National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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Waterproof Expansion Joints for Bridges

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 12-3, "Development of Waterproof Roadway Joints for Bridges," prepared by J. E. Minor and E. W. Kiesling, Southwest Research Institute.

THE PROBLEM AND ITS SOLUTION

Failure to achieve an effective seal in a bridge expansion joint will often invite corrosion and erosion of structural elements and backslopes due to the passage of water through the joint. Absence of an effective seal also invites the accumulation of foreign matter in the expansion space, with subsequent local failure of the bridge deck. The problem of sealing a bridge joint is complicated by the wide range of possible movement, skew angles, and changes of direction in the seal necessitated by raised medians, safety walks, and the like. In addition, the large number of devices and designs advanced by manufacturers make the selection of a specific device for a specific application a difficult matter for the practitioner.

The methods and devices currently available for sealing bridge joints needed to be evaluated. Recommendations concerning the reliable use range for liquid seals, compression seals, and mechanical seals needed to be formulated. Beyond this state-of-the-art evaluation, a need exists to develop better joint seals that can perform successfully for longitudinal movements of several inches and skew angles up to perhaps 45 degrees.

Bridge designers will find that a comprehensive evaluation of existing seals has resulted in specific recommendations that should be useful in selecting the best type of seal for a given application. Beyond that, information is available to offer guidance about environmental limitations for specific materials and devices in the liquid seal and compression seal categories. This information is presented in an explicit manner and does not need to be combined with other supporting data. Because it is the product of a state-of-the-art evaluation that included the usual literature search, a personal interview survey covering several states, and laboratory experiment observations, it is considered reliable and ready for use by the practitioner.

Certain theoretical approaches to the design and prediction of fatigue life for seals were developed, but do not appear to be immediately useful tools in their present state of development. The analytical developments will probably be of interest primarily to researchers working with elastomers for use as joint seals.

FINDINGS

Note: These findings apply to specific materials and products identified in the report. They are not intended to be used as generalisms true of all materials and products offered as bridge expansion joint seals. The reader is advised that the presentation of findings in this Digest is for the purpose of indicating the nature of the contents of the report. The findings are valid only within the scope of investigation described in the full report.

General: Although the problem of sealing bridge expansion joints is a serious one, designs and installation procedures are available that will provide joints that not only will exclude foreign material but also will be waterproof. To accomplish this, proper attention must be given to anticipated movements, seal capabilities, expansion joint design details, and installation practices. Current seal materials and designs, although adequate in terms of specific capabilities, are limited in the range of joint widths and movements that can be successfully accommodated. Improvements in seal materials and joint designs, as well as development of new sealing concepts, are desired to improve the reliability of joint seals.

The maximum desirable opening in the bridge expansion joint was found to be 2 in., the joint opening limit being 3 in. The opening in an expansion joint should not be confused with expansion joint width (gap provided between bridge components into which the expansion joint is placed). The desirable joint opening limit of 2 in. is determined by considerations related to driver comfort, roadway riding quality, and, in the case of skews, minimization of the hazard presented by the vehicle wheels tending to track in gaps in the roadway.

A definite trend toward armored or steel-faced joints is evident in the case of bridge expansion joints, although the sawed joint in concrete is being effectively used in constructing bridge joints less than 2 in. wide. The advantages realized in utilizing a sawed joint lie in the ability to establish proper joint widths at the time the expansion joint is installed and in the assurance of obtaining parallel joint sides. This practice requires quality concrete in the bridge deck.

Compression seals and mechanical devices are used extensively in bridge expansion joints, with specific selection of designs being accomplished by considerations of joint movement, width, and cost.

Failures in the field are frequently attributed to poor installation procedures or inadequate attention to design requirements rather than shortcomings of the seal itself. Exceptions to this observation concern use of seal concepts or products not capable of effectively sealing a bridge expansion joint (e.g., use of the finger joint, thin-webbed compression seals, or mastics).

Liquid Seals: Liquid seals are recommended for use in bridge expansion joints only if the joint opening is less than 1 1/2 in. and if joint movements are less than 33 percent of the original width. Joint movements up to 33 percent of the original joint width can be accommodated by certain polyurethane liquid seal materials and joint movements up to 25 percent can be accommodated by certain polysulfide liquid seal materials if recommended installation procedures are followed carefully. A width-to-depth ratio of 2/1 is the recommended cross-sectional geometry for a liquid seal.

Field performance experience supports the polyurethane seal as the most promising of the several liquid materials used in sealing bridge expansion joints. Most polyurethane products are two-component compounds. This requires a thorough on-site mixing and presents difficulties with proportioning of components. As in polysulfides, air may be entrained during mixing and should be removed by a suction pump or by mixing in a closed evacuated container. Polyurethanes do not tend to relax in a given position as much as polysulfides, thereby minimizing problems caused by the folding effect. Field experience dictates the use of a primer because polyurethane is affected by alkalies in the concrete.

Compression Seals: The findings indicate that although the compression seal concept is valid, effective utilization is limited to a relatively narrow width and movement range. Roadway riding quality considerations limit openings in the roadway to a desirable maximum width of 2 in. and an absolute maximum of 3 in. Hence, the largest compression seal that can be effectively employed is limited to a nominal width of approximately 2 1/4 in. The compartmented compression seal is displacement-orientation sensitive and performs best in non-skewed joints. The foamed compression seal is not as displacement-orientation sensitive as the compartmented compression seal and performs in a similar fashion in both non-skewed and skewed joints. Specifically, the thick-webbed triangular compartmented compression seal is recommended for use in non-skewed bridge expansion joints less than 2 in. wide. The mechanically gas-blown foamed compression seal is recommended for use in non-skewed and skewed bridge expansion joints less than 2 in. wide. The thin-webbed rectangular compartmented compression seal and the chemically-blown foamed compression seal were judged by the investigators to be lacking in capability for effectively sealing bridge expansion joints.

The contact pressure on joint faces required to maintain a watertight joint with a compression seal is considerably less than the contact pressure required to assure that the seal will stay in the joint. Watertight seals can be effected with as little as 1 psi of contact pressure, but a minimum contact pressure of approximately 5 psi is required to assure that the seal will not be lifted out of the joint by traffic or joint action.

Mechanical Seals: The findings concerning mechanical devices relied heavily on reports of field experience and the suggestions and opinions expressed by engineers. These findings are more subjective in nature than those for the liquid and compression seals. It was found in reviewing field tests and experiences that certain relatively simple mechanical device designs can effectively seal a bridge expansion joint if proper attention is given to joint design and installation. Mechanical devices commonly contain a component which is called upon to carry direct wheel loads. This characteristic enables mechanical devices to accommodate large joint movements and joint widths without presenting openings in the roadway wider than the 2-in. desirable limit mentioned previously. Several simple mechanical device designs have evolved which can effectively seal expansion joints with movements beyond the approximately 1-in. maximum that can be accommodated by compression seals. These devices are more expensive than compression seals, are installation-procedure sensitive, but are less complex than the more elaborate mechanical device designs that can accommodate movements of several inches. Specifically, an aluminum expansion joint design, a modular design employing compression seals and wheel load carrying components, and a steel plate-polychloroprene cord combination design are suggested for use in sealing bridge expansion joints with movements up to approximately 2 in., although these devices have not been extensively tested in the field. Beyond this approximate limit, more complex and more expensive mechanical device designs are required. All types of finger joints evaluated were judged by the investigators to be unsatisfactory in effectively sealing bridge expansion joints.

APPLICATIONS

The application of the findings resulting from this research study are reasonably straightforward. Because the findings are primarily the result of a state-of-the-art evaluation, they indicate to the practitioner the most popular bridge expansion joint seals being used and how successful that utilization seems to be. A seal selection guide which illustrates the range of joint movement considered practical for each seal category can be used directly. Illustrations are included which show values for the physical response of many liquid seal and compression seals under various temperatures and movements. These types of data are provided the practitioner so that he may examine them and draw his own conclusion as to the potential application of a given material or design.

The theoretical material contained in the report will be of interest to researchers working in the topic area. However, it does not seem to be suitably developed to the point of being directly applicable to practice.