TECHNICAL ASSISTANCE REPORT

AN EVALUATION OF BRIDGE DECK JOINT SEALING SYSTEMS IN VIRGINIA

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ABSTRACT

The design and fabrication of bridge expansion joint (or movement) systems comprise a rapidly evolving industry. New designs are constantly being presented for trial, often on a piecemeal basis. Occasionally, failures of products occur without sufficient documentation, resulting in inadequate dissemination of the details of the installations to other potential users. It was believed that a systematic evaluation process involving users of joint sealing systems and the Virginia Department of Transportation's (VDOT) New Products Committee was required to ensure that up to date information on available products, their prescribed uses, installation procedures, and performance would be available across VDOT.

The research procedure employed in this evaluation was a series of case studies of individual trials of joint sealing systems. Care was taken to ensure the involvement of all interested parties within VDOT and to include the joint manufacturer (vendor) in any experimental installation. The subject study was a limited evaluation of those joint sealing systems used by VDOT during the past several years. It did not include the full array of products available to the bridge engineering community, and it was not necessarily based on numerous installations of every joint system. Since the study concentrated on joint sealing systems, open expansion joint systems, including butt, sliding plate, and finger joints, were not evaluated. Larger modular joint systems were also excluded.

The results of this study were mixed with regard to the performance of the generic systems evaluated. Each system has served successfully, and evaluations have shown failed installations of each. None can be assumed to last indefinitely. Adherence to recommended installation procedures is essential to attaining satisfactory service from a joint sealing system. The vendor should be required to have competent representation present during the entire time of the initial installation of any product. The individual in charge of the installation must be completely familiar with the details and the underlying logic of the operation. Bonding of the elastomeric component of the sealing system (which accommodates joint movement) to the faces of the joint is a critical factor in the performance of most systems. Due care should be taken in cleaning the joint faces, ensuring that the surfaces are dry, and properly applying any adhesive.

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INTRODUCTION

There is national interest in the design, fabrication, and performance of expansion joint systems, which comprise a rapidly evolving industry. The National Cooperative Research Program (NCHRP) recently published the results of performance tests for modular bridge joint systems.[1] An earlier NCHRP project addressed fatigue cracking in modular joints.[2] More in line with the subject evaluations, a recent NCHRP synthesis project on bridge joint performance collected information on the use and performance of the more commonly used bridge joint materials and systems that accommodate a range of movements.[3] This report, which is currently under review prior to publication, offers a national perspective on the performance of and problems associated with a variety of systems. Limited performance data are also available in reports by other state and local agencies.

New designs for expansion joint systems are constantly being presented for trial, often on a piecemeal basis, to the Virginia Department of Transportation (VDOT), including designers in VDOT's Structure & Bridge Division, VDOT district bridge engineers, VDOT's New Products Committee, and the Virginia Transportation Research Council (VTRC). VDOT formed its New Products Committee to provide uniform evaluations of products "not covered by specifications, plans, or other Department standards" submitted by manufacturers or vendors. Representatives from each VDOT division meet twice a year to determine the potential utility of the products submitted to the committee and to provide expertise in the evaluations, which continue for 1 year after installation. The committee maintains a Special Products Evaluation List (or SPEL) that lists the proprietary products under evaluation and those that have been accepted or rejected for use.

Occasionally, failures of products occur without sufficient documentation, resulting in inadequate dissemination of the details of the installations to other potential users. It was believed that a systematic evaluation process involving users of joint sealing systems and the New Products Committee was required to ensure that up-to-date information on available products, their prescribed uses, installation procedures, and performance would be available across VDOT. VTRC personnel who have followed joint installations for several years played the lead role in coordinating and reporting the results of evaluations under this more formal process.

PURPOSE AND SCOPE

The purpose of this study was twofold: (1) a limited evaluation of the joint sealing systems used by VDOT during the past several years, and (2) the development of a procedure to evaluate new joint sealing systems that come on the market. The evaluations neither included the full array of products available to the bridge engineering community nor were necessarily based on numerous installations of every joint system. Since the study concentrated on joint sealing systems, open expansion joint systems, including butt, sliding plate, and finger joints, were not evaluated. Larger modular joint systems were also excluded.

Because the study was conceived as a very limited evaluation intended to provide information on current findings to VDOT bridge engineers, the results of the evaluations should not be extrapolated beyond its scope.

METHODOLOGY

Overview

The procedure employed in this evaluation comprised a series of case studies of individual trials of joint sealing systems. Care was taken to ensure the involvement of all interested parties within VDOT and to include the joint manufacturer (vendor) in any experimental installation. The lead in documenting the evaluations was played by a VTRC staff member who was a member of the New Products Committee. To the degree possible, the documentation process encompassed the entire installation of a new expansion joint system from the first contact by the vendor until failure of the system or its acceptance by VDOT. In the event of a failure, its cause was documented.

Generic Joint Seal Systems Evaluated

The study included the bridge joint sealing systems listed here. More complete information on these systems is provided in the literature.

- *Field molded seals.* This commonly used system consists of a self-leveling sealing material that is poured into the joint. A closed cell foam backer rod placed in the joint below the sealer supports it until it has cured. After curing, the sealing material remains flexible to accommodate horizontal and vertical movements. Today, a cold poured silicone rubber material is generally used. The system is commonly used where joint movement is $^{3}/_{16}$ inch or less, although manufacturers claim suitability for larger movements.[3]

- *Open cell compression seal.* There are several proprietary configurations of open cell compression seals. In general, they are neoprene rubber strip members that are rectangular in cross section with various configurations of internal diagonal and vertical webs. The seals are placed in the expansion joint while in compression with the aid of a lubricating adhesive, which cures to bond the sides of the seal to the joint faces. Compression seals can accommodate joint movements ranging from ¼ to 2½ inches.[3]

- *Closed cell compression seal.* A low-density closed-cell foam rectangular-shaped strip member is compressed into the joint with an elastomeric primer to function in a manner similar to that of the open cell compression seal.

- *Strip seal.* These are V-shaped strips of elastomeric materials, which generally are mechanically locked to metal retainer members at the edges of the expansion joint. One strip seal evaluated in this study was bonded to the sides of the joint. Strip seals, which are highly regarded nationally, accommodate movements up to 4 inches.[3]

- *Plug seal.* Plug seals are deformable polymer-modified asphalt concrete material placed in a cutout area over the expansion joint at the deck surface. A backer rod is compressed into the joint opening below the cutout, and the entire blocked out area is sealed with the binder material used in the mix. A plate placed over the joint opening and sealed with the binder material supports the elastomeric asphalt layer, which accommodates the movement of the deck. Plug seals are appropriate for a maximum joint movement of 2 inches.[3]

- *Inflatable neoprene seal.* The system consists of a preformed open cell neoprene strip member bonded to the edges of the expansion joint with a structural epoxy adhesive. The sides of the seal and the joint face are coated with an epoxy adhesive, and the seal, which is sized to match the midrange joint opening, is inflated to ensure a positive seal with the joint face. Inflation is maintained during the entire curing time of the adhesive, and the seal is then allowed to deflate as the air bleeds out.

FINDINGS

General Findings

Observations of several installations of the sealing systems evaluated indicated particular areas of difficulty that relate to joint performance. VDOT policy mandates the attendance of a representative of the manufacturer who is familiar with the installation of the joint sealing system during the entire time of the installation of any new joint sealing system. It is intended that the representative be responsible for ensuring that the manufacturer’s recommended installation process be strictly followed. Unfortunately, this has not been the case in every instance, and this has been a major cause of poor performance.

Details of scheduling can complicate the installation operations. Ideally, cleaning of the joint faces, priming of the surfaces, and placement of the sealant must be sequenced quickly to minimize the chances of contamination. Sufficient time has not always been allowed to complete these steps on the same day. Poor communication among VDOT, the contractor, and the manufacturer of the system can shorten the time available for the installation operations. As a minimum, personnel in other agencies provided as sources by system manufacturers should be contacted prior to field trials.

Other factors noted during this study included the following:

- There was confusion as to who would furnish needed equipment.
- The schedule of the manufacturer's representative allowed insufficient time at the site.
- The manufacturer's representative misunderstood the scope of the work to be performed.
- Compression of the time that the representative was available on site resulted in the joint seals being installed when the temperature was at the lowest allowable value or when inclement weather was forecast.

Specific Findings

Field Molded Seals

The field molded seal used most frequently in Virginia is the two-component silicone joint sealant, which may be installed directly to the concrete joint faces, or in conjunction with a nosing material at the joint faces. Performance seems to be good if the material is installed properly and the joint opening is 2 inches or less. Failures are generally manifested as disbanding from the sides of the joint, but repair is possible. Engineers using the product report that the sealant is very tolerant of irregularities in the joint opening. Joints in the parapets have been sealed using a dry mixture of the nosing material, but the finished parapet joint did not appear watertight and a further application of a surface sealer seemed warranted. Field molded seals are used in both new construction and maintenance applications. Once trained, state crews or contractors can install the familiar silicone sealant.

Open Cell Compression Seals

Although the open cell seals have been used with some success for many years, at least one district bridge engineer believes failure of open cell compression seals to be inevitable in maintenance operations. Research notes tend to support this view. Successful installations of open cell seals were observed during the subject evaluation. However, despite the use of neoprene in their manufacture, most of the compression seals that were inspected showed signs of weathering after a few years of service, including embrittlement, cracking, and leaking. Many were observed to have fallen out of the joint onto the underlying substructure elements early in their service lives. This early failure could be due to non-uniform application of the lubricant adhesive, which is sometimes squeezed out of the joint opening as the compression seal is pressed into the opening. The resulting loss of bond could be critical if the relatively stiff compression seal fails to move in unison with the joint faces when the joint opens. Nevertheless, open cell compression seals remain popular for sealing joint openings wider than 2 inches.

Closed Cell Compression Seals

There was only one closed cell compression seal evaluated during this study, and satisfaction with its performance varied among districts. Several installations in one district had good performance, including one that had been in place for more than 10 years. Ratings were more disappointing in a second district. Although a successful installation of three joints on a single structure was noted, subsequent conversations indicated that the joints had been redone as many as three times. Those closed cell joints in place showed some evidence of oxidation of the top surfaces, but all were tightly adhered to the joint faces, with no signs of leakage. Other closed cell joints on the same structure eventually had been replaced with open cell configurations. Inspections of another structure by research personnel revealed loss of adhesion and possible evidence of repair. No cause for the failures were determined during conversations with the manufacturer, and further use of the closed cell seal is unlikely in that district.

Strip Seals

Conventional strip seals, which are locked into metal retainers at the joint faces, have been used in new construction in Virginia. One such joint, which is attached to the joint faces by an adhesive, and has been accepted, was installed twice and failed twice on a bridge in the Culpeper District. Research inspections of the two joint seals on that structure noted two areas on one of the joints at which the gland had disbonded from the joint faces. Although the disbonded areas were only 5 inches 3 feet long at the time of the inspection, it was believed that the distress, which was likely due to poor installation techniques and insufficient cleaning, would increase with time. Acceptance of this particular strip seal system by VDOT’s New Products Committee indicates satisfactory performance on other structures not evaluated in this study.

Asphalt Plug Seals

The Culpeper District reported that several asphalt plug seals have been installed and that, overall, they have performed reasonably well. Some concern was expressed over the ability of a general contractor to install the seal properly and the capability of VDOT’s generic specification to provide for variation in the formulation of the binder material to meet the requirements of expected temperature ranges.

Inflatable Neoprene Seals

There currently is only one inflatable neoprene seal on the market. Its performance across the state has been erratic. One district reports good performance, superior to that of other, stiffer compression seals, but several failures have been noted elsewhere. Some of the failures appear to be related to poor installation practices and loss of adhesion, but others, including failures of the nosing material and adhesive, are less easily explained. Failures have been noted when the seals were installed in conjunction with polymer overlays when the seal was installed before the overlay was placed. Sharp fragments of the polymer material at the edges of the overlay, dislodged by traffic, were driven into the seal.

DISCUSSION

General

The service demanded of bridge joint sealants is severe in terms of the stresses and deformations that must be endured. Deformations due to thermal movements and those transmitted to the joint due to rotations of the beams, complicated by the effects of skewed slabs, challenge every component of the sealing system. Failures can result from tearing of the elastomeric component of the joint, loss of adhesion at the joint faces, or failure of a mechanical anchorage to secure the elastomeric component to the slabs. It is critically important that the joint sealing system be designed to meet the movements of the superstructure and that the manufacturer's recommended installation procedures be strictly followed to attain a satisfactory service life.

The limited evaluation program that formed the basis of the subject study demonstrated significant differences in the performances within each of the generic systems. In simplest terms it can be stated that:

- Each of the joint systems evaluated can provide satisfactory service.
- Each system is subject to failure due to poor design considerations or installation procedures.
- No joint system can be expected to last indefinitely.

Each joint system has its champions, and each its detractors. Differences in performance across the state are likely due to unsatisfactory results related to installation details rather than to the capabilities of the personnel involved. Uniformly good results were observed where crews installed a familiar system and essential installation details were rigidly enforced.

Many of the sealing systems depend on adhesives to connect the body of the seal to the joint faces. Success or failure depends on the strength of the bond developed. Adhesives are very sensitive to conditions at the site, including the ambient temperature, the cleanliness of the surfaces to be bonded, and the presence of moisture. Great care must be taken to attain the necessary bond between the elements of the joint. Although most of the sealants or sealing components of the systems evaluated are durable, debris trapped in the joint and impacted by crossing vehicles can tear the seal. For this reason, periodic cleaning of decks can lengthen the service lives of the joint seals and the installation of polymer overlays, which chip at the joint edges, should be completed before the deck joints are sealed.

Some of the sealers can be used to seal the joints in the parapet walls. In the case of the pourable sealers, the nosing material may be used in the parapets, but it may be a better choice to leave the existing parapet joints alone.

Products Included in VDOT's *Road and Bridge Specifications* and the SPEL

Section 212, "Joint Materials," of VDOT's *Road and Bridge Specifications* specifies the generic requirements for an ultra low modulus self-leveling rapid curing two-part silicone seal, a preformed elastomeric joint sealer, and an elastomeric gland or strip seal.[4] Specifications for the necessary backer rods and lubricant adhesive are also provided.

Proprietary products submitted to the New Products Committee for evaluation but not yet incorporated into the specifications are included in the SPEL under "Joints, Crack Sealers, Fillers, and Grouts." (The SPEL may be found on the website of VDOT's Materials Division (http://www.virginiadot.org/business/resources/bu-materials-SPEL.pdf). The SPEL lists the R. J. Watson Silicoflex strip seal as accepted, along with the Evazote 380 closed cell compression seal and the Hydro Jeene inflatable compression seal. The X.J.S. Expansion Joint System, which uses the accepted Dow 902 two-part silicone filler in conjunction with a proprietary nosing material, has also achieved acceptance. Evaluations are currently pending in the cases of the Matrix 502 asphalt plug expansion joint system and the Tron-Flex expansion joint material (formerly the Iso Flex 900 system). Other systems listed as inactive may not be marketed now or may have been replaced by a modified compound, as may be the case with the Iso Flex 900.

SUGGESTED PROCEDURE FOR EVALUATING NEW JOINT SEALING SYSTEMS

A major objective of the subject research effort was to initiate statewide evaluations of new joint sealing systems and issue periodic reports of the results, either satisfactory or unsatisfactory. This objective would be accomplished quite effectively through the actions of the New Products Committee if the evaluation procedure shown below were followed. Frequent updating of the SPEL will avoid duplication in the use of unsatisfactory products. Referral to the latest SPEL is essential when selecting a joint sealing system, as failing products are often withdrawn during the evaluation period or modified and marketed as a new product.

An outline of a suggested evaluation process that might be applied to joint sealing systems is as follows.

1. The vendor makes the initial contact with VDOT.

2. The vendor submits a new product application and product information to the New Products Committee.

3. A district bridge engineer agrees to use the product to be evaluated.

4. A test structure is chosen for the evaluation.

5. The manufacturer, VDOT, and/or contractor personnel review the installation details.

6. A VDOT representative observes the installation and prepares an installation report describing the particulars of the procedure and any deviations or problems encountered. The report is distributed to designers in VDOT's Structures & Bridge Division, all district bridge engineers, and the Federal Highway Administration. The vendor *must* have representatives present at the first installation of a new product.

7. VDOT personnel familiar with the system periodically evaluate the performance of the joint and note any distress. At present, evaluations continue for 1 year until the joint seal is accepted or its failure is documented in an inspection report, but a 2- to 3-year follow-up review is recommended. The SPEL is updated to reflect the results of the evaluations. The VDOT inspector documents the causative factors in any failure.

8. After a new joint sealing system is approved, a generic specification is developed to allow its use where appropriate.

CONCLUSIONS AND RECOMMENDATIONS

- The results of this study were mixed regarding the performance of the generic systems evaluated. Each system has served successfully, and evaluations have shown failed installations of each. None can be assumed to last indefinitely.

- Adherence to recommended installation procedures is essential to attaining satisfactory service from a joint sealing system. The vendor should be required to have competent representation present during the *entire* time of the initial installation of any product. The individual in charge of the installation must be completely familiar with the details and the underlying logic of the operation.

- Bonding of the elastomeric component of the sealing system (which accommodates joint movement) to the faces of the joint is a critical factor in the performance of most systems. Due care should be taken in cleaning the joint faces, ensuring that the surfaces are dry, and properly applying any adhesive.

- When an overlay is to be placed on a deck in conjunction with the installation of a joint sealing system, sealing the joint should be the final step in the construction sequence.

- Evidence of distress of sealers caused by debris retained in the joints indicates that regular cleaning of the decks would improve the service life of the systems. The sensitivity of a system to damage by debris should be a consideration in its selection.

- A representative of VDOT should monitor the performance of any joint sealing system until its adequacy is proven and maintenance personnel are familiar with the product. VDOT personnel should make an independent analysis of any failure.

- Joint sealing systems that demonstrated serious flaws were often withdrawn from the market during the evaluation period and sometimes modified and marketed under a new trade name. In such cases, documentation of the modifications should be required of the manufacturer and evaluated in light of the performance of the original system.

- Awareness of the performance of new systems, including the results of trials by other agencies, is essential. A representative of the New Products Committee familiar with the joint sealing field could be a valuable resource in ensuring that VDOT realize the worth of the costly systems. A suggested procedure for maximizing the effectiveness of the committee and its SPEL was presented in this report. Tracking the performance of systems available in the rapidly evolving joint sealing field is a worthwhile activity.

- VDOT should evaluate the claims of joint manufacturers relative to the overall range of joint opening widths and movements that can be accommodated by a system in addition to performing the field evaluation. Successful performance in sealing a narrow joint does not ensure success in sealing wider joint openings. If practical, the range of openings should be evaluated in the field.

- VDOT should periodically review its office practices for the selection of joint systems and make adjustments based on their performance and maintenance requirements.

- Consideration of the service life of any system, as indicated by field trials, versus the cost of the system should be included as part of the design process. The effects of location and traffic count on the potential service life and the difficulty, and cost, of repair or replacement operations should be considered by the engineer in the selection process.

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REFERENCES

1. Dexter, R., Connor, R., and Kaczinski, M. Performance Tests for Modular Bridge Joint Systems. *National Cooperative Highway Research Program Report 467.* Transportation Research Board, Washington, D.C., 2002.

2. Dexter, R., Mutziger, M., and Osberg, C. Fatigue Criteria for Modular Bridge Expansion Joints. *National Cooperative Highway Research Program Report 402.* Transportation Research Board, Washington, D.C., 1997.

3. Purvis, R. Bridge Deck Joint Performance. *NCHRP Synthesis of Highway Practice 319.* Transportation Research Board, Washington, D.C., In Publication, 2003.

4. Virginia Department of Transportation. *Road and Bridge Specifications.* Richmond, 2002.