

Bridge Joint Sealing—Its Materials and Mechanical Problems

H. B. BRITTON

New York State Department of Public Works

An extensive search for materials to seal joints in structures was undertaken in 1952. Materials investigated included hot poured or extruded rubberized asphalt, silicone rubbers, liquid neoprene, asphalt emulsion, urethane, latex and a nonmeltable mastic. Materials formulated with liquid polysulfide polymers appeared to have the physical characteristics required for effectively sealing joints in structures. Shore A hardness limits were derived from determining a workable material at -20 F. The physical properties of the material required should be as follows: (a) Shore A durometer at 77 F of 10-15; (b) not flow at high temperatures; (c) retain flexibility and have extensibility at -20 F of at least 100 percent; (d) be capable of effecting chemical or mechanical bond at a temperature of approximately 40 F; (e) cure rapidly; and (f) be thixotropic and have the ability to withstand invasion of foreign particles.

Field test installations indicated a definite relationship between the depth and width of material placed. In structures where a depth of material was approximately one-half the width of the joint opening, the sealant performed much more satisfactorily than when the depth of material equaled or exceeded its width.

Some reasons for failure of materials are outlined; the areas of responsibility with regard to obtaining properly sealed joints are listed.

•WHEN TWO-LANE highways were the ultimate in the network of roads, sealing of joints in structures was looked on as a necessary evil and received little, if any, attention or inspection. It was not until the advent of the limited-access highway and the extensive use of elevated structures in metropolitan areas that the necessity of adequately sealing bridge joints was fully realized. Just as no one person or segment of this industry is at fault for this condition, no one person or segment is responsible for the progress that has been made toward its solution. There has been considerable effort extended by a few who have contributed much to a better understanding of the problems involved, both with regard to material requirements and joint geometrics and construction.

An analogy might be drawn between the roof of the covered bridge of the past and the bridge joint sealers of the present. The roof or covering of a bridge of a century or more ago was the means employed to protect the structural components from the assault of the elements. Today the modern counterpart of this roof is the lowly, but none the less important, joint sealer. It is on this joint sealer that we must rely for complete sealing in structural decks and wearing surfaces, thereby protecting such vital members as bearings, structural steel, and supporting concrete from the onslaught of deleterious solutions.

It is safe to conjecture that before 1957 not more than 50 lines were devoted to the subject of joint sealing in any set of state specifications. Up to this time, joint sealers

were not an item of the contract. In most instances the cost of sealing joints, which included all labor and materials charges, were contained in the price bid for the various concrete items in the contract.

In 1952, New York State began an intensive search for materials that would conceivably seal the expansion and contraction joints required in normal bridge construction. The first material that appeared to have possibilities was a rubberized asphalt joint sealing compound. This material was a hot-poured or extruded type conforming to the requirements of Federal Specifications SS-F-336a. The samples submitted were laboratory produced and consisted of two 2- by 2- by 2-in. concrete blocks bonded together with $\frac{3}{4}$ in. of sealing material. These samples were not subjected to any standard test procedures, nor were duplications of the samples produced by our personnel. After much handling and inspection of these samples, the material was adopted by the Department and specified for use on structures. Under construction conditions this material failed to produce the desired results in that it failed to adhere to the interface of the joint. In fact, some in its extruded form was placed in the joint without removing the protective shipping film.

By 1954 there was a marked increase in the number and type of sealants being submitted to the Department for approval. The then Deputy Chief Engineer, C. F. Blanchard, directed that no materials would be approved without qualified tests being made. With our limited knowledge or perhaps our superb ignorance, it was decided to test all new materials under actual construction conditions.

At this time, the New York State Thruway was nearing completion and all structural joint sealing failures had to be repaired. Joseph W. LaFleur, the Bridge Maintenance Supervisor, selected one bridge carrying the Thruway on which experiments were made with a number of joint sealers. Because the bridge maintenance crew was well trained and equipped, joint areas could be properly prepared in compliance with the knowledge then available, which was that the sidewalls or interfaces of the joint must be sound and clean.

All sealers selected for test on this structure were of the cold-pour variety. Test installations were made of two silicone rubbers, one liquid neoprene, one asphalt emulsion, one urethane, one latex, and one nonmelttable mastic which is a blend of refined asphalts, resins and plasticizing compounds, reinforced with long-fiber asbestos.

One silicone rubber employing a liquid accelerator or catalyst failed in less than a month. The failure was both in adhesion and cohesion. A considerable loss in volume was evident which can be expected when volatile liquids form a considerable part of the mixture. The neoprene failed in cohesion, perhaps because the material contained only 60 percent solids and the volume loss exhibited was considerable. The asphalt emulsion failed for the same reason. The urethane and latex disintegrated within a month. One silicone rubber and the nonmelttable mastic produced an effective seal until they were removed approximately two years later.

All materials were placed by representatives of the companies involved in full compliance with their recommendations. There were disadvantages in all these products in that none but the mastic was thixotropic. All were difficult to place and most required a primer which had to be applied to the interface of the joint anywhere from $\frac{1}{2}$ to 4 hr before application of the joint sealer.

By late 1955, little progress had been made in effectively sealing structural joints but we had made some important contacts with technical representatives of sealer manufacturers who were willing to give of their time and materials to aid in the attempt to solve the problems.

By the spring of 1956, much technical data and boxes of samples, both preformed and liquid, had been accumulated. The prefabricated samples were evaluated in an improvised laboratory. It was important that physical characteristics of these materials be studied in relation to the structural and climatic conditions to which they would be subjected. At this time only extensibility and the adhesive and cohesion properties of joint sealers were considered. Preformed samples were tested in a jig adapted for use on a machinist's vise. All preformed samples were still of 2- by 2-in. concrete block bonded with from $\frac{3}{4}$ to 1 in. of joint sealer. The samples were subjected to temperatures ranging from -20 to 350 F and to extension and rotation tests at -20 F. They were also immersed in salt solution, gasoline, kerosene, alcohol and permanent antifreeze.

Materials tested were four liquid polysulfide polymers, four polysulfide polymers extended with coal tar, one latex rubber, and one silicone rubber. Test samples were produced from the bulk material supplied by the various producers and were subjected to the same series of tests that were applied to the preformed samples.

At this time, it became apparent that some relationship should be established between the hardness of the cured sealer and the temperature range within which it could be expected to function. Working with a low temperature limit of -20 F, it was determined that a Shore A durometer of 40 is the upper limit at which these materials would retain the desired elastic properties. It was determined through trial and error that at 77 F the sealer must have a Shore A durometer of 10 to 15.

By the spring of 1956 three materials showed definite promise: (a) one liquid polysulfide polymer, (b) one liquid polysulfide polymer extended with coal tar, and (c) one silicone rubber.

These joint sealers were next placed in the transverse expansion and construction joints of three already constructed bridges. It was felt that if this type of joint could be successfully sealed, there would be no difficulty in sealing longitudinal joints.

Existing material was removed from the joint areas and the interfaces were prepared to accommodate the new joint sealing material. The first attempt at cleaning the interface of the joints was made by power-driven wire brushes, but this proved unsuccessful and sandblasting had to be used. The joint area was then blown clean of all extraneous materials.

On June 5, 1956, the liquid polysulfide polymer extended with coal tar was installed. This material was a two-component 1:1 mix, thixotropic in nature, requiring no primers, and exhibiting skin or surface cure in approximately 15 min at 75 F. Application was accomplished by a machine developed by the formulators of the material. This equipment was not completely satisfactory because the metering pumps did not provide a continuous positive supply of the two-components to the mixing chamber located 6 or 8 in. from the nozzle from which the sealant was extruded. The equipment was capable of applying the joint sealer at a rate of approximately 10 ft/min.

The four joints tested were from $1\frac{1}{4}$ to $1\frac{1}{2}$ in. in width and $\frac{1}{2}$ to $\frac{3}{4}$ in. in depth. The structure is on a 40° skew and the length of each joint was approximately 60 ft. All appearances that day indicated that we were approaching the solution to the sealing problem.

The next day, the equipment was used to place this same type of sealing material in the joints of a Thruway structure. Faulting of the equipment caused delivery of improperly proportioned material to the mixing chamber with the result that the sealant failed to cure properly, thus failing to produce the desired product. Corrections and adjustments were made to the equipment and the sealing of the joints progressed in a satisfactory manner. The transverse joints on this square structure were approximately 45 ft long and ranged from 1 to $1\frac{1}{4}$ in. in width and $\frac{3}{4}$ to 1 in. in depth.

On July 10 and 11, the liquid polysulfide polymer was installed. This was a two-component 1:10 mix, available in two grades, one for horizontal joints and a heavy type for vertical joints. It required that a primer be applied to dry concrete interfaces and allowed to air dry. Surface cure time at 75 F was approximately 4 hr. The structure was square with joints approximately 72 ft long and ranging from $1\frac{1}{2}$ to $2\frac{1}{2}$ in. in width and $1\frac{1}{2}$ to 2 in. in depth. The material was hand mixed in $\frac{3}{4}$ -gal kits and poured directly from the container into the joint.

On July 12 and 13, the silicone rubber joint sealer was installed. This material was a 3:1 mix requiring a primer and exhibiting skin or surface cure in approximately 2 hr at 75 F. Because of flow characteristics, it could only be used in horizontal joints. We attempted to use this material in the vertical joints by providing a bulkhead but the results obtained were very unsatisfactory. The joints in this square structure were in very poor condition due to the spalled faces. Some joints were as much as 4 in. wide and the average depth was 2 in.; the length was approximately 36 ft. The material was again hand mixed in $\frac{3}{4}$ -gal kits and poured directly from the container into the joint.

The material in these three test installations failed or showed signs of failure in less than 2 mo. We had, however, gathered considerable information on the physical and chemical characteristics of the materials employed and some on the behavior pattern of these sealants with regard to their dimensions within the joint.

The 40 Shore A durometer hardness of these materials at 75 F was definitely too high. Either the sealing material or the primers were not compatible with the pre-molded bituminous joint material already in place in the structures. There appeared to be a definite relationship between the depth and width of material that would effectively produce a properly workable sealed joint. This has since become known as the shape factor. On the structure where the liquid polysulfide polymer extended with coal tar was placed, the depth of material was approximately one-half the width of the joint opening and the sealant performed much more satisfactorily than on those structures where the depth of material equaled or exceeded its width.

For reasons of economics it was decided to concentrate on the liquid polysulfide and the liquid polysulfide polymer extended with coal tar. As a result of many conferences it was decided that the material used in New York State should have a Shore A durometer hardness at 77 F of 10 to 15, not flow at high temperatures, retain its flexibility, have an extensibility at -20 F of at least 100 percent, be capable of effecting chemical or mechanical bond at approximately 40 F, cure rapidly, be thixotropic, and have the ability to withstand invasion of foreign particles.

With the aid of two manufacturers, by the winter of 1956 to 1957, after the expenditure of several hundred thousand dollars in research, development and engineering of equipment, it appeared that materials could be produced effectively to seal expansion and construction joints in bridges.

In June 1957, the joint areas of the two structures sealed with liquid polysulfide polymer, alone and extended with coal tar, were again prepared for resealing with the same materials. With the experience gained previously, these applications proved far more successful. With these exhibited improvements, it appeared reasonable to utilize these materials with a full understanding that there would be improvements made in the sealants and method of application. It is a basic economic fact that further research and development of these materials would be accelerated if the manufacturer could realize a return on their initial investment. The benefits of these improvements would then accrue to the user.

In 1957, New York State issued special specifications for the use of these materials for sealing bridge joints. One significant difference from previous practice was that sealing of joints was made an item of the contract and paid for accordingly.

There was still a lot to be learned. It was soon realized that not only the ratio of depth to width was important but also a bond-breaker was required at the bottom of the sealant to eliminate or reduce any restraint to free movement. This resulted in the use of wax-backed or polyethylene tapes at the bottom of the joint areas to be sealed. Later we learned that extensibility was not the only requirement in a joint sealer. Since time of construction, the contractor's schedule of operation, and temperature could dictate the time at which the joint would be sealed, compression could be the controlling factor. With this in mind, joint details were revised and a layer of upholsterer's piping cord, later revised to utilize a flexible urethane foam, was required between the pre-molded joint material and the polysulfide sealant. Premolded bituminous joint material was replaced by self-expanding cork.

Failures were still prevalent. The reasons were many and could be attributed to poor joint design, or construction, apathy with regard to inspection, ignorance or misunderstanding of preparation of joint surfaces and mixing and applying of the sealer, or a total disregard of the specifications for an item of the contract. Some typical examples point up the preceding comments:

1. A steel expansion dam was designed with a width of $1\frac{1}{4}$ in. providing a sealable joint interface of $\frac{5}{8}$ in. These dams as constructed and ready for sealing had a width of from 3 to 4 in.

2. Joints detailed as 1 in. with a joint interface of $\frac{1}{2}$ in. when constructed and ready for sealing were 1 in. in width and the preformed joint filler was so positioned that only $\frac{1}{8}$ in. of joint interface was available to receive the sealer.

3. Joints were sealed without supervision or inspection in the rain with mud present in the joint area.

4. Two-component materials which required machine mixing and placing were measured out in separate cans and poured into the joint opening.

5. On one job, the crew did not even bother to put the A and B components into the same joint. Instead, they used up each component separately.

6. Maintenance personnel, not recognizing the new materials, did their usual good job, pouring hot tar on top of the sealants. On cooling, a rigid material was left in contact with the upper face of the sealant, restraining the movement in the extreme fibers, thereby contributing to their failure.

During the past 6 years the sealant manufacturers have been most cooperative. They have studied the problems and have attempted to produce the material required to seal properly designed and prepared joints.

Sealant materials other than those based on the polysulfide polymer have been formulated in the past 2 or 3 years with the hope that they might solve the problem. Three joint sealers in particular have been subjected to limited test applications: a two-component flexibilized epoxy, a two-component urethane rubber, and a premolded neoprene.

The flexibilized epoxy material showed considerable possibility. It performed satisfactorily with regard to adhesion and cohesion, expansion and compression. Temperature change had only a slight effect on the hardness of the cured material. The differential in Shore A hardness of this material was only eight points in 95 degrees of temperature change, indicating that a Shore A durometer of 30 at 75 F could be effectively employed. The formulators of this material, however, withdrew it from the market when they encountered difficulty in reproducibility from batch to batch. The urethane rubber joint sealer has not been given sufficient chance to demonstrate its capabilities.

The premolded neoprene joint sealer was placed on October 26, 1963. The joint as designed and detailed calls for a width of $\frac{3}{4}$ in. and a depth of $2\frac{1}{2}$ in.; as constructed, it was 1 in. wide and $2\frac{1}{16}$ in. deep. The top of the joint area had been given a $\frac{1}{2}$ -in. radius tooled finish. This type of joint filler is designed to function under conditions of compression only. The material supplied was 2 in. wide by 2 in. deep and, when compressed to meet the requirements of 1 in. width of joint, had a depth of $2\frac{1}{2}$ in. Portions of the preformed cork joint filler and of the structural slab had to be removed to provide sufficient depth for the placement of the compressed material. The concrete interfaces were poorly constructed in that honeycombing was evident approximately 1 in. below the top surface. This material is not designed to and cannot seal a concrete joint interface that exhibits spalling.

In recognition of the experience gained to date, the HRB Subcommittee on Joint Sawing-Sealing in Overlays has, after several meetings during the past two years, attempted to assess the areas of responsibility with regard to obtaining properly sealed joints as follows:

1. Engineer (Design).—Design and detail expansion and construction joints giving full recognition to the shape factor requirements of the material to be used, indicating the limits of anticipated movement, together with a possible indication of the desirable joint confirmation with relation to time for sealing.

2. Engineer (Construction).—Supervise the construction of expansion and construction joint areas to insure their compliance with the Design Engineer's requirements as it relates to time and temperature. Supervise and inspect the preparation of joint areas together with the preparation, mixing and placing of the joint sealant in full compliance with the specifications and manufacturer's recommendations.

3. Contractor (or Subcontractor).—Construct joints as designed and detailed in full compliance with contract requirements. Guarantee the employment of only qualified personnel to insure the proper preparation of the joint areas as well as the preparation, mixing and placing of the sealant in full compliance with the requirements of the specification and the sealant manufacturer's recommendations.

4. Sealant Manufacturer.—Formulate quality-controlled materials capable of sealing properly designed joints indicated on the contract plans. Recognition should be given to the time needed for fully curing the material as well as the required functioning of the joint with relation to the structure. Complete recommendations should accompany each unit of material, outlining procedure to be followed with regard to preparation of the joint interface surfaces as well as the proportioning, mixing and placing of the

sealant. The manufacturer should be familiar with the conditions of bridge construction and should provide technical assistance to the sealing applicator who inspects the joint areas before sealing. Should the joints, as produced, or the surface preparation be in violation of the design, construction or specification requirements, the manufacturer should refuse to supply any materials, if in his opinion, these violations will preclude a successful application.

A recent investigation conducted by California has added some very interesting information relative to observed sealing failure. Failures were occurring at the approach side of the leading edge of spans only. Observation under normal traffic indicated a positive jump of the deck in the direction of traffic. This phenomenon is attributed to the impact forces imposed by high-speed truck traffic on initial contact with the deck surface.

Corrective measures included closed cell neoprene sheet cut to conform to the joint dimensions, leaving room for the joint sealant at the top surface. The neoprene sheet was cemented to one interface only. On completion of cure of the adhesive, a barrier strip of pressure-sensitive polyethylene tape was placed over the upper face of the neoprene sheet and the sealing of the joint was completed using a liquid polysulfide polymer extended with coal tar. This type of investigation and approach to a solution constitutes a significant contribution to the solving of a most troublesome problem.

Some recent experimental work carried on by John P. Cook at Rensselaer Polytechnic Institute has produced some much needed data regarding the behavior of these materials. His findings indicate that further research in the development of elastomeric sealants would be to the advantage of all concerned with this problem.

ACKNOWLEDGMENTS

Special thanks are extended to M. O. Huntress and C. A. Peters of Allied Materials Corp.; George Gregory, Richard Ely and Joseph Amstock of Products Research Corp.; Harry Shields of the Prestite Division of Interchemical Corp.; and the research and technical personnel of these organizations. The author also wishes to thank Raymond J. Schutz of Sika Chemical Corp.; Joseph W. LaFleur and the Bridge Maintenance Unit of the New York State Thruway Authority, Newton Ronan, Vernon J. Burns, and the maintenance forces of the New York State Department of Public Works; Egons Tons of Massachusetts Institute of Technology; and John P. Cook of Rensselaer Polytechnic Institute.

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