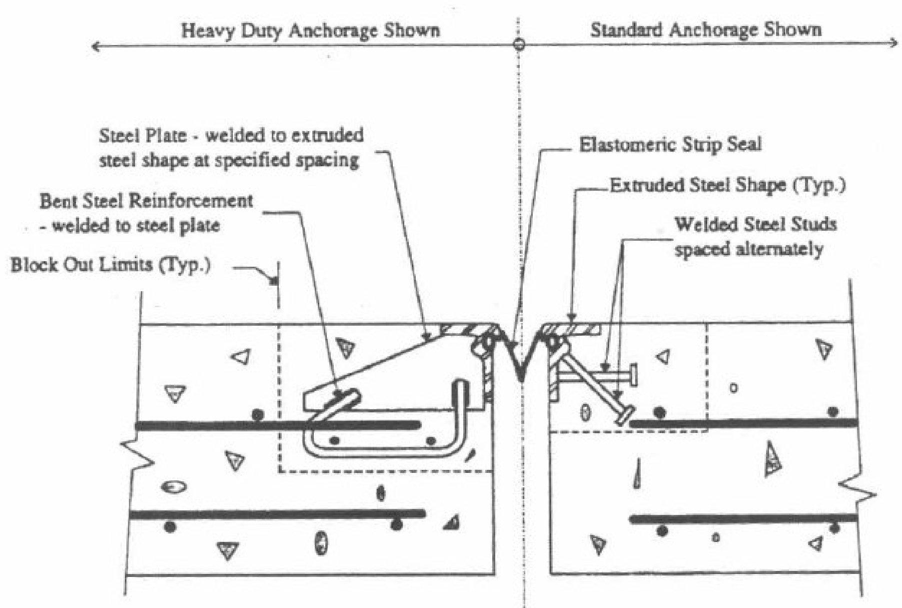


Figure 6: Typical Strip Seal Joint (3)

Problems associated with strip seals are that they are difficult to replace, no splicing can be done, snowplows can damage them, and incompressible material can cause tears if lodged in the membrane (3). Traffic can also be harmful to these seals if there is much debris in the membrane area (3).

2.1.2.4. *Plug Seals*

Plug seals consist of a backer rod that is placed in the joint below the blockout (rectangular box cut-out of the roadway) that is created and then coated with an asphalt binder (3). Next the blockout is filled with aggregate and consolidated (3). Finally, the asphalt binder is poured over the aggregate filling up the remaining voids (3). Plug seals are best used for expansion joints with movements less than 2 inches (3). A typical plug seal can be seen in Figure 7 below (3).

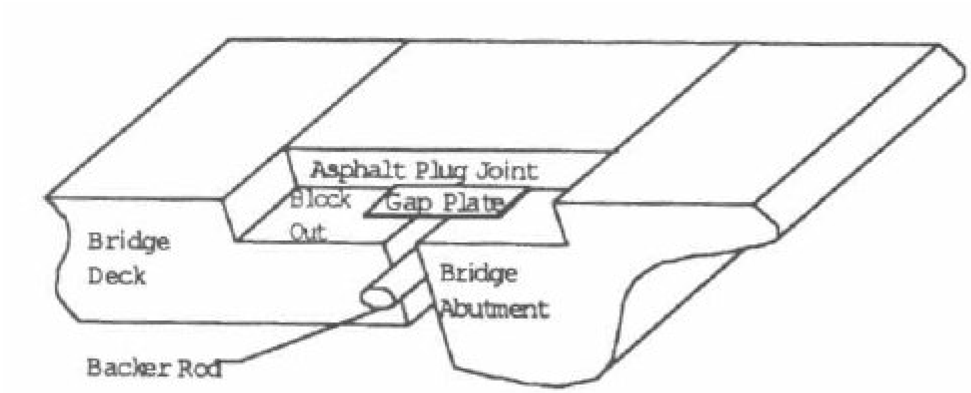


Figure 7: Typical Plug Seal (3)

The cost of plug seals is relatively low and repair is not difficult which makes this system appealing (3). On the other hand, if the deck joints are somewhat skewed, early failures have been known to arise due to the bridge movements (3). Also, major changes in temperature have caused damage to these plug seals (3).

2.1.2.5. *Inflatable Neoprene Seals*

Inflatable neoprene seals are placed into the joint after having bonding material placed on them (3). They are then inflated for 24 hours which pushes the seal up against the joint walls to help form a bond (3). After 24 hours, the seal is deflated and the seal is bonded (3). A typical inflatable neoprene seal can be seen in Figure 8 below (3).

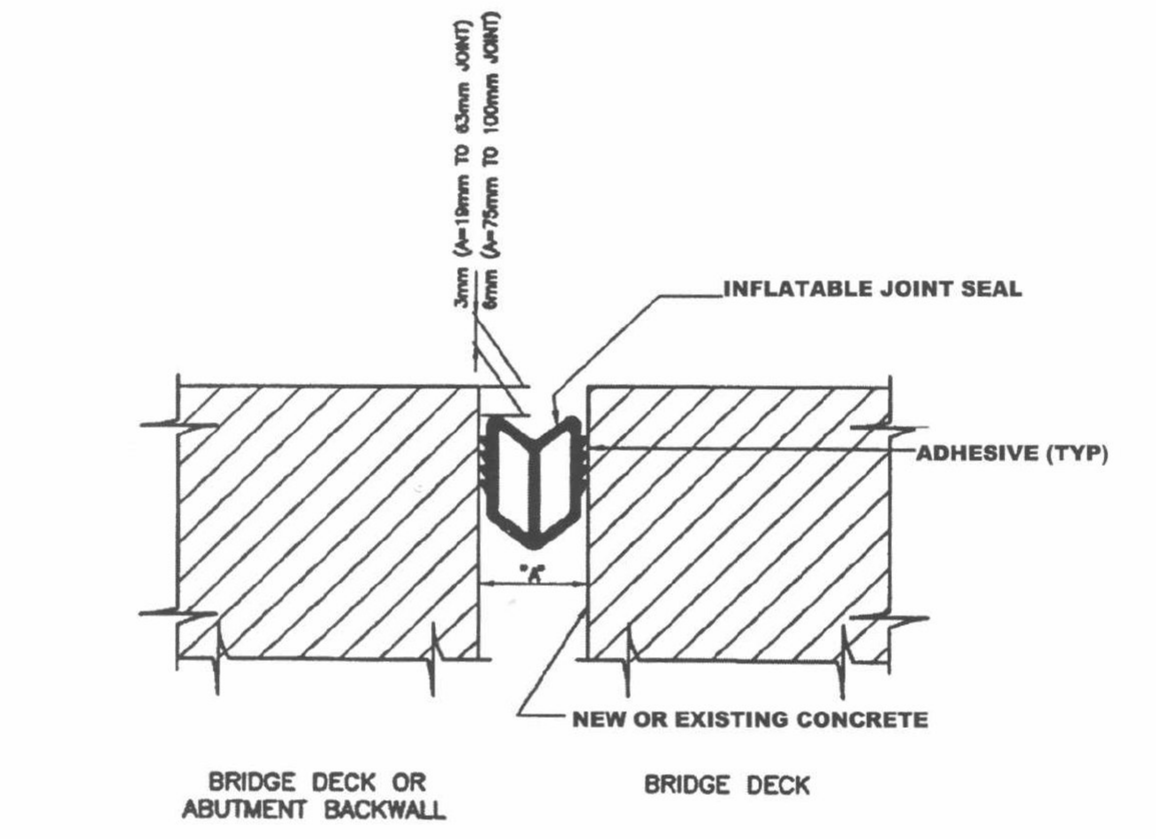


Figure 8: Typical Inflatable Neoprene Seal (3)

These inflatable neoprene seals are typically used for repairs on existing bridges, due to their relative ease and quick installation time (3). One major problem with the seal is the reliance on the bond between the seal and the joint wall to remain watertight while it is in place (3).

2.1.2.6. Cushion Seals

Cushion seals are a steel reinforced neoprene pad that is placed over the joint and anchored to both sides of the joint (3). The neoprene allows the joint to expand and contract over the joint while the reinforcing steel helps make this system more durable to traffic and other loads (3). These seals can work with expansion joint movements up to 4 inches. A typical cushion seal can be seen in Figure 9 below (3).

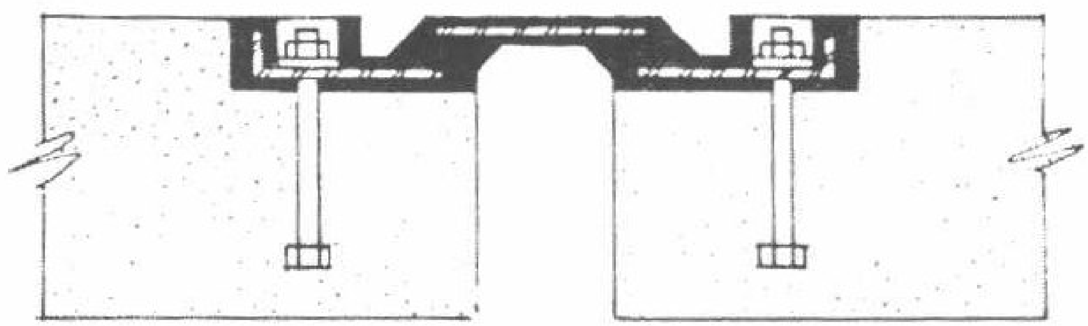


Figure 9: Typical Cushion Seal (3)

Since these joints are placed at road height, one of the major problems associated with these joints is that snowplows can cut the neoprene (3). Also, these joints are installed without splicing and any tears in the joint results in total replacement of the joint (3). One final problem is that these cushion seals work best when they are installed at proper temperatures (3). If it is too warm or too cold, cushion seals have been shown to fail with changes in temperature (3). These failures are the result of either too much stretching or buckling of the material (3). Because of this, there are limited times of the year when cushion seals are best to be installed (3).

2.1.2.7. Modular Joint Sealing Systems

Modular joint sealing systems are for those major joint movements in excess of 4 inches (3). Three main sections or components make up modular joint systems (3). These three sections are support bars, separator beams, and sealers (3). The bars support separator beams which are sealed to make the riding surface and form a watertight seal (3). A typical modular joint sealing system can be seen in Figure 10 below (3).

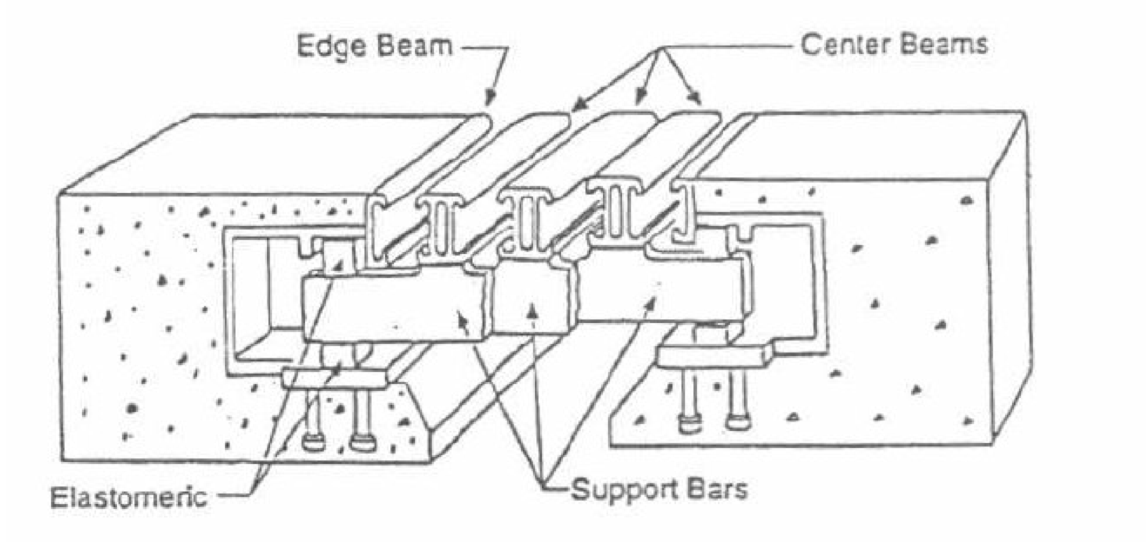


Figure 10: Typical Modular Joint Sealing System (3)

Designing one of these modular joint systems is much like designing another short span for the bridge except this joint must be able to expand and contract while keeping water from getting through. The sealing material must also be able to withstand expansion, contraction, loads, and damage from debris or snowplows (3). The modular joint system should be designed and installed very precisely so as to make sure these problems are minimal.

2.1.3. Cost of Expansion Joints

Information on the costs of the different joints has been scarce. AHTD provided some of the information that can be seen in Table 1. In Table 1, one needs to be aware of the units that are used for each joint and understand that all numbers are related to that unit for that joint. For example, the preformed joint seal is in Linear Feet (LF), while the structural steel is in Pounds (LB). Cubic Inches (IN^3) and Tons (TON) are the other two abbreviations used in Table 1.

The information in Table 1 only contains costs for neoprene strip seal joint, silicone joint sealants, and preformed joint seals from 2006. Prices and quantities of structural steel are shown here as well and armored strip seals and finger joints are bought as structural steel. Finger joint costs were also given from a 2002 construction job where the joint movement was 5" and the weight of the joint was 6586 lb. Finger joints need not be considered in a comparison with the silicone sealant joints since they are used for particularly large movements. For armored strip seal joints, one must buy both the neoprene strip seal and the structural steel plates that armor the parapet railing at the joint. The armored joint is shown in Table 1, but without the added cost of the steel plate armor for the parapets. AHTD has said that these plates typically weigh 150-200 pounds per joint and that the plates are not a function of length. The additional cost is then just 200 lb. at $1.41/lb. which is only around $280 per joint. This is not much considering the cost of the strip seal. These joints appear to be the most used types of joints throughout Arkansas at the current time.

Table 1: Costs of Expansion Joints in Arkansas

				CONTRACT PRICES		WEIGHTED
ITEM	ITEM DESCRIPTION	UNIT	QUANTITY	HIGH	LOW	AVERAGE
807	STR.ST.BM.SPANS(M270-GR36)	LB	73330	4.25	1.95	2.11
807	STR.ST.BM.SPANS(M270-GR50)	LB	1702120	5.8	1.27	1.52
807	STR.ST.BM.SPANS(M270-GR50W)	LB	4401710	2	1.19	1.55
807	STR.ST.PL.GRD.SPN(M270-GR36)	LB	102170	2.25	2.25	2.25*
807	STR.ST.PL.GRD.SPN(M270-GR50)	LB	2247900	2	1.31	1.6
807	STR.ST.PL.GRD.SPN(M270-GR50W)	LB	1742600	1.43	1.4	1.41
807	PAINTING STRUCTURAL STEEL	TON	2054.9	275	184	212.53
808	ELASTOMERIC BEARINGS	IN^3	910052.4	2.75	1	1.47
809	PREFORMED JOINT SEAL	LF	1049	100	30	51.69
809	ARM. JT W/NEOPRENE STRIP SEAL	LF	1192	125	90	111.16
810	SILICONE JOINT SEALANT	LF	1276	69.55	35	51.19

As mentioned previously, LF in Table 1 stands for linear feet, and therefore the quantity is the total number of linear feet used for the entire year at a price of $X/LF. The costs of joints per linear foot ranged from $51.19 to $111.16 for the year of 2006.

2.2. Movement of Bridges

Bridge movement is caused by several different factors that are due to the environment and material used to construct the bridge. Some of these movements include those resulting from changes in temperature, shrinkage and creep of concrete, and earth pressures that cause settlement or consolidation of one or more of the abutments that support the bridge (1, 6).

2.2.1. Temperature

The most significant factor that affects bridge movement is temperature changes resulting in thermal expansion and contraction of the concrete and steel girders in the bridge deck (1). Usually this results in movements in the direction of the bridge (1). This is easily predicted because the coefficient of thermal expansion for concrete is well known and understood. Knowing the "temperature range of the structure" is one of the important parts when designing the bridge expansion joints according to Manning and Witecki (8).

2.2.2. Shrinkage and Creep

Concrete shrinkage and creep can usually be accounted for and the bridge deck joints can be designed accordingly (1). Shrinkage is the reduction in volume of concrete due to a loss of moisture after the concrete hardens, while creep is the increase in deformation of concrete due to loading (17). Each of these takes time and most state agencies have their own methods of estimating total changes over time. These movements are usually not too significant unless there was poor installation of the concrete. In this case, the design engineer cannot account for poor construction techniques.

2.2.3. Earth Pressures

Earth pressures caused by settlement, consolidation, or compaction can result in movement of the entire bridge deck due to one or more of the abutments moving (1). In the design of bridge deck joints, settlement and long term consolidation are normally not considered (1). Temperature and superstructure movement are the only parts considered

(1). Due to this, unaccounted movements could take place that result in joints that are uneven or completely different from the design (1). Settlement or consolidation of one or more abutments could lead to these uneven joints (1). Since engineers do not normally consider these affects, it is good to have an expansion joint that can accommodate these movements (1).

2.2.4. Miscellaneous

There are some other minor causes that could lead to movements in bridge decks. One of these is pavement pressures that could lead to joints coming closer together and causing damage (1). Moisture changes on bridge decks can also cause movements, but these are usually not very significant when compared with temperature changes. Also, vehicular forces, especially from overloaded big trucks can cause damage to bridge decks joints (1). These movements are cyclic or in other words the bridge moves up and down with the passing of vehicles over it (1).

Two other movements that are not usually accounted for are movements due to earthquakes or extreme winds. These forces should only be accounted for in particular locations and special engineering techniques may need to be used to design the joints properly.

2.3. Expansion Joint Failures

There are several avenues of failures for bridges and sometimes the expansion joint is to blame for allowing water and chemicals through to the abutments where corrosion occurs. Snow plows, traffic, incompressible material, and freeze/thaw cycles on joints can contribute to causing the joint to fail which could eventually lead to a major bridge failure of the superstructure.

2.3.1. Corrosion

Corrosion will first be explained since it is the major reason for sealing a joint and for providing a drainage trough. As explained by Kassir and Phurkhao, corrosion occurs by chloride ions penetrating through the pores of concrete and reaching the reinforcing steel where it reacts and causes corrosion which eventually leads to failure (12). The chloride ions normally come from deicing salts that are used on concrete decks during winter months to keep roads bare and clean for traffic (12). According to Stewart and Rosowsky, corrosion is the primary concern for protecting bridge decks (14). Corrosion of reinforcing bars is the main source of failure in bridge decks and is one of the most important things to consider when trying to extend the life of a bridge (14). By designing expansion joints correctly, abutments and the understructure of the bridge can be protected from harmful chloride ions that could lead to corrosion and a costly repair job.

2.3.2. Snow Plows, Traffic, and Incompressibles

Expansion joints also fail due to snow plows, traffic loading, or incompressibles (1, 7). Snow plows can often be angled in such a way that they can damage expansion joints enough to allow water and debris through to the understructure (1). Traffic loading can exert shear forces on the expansion joints, and traffic can also cause the entire bridge to move leading to joint movements that are in excess of design (1). Normally, the design of bridges can easily accommodate for these traffic loading forces at the expansion joints. Finally, incompressibles are materials like rocks that get lodged in the joint and as the joint contracts due to the expansion of the bridge; the incompressibles may chip off part of the concrete or steel (7). Incompressible materials may also damage the sealant material (7). This is part of the reason for having closed joints, so as to keep any incompressible material from becoming lodged in the joint and damaging it.

2.3.3. Freeze/Thaw

Freeze/thaw occurs when concrete becomes saturated and freezes during cold temperatures. When frozen, the water in the concrete expands approximately 9%. The forces exerted by the freezing can exceed the tensile capacity of the concrete which will cause cracking in the concrete. This cycle is repetitive and can eventually deteriorate the concrete. In the case of joints, determining how well the material will stay bonded to the concrete or metal sides of the joint while freezing/thawing is occurring is very important.

Due to the increase in use of deicing salts over the past several years, an increase in corrosion due to the amount of chlorides from the salt has also increased (5). This is mostly a result of the freeze/thaw cycle that occurs every year in many bridge decks (5).

2.4. Silicone Sealants

Silicone sealants as mentioned before are a special type of field molded sealer that consists mostly of silicone. Silicone sealants have been shown to be very valuable since they can be used to seal many different types of joints in many different types of environments. This versatility makes silicone sealants unlike other sealants available (7). Bridge deck joints are major users of silicone sealants because the sealants are relatively inexpensive and fairly reliable when installed correctly.

2.4.1. Function

Silicone sealants are composed of long polymer chains of silicone, curing agents, and filler (7, 24). Silicone and oxygen alternate to form one long strand after the sealant has cured, which in-turn makes the sealant resistant to ultraviolet radiation (7, 24). Since they are unaffected by ultraviolet radiation, silicone sealants can be used in any kind of weather (7, 24).

Silicone sealants differ from one another by the modulus value or the ability of a material to elongate and return to its original form without changing its properties much like the modulus of elasticity (7, 24). Lower modulus silicone sealants can elongate much farther than high modulus silicone sealants and still return to their original form, meaning they have higher yield strength (7, 24). Also, low modulus silicones can withstand higher cyclic joint movements, or in other words, low modulus silicones have higher fatigue strengths (7, 24). On the other hand, high modulus silicones are more useful where strength is needed, but in the case of bridge deck joints this is usually unnecessary (7, 24). Most bridge decks use low to very low modulus silicones to withstand the movements that occur. Typical modulus values can be seen in Table 2 below (7, 24).

Table 2: Modulus Values for Sealants (7)

Sealant Classification	Force at 150% Elongation	Ultimate Elongation	Cyclic Joint Movement
High Modulus	>100 psi (690 Mpa)	<500%	±25%
Medium Modulus	40-100 psi (276-690 Mpa)	500-1200%	±35% ±40%
Low Modulus	<40 psi (276 Mpa)	>1200%	±50% +100% -50%

2.4.2. Forces on Silicone Sealants

Four different stresses affect silicone sealants when they are in place. These include tensile, cohesive, peeling, and compressive stresses (24). Tensile stress or adhesive stress refers to the sealant separating from the joint wall (24). Tensile failures can occur when the joint wall is not properly cleaned and primed, the shape factor is incorrect, the sealant is not placed properly, or the sealant hardens too soon (24). Cohesive stress refers to the sealant separating when the joint is expanding (24). This is normally due to poor bonding of the sealant, improper mixing of the sealant, reduced elasticity of the sealant, or a thickness to width ratio being too high (24). Peeling stresses are when the corners of the sealant come off the joint wall, which is usually due to incorrect installation techniques (24). Finally, compressive stresses occur when the joint closes and the sealant rises above the roadway surface (24). These failures can be due to improper design of the joint, sealant being too fluid, or the joint closing more than was anticipated (24). All of these forces should be taken into account when selecting the silicone sealant best suited for the expansion joint (24).

2.4.3. Advantages/Disadvantages

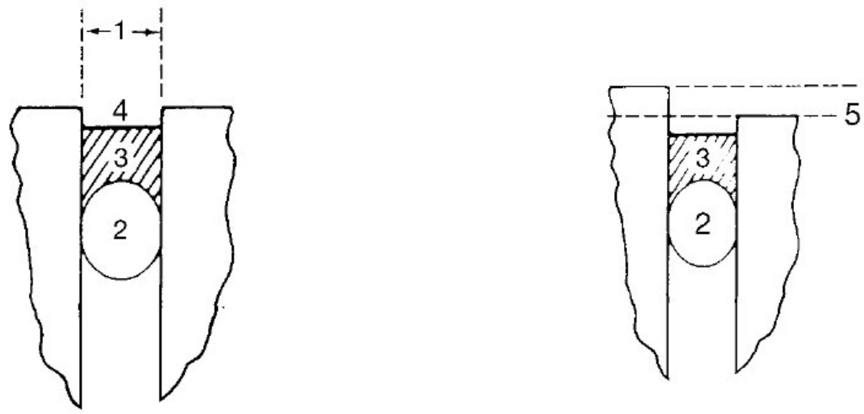
Silicone sealants can be used at nearly any temperature and are not subject to atmospheric conditions (7). Another advantage of silicone sealants is that they recover very well from being compressed (7, 24). In fact, low modulus sealants recover almost all of their elastic abilities after compression of as much as 90 % (7). This is one of the reasons low modulus sealants are used more often today due to the cyclic movement of joints (7).

However, there are disadvantages to using silicone sealants as expansion joint sealants. For one, they cannot exceed the movement rating assigned to them by the manufacturer or in other words, they are limited in the amount of movement they can withstand (7). One must be aware of the amount of contraction and expansion the sealant can withstand and the overall movement of the bridge when choosing a silicone sealant

(7). Also, silicone sealants cannot take much punishment from traffic, debris, or snow plows (7). Due to this, it is normally recommended to recess the sealant in the joint at about ½ of an inch (7). Checking all of these factors is important when selecting the correct type of silicone sealant to be used for an expansion joint (7).

2.4.4. Shape Factor and Backer Rod Importance

One of the most important factors in placing a silicone sealant is its shape factor, which is normally determined by the installation process and the size of the backer rod that is used. The definition of shape factor is the ratio of the thickness of the sealant to its width (24). Shape factors normally used are between 0.5 and 1.0, where the thickness of the sealant is 0.25 to 0.5 inches (24). The sealant should also be installed at the correct recess from the roadway (24). Figure 11 shown below shows the correct placement and shape factor for the backer rod as well as the sealant (19).



Standard Joint

Design if Grinding is Anticipated

1. Joint width wide enough to accommodate movement.
2. Proper backer rod placement to prevent three-sided adhesion.
3. Sealant installed to proper depth and width.
4. Sealant recessed a minimum of ½ inch (13 mm) below pavement surface.
5. Depth of lowest slab determines the amount of recess required if grinding is anticipated; once grinding is complete, the sealant will have proper recess below the pavement surface.

Figure 11: Correct Backer Rod and Sealant Placement (19)

The backer rod is a foam tube that holds up the silicone as it cures and provides very little support to the sealant. Choosing the correct size of backer rod for the joint is very important, so as not to produce a bad shape to the sealant (24). One can see backer rod recommendations in Table 3 below.

Table 3: Backer Rod Diameter Selection (22)

TABLE III
ROD SIZE TO JOINT WIDTH

Joint Width	Rod Diameter	Joint Width	Rod Diameter
3/16"	¼"	1"	1¼"
¼"	⅜"	1⅛"	1½"
⅜"	½"	1⅝"	2"
½"	⅝"	2"	2½"
⅝"	¾"	2½"	3"
¾"	⅞"	3½"	4"
⅞"	1"	4½"	5"
		5½"	6"

For metric joint widths under 25 mm, it is recommended the backer rod diameter be at least 3 mm larger. (oversized) For metric widths above 25 mm, it is recommended the backer rod diameter be between 6 mm and 13 mm larger. (oversized)

Without the correct shape factor or improper installation of the backer rod or sealant, the sealant properties may not be the same as indicated from laboratory results. By changing the shape factor, one changes the stress distribution within the sealant, and this may therefore lead to early failure of joints where the sealant has been installed.

2.5. Previous Research

The quote below by Chang and Lee summarizes the importance of proper design and proper installation of expansion joints to both the life of the bridge and the life of the bridge expansion joint.

> "The results of an improper expansion joint system can be extremely expensive. However, if the expansion joint is carefully designed and detailed, properly installed by specialists and functioning, and given reasonable maintenance in service, there is no reason why it should not give trouble-free performance for its lifetime" (16).

The highest reported problem for bridge deck expansion joints according to the Arizona DOT was that leakage problems and debris build-up were a consistent problem on bridges throughout the state (17). This is one area that needs to be minimized by designing bridge expansion joints properly.

2.5.1. Temperature

According to Hua et. al., the precise estimation of extreme temperatures is a very important part in the design of bridge deck expansion joints (11). Determining the extreme temperature values accurately leads to improved prediction of the total bridge movement throughout the entire year (11). Estimating too high temperatures could lead to an over design and making an uneconomic bridge, while underestimation could lead to failures at the expansion joint or problems with the entire bridge (11). With this information, the joints can be designed accordingly, and this will help to extend the lifespan of those joints for a longer period of time (11).

2.5.2. Freeze/Thaw

According to Abo-Qudais et. al., freeze/thaw cycles can have a significant effect on a silicone sealants' lifespan (13). In their report, three different silicone sealants were subjected to freeze/thaw cycles in a laboratory and then put under cyclic loading conditions that would be similar to field joint movements (13). These three sealants included a one component low modulus silicone that is cold applied and does not need primer to bond to concrete, a one component silicone that was self-leveling and very similar to the first sealant, and finally a one component polyurethane sealant that is cold applied and bonds after a primer has been applied to the joint walls and set for one hour (13). The one component low modulus silicone sealant and polyurethane sealant returned results that indicated that freeze/thaw cycles reduced the lifespan of the sealant when compared to specimens that had not undergone any freeze/thaw cycles (13). On the other hand, the self-leveling sealant could withstand more freeze/thaw cycles and they concluded that the sealant cured better under freeze/thaw cycles (13). Additionally, conclusions derived from these results included that the sealants may have had a reduction in stiffness and ductility as well as the material properties may have changed some due to the freeze/thaw cycles (13). Specifically, it was found that the self-leveling sealant performed the worst under freeze/thaw cycles while the primed polyurethane sealant worked the best (13). When placing these sealants, location and climatic changes need to be considered so that the desired results can be obtained from the specific silicone sealant and the possibility of early failures minimized (13).

2.5.3. Drainage

One area that has not been discussed but is important in the design of silicone sealants or other sealed joints is drainage of water and debris from the joint and roadway. Unlike open joints, bridge deck geometry must be taken into account to ensure that water and debris do not stay in the roadway or the expansion joint (8). According to Manning et. al., some sealed joints have been found to hold water during the winter months which will freeze and limit the movement of the sealant in the expansion joint (8). This could lead to premature failures of the joint. Debris can also build up in expansion joints if they do not drain well. This could lead to failures when vehicular loads push down on the debris and tear the sealant away from the joint sides. The designer must consider bridge drainage and sealed expansion joints to prevent premature failures of sealed joints.

2.5.4. Silicone Sealants

Findings of Chang et. al. state that silicone sealants did not perform well in the states of Indiana, Michigan, Ohio, Illinois, and Kentucky (16). Some of the problems that were noted by the DOT's were that the silicone epoxy often came into contact with traffic, the silicone was also not mixed correctly, debris and gravel were often causing problems in the joint, and the nosing materials were often damaged (16). Several of these problems were attributed to poor installation techniques and poor bonding agents, which led to damages in the silicone (16). Three suggestions were made to improve joint performance and increase service life and included 1) keeping the polymers below the deck and the chamfer large enough to prevent "spalling of the nose," 2) placing the silicone at the correct thickness and depth while making sure it is mixed properly, and 3) having a detailed installation plan (16). The one positive note from the respective highway departments is that they did enjoy the ease of use and repair as well as the speed at which this joint could be installed (16). Finally, the estimated joint life was 5.19 years (weighted average) with a standard deviation of 3.97 years (16).

Findings from the Virginia Department of Transportation (VDOT) done by French et. al. shows that silicone sealants work rather well on joint widths less than 2" when the installation was done correctly (15). Also, failures occurred when the material pulled off of the joint, which was most likely due to improper installation (15). It was noted that repair was easily done with the silicone sealants (15). Finally, VDOT engineers found that no matter the shape of the opening, the silicone sealant performed rather well (15).

The Arizona Department of Transportation (ADOT) found that properly installing this joint led to life expectancies of about 10 years and that this was very comparable to compression seals which cost much more (17). Also, ADOT noted that installation costs and replacement costs were relatively inexpensive and very simple to teach throughout the highway department (17). One last advantage found by ADOT was that the sealant could be placed on half the bridge at one time and the other half later, which allowed traffic to continue while only closing one lane at a time (17). Conclusions made by ADOT engineers stated that the poured silicone sealant should be used on bridges where little movement occurred and that it should be used to replace old joints due to the ease and quickness of installation (17).

2.5.4.1. Limitations

Some of the limitations noted for the silicone sealants are not being able to install the material during rain, not being able to apply the material to a wet surface, not being able to use the material in moisture environments, and it may not bond to weathered steel (17).

2.5.4.2. Installation Techniques

The quote below was taken from *On-Site Evaluation of Bridge Deck Expansion Joints.* The researchers monitored a bridge deck containing a silicone joint for one year (2). From observation of recent installations, AHTD follows these steps rather closely, except the armor angle is normally left in the joint.

> "Installing the X.J.S. Expansion Joint System consisted of the following steps: 1) removing the armor angle and spalled concrete, 2) sandblasting the concrete and steel in the joint, 3) cleaning the joint with compressed air, 4) placing styrofoam

to prevent the nosing material from entering the joint, 5) painting the bottom and sides of the joint with Silspec 9,00 PNS "neat" primer, 6) mixing and placing the Silspec 900 PNS (the nosing), 7) allowing the nosing to cure for one (1) hour, 8) spraying Dow Corning 1205 Primer inside the joint (on the vertical surfaces), 9) Placing a backer rod in the joint, and 10) mixing and placing the Dow Corning 902 RCS Joint Sealant" (2).

Another installation consideration is that the shape factor should be 1.0 to 1.5 while the sealant thickness should be 0.5 inches or more as stated by Yuen (10). These values differ somewhat from what was found in other resources and was commented on earlier. Dow Corning specifications also have their own values for shape factor and sealant thickness which are discussed in Section 2.6 and those values should be followed when using their material.

2.5.5. Other Findings for Silicone Sealants

Joint movements that occur during the cure time of the silicone sealants affect the sealant somewhat. According to Merchant, laboratory tests were done on different silicone specimens during curing by applying cyclic joint movements to the silicone. It was found from results that the portion of the silicone that was nearest the backer rod or touching it was found to contain many "cracks and voids" (4). Due to the cyclic movements during curing, the elasticity of the silicone was decreased approximately 20% from manufacturer's specifications. No tests were done to determine if removing the backer rod after the silicone had bonded to the joint sides would have improved performance (4).

2.6. Dow Corning Specifications

Dow Corning 902 RCS (Rapid Cure Silicone) Joint Sealant is used by AHTD on most Arkansas bridge decks where a pourable sealant is used. 902 RCS is an ultra low modulus sealant or in other words a sealant without much strength but great elasticity (19). The 902 RCS Joint Sealant consists of a two-part silicone rubber and is self-leveling (19). Low modulus sealants are those with values less than 100 psi (7). Dow Corning 902 RCS Joint Sealant has modulus values between 3-12 psi after it has fully cured (19). As was described earlier, the installation process for silicone sealants is short and thereby reduces the time traffic is disrupted (19). Also, the 902 RCS Joint Sealant is a two part system that comes in two "sausages" that are mixed together with a special gun (20). In Figures 12 and 13, one can see pictures of the gun used to install the sealant and the "sausages" containing the sealant.

Figure 12: Gun used to install Sealant

Figure 13: Parts A&B of Sealant

2.6.1. Advantages

Some of the advantages of using Dow Corning 902 RCS Joint Sealant include the quick curing time, the ability of the sealant to self-level, the elasticity, the ability to work with irregular surfaces due to self-leveling, the ability to withstand various environmental conditions, long service life span, and the ability to bond to itself making it ideal for repair jobs as well (19, 20). The 902 RCS Joint Sealant can also accommodate movements on joints 1-3 inches wide of +100/-50% and joints greater than 3 inches wide, it can accommodate movements ±50% (19). When designing or installing 902 RCS Joint Sealant, these values need to be considered so as not to have premature failure.

2.6.2. Installation Procedure

The following installation procedure is taken from *Installation Guidelines and Equipment Recommendations* (18) and *Primer Recommendations* (21) as used for Dow Corning 902 RCS Joint Sealant.

1. If there is a joint already in place, completely remove the old expansion joint used.
2. Sandblast the joint deep enough to accommodate for the recess, ½ inch depth of silicone, and ½ the diameter of the backer rod. The correct recess depth can be determined from the following Table 4 from *Dow Corning 902 RCS Joint Sealant Joint Width vs. Temperature Recess Chart* (23).

Table 4: Recess Depth of Silicone Sealant Based on Temperature and Joint Width (23)

Joint Width At Time Of Sealing		Movement Rating (percent)	Recommended Recess Based On Temperature At Time Of Sealing (inches, min.)				
Inches	mm		< 40°F	40°-55°F	55°-75°F	75°-90°F	> 90°F
1.00	25.4	+100/-50	.625	.50	.50	.50	.50
1.25	31.8	+100/-50	.625	.50	.50	.50	.50
1.50	38.1	+100/-50	.625	.625	.50	.50	.50
1.75	44.5	+100/-50	.625	.625	.50	.50	.50
2.00	50.8	+100/-50	.625	.625	.50	.50	.50
2.25	57.2	+100/-50	.75	.625	.50	.50	.50
2.50	63.5	+100/-50	.75	.625	.50	.50	.50
2.75	69.9	+100/-50	.75	.75	.50	.50	.50
3.00	76.2	+100/-50	.75	.75	.50	.50	.50
3.25	82.6	±50	.75	.75	.625	.50	.50
3.50	88.9	±50	.75	.75	.625	.50	.50
3.75	95.3	±50	.75	.75	.625	.50	.50
4.00	101.6	±50	.75	.75	.625	.50	.50

3. Next air-blast the joint to remove debris from the joint.
4. Prime the joint with the proper primer. This must be done on the same day as the sealant is applied and should not be done more than 1 hour ahead of sealing the joint. (Field procedures done in Arkansas are somewhat different.)
5. Place the backer rod at the correct depth of ½ in. below the silicone top and at least 1 in. below the roadway. Make sure to use the correct backer rod diameter as determined from Table 3 (22).
6. Before applying the sealant, make certain the joint is clean and dry.
7. Install the sealant making certain that Parts A and B are mixing properly and that both joint walls are being applied with the sealant.
8. Do not allow the mixer (gun) to be idle for more than 5 minutes while switching out tubes.

9. Finished sealant cross-section should look similar to Figure 14 (18).

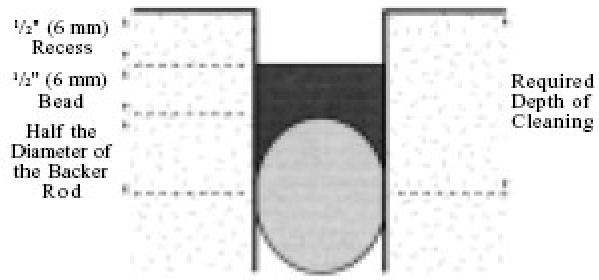


Figure 14: Cross Section of Silicone Sealant and Backer Rod (18)

2.7. Highway Specifications

Little information is available on the surrounding states' specifications for installation of Dow Corning 902 RCS Joint Sealant. The Missouri Department of Transportation (MDOT) provides technical drawings for installation of a sealant for expansion joint that is very similar to Figure 14 and can be seen in Figure 15 (25). As one can see in Figure 15, little is said about the silicone sealant, so one is to assume that the sealant is to be done to manufacturer's recommendations. The Oklahoma Department of Transportation (ODOT) is also following specifications given by the manufacturer when placing the silicone sealant.

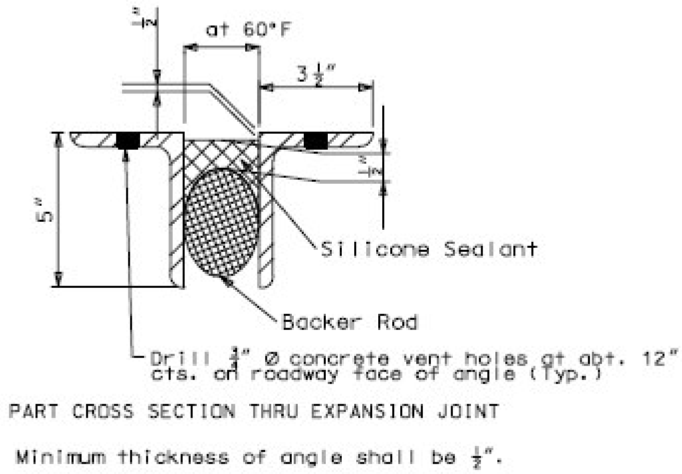


Figure 15 - MODOT Silicone Sealant Expansion Joint Detail

Currently, AHTD is using the specifications provided by Dow Corning for installing their sealants. A major part of this project is to produce a more detailed installation manual for AHTD and contractors to use when installing Dow Corning sealants on bridges throughout the state.

2.8. Summary

Many different types of expansion joint systems are available for use, and each individual bridge designer should determine the best expansion device to accommodate bridge movements as well as keep corrosion to a minimum. Also, cost issues should be considered when designing a bridge deck expansion joint.

Cost is one of the main reasons silicone sealants are becoming more popular. Silicone sealants have proven in several states to last for a number of years and are easily repairable. Also silicone sealants are relatively inexpensive when compared to other closed joint types, which make them very attractive to many highway departments for small bridge movements.

Installation of silicone sealants should be done with great care and should follow all manufacturer or highway department recommendations. By installing the silicone sealant correctly, there is a good chance the sealant's lifespan will be years longer. With further testing and research of silicone sealants, we may soon be able to determine a reasonable life expectancy for the sealant with proper installation.

Chapter 3

Highway Department Survey Results

3.1 Purpose

The purpose of this survey was to determine the knowledge of surrounding states usage of silicone joints sealants on bridge deck expansion joints. Engineers in charge of maintenance departments for Louisiana, Mississippi, Texas, Oklahoma, Tennessee, and Missouri were sent the survey to determine the scope of their knowledge. Maintenance departments were asked since they are the ones that continually check the bridges and expansion joints as well as are often a part of the installation process.

3.2 Survey of Surrounding State DOTs

As previously mentioned, the survey was sent to only six surrounding states that were contacts of Glenn Cheatham at AHTD. Each individual that replied to the survey was asked to be somewhat knowledgeable about the current practices in installation and failures associated with silicone joint sealants used in their state.

3.2.1 The Survey

The survey questions are listed below followed by tabulated values or answers representing the overall response to the question. These responses represent the surrounding states DOTs answers to the questions concerning silicone joint sealants used on bridge deck expansion joints. Of the six states where the survey was sent, five responded to the survey. Louisiana was the only state that did not respond to the survey.

All five respondents stated that the information they gave were educated guesses on their parts seeing there is not much expertise involving procedures with silicone joint sealants. Many questions were left unanswered by different states due to the fact that the question went into more detail than the respondent was aware of concerning silicone joint sealants.

3.2.2 Questions and Responses

Please state the silicone sealant primarily used in your state as well as the manufacturer of the sealant.

Four of the five states knew the silicone sealant that is used within their state. Tennessee, Oklahoma, Missouri, and Texas all stated that Dow Corning 902 RCS Joint Sealant was used primarily within their state. Tennessee also stated that Watson Bowman Acme which is made by Crafco is also used as a two component self leveling sealant within their state. Tennessee also indicated that on occasions where cure time is no problem, Dow Corning 890 is used in place of 902, and that 890 is a one component self leveling sealant. Texas was the only other state to indicate using other types of silicone sealants, and indicated that Watson Bowman Wabo Two Part Silicone is the other sealant used within the state.

1. *What is the average life of the silicone joints currently used in your state?*

Only Mississippi said the average life of their joints was between 1-2 years. The other four states indicated that the average life of their joints was over 4 years at least, with three states stating that the average life of their joint was over 5 years.

2. *What is the primary source of failures in your silicone joints?*

Detachment of the silicone from the sides of the joints was the main answer given by three different states including Tennessee, Mississippi, and Missouri. Mississippi also stated that puncture through the joint from debris, snowplow, etc. was a primary source of failures for the joints. Texas answered other and stated that incorrect installations were the primary source of failures for the joints. Finally, Oklahoma did not know the primary source of failures for silicone joints in their state.

3. *If failure is related to poor installation procedures, which installation procedure may have been the cause (Can choose more than one if several factors may have led to problems)?*

Many different factors were allowed to be chosen by the different respondents and varying installation problems were found from state to state. The answers chosen by each state can be seen below.

- Poor sandblasting – Tennessee and Mississippi
- Primer not given proper set time or not thoroughly applied - Missouri
- Silicone not installed at the correct depth - Texas
- Silicone depth too small - Texas
- Silicone depth too large - Tennessee
- Backer rod diameter too small - Mississippi
- Backer rod diameter too large - None
- Silicone installed in wet conditions - None
- Silicone expand/contract requirements cannot meet bridge expand/contract requirements – Tennessee and Mississippi
- Other (please explain) – Mississippi – "small spalled areas of the concrete adjacent to the joint."

These varying results from state to state lead one to conclude that installation procedures are all done differently for the same type of product. Many of these answers were educated guesses on the part of the engineer that replied to the survey seeing as they were not at many installations. It should be pointed out that two states replied to two very critical areas which included sandblasting poorly and knowing the bridge movements when compared with the extent of movement that the silicone sealant can handle.

4. *Has silicone been used to repair damaged silicone joints by applying the silicone to only the damaged areas?*
   - Yes – Tennessee, Texas, and Missouri.
   - No
   - Do not know – Mississippi and Oklahoma
5. *If yes to question 4, have there been any problems associated with this?*
   - Yes
   - No – Missouri.
   - Possibly – Tennessee and Texas.

Tennessee and Texas were both unaware as to whether any problems had occurred due to repairing silicone joints by applying silicone directly to the damaged areas. Tennessee even mentioned that individual maintenance departments do all that work for their state. No other special comments were mentioned by any of the states pertaining to questions 4 or 5.

6. *Have there been any noticeable effects of road salts pertaining to the silicone joints?*

Tennessee, Texas and Missouri all indicated that no effects were noted from the use of road salts on bridge decks to the silicone sealants. Only Mississippi said that there could have been effects from road salts but were unable to tell if this is what led to failures or if it was some other problem that was the primary source of failures.

Oklahoma did not know whether or not road salts had led to any problems with these joints or not.

7. *Have there been any noticeable effects of silicone bonding to itself during installations since the pour is normally split up due to the amount that can come out of tubes?*

All of the states, not including Oklahoma, answered that “no noticeable effects” were found from the switching of tubes during installations. Oklahoma did not know whether the switching of tubes caused a problem or not.

8. *Could weather conditions and/or temperature conditions on the installation day lead to problems with the silicone joints?*

All of the states except for Mississippi answered “yes” to this question. Some of the comments made included wet conditions being a problem, the width of the joint being too small when it is particularly warm, the product being temperature sensitive, and cold weather leading to longer set time for the material and primer. Mississippi did not know whether or not weather or temperature conditions affected the joint installation of silicone sealants.

9. *What is the percentage of joints installed by contractor/state (for example “0/100” would mean that 100% of the silicone joints were installed by the state)?*

Missouri was the only state that indicated that more of the joints were installed by the state than by the contractor indicating that it might be close to 100% done by the state. The amount done by the contractor was unknown to Missouri. On the other hand, each of the other four states indicated that contractors did at least 75% of the installations.

Oklahoma indicated that the contractor was doing upwards of 90% of the installations for the silicone sealants.

10. Rating of the contractor/state installations (Very Good = very little problems with joint for several years after installation, Neutral = some problems with joint that could occur within the first couple of years, Bad = problems with joint occurring very soon after installation and possibly many problems occurring within first few years).

Three states including Tennessee, Texas, and Oklahoma all indicated that both contractor and state installations were neutral on the scale given in the question. Mississippi indicated that both the contractor and state installations were both very bad. Only Missouri indicated that contractor installations were very good whereas state installations were neutral.

11. Is there build-up of small debris in the joints, specifically on the shoulders of the road, and if so has it led to any problems?

Tennessee and Texas both answered that no build-up of debris was noticed in the joints. Mississippi, Oklahoma, and Missouri all answered that there was a build-up of debris in the joints. Only Mississippi indicated any problems due to the build-up of debris in the joints stating that "pushing the joint material down, thus tearing the material or the bond being sheared." Oklahoma was unsure as to whether or not any problems had been caused by this build-up, while Missouri indicated little to no problems associated with the build-up of debris in the sides of the joint.

12. Concerning silicone joint installations, what time of year has been observed to lead to the best results for the silicone joints?

Another wide range of answers were given for this question. Mississippi and Missouri indicated that the summer and fall were the best times of year for installations of these joints. Tennessee also mentioned that fall installations had led to good results for silicone joints. Only Texas indicated that the winter was the best time of year for installations. Oklahoma did not know the best time of year for installations.

13. Concerning silicone joint installations, what time of year has been observed to lead to the worst results for the silicone joints?

Mississippi, Oklahoma and Missouri all indicated that winter installations led to bad results for silicone joints. Mississippi also mentioned that spring installations were not favorable either. On the other hand, Tennessee and Texas indicated that summer installations led to the worst results for silicone joints.

14. Concerning silicone joint installations, what temperature range (°F) has been observed to lead to the best results for the silicone joints?

Tennessee, Texas and Missouri were the only states that had an answer for this question. These three states indicated that the best temperature range was around 50-60°F. Tennessee went as low as 40°F for good installation temperatures and Missouri went as high as 70°F for its installation temperatures. Missouri also commented that the installation temperature can affect both the joint width and how the material behaves as it is setting up. The joint width may be too small in too warm of temperatures for installation of the sealant to be done properly. Tennessee also mentioned the joint width being too small in very warm temperatures for adequate installations when commenting on question 15.

15. Concerning silicone joint installations, what temperature range (°F) has been observed to lead to the worst results for the silicone joints?

Tennessee, Texas, and Missouri all indicated that installations greater than 70°F led to bad results for silicone joints. Oklahoma and Missouri both indicated that installations done at 30°F or below led to bad results for silicone joints as well. Mississippi did not know the temperature range for its bad installations.

3.2.3 Survey Conclusions

Other comments were mentioned by some of the respondents. Texas commented that proper installation of the silicone joints was the biggest factor towards the lifespan of these joints. Missouri indicated that the set time of the primer was the biggest problem. Allowing the primer to dry properly takes at least 1 hour normally and can hold up the entire installation process. Missouri would like a much faster drying primer so that installations are not held up and primer still sets up properly so that failures are not attributed to this. Tennessee indicated that many of these installations are rushed by the contractor near the end of the bridge construction process, so many of the steps are not followed properly. Other problems Tennessee indicated that sandblasting and cleaning the joint need to be done properly so that bonding occurs between the silicone and the metal. Finally, Tennessee indicated that knowing the correct movement range of the material and the bridge was very important to determining whether or not to use this material for the bridge deck expansion joints.

Oklahoma did not know many of the answers seeing as Dow Corning is located in Oklahoma and does all its installations and repair jobs. Many of the questions were unknown to the engineers who answered the surveys from their states in part due to the fact that contractors do the installations of these joints and individual maintenance crews go out to check on them and may repair them. Contractors possibly do many of the repair jobs as well. Due to this, the level of expertise is not very high from state to state over silicone joint sealants.

3.3 Conclusions and Recommendations

The survey completed by the surrounding states showed that they do not have much knowledge of silicone joint sealants. Each state did understand and indicate that proper installation of the joints was critical to the lifespan of the joints.

Future considerations need to include detailed installation procedures for highway departments for each state. With a detailed installation manual, state officials can either install the joints correctly or make sure the contractor installs the joints correctly. More information regarding the best time of year to install the joints will have to be determined, but at least most states indicated a median temperature range for installations. Temperatures that are too high or too low may allow more movement of the joint than the material can handle. Before installation takes place, the movement range of the bridge needs to be taken into consideration and compared with the movement range of the material to avoid premature failures.

Chapter 4

Task 4 Field Results

4.1 Introduction

This chapter contains results obtained over the past year on the application and installation of silicone joint sealants and more specifically the Dow Corning 902 RCS Joint Sealant currently being used for bridge deck expansion joints. In order to encompass the various reasons silicone seals may fail prematurely, an assortment of project sites around the state were selected and included new installations, previously installed joints of various ages and a number of joints exhibiting past and pending failures. In an effort to determine the facts surrounding any imminent or premature failures, it is the object of this report to disclose findings obtained from the field visits.

4.2 Experimental Program

The experimental program consists of two parts that include inspecting 15 existing bridge deck joints that exist throughout the state and to monitor 5 installations of bridge deck joints where Dow Corning 902 RCS Joint Sealant is to be used. After observing the installations, the silicone joints were monitored every 4-6 weeks for up to one year.

Properties recorded of the bridge deck joints at both the installation sites and the existing sites include air temperature, surface temperature (when available), width of joint, depth to silicone, date, location (over water, other roadway, etc.), and the overall condition of the silicone joint at the time of inspection. During installations, the overall installation process was recorded in its entirety for each site. Some of the installation process that was recorded included timing required for each part of the process, equipment, amount of silicone used, backer rod properties to name just a few.

Fifteen existing bridge joints were inspected over the past two years. The existing bridge decks consisted of very good to very poor performing joints located throughout the entire state. Each of these bridges was installed at different times of the year, and each has been inspected at different times throughout the past two years.

Six installations have been observed and each of the joints was monitored for a year. The sixth joint was installed in August 2007 and only monitored until January 2008. Approximate monthly inspections occurred for each of the six bridge deck joints during the field visiting stage.

Finally, the word failure is used throughout the following sections to highlight any area of the silicone that allows water to pass through to the sub-structure of the bridge deck. Failures may include a puncture of the silicone, tearing of the silicone, and detachment of the silicone from the joint sides to list a few examples.

4.3 Inspected Bridge Deck Joints

The following section contains the findings and observations of the 15 inspected bridge deck joints. Unless otherwise noted in the summary of the particular bridge deck joint, assume that the width of the bridge is that of a normal two-lane highway bridge. In Table 5 below, the major observations are summarized for the 15 bridge deck joints. These observations should be taken as averages, and more detail of the actual bridge conditions should be looked over within the report.

Table 5: Inspected Bridge Deck Joints

Joint	Job Number	Bridge Number	Location	Air Temperature (°F)	Installation Date	Inspection Date	Avg. Joint Width (in.)	Avg. Depth to Silicone (in.)	Joint Quality
Lee Creek Road over I-40	040348	06969	Fort Smith	75	Mar-06	Sep-06	2 1/2	variable	poor
Mill Creek Road over I-40*	R80072	07007	Russellville	80	Jul-05	Sep-06	2	3/4	very good
Hwy. 7 over I-40*	080133	06803	Russellville	70	Feb-06	Oct-06	2	variable	very poor
US 65 over Big Branch Creek	080143	06914	Choctaw	50	Oct-03	Mar-07	1 1/2	1/2	good
Co. Rd. over Cadron Creek	BR7102	04886	Choctaw	50	Jan-06	Mar-07	1 3/4	1/2	failed
Hwy. 63 over Forty Island Creek	050064	06950	Hardy	70	Nov-05	Mar-07	3	3/4	poor
I-40 over Shilcott's Creek	B60117	A6906	Little Rock	80	Jan-07	Mar-07	1 7/8	variable	poor
I-40 over Shilcott's Creek*	B60117	A6906	Little Rock	85	May-07	Jun-07	1 3/4	1/4	good
Hwy. 270 over Saline River	020183	06709	Malvern	85	Feb-99	Jul-07	1 3/4	3/8	failed
Grisby Ford over I-30*	B60123	05026	Malvern	85	Jan-02	Jul-07	variable	variable	variable
Hwy. 8/51 over I-30	070180	06962	Arkadelphia	85	Jun-05	Jul-07	1 1/4	1/2	good
Co. Rd. over South Fork Caddo River	BR4904	04862	Glenwood	90	Jun-03	Jul-07	1 1/4	1/2	good
Highway 309 over Smith Creek	040347	06963	Ozark	45	Sep-04	Jan-08	1 1/2	variable	very good
Pecan Street over US 67	050096	05226	Beebe	40	Nov-05	Jan-08	variable	variable	good
US 64 over Cache River	110289	06960	Patterson	40	Aug-05	Jan-08	2	1	poor/failed
I-440 Interchange (Southeast Ramp)	061116	D5700	Little Rock	50	Jan-06	Feb-08	2 1/8	1 1/4	failed
* = More than one installation; Refer to summary									

4.3.1 Lee Creek Road over I-40

Lee Creek Road over I-40 is located on Lee Creek Road just north of Fort Smith, Arkansas. The joint was installed in March of 2006 and inspected in September of 2006 where the air temperature was approximately 75ºF. Lee Creek Road was a three lane bridge with a span of 349 feet.

The bridge expansion joints located on Lee Creek Road were not in good condition. The existing silicone sealant was concave up in the middle as shown in Figure 16. These middle sections presented a problem due to the fact that vehicles could come in contact with the silicone and possibly rip or tear the silicone which would allow water and debris to make its way through to the understructure of the bridge. No re-inspection has been made since September, but if snow plows were used on the bridge over the past winter, the blades may have torn the sealant.

Figure 16: Silicone Concave Up in Middle

The width of both joints were 2 ½ inches, while the recess depth of the silicone at the edge of the joint was ¾ of an inch. On the other hand, there was no recess depth of the silicone in the center, and possibly some silicone protruded above roadway in places. At the time of inspection, no failures were found in the joint.

One possibility for the problems seen with the joint is the bridge deck expansion pushing silicone sealant up in the middle. Knowing the cyclic movement of the bridge is critical due to the sealant material only being able to handle +100% expansion and -50% contraction as mentioned in Chapter 2. Also, if the backer rod was too large for the joint, it could have pushed the silicone up in the middle when the expansion of the bridge deck compressed the backer rod in the joint. Another potential problem of not having any depth to the silicone in the middle is that debris now was building up on the sides of the joint due to the fact that it could not be washed away as easily since the area was smaller as can be seen in Figure 16. This debris buildup can also lead to tears forming in the silicone or a puncture through the silicone by traffic loads pushing down on the debris.

4.3.2 Mill Creek Road over I-40

Mill Creek Road over I-40 is located off of Exit 78 near Russellville, Arkansas. The joint was installed for the second time in the middle of the summer of 2005 according to the AHTD. The inspection took place in September of 2006. The surface temperature of the joint was close to 90ºF and the bridge span of 272 feet.

The joint width on both expansion joints for this bridge was 2 inches and the recess depth of the silicone was ¾ of an inch throughout the entire joint. The joint looked to be in great condition with a small amount of debris build up on the shoulders, due to turning up the ends of the backer rod and silicone. The existing sealant was actually the second installation since the first installation failed immediately. No reasons were given for the first installation failure, but it was most likely due to some poor installation techniques. Below in Figure 17, one can see a picture of the joint, and the excellent condition it is in as well as the uniformity of the silicone depth. Figure 17 can be taken as an example for an excellent looking and performing joint.

Figure 17: Mill Creek Road Bridge Deck Joint

4.3.3 Hwy. 7 over I-40

Highway 7 over I-40 is located in Russellville, Arkansas. The joint was installed in February of 2006 for the second time after the first installation failed. The inspection of the joint took place on October 11, 2006 where the air temperature was 70°F. The bridge span is 269 feet.

The width of the joint was about 2 inches with the recess depth of the silicone being anywhere from ¾ to 0 inches. The bridge was a five lane bridge over the I-40. At the time of inspection the joint was 8 months old and in very bad condition. The silicone was variable in depth throughout and was very curly. Many parts of the sealant were at the level of the roadway, while other parts were much lower and contained debris. In Figure 18 below, one can see the variability of the joint depth. This was also a second installation since the first installation failed immediately. No failures had occurred as of October 2006.

Figure 18: Highway 7 over I-40 Bridge Deck Joint

Reasons for the poor joint condition could be primarily due to installation techniques and the date of installation. The backer rod used on this joint may have been too large at the time of installation causing the backer rod to get contracted by the joint and push up the silicone sealant. Also, the joint had expanded to its greatest width at the time of installation. As the joint contracted with the following warmer months, the sealant and backer rod would have been squeezed within the joint and protruded toward the surface. Finally, the “wrinkled” texture to the silicone may also be a byproduct of the silicone sealant taking the shape of the backer rod.

4.3.4 US 65 over Big Branch Creek

US 65 over Big Branch Creek is located in Choctaw, Arkansas. The silicone joint was installed in October of 2003. The inspection of the joint took place on March 2, 2007 where the air temperature was roughly 50°F. The bridge span is 130 feet.

The joint width was 1 ½ inches throughout with a recess depth of the silicone of ½ inch throughout. This joint looked to be in great condition with no tears, or obscurities in the silicone. The silicone sealant was level throughout the width of the bridge. Refer to Figure 17 to see a picture of essentially the same joint as US 65 over Big Branch Creek. There was only a little debris located on the shoulders which did not look to be much of a problem.

4.3.5 Co. Rd. over Cadron Creek

The county road over Cadron Creek Bridge was located near Choctaw, Arkansas on a dirt road. This joint was installed in January of 2006. It was later inspected on March 2, 2007 where the air temperature was roughly 50°F. The bridge span is 350 feet.

The first major point that should be pointed out for this bridge is that it is located on a dirt road, and dirt roads are not ideal locations for installing silicone sealants. The joint width was about 1 ¾ inches with a recess depth of the silicone of ½ inch throughout the bridge. When first arriving at the bridge, much debris and fairly large rocks from the dirt road were wedged into the expansion joint as can be seen in Figure 19. After removing most of the debris, a few failures were immediately found where vehicles had pushed down on the debris which punctured the silicone. Silicone sealants cannot support loads from vehicles and so should not be used on dirt roads where debris can infiltrate the joint and be pushed through the silicone. Other than problems from debris and gravel, the joint looked to have been installed rather well and no other types of failures were found.

Figure 19: Debris in Joint at Cadron Creek Bridge

4.3.6 Hwy. 63 over Forty Island Creek

This bridge deck joint is located on Highway 63 over Forty Island Creek in Hardy, Arkansas. The joint was installed in November of 2005 and later inspected on March 23, 2007. The air temperature was roughly 70°F, and the bridge span is 500 feet.

The width of this joint was about 3 inches with a recess depth of the silicone around ¾ of an inch in most areas. One major thing to note about this joint is that the highway department had patched the joint in many places due to failures that had already occurred. These patches were done in the winter of 2006. The patches appeared to have bonded well to the older silicone, but the problem that occurred is that the silicone was now very uneven and debris was trapped in many areas. Also, the patches appeared to have been done at regular intervals, or where the silicone tubes may have been switched out during the original installation. Figure 20 below shows the intervals where patches were done and the non-uniformity of the silicone. This bridge was a 5 lane bridge that was subjected to a lot of heavy truck traffic.

Figure 20: Highway 63 Bridge with Interval Patching

Other things to note were that some places looked as though failures were about to occur again due to the sides of the joint trying detach from the silicone. This may be due to the width of the joint (larger than specifications), somewhat poor installation (not using primer correctly), and debris causing problems with the bondage at the sides. Detachment of the silicone from the side of the joint would mean a much more detailed replacement of the material due to the re-sandblasting and re-priming of the joint in that area.

4.3.7 I-40 over Shilcott's Creek

The bridge deck joint I-40 over Shilcott's Creek is located in Little Rock, Arkansas near Exit 152 on the northwest bound lane of I-40. The installation date of the joints was originally on January 26, 2007. One of the joints experienced many problems and was later replaced in May of 2007. The first inspection of the joints was on March 29, 2007 where the air temperature was 80°F. A follow-up inspection of the joints was done on May 29, 2007 where the temperature was about 80°F again. Traffic was not allowed on this bridge until late June of 2007, and then only in one lane. All three lanes were opened to traffic in July of 2007. The bridge span length is 157 feet.

The inspection of the joints in March gave a joint width of 1 7/8 inches and recess depth of the silicone of 0 inches in the middle with only about 3/8 inch on the side. No traffic had been allowed on the bridge and has only been recently opened to traffic as of June. Two failures had already occurred on the joint. One was a construction failure where the silicone sealant was punctured. The other failure appeared to be due to an inadequate pour causing a very thin joint and weak spot. The silicone thickness at this spot was approximately 1/8 on an inch. This may have also been an area where the tubes had been switched out of the gun. Finally, the silicone uniformity was very uneven throughout the width of the bridge.

A return in May showed that one of the two joints had been replaced in May. This joint looked much better with a much more consistent pour. Also, the backer rod used on this joint appeared to be the correct size, unlike the backer rods that were used when the joint was installed in March. The width of the joint at this time was 1 ¾ inches with a depth to silicone of ¼ of an inch. The recess depth of the silicone was somewhat shallow and this could pose some problems in the future. However, further protruding of the silicone is unlikely since the silicone was placed in May at warmer temperatures where the width of the joint is close to its smallest. Also, the silicone appeared to have been poured with the correct thickness in mind, unlike the first pour. In Figure 21, one can see a comparison of the originally poured joint versus the replacement.

Figure 21: Shilcott Creek Bridge - Original Joint (left) vs. Replaced Joint (right)

The joint that was not replaced appeared worse than the previous visit and may need to be replaced soon as well. Some tears had occurred in the silicone where it was pushed up in the middle above the surface of the roadway. Another look at the joint in late June, after traffic had been allowed onto the road showed that the silicone was taking punishment from the vehicles. This joint resembled the left picture in Figure 21.

4.3.8 Hwy. 270 over Saline River

The bridge deck joints on Highway 270 over Saline River are located about 10 miles east of Malvern, Arkansas. The joint was installed in February of 1999 and was inspected on July 25, 2007. This joint is located over the Saline River and has a span length of 223 feet. The air temperature on the day of inspection was 85°F.

The width of the joint was 1 ½ inches on the eastern side with a joint width of about 2 inches on the western joint. The recess depth of the silicone on the eastern joint was 3/8 of an inch while the western joint was between 0 and ½ inches. The western joint was in poor condition and contained many failures. There was also small stretches of joint that contained no sealant. The joint was 8 years old, so it was only to be expected to find some failures in the joint. On the other hand, the eastern joint was still in decent shape for its age. This may have been due to the fact that it looked to have a more uniform pour throughout and was not skewed at all creating different joint widths and depths. One final thing to take notice of was that the joint ends were not turned up, and no problems had developed with the understructure. A comparison of the eastern joint to the western joint can be seen in Figure 22. In Figure 22, one can see the non-uniformity of the silicone in the western joint when compared with the eastern joint.

Figure 22: Hwy. 270 over Saline River West Joint (left) vs. East Joint (right)

4.3.9 Grisby Ford over I-30

The bridge deck joint on Grisby Ford over I-30 is located just south of Malvern, Arkansas. The joints were installed on the existing bridge in January of 2002. The inspection took place on July 25, 2007 when the air temperature was roughly 85°F. There are six joints on the bridge with varying widths, depths to silicone and spans between one another. The various spans are 45, 71, 72, 71 and 43 feet.

This bridge contained six joints with variations in width and recess depth for all six joints. Widths ranged from 3 inches on one of the middle joints to 7/8 of an inch on a couple of the outer joints. Recess depths were typically greater than ½ an inch for most joints with the average at about 5/8 of an inch. On the other hand, one joint on the eastern most side had a recess depth under ¼ of an inch with areas at roadway height.

This was also true for the second most western joint. This second most western joint was also interesting because its width changed from 1 1/8 inches on the side with no recess depth to 2 1/8 inches on the side with a recess depth of ¼ of an inch.

Before the installation of the joints, the bridge height was increased by a few feet to allow greater clearance on the interstate. This could have influenced the joints considerably, and may be the reason why several of the joints were skewed or each side of the joint was at a different height such as the second most western joint. Another major influence on the joints may be due to an 18-wheeler hitting the bridge columns in 2005. All in all, most of the joints seemed to be in good shape. A few joints contained a decent amount of debris while some others protruded up to the roadway surface. Only one of the joints contained a small failure on the end where water and debris may be able to get through to the understructure, but this tear was small.

4.3.10 Hwy. 8/51 over I-30

The bridge deck joint Highway 8/51 over I-30 is located in Arkadelphia, Arkansas. The joint was installed in June of 2005 and inspected on July 25, 2007. The air temperature was 85°F and the bridge span was 306 feet.

The joint widths for each side of the bridge were about 1 ¼ inches with recess depths of the silicone close to ½ an inch throughout. No silicone protruded up to the roadway surface. The bridge deck was skewed some causing the joints to be skewed as well and un-uniform. Overall, both joints were in good shape. Only one small failure was found on the western joint in the roadway. This failure looked as if something had punctured the silicone. Figure 23 shows a picture of the puncture in the silicone. The only other major observation was that the sealant appeared to have been poured unevenly or later was skewed with the bridge deck to give an uneven look throughout. This bridge was a five-lane bridge.

Figure 23: Grisby Ford Silicone Puncture

4.3.11 Co. Rd. over South Fork Caddo River

The bridge deck joint County Road over South Fork Caddo River is located on a dirt road near Glenwood, Arkansas. The joint was installed in June of 2003. The inspection of the joint took place on July 25, 2007 where the air temperature was about 90°F. The bridge span is 352 feet.

The joint widths for the bridge were 1 ¼ inches throughout with recess depths of the silicone of ½ of an inch. When first inspecting the joint, it was covered in debris from the dirt road. Remarkably, no failures were found in either of the joints. No rocks or debris had been able to puncture through the sealant. Both joints looked to have had a proper placement and were only somewhat “wrinkly” in a few areas which can be seen in Figure 24 below. The southern joint contained one area that was trying to detach from the joint side, but had not done so yet. Expansion of the joint could lead to a failure in the future. All in all, the joint was in good shape for being on a dirt road for 4 years. Even though this joint had performed well, installing silicone sealants on dirt roads is not recommended due to the likelihood of debris puncturing the sealant under vehicular loads.

Figure 24: Caddo River County Road "Wrinkly" Joint

4.3.12 Highway 309 over Smith Creek

The bridge deck joint Highway 309 over Smith Creek is located just south of Ozark, Arkansas. The joint was installed in September of 2004. The inspection of the joint took place on January 15, 2008 where the air temperature was about 45°F. The bridge span is 140 feet.

The joint widths for the bridge were on average 1 ½ inches to 1 5/8 inches with recess depths of the silicone of ¾ of an inch on the southern joint and 3/8 of an inch on the northern joint. On inspection of the joint, no problems were noted or failures found. The joint looked to be in good shape with a uniform pour throughout. Refer to Figure 17 for a similar looking joint. Only one small tear was found that looked to have been caused by a rock or stick being drug along the silicone. This tear was very minor though and had not gone through the entire joint yet. The joint did contain some debris on the shoulders of the road. The backer rod was also still in place underneath the silicone and had not fallen out. Finally, the bridge was very level, producing no skewing of the joints.

4.3.13 Pecan Street over US 67

The bridge deck joint Pecan Street over US 67 is located in Beebe, Arkansas. The joint was installed in November of 2005. The inspection of the joint took place on January 16, 2008 where the air temperature was about 40°F. The span between each of the joints varied from 44 feet on the ends to 86 feet for the middle joints.

The inspection of this bridge showed that it had five silicone joints spaced as mentioned previously. The widths of the joints varied depending on the joint. The end joints contained widths of about 1 inch, while the two joints around the middle of the bridge contained widths closer to 1 ½ inches. Finally the middle joint contained a width of about 1 ¼ inches. The recess depths of the silicone of each joint varied a little from joint to joint and also varied a little within the same joint, but most were at least ½ inch. Recess depths of the silicone were started around ¾ of an inch on the northern side of the joint and went to ½ an inch or less on the southern side of the joint, which remained true for all but one of the joints.

The two outermost joints looked to be in the best shape of all the joints and contained no tears or failures whatsoever. The three joints in the middle of the bridge contained a few minor issues such as a few small depressions with small debris lodged in them and one area where the silicone had detached from the side of the joint. This detachment was very small but went through the entire thickness of the silicone, so it would be considered a failure.

One of the interesting things seen on these joints was that on the shoulders of the bridge, two backer rods had been used as can be seen in Figure 25. This may have been done to help raise the silicone on the ends of the joint to keep water and debris from washing off onto Highway 67 below. The shoulders of the road did allow debris to accumulate in the joints but very little debris was found in the joints located in the traffic lanes. All in all, the condition of the joints was fairly good except for the small detachment and the few small depressions.

Figure 25: Pecan Street Double Backer Rod in Joint

4.3.14 US 64 over Cache River

The bridge deck joint US 64 over Cache River is located just north of Patterson, Arkansas. The joint was installed in August of 2005. The inspection of the joint took place on January 16, 2008 where the air temperature was about 40°F. The span length between each of the five joints was 126 feet a piece.

On inspecting the bridge, the width of the joints was found to be on average around 2 inches, while the depths to silicone from the roadway were on average 1 inch. One interesting thing seen on a couple of the inner joints was that the width of the joint started at a little over 2 inches on the northern side of the joint and then went down to around 1

½ inches on the southern side of the joint. The recess depths of the silicone for these joints remained relatively uniform throughout the length of the joint even with these changes in widths. These two joints did not appear to have any problems that could be attributed to these changes in joint widths.

In all five of the joints, many problems were noticed with detachment of the silicone from the sides of the joint and tears in the middle of the silicone joints. On most of these joints, the spacing of these tears and detaching areas was about every 2-3 feet, which may have been the distance where tubes were changed out during the installation of the joints. Figure 26 presents a picture of the interval tearing. Many of these areas where tears and detachments were found were completely through the entire joint constituting a failure. Some though had not broken through the silicone completely and were still operating fine. Very little debris was found on the joints. Finally, one of the joints contained the two backer rods on the end which had probably been used to push up the ends of the silicone. All in all, the joints were in pretty bad shape for being only 2 ½ years old and many would need to be replaced.

Figure 26: Cache River Interval Tearing/Detaching of Silicone Joint

4.3.15 I-440 Interchange (Southeast Ramp Bridge)

The bridge deck joint I-440 Interchange (Southeast Ramp Bridge) is located in Little Rock, Arkansas. The joint was installed in January of 2006. The inspection of the joint took place on February 20, 2008 where the air temperature was about 50°F. The span length between joints varied between 270 feet and 130 feet, while the bridge width was one-lane plus shoulders.

Only one joint was examined and the width of the joint was an even 2 1/8 inches throughout. The depth to silicone on the joint was about 1 ¼ inches, but there was a level of debris or asphalt that covered the silicone with a thickness of about ½ inch which can be seen in Figure 27. After removing this debris/asphalt covering, several holes and detachments were found in the silicone constituting many failures. This debris covering was nearly bonded to the silicone and was particularly hard to remove from the joint. An AHTD official thought that calcium chloride used on the bridge deck may have allowed the debris to bond together over the top of the silicone to create the layer of debris and make it hard to remove. This layer was particularly heavy on top of the silicone as well. In summary, this joint will need to be replaced due to the many failures.

Figure 27: I-440 Interchange Debris Build-up on Joint

4.4 Joint Installation and Monitoring

The following section contains the findings and observations of the 6 installations that were observed as well as the monitoring of these sites after their respective installations. Figures 28, 29, and 30, show the average width of the joint, average depth to silicone, and average air temperature recorded at each of these sites during their respective months. These figures present averages of the depth, width, and temperature. If one is interested in the actual joint widths and depths, please refer to the section for that particular bridge deck joint.

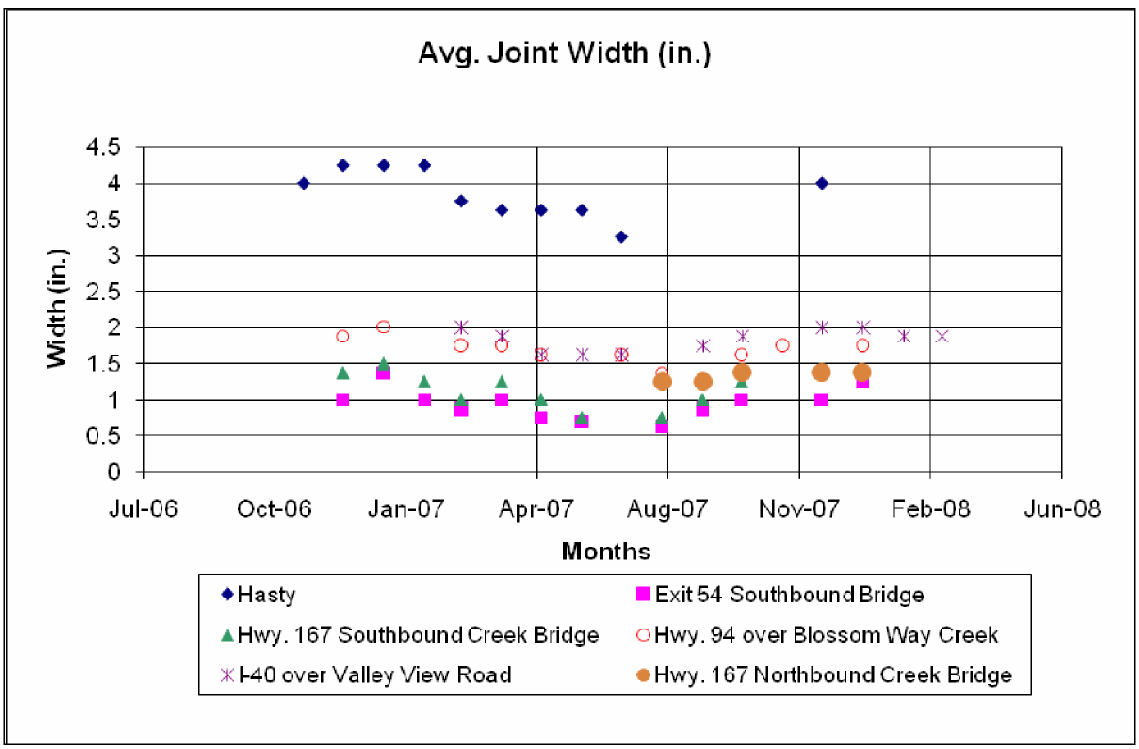


Figure 28: Average Joint Width for Monitored Bridges

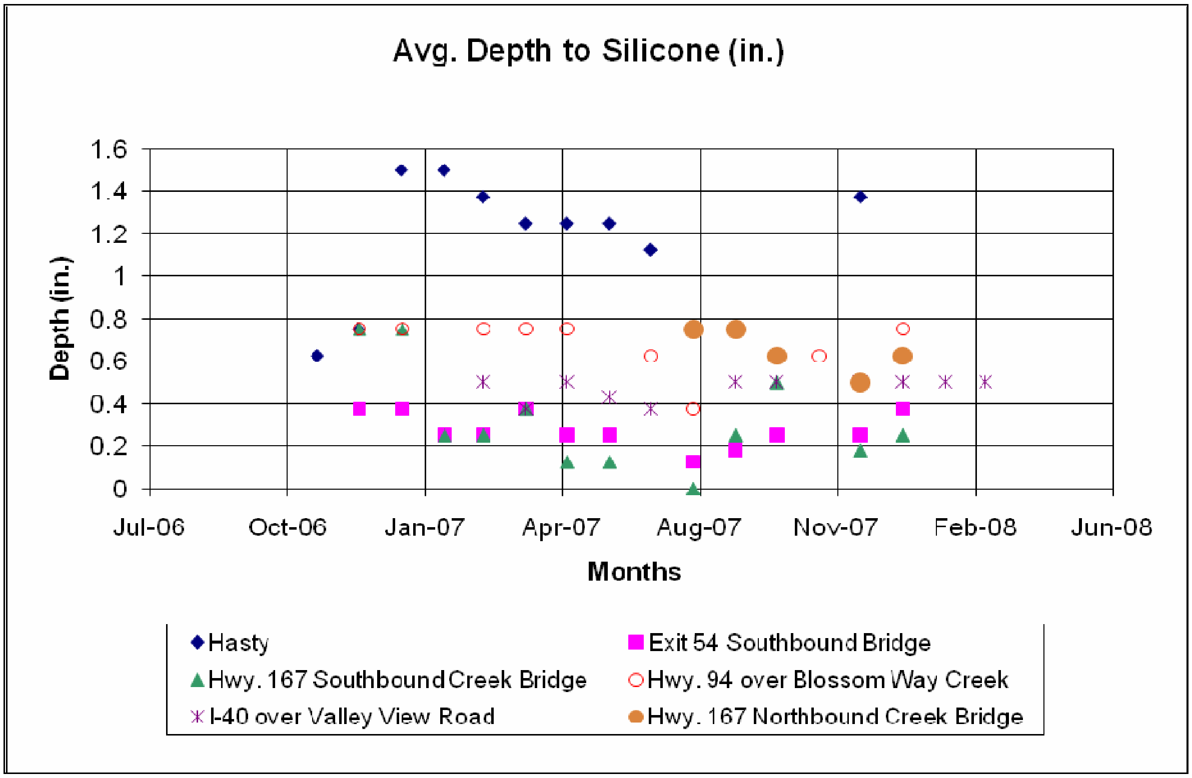


Figure 29: Average Depth to Silicone for Monitored Bridges

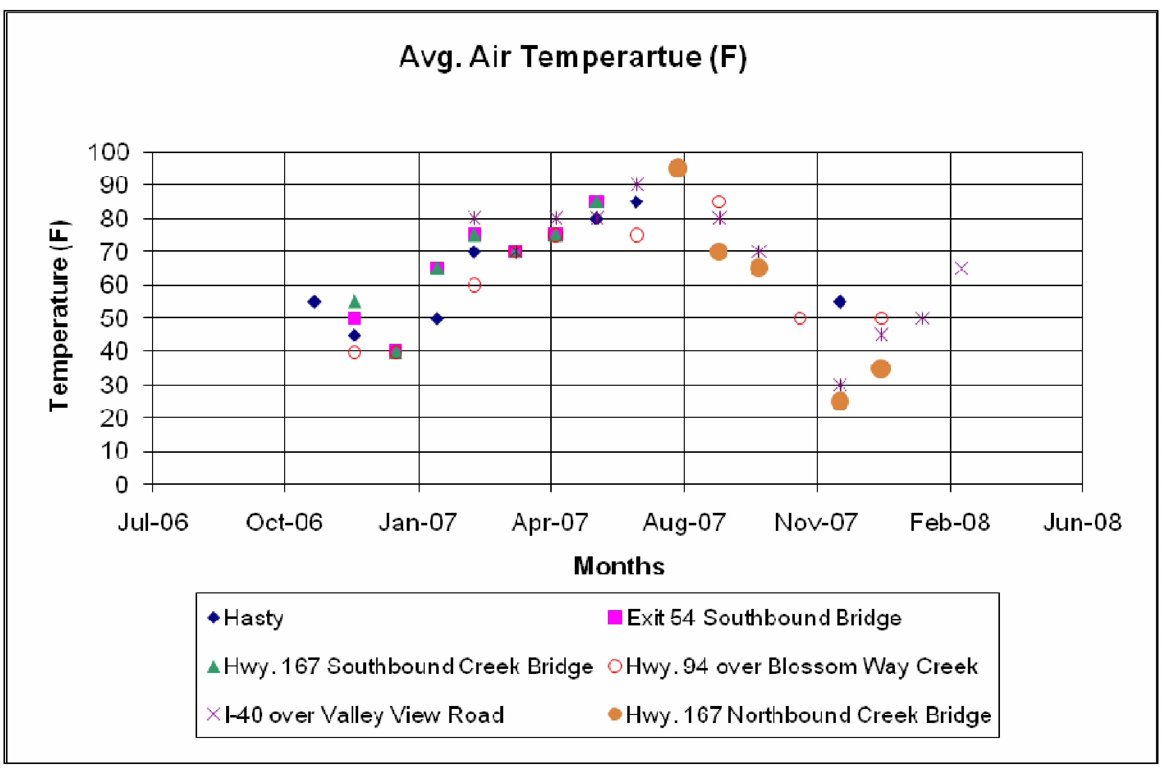


Figure 30: Average Air Temperature for Monitored Bridges

In Figures 28-30, one can see a few trends such as in Figure 28 the increase in joint width toward the winter months and the decrease in joint width towards the summer months. Also, Figure 28 shows that most installed joints or replaced joints are between 1-2 inches in width. The extra wide joint at Hasty is not seen very often for silicone applications. The closest to any trend found in Figure 29 with recess depths to silicone monitored was that possibly the recess depth decreases as the temperature gets warmer or as one heads into the warmer summer months. Extra recess depth may need to be required for the colder months due to this trend as Table 4 clearly shows. Although, in Figure 29, the data is fairly scattered so no concrete conclusions can be made. Figure 30 shows very effectively the temperature changes throughout the year in which the bridges were monitored.

4.4.1 Hasty Bridge over Buffalo River

The bridge deck joint for the Hasty Bridge over the Buffalo River is located in Hasty, Arkansas. The joint was installed in August of 2006 and has since been monitored almost monthly for the past year. The surface temperature on the date of installation was nearly 120°F.

The Hasty Bridge was the first bridge to be monitored while the Dow Corning 902 RCS Joint Sealant was installed in the expansion joint. At the time of installation, it was very hot and the joint width was 3 ½ inches on a two-lane bridge. This joint width was wider than recommended by Dow Corning specifications, and this was in the summer when the joint width was at its smallest. One of the important installation techniques implemented at Hasty when installing this material were specially cut boards. One of these boards was used to push the backer rod down to the correct depth so that the silicone could be placed with a ½ an inch thickness and ½ an inch recess. The backer rod used for this joint was approximately 4 – 4 ½ inches diameter, which was the correct size to use for a joint of this width. Another board was used to insure that the silicone was placed smoothly and at the recess of ½ an inch. All other installation procedures such as sandblasting, priming, and correctly applying the sealant were followed in accordance with Dow Corning specifications.

During the follow ups, a few tears have been noted in the material. One of these tears is in the middle of the roadway where the sealant could have been hit by the tires. This tear is most likely a material failure, due to the wide range of movement that occurred on this joint. In the middle of winter, the joint widths were 4 ¾ inches. Since the joint is so wide, the material may not have been able to withstand that amount of movement as well as the force of the tires pushing down on the sealant. With the summer months in progress, this tear has closed up somewhat and is not much of a problem at the moment, but the tear may grow during the winter. This tear can easily be fixed with the application of more sealant, since the sealant can bond to itself.

Another area where a failure was beginning to occur was where the joint wall and the sealant connected. There is a small area on one end of the bridge where the sealant is pulling away from the side wall. This problem is probably due to not applying the primer correctly or at all. The problem can easily be fixed by cutting out the small section of sealant, re-sandblasting, re-priming, and re-installing the sealant. Once again, the sealant will bond to itself so no problems should be encountered.

The major problem with using this material on the Hasty Bridge is the joint width, which is somewhat beyond what Dow Corning recommends in its specifications. The material failure mentioned above could be due to this, and more material failures may present themselves in the years to follow. One final thing to note is that since the correct backer rod size was used, the backer rod fell out of the joint sometime during the winter months, which is best because during the summer months it does not push the silicone up to roadway height. Also, since the backer rod fell out, the depth to silicone is approximately 1 inch or more, due to the silicone sagging somewhat from lack of support. The sagging is also a result of the installation on a very hot day where the joint width was at a minimum. No problems seem to be occurring from this sagging, and the extra recess helps to keep vehicles from pushing down on the sealant. The backer rod was not turned up on the ends either which has allowed debris and water to flow off the sides and not build up on the shoulders.

4.4.2 Bald Knob Bridges

The following three bridge deck joints are all located in Bald Knob, Arkansas close to Exit 54 on Highway 167. The first two joints were installed on December 13 and 14 of 2006 and have been monitored since. The last joint was not installed until August 9, 2007. The monitoring will help determine whether the installation in the summer or the winter is more beneficial for the sealant material. Monitoring of these bridges continued every 4-6 weeks until January 2008.

4.4.2.1 Hwy. 167 Exit 54 Southbound Bridge

The bridge deck joint located at Exit 54 in the southbound lane of Highway 167 was installed on December 14, 2006 when the air temperature was approximately 45°F. The surface temperature of the joint was approximately 40°F.

The installation procedure followed Dow Corning recommendations and Dow Corning did have representatives on-site for this installation and the other two Bald Knob installations. The width of the joint on installation ranged from 1 3/8 inches to 1 inch when going from one side of the bridge to the other. The joint was initially sand blasted and then air blasted. Next the primer was applied with a small roller and allowed to dry for at least 1 hour before the sealant could be applied. Before the sealer could be applied, the primer needed to have a “flakey” appearance. After the primer was ready, the backer rod was put in place. The backer rod was too large in places and was cut in half in order to be placed in the joint. In areas, the backer rod had to be forced into place, and the shape of the backer rod was very uneven and “wrinkly” as can be seen in Figure 31. This may have led to a bad shape factor for the silicone. One can also notice in Figure 31 that there is very little depth from the roadway to the backer rod, which led to the silicone being recessed very little. The width of the joint on the installation day was approximately 1 inch, and the backer rod diameter was approximately 2 ½ inches. After the backer rod was installed, the silicone was placed with the gun shown in Figure 12. Small measuring devices were used at intervals to check the depth and thickness of the silicone and backer rod, but no specially built objects were used to install the backer rod at the correct depth and level the sealant at the correct depth. The end result had the sealant about ½ an inch below the roadway one side of the joint, while the other side of the joint remained with little or no depth from the roadway to the silicone surface. The ends of this joint were turned up so as to keep water and debris from draining off onto the roadway below. Also, only one lane of traffic was closed at a time, so after finishing one side of the joint, the other lane was closed and the process was repeated for the other joint.

Figure 31: Bald Knob Exit 54 "Wrinkly" Backer Rod in Joint

From December 2006 to January 2008, the joint has been monitored. The width of the joint has gone from being at most 1 ¼ inches (on average) in the winter months to 5/8 of an inch in the warmest summer months. This movement is just within the allowable movement of a joint for the sealant to work, due to its 50% contraction capabilities. The area that started at 1 3/8 inches went down to 5/8 of an inch and did protrude above the surface of the roadway on the shoulder, but there was very little recess depth given here to begin with. Traffic lanes did not have sealant protruding above the top surface of the joint. The depth of the sealant during this period did not change much from the depth it was installed at except as stated above. On one end of the bridge, there is no depth due to the turn-up of the sealant and the small amount of space available to push the backer rod into place. The silicone depth increases as one moves across the width of the bridge until it gets to a maximum depth around ½ an inch. Due to the width becoming so small during the summer months, the sealant was pushed up somewhat toward the roadway, and began to take on several of the characteristics of the backer rod including a "wrinkled" and "curly" texture. Figure 32 below shows a picture of the sealant being pushed up to the roadway near and on the shoulder. Also, the sealant is uneven in depth throughout its entire span. Finally, several places in the joint contain embedded debris which may be due to allowing traffic on the joint immediately after it was completed when the silicone had not set-up entirely.

Figure 32: Bald Knob Exit 54 Joint Sealant Pushing Up to Roadway (8-9-07)

The backer rod for this joint was attempted to be removed in June, so that there might be a little more room for the silicone sealant to recess and not push up to the roadway. The joint was too tight to allow anything to pull the backer rod out from underneath. The winter months showed that the sealant recessed a little more as the width of the joint increased. To date, no failures have occurred on this joint.

4.4.2.2 Hwy. 167 Southbound Creek Bridge

The bridge deck joint for Highway 167 of the southbound lane over the creek is located just after Exit 54 on Highway 167 in Bald Knob, Arkansas. The joint was installed on December 13, 2006 where the temperature was approximately 45°F and the surface temperature of the joint was 40°F.

The installation procedure followed for this bridge was identical to that of the Exit 54 Bridge as was described above. However, the backer rod was not cut in half for this joint, but was still about 2 ½ inches in diameter and had to be forced into the joint in places. On the day of installation, the joint width was approximately 1 3/8 inches wide throughout. The depth to silicone was ¾ of an inch, which was somewhat deeper than the Exit 54 Bridge.

The monitoring of this joint showed that the silicone has continued to protrude upwards toward the roadway surface and as of August 2007, many spots are higher than the surface of the roadway in traffic lanes as well as the shoulder of the road. These areas are even in traffic spots and this has allowed traffic to start tearing the joint. From August 2007 to January 2008, the sealant began to recess some as the joint widened, but the depth at most was ½ inch from the roadway. The spot that was being hit by vehicles recessed enough so that it was no longer at roadway height. No failures had occurred in the joint, as one can see in Figure 33, the joint did take some significant damage.

Figure 33: Southbound Creek Bridge Joint Damage (8-9-07)

On June 12, 2007, the bridge deck joint's backer rod was removed from underneath the roadway. The theory was that this would help alleviate some of the pressure on the sealant that was making it push up to the roadway surface. Due to the temperatures though, the joint only contracted more and pushed the sealant farther up toward the roadway. On August 9, 2007, the joint width was only 5/8 – ¾ of an inch in places from the original installation of 1 ½ inches in width. This is more than a 50% contraction which exceeds the maximum contraction that the Dow Corning 902 RCS Joint Sealant can withstand. The joint did begin to recess a bit through the fall and into the winter. Only checking the joint in the summer of 2008 again will determine whether or not the removal of the backer rod was a success and alleviated the pressure pushing up on the sealant. If the sealant is at or above roadway height again, the removal of the backer rod was not enough to help keep the sealant recessed.

4.4.2.3 Hwy. 167 Northbound Creek Bridge

The bridge deck joint for the Highway 167 Creek Bridge located in the northbound lane is directly across from the southbound lane bridge mentioned above. This joint was installed on August 9, 2007 where the air temperature was approximately 95°F and surface temperature readings were measured at 103°F. Monitoring of this bridge deck joint only lasted until January of 2008.

The joint width on the day of installation averaged 1 ¼ inches and the target thickness of the silicone was ½ an inch. The backer rod was 2 ¼ inches in diameter which is above the specifications listed in Table 3. The backer rod was once again cut in half to be placed into the joint. During this installation, care was taken at placing the backer rod to assure it was at the correct depth and to make certain the backer rod had a uniform "non-wrinkled" shape. All other installation procedures used at Bald Knob in December were followed once again. The only change was that the Dow Corning representative stated that the primer should be given at least 2 hours to set instead of 1 hour as was previously indicated. Another minor change made for this joint was that the backer rod ends were left down so as to allow drainage off the bridge into the creek below and to prevent debris build-up from occurring as was observed on the other two Bald Knob bridges.

Since the installation, the bridge deck joint has performed very well and no problems have been found on the sealant. The width of the joint got up to 1 ½ inches in

January 2008 where the depth stayed at 5/8 of an inch throughout. The original depth to the silicone sealant was between 5/8 and ¾ of an inch, so the depth has not changed over the months since installation. Also, the sealant has maintained a very uniform depth throughout the width of the bridge and throughout the months since installation as can be seen in Figure 34. Very little debris has been found in the joint in the roadway area, but there is still a build-up of debris on the shoulders, even after the turn-down of the ends of the joints.

Figure 34: Bald Knob Northbound Creek Joint (1-16-08)

4.4.3 Hwy. 94 over Blossom Way Creek

The bridge deck joint for Highway 94 over Blossom Way Creek was installed on December 21, 2006. Only the joints on the two lanes of the bridge on the eastbound side were installed on this day, because the remaining traffic lanes had already been installed several months before. The air temperature for the installation was approximately 40°F. Since the installation, continual monitoring has occurred about every 4-6 weeks.

The expansion joints were installed for the Blossom Way Creek Bridge during the winter, and the joint width averaged 1 ¾ inches at the time. Contractors installed the sealant for this joint and followed the procedures according to Dow Corning specifications. A 2 ½ inch backer rod was placed in the joint. Also, a specially made board was used to insure the backer rod was placed at the correct recess. By doing this, the silicone had a thickness of ½ an inch and was placed at a depth of ¾ of an inch. Also, the backer rod was placed so that the backer rod was free of wrinkles. These wrinkles could lead to a poor shape factor of the silicone.

Through the following months, the joint was continually monitored and no signs of damage could be seen to the sealant. The bridge was opened to traffic at the end of June, 2007. The only major observation at this joint was the debris build-up in the joints which was probably due to excess construction waste. Some of this debris would need to be removed before traffic was on the bridge, due to the fact that it could puncture the silicone. Also, upon checking underneath the bridge, it was found that several of the backer rods had come out. This is due to the joint width widening during the colder winter months, and it was also due to the fact that the correct size backer rod was used.

Joint widths changed very little from the installation of the bridge. In the warmer summer months, the eastern joint was 1 3/8 inches wide while the western joint was about 1 ½ inches wide. The colder months led to joint widths on the eastern side of 1 5/8 inches and western side closer to 2 inches. Recess depths of the silicone for the eastern joint were about ½ an inch in the summer and ¾ of an inch in the winter. The western joint recess depths were ¼ of an inch in the summer and ¾ of an inch in the winter. Each respective joint had relatively uniformity to the sealant level throughout the half width of the bridge.

Further monitoring of the joints showed that no problems were found to have arisen due to the excess debris within the joints. The only noticeable things found on the joint were a few soft spots which may have been from inadequate thickness of the sealant. Also, during the summer months the western joint had one spot that got up to the roadway height and allowed traffic to hit it some as can be seen in Figure 35. No damage was caused to the sealant since it did not go above the roadway.

Figure 35: Blossom Way Creek Joint with Sealant at Roadway (8-14-07)

4.4.4 I-40 over Valley View Road

The bridge deck joint on I-40 over Valley View Road is located in Little Rock, Arkansas near exit 152 on the northwest bound lane of I-40. The joint was installed on March 29 and 30 of 2007 where the air temperature was approximately 80°F. The joint has continued to be monitored every 4-6 weeks since its installation.

The installation of the joint for this bridge followed the same procedures as was done in Bald Knob and Rogers. The joint width at the time of installation was 2 inches. Priming of the joint was done with a 1 hour waiting period, but a few places were missed and were re-primed immediately before the placing of the backer rod and applying the sealant. The backer rod used on this joint was 3 inches in diameter which was much too large for this joint. The backer rod was forced into place. Finally, the depth to silicone was ½ an inch with a silicone thickness of ½ an inch.

Upon returning visits, a few problem areas were discovered. One spot in the joint looked as though something had tried to puncture the sealant. Construction workers should be aware of the silicone sealant expansion joints so as not to damage them, or the sealants should not be installed until a few weeks before the bridge opens to avoid construction problems altogether. At the time, the bridge had not yet opened to traffic. Since July 2007 when the bridge opened to traffic, the puncture area has performed very well. Some debris has collected within its depression, but no problems or failures have been noticed.

Another problem area was discovered where it looked as though concrete had attached to the sealant. A few days after the installation of the sealant, concrete was poured for the ends of the bridge deck. Splashes from the concrete pour were found in the joint. This may have had unknown effects with the sealant that was still curing. Upon inspection of the joint, the sealant was being torn away from the joint sides where a splash of this concrete was found. The unknown chemical process could have caused this small tear, or the more probable solution was that the tear may have been caused by the primer not having the proper curing time before placing the sealant. This area was one of the spots that were hastily gone back over with primer right before placing the backer rod and sealant material.

Upon the last visit on March 31, 2008, the area that was originally noted as having a small tear before traffic had been allowed onto the bridge, now was about a 3 inch long tear. This tear was completely detached from the joint side and allowed debris and water to get through to the understructure of the joint constituting a failure. The spot was only recently noticed since it was in the middle of a very high traffic 3-4 lane bridge.

Finally, due to the backer rod being so large, the silicone depth is somewhat less now and it is approaching the roadway height in some areas. Also, some areas of silicone seem to be taking on the appearance of the backer rod's "wrinkly" surface from improper placement. No problems have been noticed due to the recess depth of the silicone or the "wrinkly" appearance of the silicone in a few places. The only major problem as noted above was the detachment of the silicone from the side of the joint.

Chapter 5

Summary, Conclusions and Recommendations

The following sections give some installation recommendations that have been discovered by visiting the bridge sites and monitoring them. Also, some possible reasons for failures are presented with possible solutions to the problems.

5.1. Installation Recommendations

1. Sandblast the joint down to the depth where the silicone will be attached to the sides of the joint wall. Figure 36 shows an example of the minimum depth needed for sandblasting. The equation used to know the minimum depth for sandblasting or priming would be: Recess Depth of Silicone (Refer to Table 4) + Silicone Thickness (½ inch) + ½ Backer Rod Diameter (Refer to Table 3).

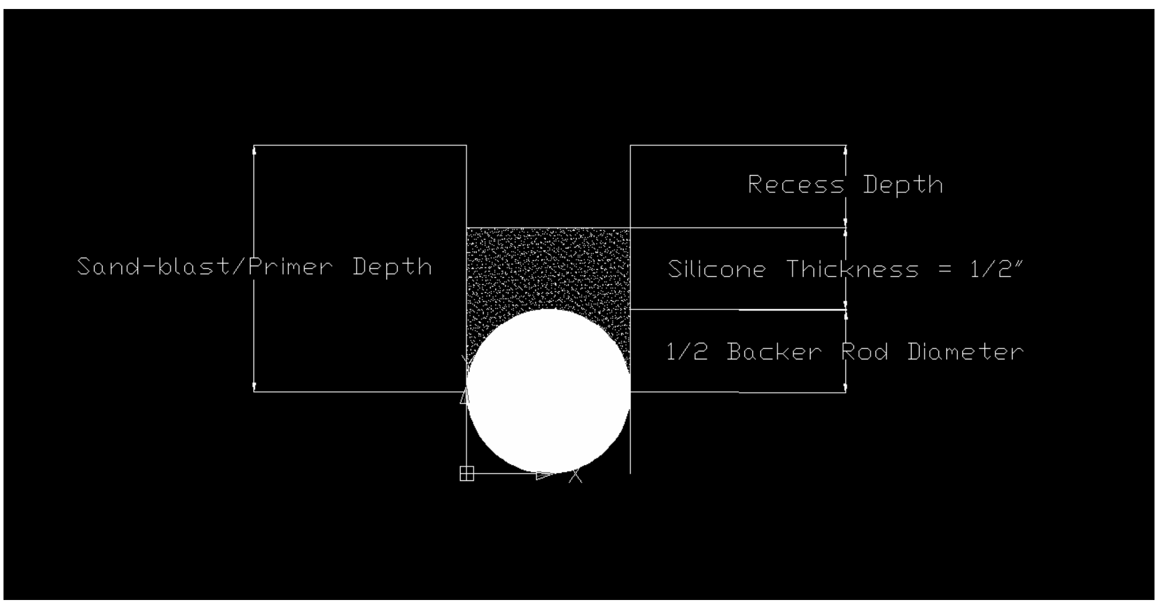


Figure 36: Sandblast and Primer Application Minimum Depth

2. Airblast the joint to remove any excess debris. No debris should be present when applying the primer or placing the silicone.

3. Prime the joint with the correct primer as specified by Dow Corning. If the primer comes in contact with rain or debris during its cure period, the primer must be removed and the process started again, beginning with sandblasting the joint. The minimum depth to prime can be seen above in Figure 36. Also, the equation mentioned for minimum sandblasting depth can also be applied to minimum primer depth.
4. The primer should set for at least an hour, and then it should be checked by slicing a small part off in a few different areas with a pocket knife. If the primer comes off your fingers flakey, then it has set long enough and placement of the backer rod can begin. Dow Corning currently recommends 2 hours for the set time of the primer.
5. Place the backer rod at the correct recess, so that the silicone will be at the correct recess from the roadway. A depth of 1 - 1 ¼ inches is adequate. It may be beneficial to construct a tool to do this, but the tool should place it at 1 ½ inches deep, due to the rebound from the backer rod. Rebound may occur because the backer rod is made of soft material that gives a little when one pushes on it. Due to this, placing the backer rod at the correct depth needs to be taken with extreme care, especially when using specially made boards to place the backer rod. The backer rod needs to be uniform throughout its length with no crinkles or odd spots. Also, the backer rod needs to be the correct size, usually no greater than ½ an inch plus the joint width in diameter. Dow Corning specifies backer rod diameters for a range of joint widths and temperatures as shown in Table 3.

6. Place the silicone sealant by combining Parts A and B in the special equipment gun. Make sure the silicone is about ½ an inch thick, so if the backer rod is at 1 ¼ inches deep, make the silicone sealant has a recess depth around ½ - ¾ inches deep. Construct a special tool if necessary to create a smooth surface on the top surface of the silicone and to insure the silicone is at the correct recess. Dow Corning specifications also contain correct recess depths for backer rods and silicone based on joint width and temperature. The above is a general guideline.
7. Allow the silicone to set for 30 minutes to 1 hour if possible before opening to traffic. This will insure that no debris becomes embedded in the un-cured silicone.
8. Consider removing the backer rod after 1 month if possible. The backer rod is only needed to insure that the silicone sealant can set properly in the joint and is not needed after the silicone has cured.

The first three steps are the most critical to the success of these joints and extreme care should be taken. Following these guidelines should help to insure that the silicone sealants lifespan is more on par with laboratory testing.

For newly installed joints on new bridge decks, limit the time the joints are exposed to construction work. In other words, place the silicone a few weeks before the bridge opens to regular traffic so construction activities do not damage the joint. One week is ample time for the material to cure and work well with the joint. Only 8 hours is actually needed for the material to cure enough to accommodate joint movements as stated by Dow Corning. The only problem that may be encountered with this is the exposure of the bridge to weather during the months it is not in operation. The only other solution is to inform the construction crews of the importance of the silicone sealants, so they do not inadvertently cause damage.

5.2. Reasons For Failures

1. Temperature: Installing the silicone sealant in the winter when the joint width is the widest seems to produce the most problems such as the sealant protruding above the roadway surface. Backer rod diameters that are too large and put in during the colder months could also lead to these problems. Solutions to this problem should be to use backer rods only ¼ of an inch bigger than the joint in the cold months. Also, recessing the joint sealant an extra ¼-½ an inch in the winter may help prevent it from protruding above the roadway surface. Finally, if possible installation should occur in median months of the spring and fall. Summer installation can lead to problems with the material not being able to expand enough to handle the joint movement. Summer months do seem to be preferable to winter months if installations are necessary.
2. Knowing the total cyclic movement of the joint: The total movement of the joint throughout the year needs to be known before installing Dow Corning 902 RCS Joint Sealant. The silicone sealant is only suitable for 100% expansion and 50% contraction; otherwise it is prone to failure. Installing in the winter on many joints, as noted by Bald Knob, can lead the joint to protruding above the surface and ultimately premature failure. By knowing the joint movement during the year, one can decide the optimal time to install the joint to insure the longest

service life. At a minimum, installing the sealant when the joint is somewhere between its extreme contraction and expansion would be best.

3. Joint width too large: Joint widths that are 3 inches or more do not perform as well as those that are 2 inches or less. At joint widths between 2 and 3 inches, some success has been observed. Those joints 3 inches or more seem to put too much stress on the sealant material as well as allow more debris to accumulate in the joint. Also, vehicle tires can come into contact with more of the sealant on the larger joint widths. Possibly recessing the sealant deeper into the joint could help alleviate some of the problems, but may present more by allowing more and larger debris to get in the joint. At the very least, other alternatives should be considered with widths greater than 3 inches.
4. Debris build-up on sides: The backer rods are typically turned up at the shoulders of the bridges to prevent water and debris from draining off the sides. However, water and debris often get stuck in the area around the silicone on the shoulders. This could lead to possible punctures or the silicone being forced completely out of place by traffic. A solution to this is to leave one side turned down so that drainage can occur. This would only be a viable solution for those bridges with drainage primarily toward one side. Also, extend the sealant out to the edge of the bridge so that no water and debris hits the understructure and causes corrosion.
5. Primer set-time: The set time for the primer has been found to be a major problem. Both contractors and state officials would like a quicker set time for primer so that they are not stuck there waiting for an hour or more. Also, due to

this lengthy set time, many installations are rushed and the primer is not allowed to set properly before applying the silicone which often leads to premature failures where the silicone pulls off the steel on the side walls of the joint. Future considerations for this primer performance would include a quicker set time, less than 30 minutes so that this step is not rushed on the jobsite. If this is not possible, rigorous guidelines, as presented in the Installation Procedure, need to be set so as to insure the primer sets the proper amount of time, covers the entire joint, and is applied to the correct depth.

6. Improper backer rod placement: Figure 31 shows an improper backer rod installation where a backer rod much larger than the joint width was attempted to be pushed into place. By placing the backer rod improperly, the shape of the silicone is affected and can lead to premature failures. Also, using too large of a backer rod can put excess stress on the silicone sealant from underneath which can add to the pressure that acts on pushing the silicone up toward the surface of the roadway. Improper backer rod placement can also lead to a “wrinkly” texture of the silicone as can be seen in Figure 18.
7. Dirt road installations: Dirt road installations have shown variability for these sealants. The joints do contain a lot more debris on dirt roads than on other roads. This excess debris build-up can lead to premature failures of the joints including punctures. One solution for this problem may be to install a type of screen over the joint to keep a decent amount of the debris out. Other solutions may include using an armored joint on dirt roads, or making sure someone cleans out the joint every month.

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