EVALUATION OF JOINT SEALANT MATERIALS

(INTERIM REPORT NO. 1)

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ABSTRACT

This report illustrates some of the problems caused by ineffectively sealed joints and points to the great need for properly sealing joints in both concrete pavements and structures.

The principles of design including slab lengths, joint dimensions and joint formation as well as the projected effects of debris, traffic and the environment have been reconsidered and re-evaluated. Recent changes in pavement design have led to the use of 20 foot panel lengths and 7/16 inch width joints sealed with a 13/16 inch compression seal. Bridge joints are armored, with the joint width dependent upon predicted movement. These predicted movements are now being actually checked to improve the accuracy of prediction.

The asphaltic based materials, asphalt cement with mineral filler, rubberized asphalt and "improved" rubberized asphalt, are the materials that were extensively used in the past for sealing joints. These materials have been found seriously deficient and are no longer specified in a joint that exhibits movement. Several of the polymeric catalyzed materials have been found to possess physical properties which are sufficiently effective in a laboratory environment; but in the field, the majority of the results have been disappointing. However, if techniques for accepting installations could be established, some of these products could be used. The neoprene compression seals have been effective on both the roadways and bridges, and are the only sealants now specified for joints exhibiting movement.

IMPLEMENTATION

This project has already produced immediate benefits for the Department. Many of the changes have been direct, while some have evolved indirectly, caused more by a change in philosophy than by direct test results. The major changes are as follows:

1. More focus has been directed at the problems of joint formation, joint size and good construction techniques, and improvements such as increased life for joint materials have been realized.

2. Materials have been found that are effective sealants, and these materials are now being used. Some recent modifications have been made which should extend the performance life of these sealants.

3. Re-evaluation of pavement slab lengths, pavement joint design, bridge joint openings and bridge joint design have resulted in numerous changes. The philosophy on bridge joints has been changed to one of attempting to seal all joints in bridges. Experimental joints of modular design and Transflex are being evaluated to replace the finger joints on the openings which exhibit large movements.

The Department's latest specifications have been formulated as a direct result of this research study.

More attention has been directed towards problems caused by ineffectively sealed joints, and better maintenance techniques have been realized. More extensive maintenance has been directed toward correcting problem areas.

INTRODUCTION

Joints in concrete, both pavement and structural, are designed for specific functions. In order for the actual joint to perform as expected, it is paramount that it be protected from the elements. A vital need exists for adequate solutions to the problem of joint sealers, both for bridges and roadways. Sealing qualities, life expectancy and economics are the prime factors in the use of joint sealers.

The purpose of this study is as follows:

1. To study the performance of the available concrete bridge joint sealers under field conditions and determine which are preferred for use as well as to *determine installation procedures for developing interim specifications.*

2. To study the performance of the available concrete roadway joint sealers under field conditions and determine which are preferred for use as well as to determine construction procedures for developing interim specifications.

3. To obtain samples of all the joint materials used in the above studies and test these materials using present tests available. An attempt will be made to correlate these laboratory results to field results by making the necessary changes in present test procedures and/or equipment. Interim joint material specifications will be developed for both concrete bridge and roadway pavements after studying the results of these laboratory tests in conjunction with installation control procedures and the corresponding field performance of the sealers tested.

4. To determine and evaluate under field conditions the effects of using different joint widths, spacings and shape factors in relation to the laboratory results. The laboratory and field results will be re-evaluated in conjunction with results of this phase, and final specifications for both bridge and roadway joint materials will be developed.

SCOPE

This study was to investigate the best sealants currently available. Construction techniques, installation procedures and basic design consideration were to be examined. The laboratory investigation was to attempt to identify and examine material properties. Attempts are being made to devise meaningful tests correlated to field performance.

METHODOLOGY

Phase I (Bridge Installation)

Thirty suppliers of joint sealing materials were contacted and requested to participate in this study by submitting samples; recommending specifications, construction procedures and controls; and actually placing their sealers in three or more joints (for each different type material used) on a bridge for evaluation under actual field conditions. Installation controls and construction procedures were entirely up to the suppliers. Sandblasting of the joint faces and traffic control functions were performed by Louisiana Department of Highways personnel. The northbound bridge of the I-10 twin bridge (New Orleans area) across Lake Pontchartrain was the site selected. This 5 1/2 mile bridge has one inch armored joints with concrete joint faces for the curb and sidewalk. (See Figure 1 for a joint diagram.) Because of traffic, only two of the three lanes were sealed; however, the sealants extended through the concrete curb and sidewalk on one side so that the adhesion of the material to both concrete and steel could be evaluated. The bridge was built in 1963 with pre-fabricated slabs.

Simple scribe gauges were installed on each joint to record the maximum and minimum joint opening for the entire period of study. Field performance reviews were initially conducted at three month intervals and are presently being conducted at six month intervals. Both color slides and black and white photographs were obtained during installation and during the performance review to pictorially show each sealant's performance record.

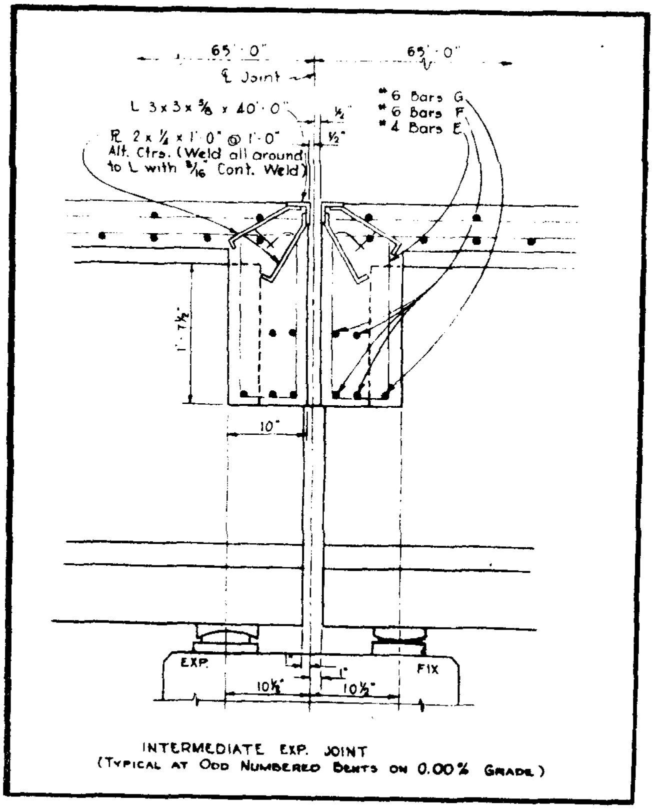

FIGURE 1

Phase II (Roadway Installation)

Forty suppliers were contacted and requested to participate in this study by submitting samples; recommending specifications, construction procedures and controls; and actually placing their sealants in five or more joints (for each different type material used) on portland cement concrete roadway pavement for evaluation under actual field conditions. Installation controls and construction procedures were entirely up to the suppliers. The joint formation, joint cleaning and sandblasting of the joint faces just prior to installation were performed by Louisiana Department of Highways personnel to the satisfaction of the material suppliers. The site selected for the evaluation was a portion of the I-12 westbound roadway near Denham Springs in Livingston Parish. This pavement had 3/8 inch joints spaced at 58.5 feet; however, as explained in "Discussion of Results," the joint widths were 5/8 inches wide in the joint evaluation portion of this project. The joints were constructed by forming and sawing out the form insert material to the required width and depth.

Field performance reviews were initially conducted at three month intervals and are presently being done at six month intervals. Both color slides and black and white photographs were taken during installation and during the performance reviews for a pictorial record of performance.

Simple scribes placed within the joints as well as joint width measurements taken during temperature extremes accurately monitor the actual movements to which the individual sealants are subjected.

For both Phase I and Phase II, the installed materials are being evaluated in the field for their ability to adhere to the joint walls, to resist penetration of foreign materials, to resist splitting (cohesion failure), to resist wear and, in general, to keep the joints sealed. Failure is considered complete when 15 percent of the joint is ineffectively sealed.

Phase III (Laboratory Testing)

This phase involves laboratory testing which is currently in progress. The major effort to date includes approximately 1 1/2 years of intensive work. The complete goal of Phase III is detailed below.

It is felt that the requirements for a joint material, as regards laboratory tests in relation to performance criteria, can basically be grouped under the following four main headings.

1. Installation requirements
2. Ability to wear that is, to reject and/or resist the effects of foreign materials
3. Ability to resist effects of movement
4. Ability to properly seal (adhesion)

These four performance criteria are considered sufficient to cover the major performance requirements for a good sealant material as far as necessary testing is concerned.

A review was conducted of the available tests as contained in ASTM, as referred to in the Federal Specifications, as devised by other states, and as developed by the individual joint material suppliers. The tests could be grouped under the above four headings according to the following descriptive terms.

Installation Requirements - Application life, tack free time, change in weight and volume, flow, self leveling, viscosity and mixing.

Wear - Hardness, tensile strength loss, elongation loss, hardness change, oil swell, ozone resistance, low temperature hardness, high temperature hardness and resistance to weathering

Movement - Tensile strength, compression set, elongation at break, permanent set at break, low temperature recovery, high temperature recovery, tear strength, cycling rate (temperature controlled, number, distance) and resilience.

Seal - Adhesion, penetration, bond to concrete, bond to steel and peel strength.

It is intended that all the samples obtained during Phase I and II be tested according to the pertinent tests, and in addition, that any changes necessary in the present tests or equipment for better correlation with the field performance be adopted.

The Bostik machine, a cycling machine which can be controlled to vary the rate of cycling, number of cycles, joint width and temperature, has been purchased (Figure 2). Cyclic testing has been and will continue to be performed on a routine basis using movement and joint data obtained from Phase I and II. Joint openings, shape factors and joint movements have been varied in an effort to evaluate the effects of these factors. Correlations between the laboratory data and field performance are being attempted.

Property changes, especially pressure decay, of the neoprene compression seals have been and will continue to be observed with an attempt being made to predict projected performance. A device has been constructed in an attempt to determine the minimum sidewall pressure necessary for successful performance. (See Figure 3).

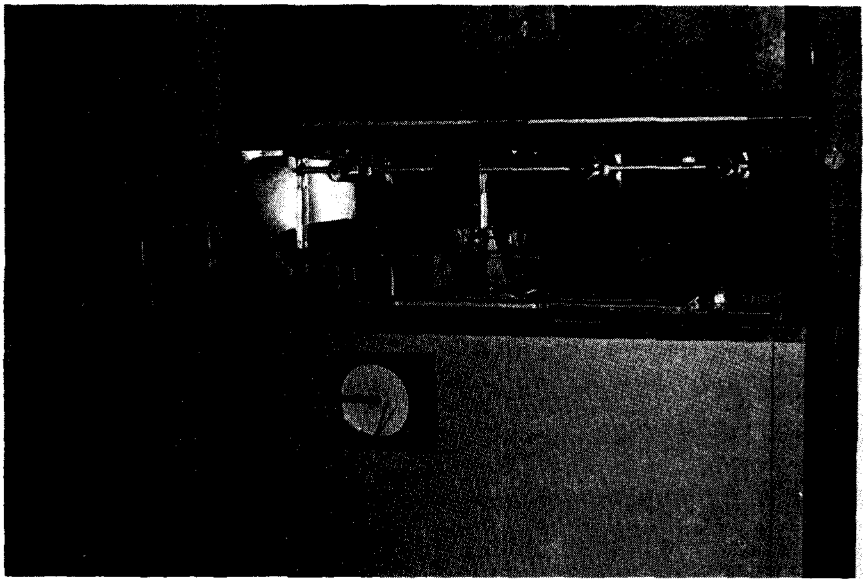

FIGURE 2

Bostik Cycling Device

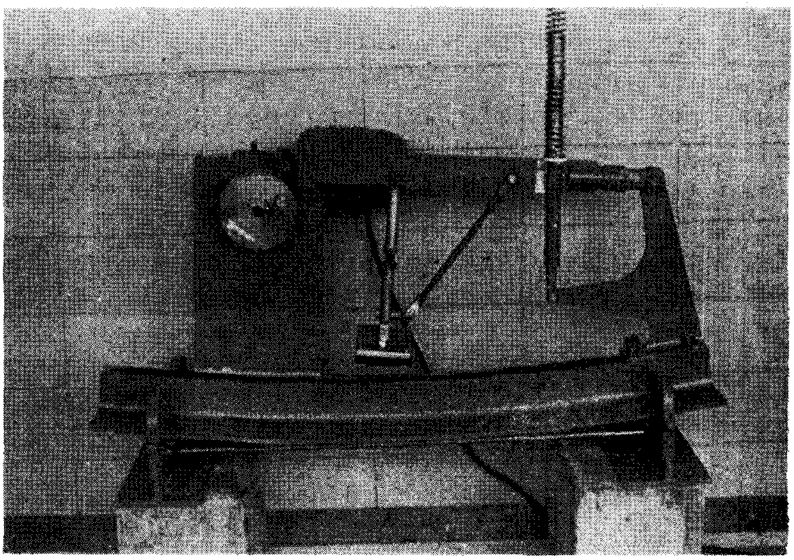

FIGURE 3

Louisiana Water Leakage Tester

GENERAL DISCUSSION

PROBLEMS CAUSED BY IMPROPERLY SEALED JOINTS

Prior to the inception of this study, it was generally believed in Louisiana that the state did not experience considerable trouble with bridge joints, largely because Louisiana's mild climate rarely requires the use of deicing salt with its associated destructive action. However, additional emphasis on bridge inspection by both the Federal Highway Administration and the Department following the collapse of the Silver Bridge at Point Pleasant, West Virginia, revealed bridge joint problems and vividly illustrated the necessity for properly sealing bridge joints.

On the other hand, prior to this study, it was generally known that improperly sealed joints in concrete pavements are very detrimental because, with Louisiana's 60 inches of rainfall per year, concrete pavement's three worst enemies (water, water and more water) were constantly on attack. However, when the problems associated with concrete pavement joints did occur, the causation was generally attributed to poor maintenance, rather than to design,materials or construction procedures, even though general observation revealed that certain exceptionally well maintained roads still experienced joint problems. Detailed inspection of concrete pavements have repeatedly exhibited patterns of troubles associated with poor joint system performance.

Bridges

Improperly sealed joints in bridges allow water to work its destructive action and incompressible materials to infiltrate, thereby freezing an opening meant for expansion.

Water in nature is rarely pure, and when combined with the sulphides and chlorides from pollution or the nitrates from chemical fertilizers, this water can be a corrosive as well as an erosive force. Stained caps from water leakage are a universally common slight but on an aesthetically pleasing structure this can be visually disconcerting. Because of this water leakage, steel members require frequent and expensive maintenance, and concrete members can deteriorate leaving the reinforcing steel vulnerable to corrosion. Due to Louisiana's mild climate, deicing salts are very seldom used; however, the effects of corrosive elements present in an open air structural environment are found on structures where deicing salts had not been used. Figures 4 through 10 illustrate the problems.

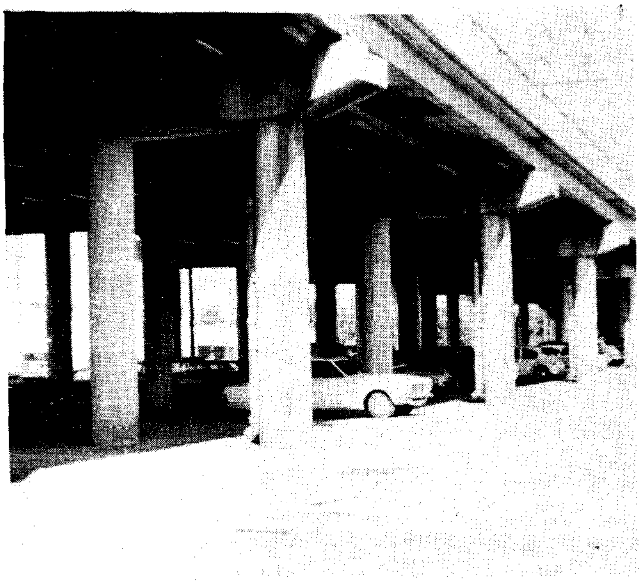

FIGURE 4
Water Stained Bridge Caps

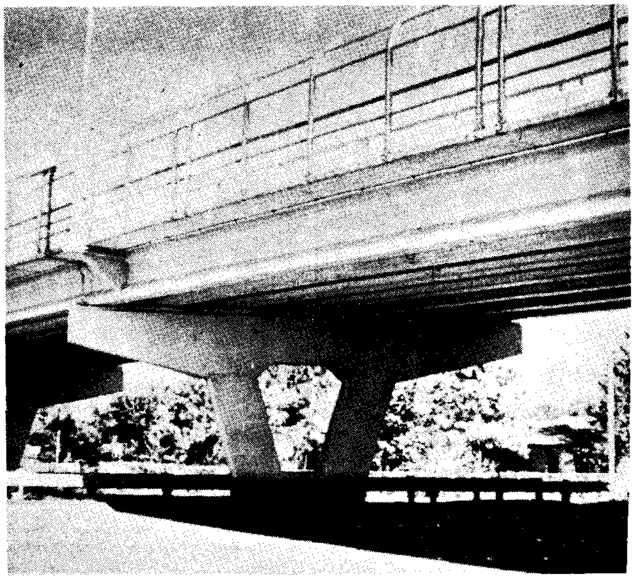

FIGURE 5
Aesthetic Pier

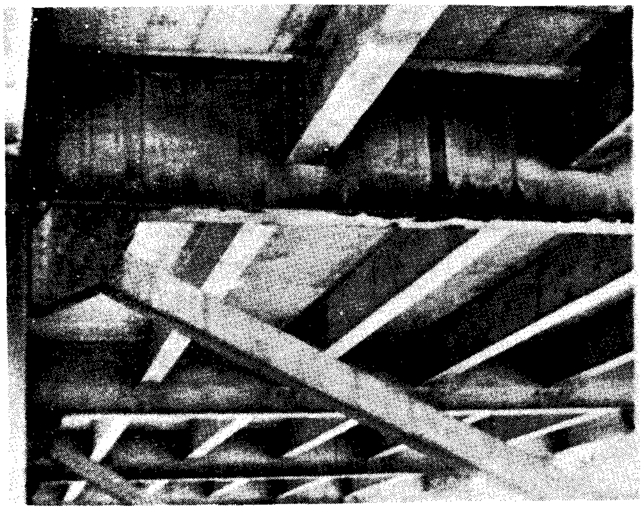

FIGURE 6
Water Leakage Damage

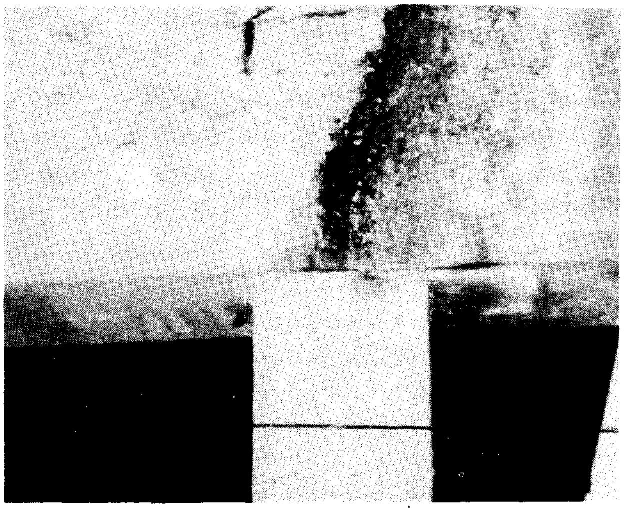

FIGURE 7
Water Leakage Damage

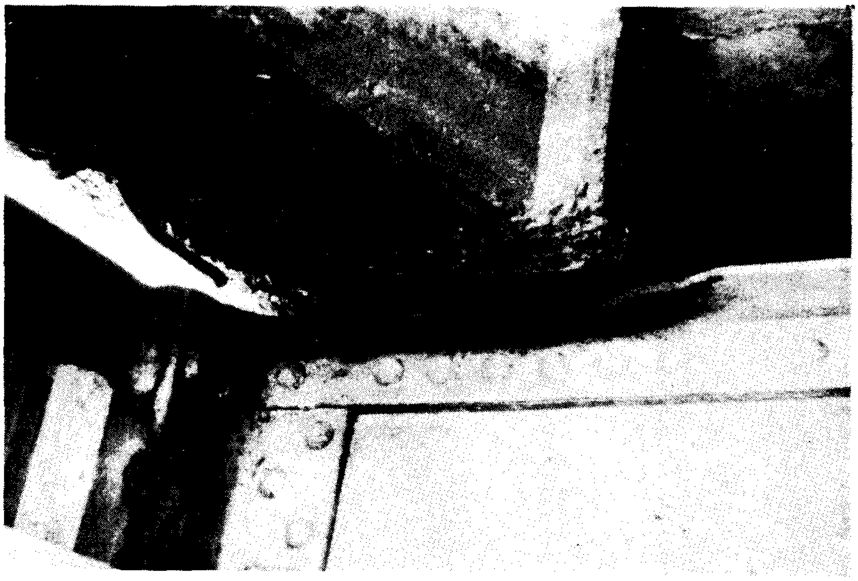

FIGURE 8
Steel Corrosion Due to Unsealed Joint

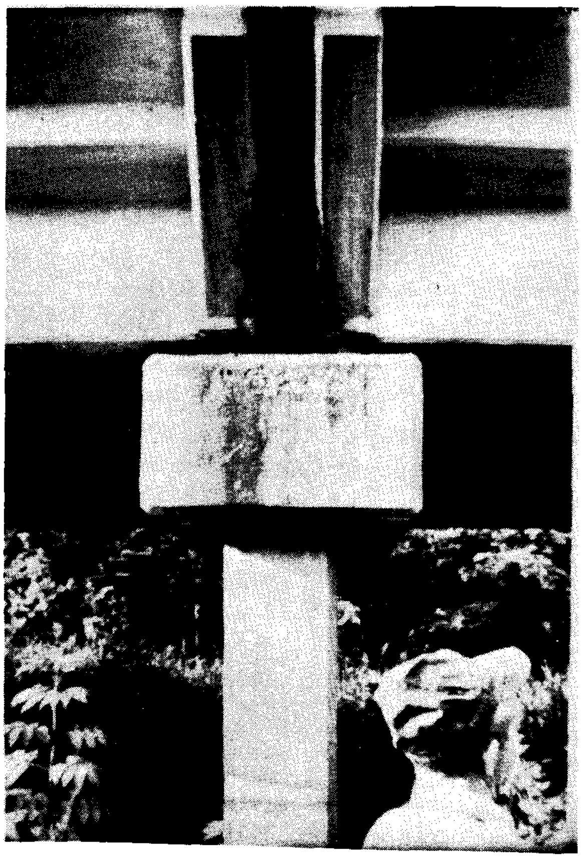

FIGURE 9
Concrete Deterioration Due to
Water Leakage

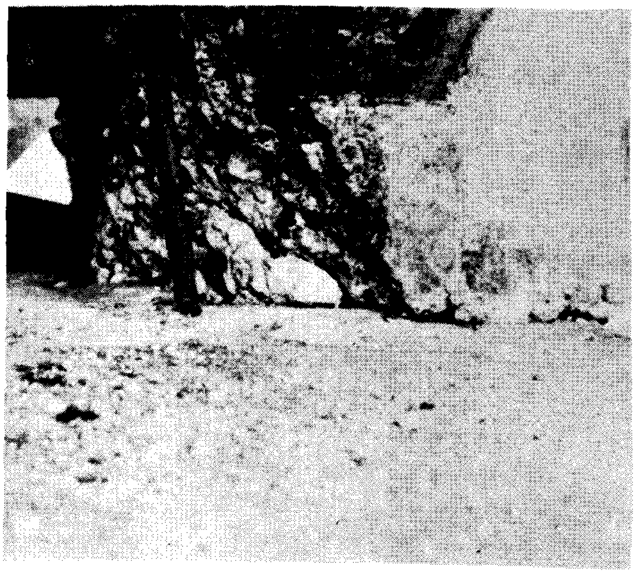

FIGURE 10
Unsealed Joint Damage

Multi-land use as shown in Figure 11 is in vogue today; therefore, the joint should be reasonably watertight, and runoff water must be controlled. Again, aesthetic appearance is important; water stained substructures must be avoided. In some metropolitan areas, city ordinances require that overhead structures be sealed watertight and runoff water be properly controlled.

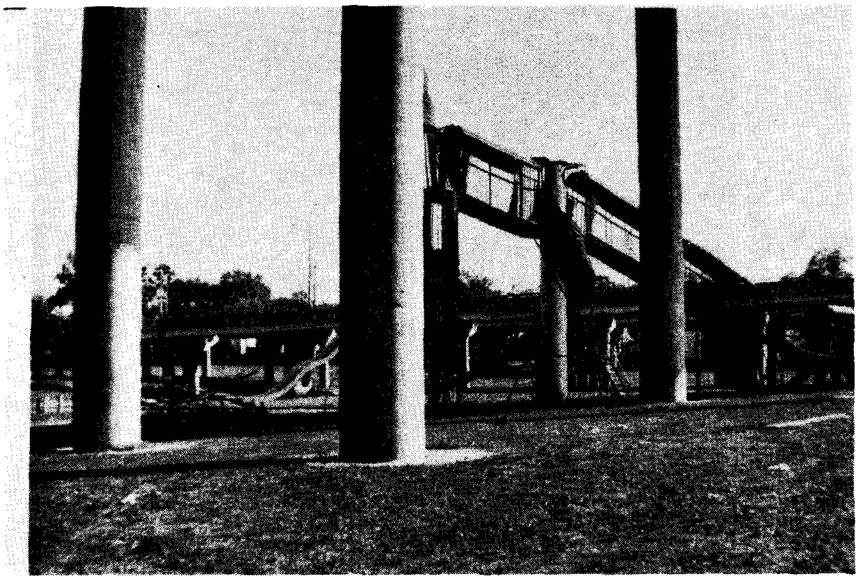

FIGURE 11

Incompressible materials that find their way onto a bridge eventually invade unprotected joints. Sliding plate joints and finger joints are not effective (Figures 12 and 13). The buildup of material over several years can be substantial; Figure 14 depicts an unexpected roof garden complete with willow trees growing in debris on the bridge. Figure 15 shows a runoff outlet completely clogged with debris on a bridge which spans a lake; the outlet is located over two miles from land. The destructive effects of this incompressible buildup can be seen in Figures 16 and 17, the 1 3/4 inch joint has been rendered rigid, and the triangular extensions on the cap in Figure 17 are "saddles" built to prevent the girders from falling off the cap. When a bridge with skewed joints is subjected to unexpected compressive forces, a diagonal movement exists (Figure 18). If the bearing pads allow too much friction, the whole pier may lean as shown in Figure 19.

These examples are not unique; rather, they occur uncomfortably often. Other writers such as Cook and Lewis (1)[*], Williams (2) and Watson (3) have reported similar findings. Thus it is paramount that an effective joint sealant system be utilized.

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[*] Numbers in parentheses refer to reference numbers.

FIGURE 12
Typical Sliding Plate Joint

FIGURE 13
Typical Finger Joint

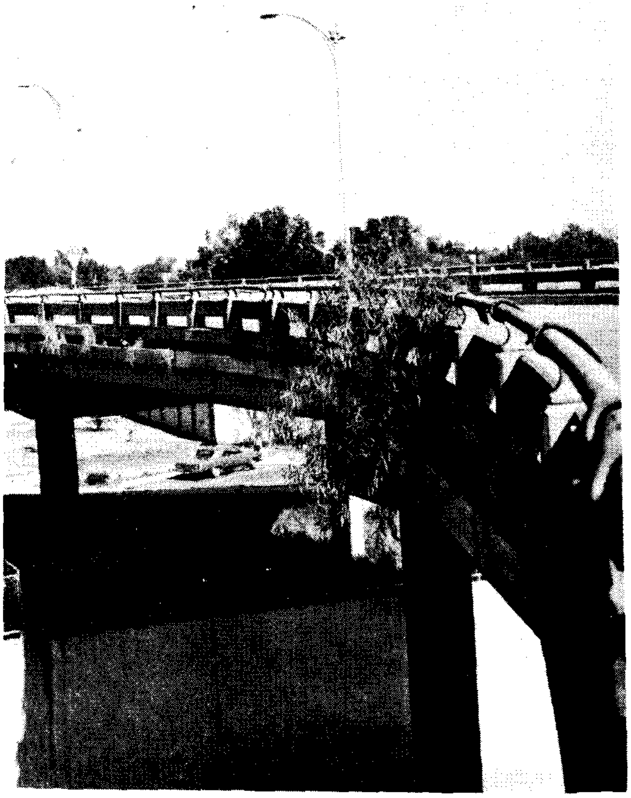

FIGURE 14
Bridge Debris

FIGURE 15
Bridge Debris

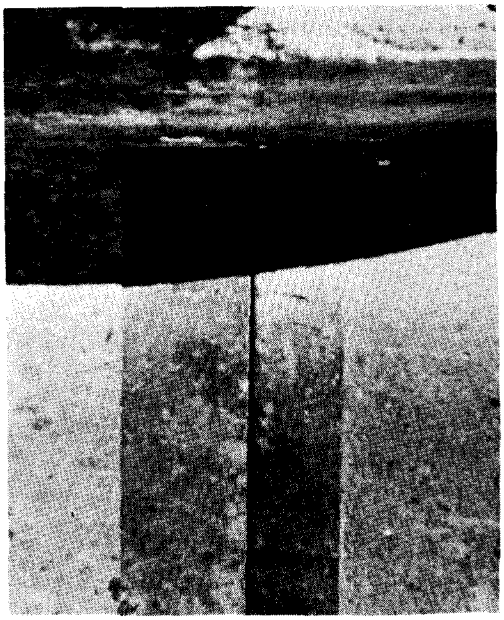

FIGURE 16
Expansion Joint Unable to Function

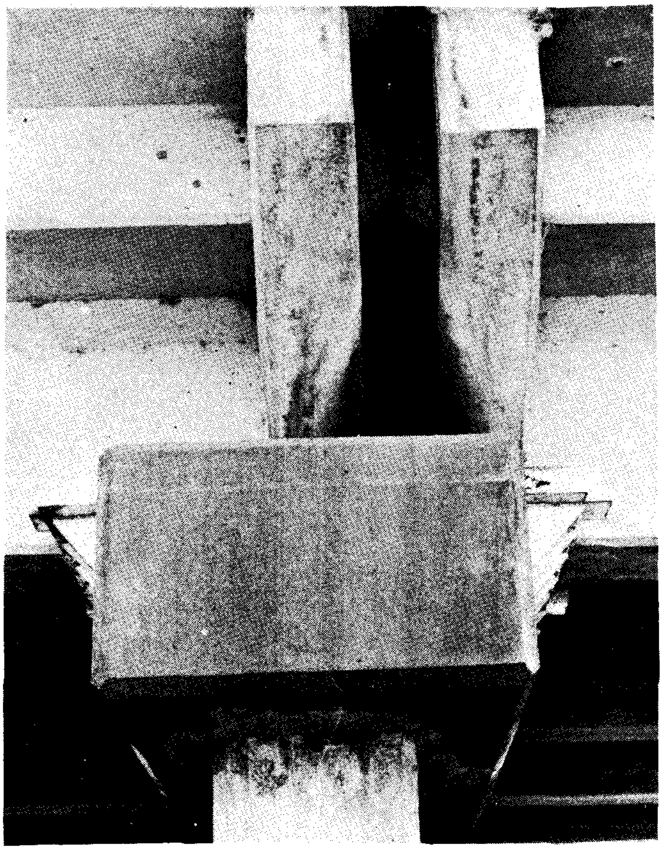

FIGURE 17
Bridge Being Pushed Off Cap

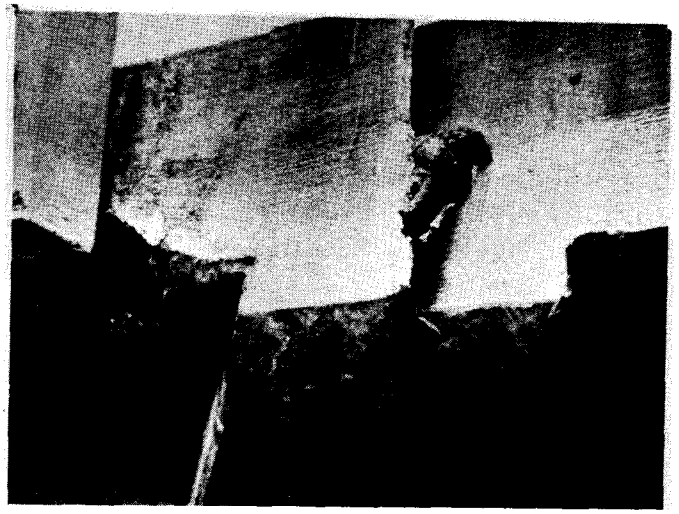

FIGURE 18
Joint Closure of Skewed Joint

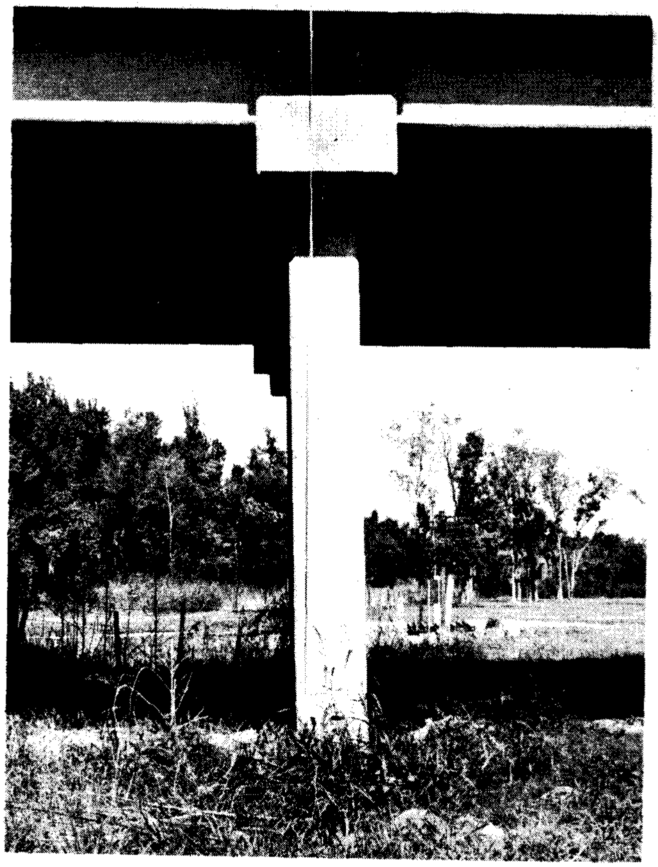

FIGURE 19
Leaning Bent

Pavements

Henry (4) has reported the damaging effects of pavement thrust upon bridges. Cook and Lewis (1) have reported on the pernicious effects of improperly sealed pavement joints. The culprits of improperly sealed pavement joints are the same as those on bridges: water with its corrosive as well as erosive forces and the entrapment and subsequent buildup of incompressible materials.

Some sealants, including some hot poured sealants, appear to be effective in sealing longitudinal pavement joints that are tied with steel and can therefore exhibit only minute movement. However, in transverse expansion or contraction joints which must relieve thermal forces of expansion and contraction, the sealant is required to perform several functions other than just filling the joint.

Figure 20 illustrates the progressive inclusion of incompressible material into a typical hot poured sealant such as the one in Figure 21. Adhesion failures of a two component catalyzed material (Figure 22) or compression set of a neoprene sealer (Figure 23) allows incompressibles to infiltrate. Once the incompressibles do infiltrate, trouble begins. Figure 24 is a typical pavement joint, the width being dependent upon the slab length. If incompressible material fills the joint reservoir, when the pavement expands the incompressibles cause concentrated compressive stresses in a small area, and the result is a spall (Figures 25 and 26). When the incompressibles infiltrate beyond the joint reservoir into the lower joint where concrete butts against concrete, the joint cannot close during pavement expansion, and tremendous compressive stresses build up and either cause blowups (Figure 27) or, if a structure is adjacent, create tremendous pavement thrust upon the structures. This thrust has been previously reported by Henry (4), Gordinier and Chamberlin (5). Pavement thrust has twice closed the four inch wide joint in Figure 28. When the pavement thrust is not relieved, considerable damage to the bridge members may occur; such as crushing, shoving and radial thrust (see Figures 29, 30 and 31).

FIGURE 20

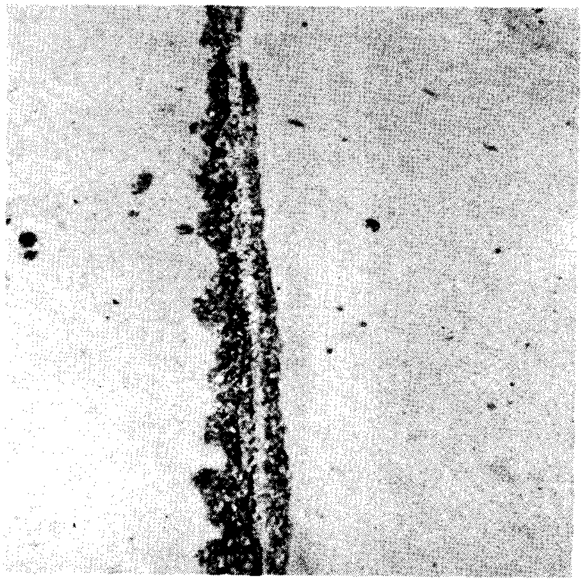

FIGURE 21
Hot-Poured Sealant with Trapped Incompressibles

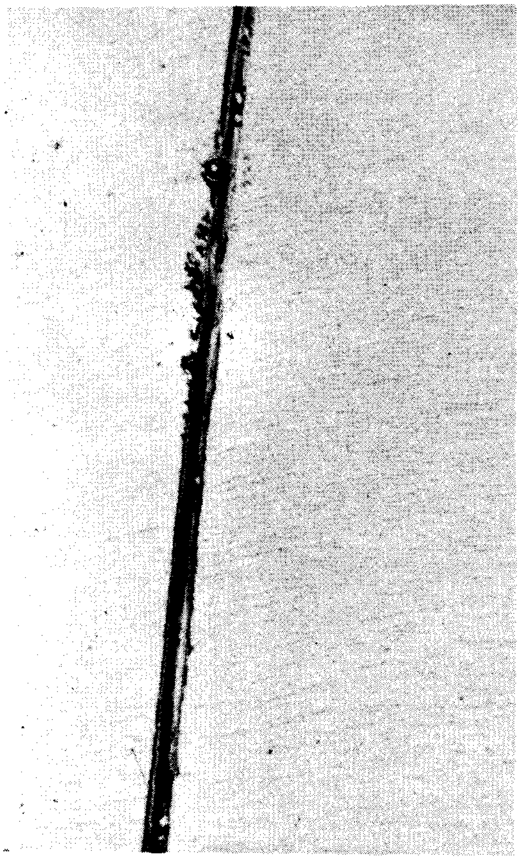

FIGURE 22
Foreign Material in Liquid Poured Sealant

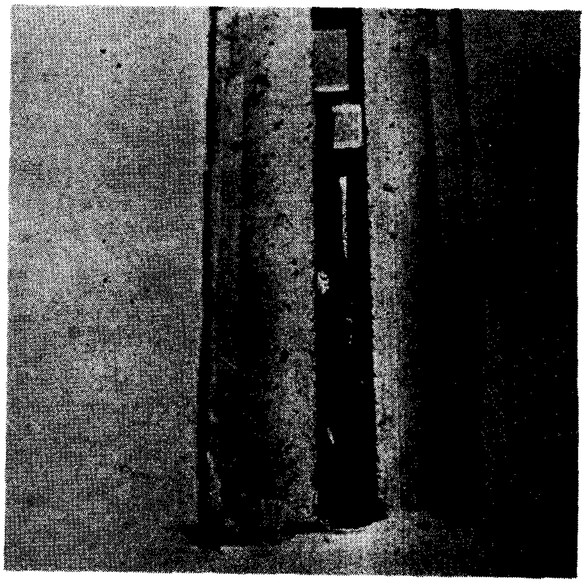

FIGURE 23
Foreign Material in Neoprene Sealant

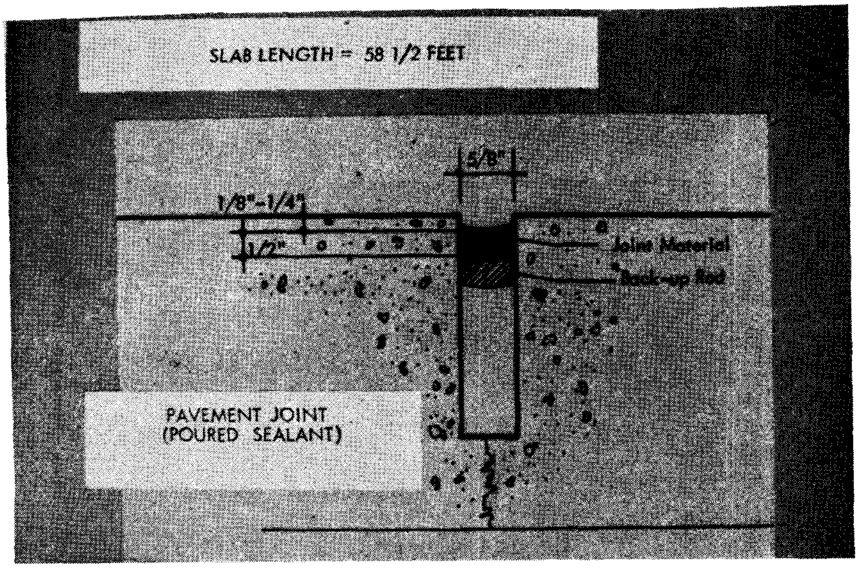

FIGURE 24
Typical Pavement Joint

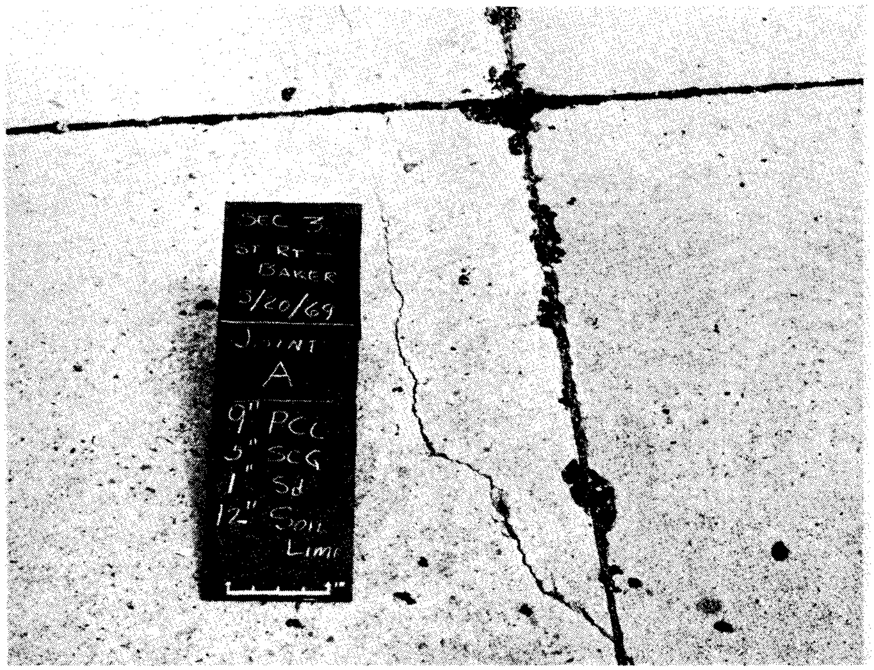

FIGURE 25
Pavement Spall

FIGURE 26
Pavement Spall

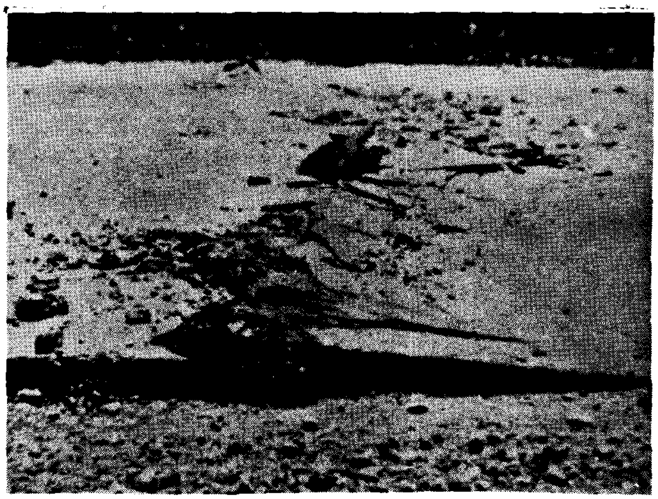

FIGURE 27
Pavement Blow-up

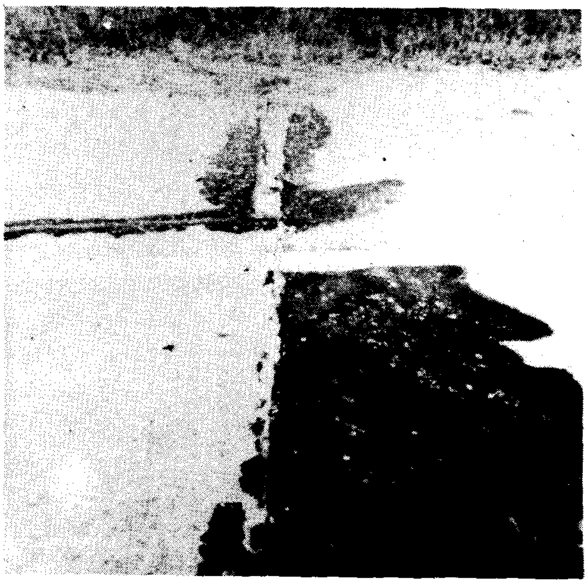

FIGURE 28
Complete Closure of 4 Inch Joint

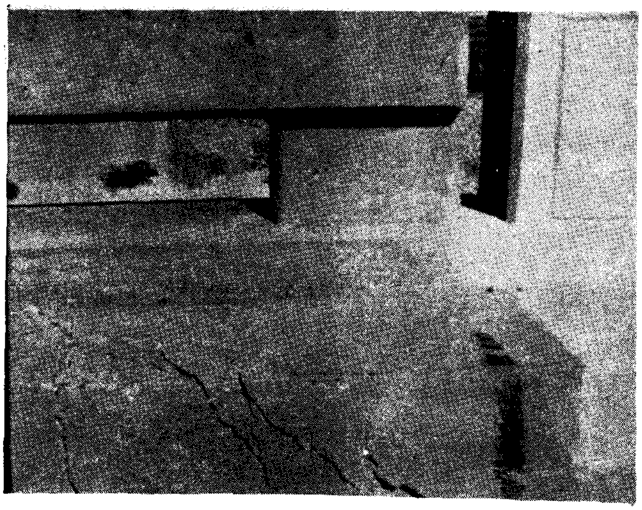

FIGURE 29
Crushing Due to Pavement Thrust

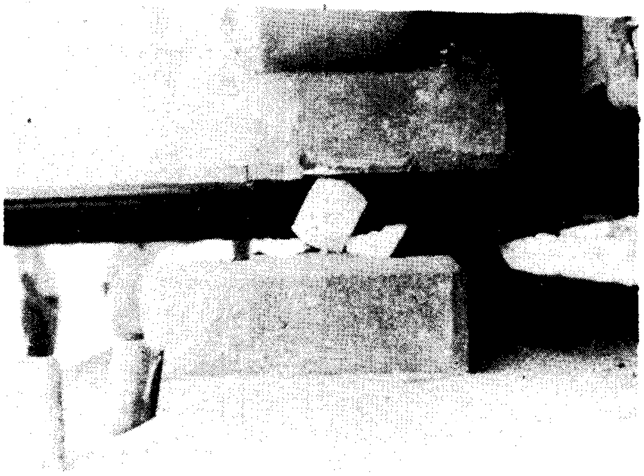

FIGURE 30
Shoving Due to Pavement Thrust

FIGURE 31
Radial Movement

In a 1000 foot section of pavement 24 feet in width and 10 inches thick, with joints at a twenty foot spacing, if each joint was unable to close to its original position by 1/16 inch because the joints filled with debris, there would be a total pavement growth of 3 1/8 inches. Assuming the pavement could be compressed back to its original 1000 foot length, a theoretical force of 2,175,000 pounds would be required.

Much pavement distress is due to water. While Louisiana is not concerned with one particularly damaging property of water, volume expansion during the freezing process, Louisiana's pavements are greatly affected because of the sheer quantity of water they receive. Louisiana averages between 50 to 65 inches of rainfall annually; therefore, an effort is made to seal out the water.

When the subbase is not chemically stabilized or is weakly stabilized, excess water weakens the subbase. When a pavement system is susceptible to water passage, fine material from the subbase (or from the shoulders) can be pumped out creating voids beneath the slab which cause uneven support (see Figure 32). These fines can be pumped up into the lower joint opening creating pavement thrust.

FIGURE 32

The concrete pavement slabs are never at rest; they are expanding or contracting; the slab ends are warping upward or pushing downward. These effects are primarily due to thermal changes. Traffic action also has its damaging effects. When the slab ends are warped upward, traffic forces on the slab end are concentrated because of the cantilever effect. When a joint is "open" and a void exists beneath the slab ends due either pumping or slab warpage, if a vehicle is on the slab end its weight pushes down upon the slab end, forcing the water and fines either up the joint or across to the adjacent slab. Immediately upon crossing the joint, the weight is suddenly relieved, the slab rebounds upward, the void beneath the slab is increased, and the water rushes back to fill the opening. When the joint is open due to sealant failure, additional substantial suction is created, compounding the destructive effects. This constant swirling of water continually erodes the subbase thus intensifying the problem. As reported by Spellman (6), this destructive action can also cause faulting as well as slab breakage (see Figures 33 and 34).

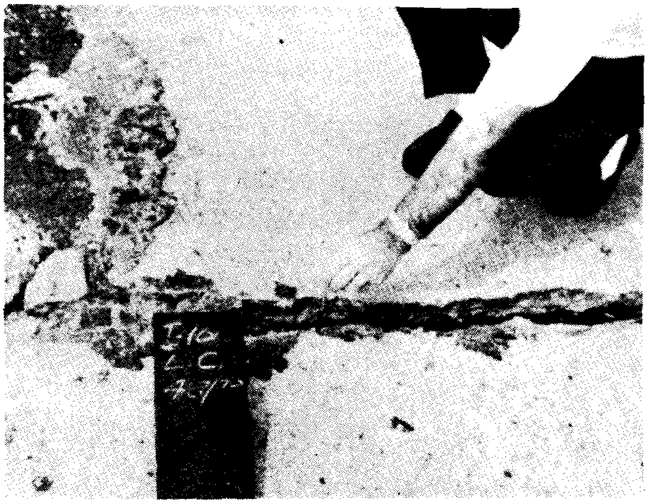

FIGURE 33
Pavement Faulting and Breakage

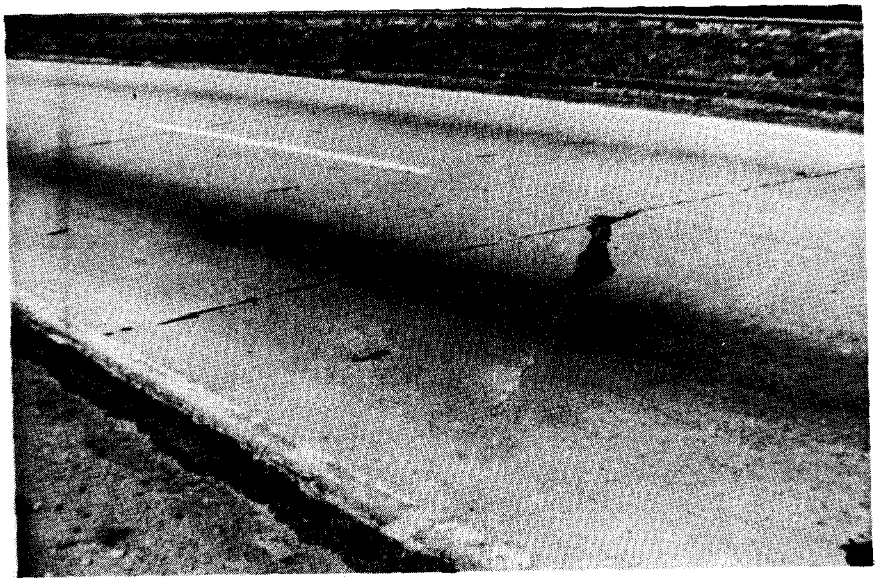

FIGURE 34
Slab Breakage

PROPERTIES DESIRED OF A SEALANT SYSTEM

The sealant should reject incompressibles and do so in such a way that, during the length of time the incompressible is in the joint, the sealant will overcome any harmful effects the incompressible would produce or transmit to the joint. The sealant system design should facilitate the cleaning action of rain and/or traffic for removal of undesirable material.

The sealant should create a watertight joint. Since the water will never be under a head, as in an environment such as a swimming pool, there would be no expectations for this sealant to withstand any appreciable amount of water pressure. There are different requirements for pavements and bridges.

1. Bridges - It is necessary that the sealant be completely watertight, allowing neither water leakage or water seepage (passage of a small amount of water over a considerable length of time). In bridges, salt concentrations are usually higher than on a roadway; more unprotected steel is available for corrosion, and any corrosion that takes place has more direct effect upon loss of performance as according to designed function. Some system of tieing the joint system into the bridge drainage system would help alleviate this problem.

2. Roadways - While complete watertightness is desireable, some water seepage (not leakage) would be allowable. Most modern pavements rest on a stabilized base which would have some capacity for absorbing a small quantity of water with no appreciable damage and while the corrosive action on the load transfer assembly would be harmful, new coatings (plastic covered dowel bars) are more protective and some of the functions of load transfer are assisted by the rigidity of the underlying stabilized base and also by the interlock between the joint faces.

The sealant should be stable, remain non-sticky, and retain sufficient performance properties to function in a typical roadway environment and at temperatures (for Louisiana) from 0°F to 160°F. The sealant system should not create any additional harm itself, such as increased spalling, rougher rideability, increased noise, etc.

The sealant system should be long lasting. A sealant should be effective for five years (when the expense is great, longer life is expected). Small failures (Figure 35 and 36) eventually will occur and are to be expected, but should not propagate.

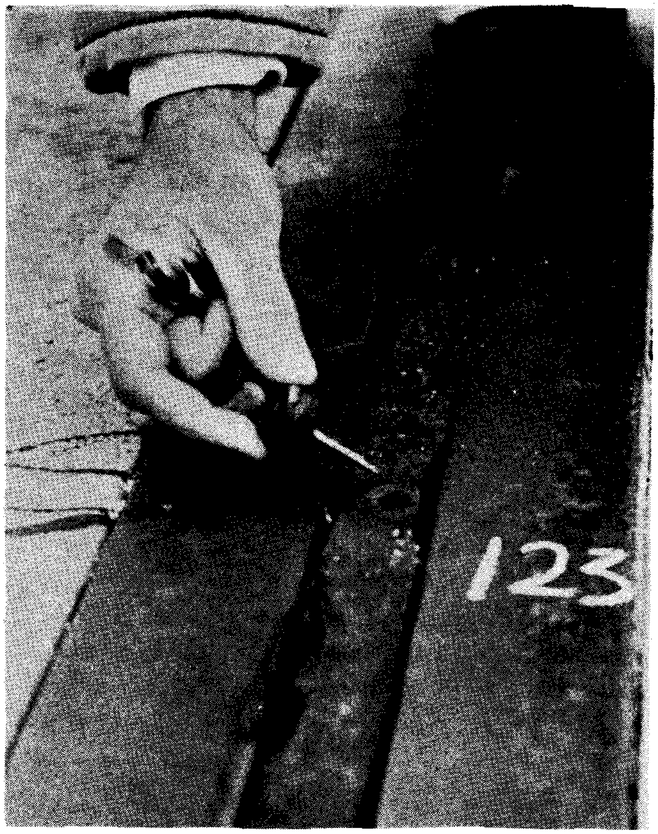

FIGURE 35
Failure Due to Truck Flare

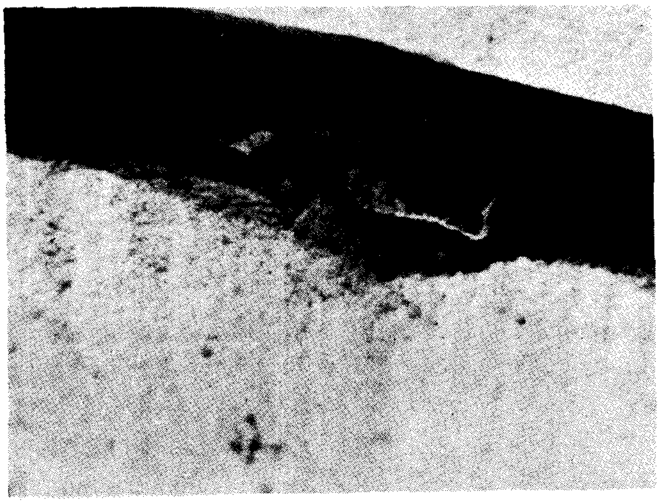

FIGURE 36
Small Spall to Substrate

DISCUSSION OF RESULTS

FIELD INVESTIGATION

Irregardless of a sealant's performance in the laboratory, actual field performance can be the only criteria in the final analysis. As more knowledge is gained regarding the inherent problems existent in the field, then better predictions of projected performance can be made. Correlation between field and laboratory performance of the sealant is most vital and is one of this project's most important goals.

Figure 37 shows the location of the two main evaluation projects.

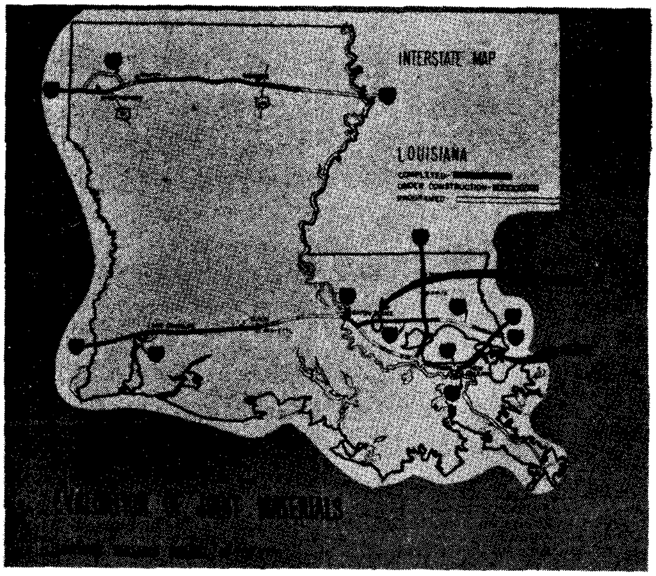

FIGURE 37

In taking the original joint opening measurements it was noted that percentage wise a relatively large number of disparities existed between the designed and the actual openings. Before installation, a recording device was placed upon the bridge to measure the actual joint movement for a 24 hour period. The results indicated that the actual joint movement approximated the theoretical thermally based movement of approximately 3/8 inch at each expansion joint. No corrections were made for curvature of the span when loaded since the exact rotation at the joint is not known. However, simple scribes (Figure 38) placed at each joint later revealed that the movement was erratic.

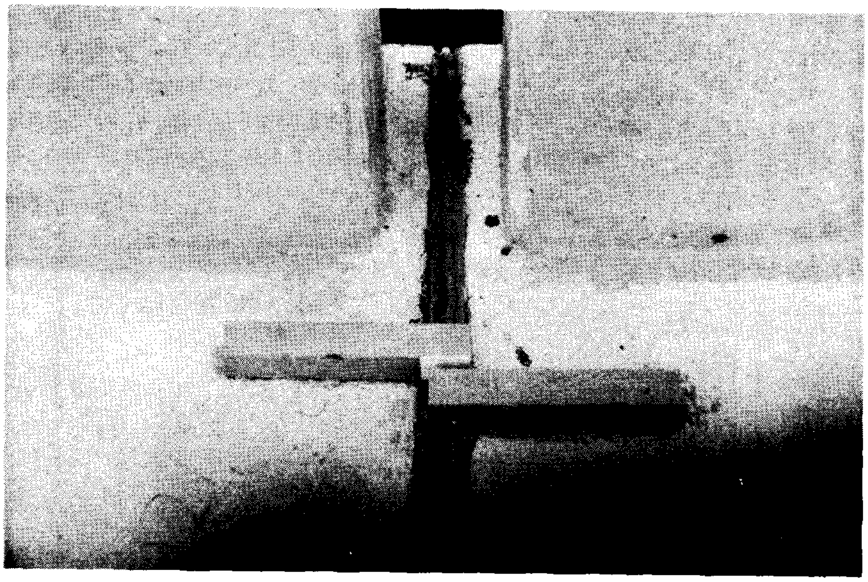

FIGURE 38
Movement Measurement Scribes

On the Lake Pontchartrain Bridge where the installation took place, an expansion joint was placed after several fixed joints. The expansion joint would sometimes lock or partially lock, the piling would deflect, and the movement would be transmitted through the fixed joints to the next expansion joint. Thus some expansion joints moved less than expected, whereas others moved much more than expected as shown in Appendix B, Table 4.

The Bridge Design Section was very interested in the actual versus the theoretical movements on this bridge, and these results raised questions concerning actual movements on other bridges. At the request of the Bridge Design Section, scribes were placed to record the maximum and minimum openings at five other bridges. These results are reported in Appendix B, Table 3.

In an effort to find the best available sealant, 40 suppliers were contacted and requested to participate. Each supplier could install his product as he desired. Each supplier was required to furnish samples for testing and a copy of his material's specifications. Eight manufacturers installed sixteen different "models" or products. As detailed in the "Methodology", a pictorial record as well as periodic inspection reviews were conducted.

The pictorial records tell a most interesting story, having the opening setting (Figure 39), the characterization (Figure 40), the thickening of the plot (Figure 41), and, unfortunately, in many cases, the conclusion (Figure 42).

The complete results may be found in detail in Appendix B, Table 4.

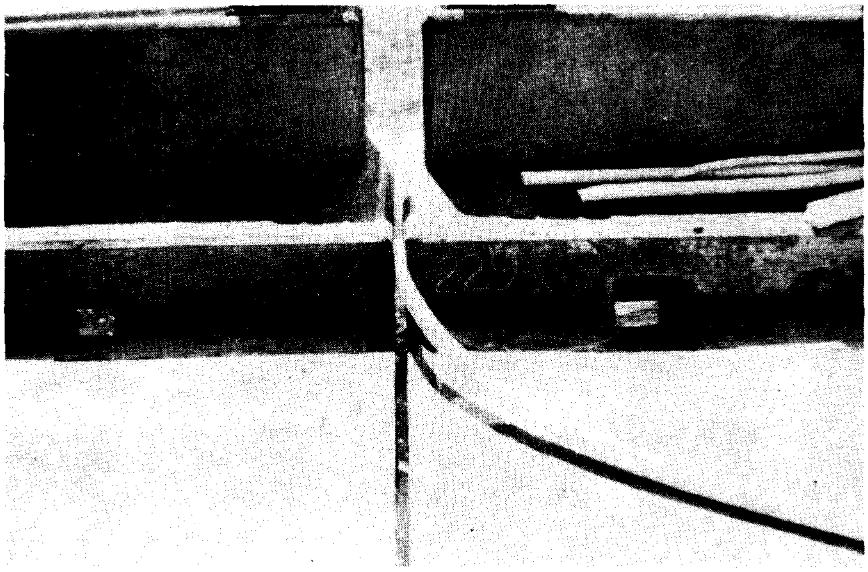

FIGURE 39
Joint Prior to Installation

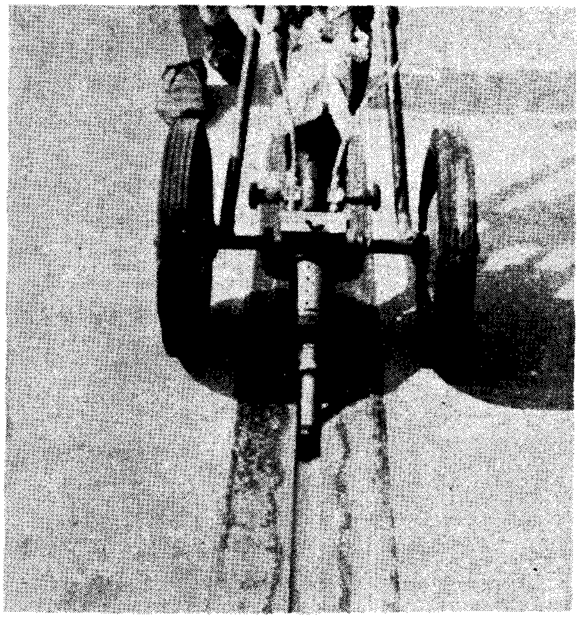

FIGURE 40
Experimental Installation

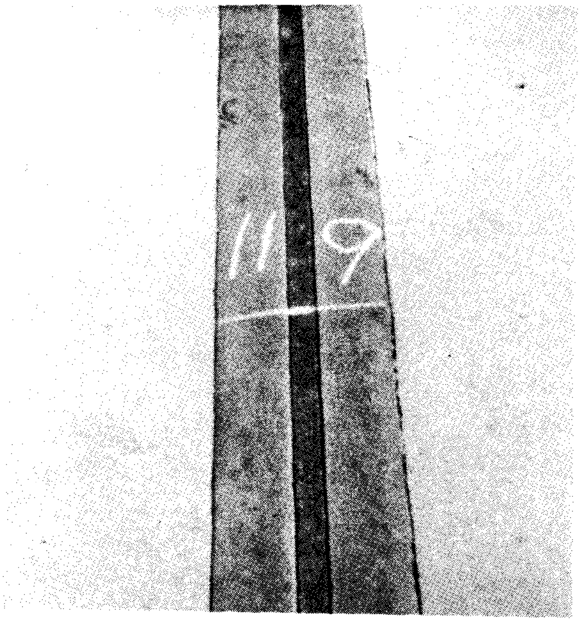

FIGURE 41
Completed, Cured Installation

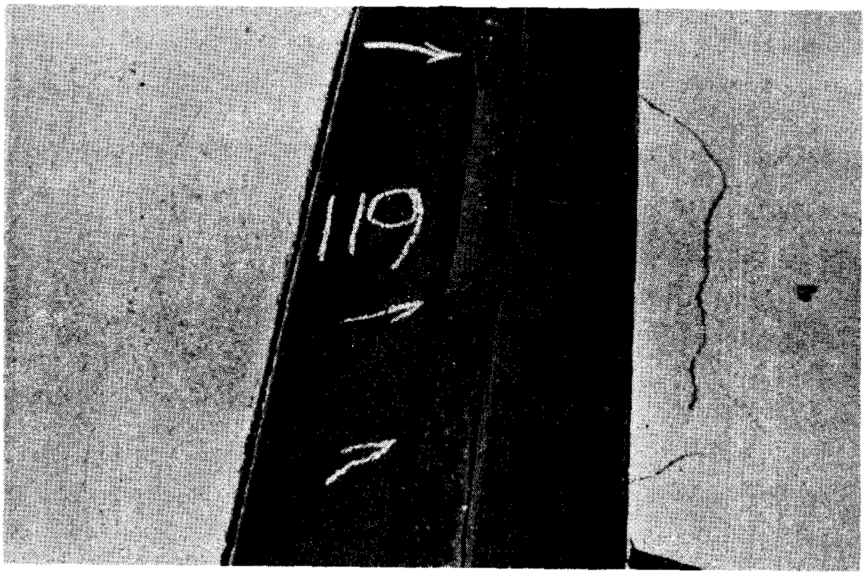

FIGURE 42
Subsequent Review of Installation

Liquid Poured:

Excluding reinstallation, only one liquid-poured material, a two component polyurethane, is still effectively sealing the joints. This same product had been previously placed experimentally in two fixed joints on another bridge and it is still functioning after six years (Figure 43). It was also previously placed on an extended elevated section and at the present time, half the joints are failing.

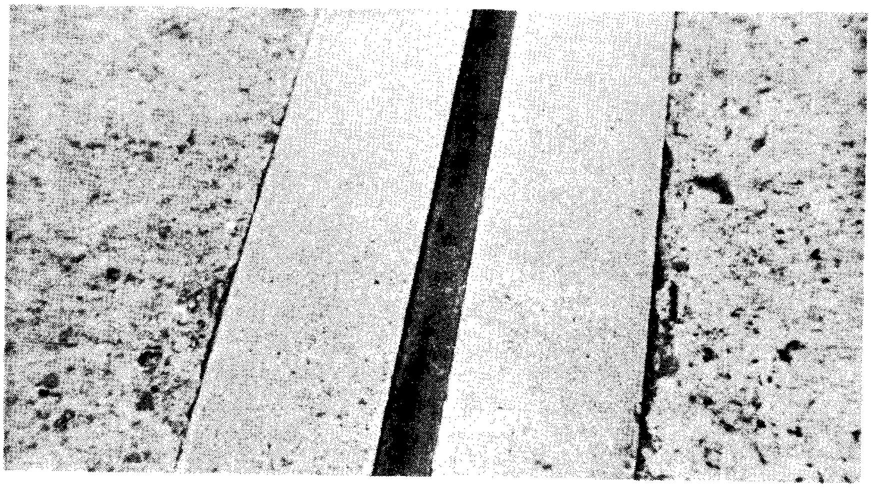

FIGURE 43

Compression Seals:

All of the compression seals still remain at least partially effective after three years in service. The two ineffectively sealed sections containing compression seals were unsuccessful because the engineering design transformed into the actual bridge design was unable to determine and control the joints' movement. In both cases the maximum joint opening exceeded the manufacturer's recommended maximum joint opening.

The "successful" compression seal installations remain effective in preventing pressure buildup due to the infiltration of incompressible material. They also appear effective in preventing water leakage; however, slight seepage of water is suspected through portions of some of the joints. This has not been actually observed partially due to the difficulty in observing the underside of a bridge which spans a lake.

One "low pressure" seal has been noted to have fines infiltrated between the seal's sidewall and the joint armor. These fines are still along the top half of the seal, and it is felt that they have not yet penetrated the seal. However, this is a detrimental condition and will most likely aid in the progressive inclusion of fines and water leakage.

One physical characteristic of a true compression seal that is necessary for successful performance is the continued presence of adequate sidewall pressure. Therefore, the sidewall pressure of each seal (at 80 percent nominal width, the most critical condition) was measured in its original condition and will continue to be measured periodically. Appendix B, Table 5 summarizes these results. Since compression seals are man-made objects, variations can exist as a result of differences in formulation, cure, extrusion speed, etc. It is not purported that this data is "scientifically valid," since a tremendously large quantity of data is needed for a scientifically correct conclusion. However, while the data offers some interesting trends concerning loss of pressure, no conclusions should be reached concerning any one sealant because of lack of data quantity.

The minimum sidewall pressure necessary for adequate performance is debatable. A device has been constructed in an attempt to determine the minimum adequate pressure; however, this testing program has just been initiated. A sidewall pressure of one psi was selected as the minimum pressure necessary for adequate performance. Projected curves (Figure 44) of the sidewall pressure loss out to 10 years service indicated an initial sidewall pressure of approximately three psi would be necessary to compensate for the pressure loss. If the pressure decay follows a straight-line ratio (Figure 44), the service life will be reduced. Therefore, the Department's recent specifications require this three psi initial pressure.

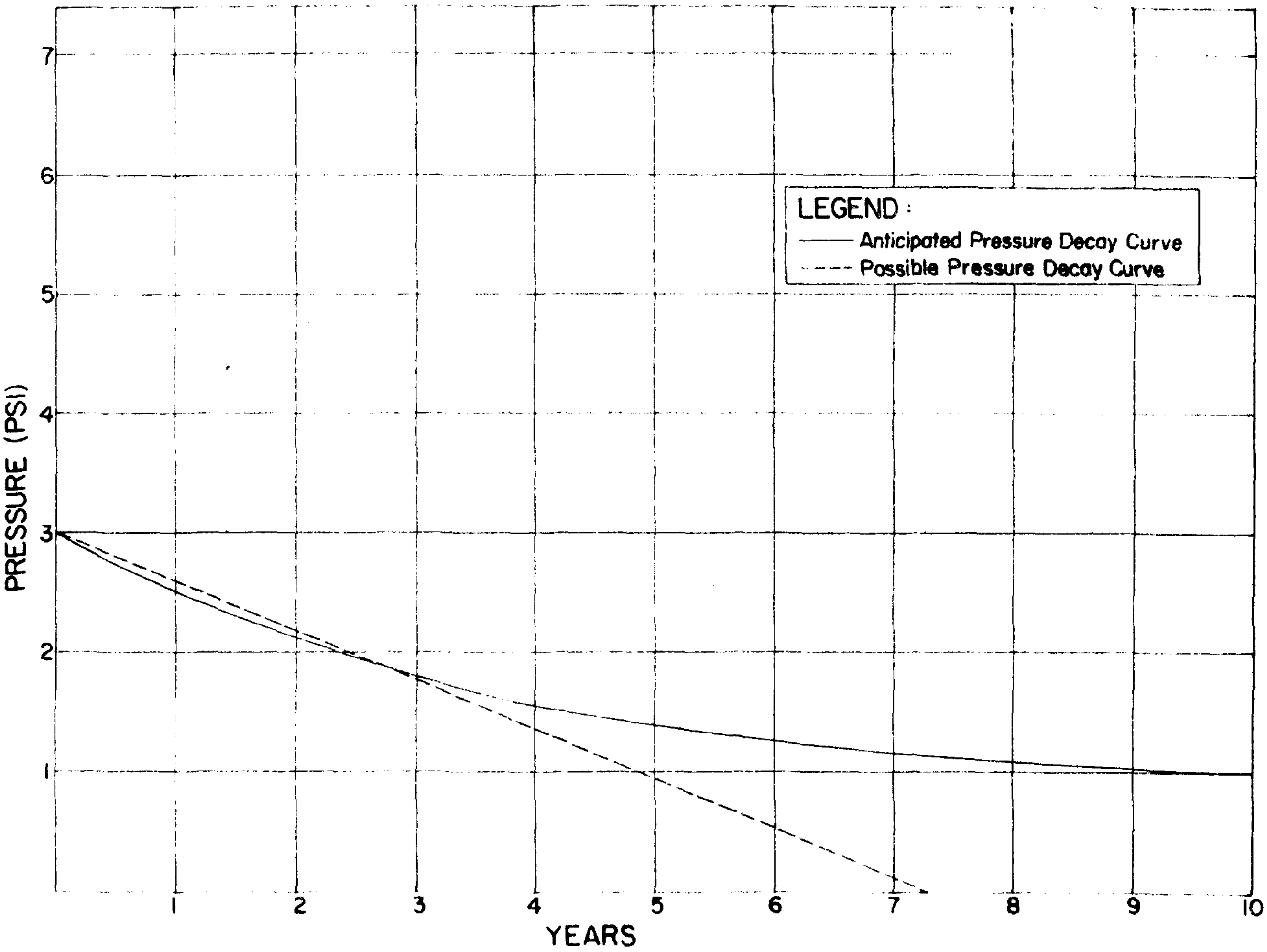

FIGURE 44
Pressure-Decay Curve

It has been observed in the laboratory that those seals generating extreme pressure deteriorate the fastest, develop web adhesions or possess the sharpest pressure loss, despite the field data of Table 5. Therefore, possibly as detrimental as a low pressure seal is a beefed up seal with "too much" pressure, assuming the seal is forced to move through a movement range between 50 percent to 80 percent of its nominal width. The amount of pressure designated as "too much" can, at present, only be speculated. Because of this unknown, the Departments' recent specifications place no maximum limit upon pressure for bridge seals. Instead this physical characteristic as well as the performance adequacy of the various seal configuration are controlled by a "qualified products list" based upon test data supported by actual field performance.

Because of the aforementioned pressure decay of compression seals, adhesion of the seal's sidewalls to the joint face seems most desireable. Many of the lubricant-adhesives appear to possess adhesive qualities in name only. This project's testing program concerning lubricant-adhesives has not yet been fully initiated, so a worthwhile opinion cannot truly be stated as regards laboratory tests. However, the field observation of relative performance follows:

One manufacturer made several installations with the aid of soap and water as a lubriciant. The top edge of the seal has curled slightly away from the joint walls, and a very small amount of fines infiltration has begun.

Two manufacturers made installations with a "low solids" (25 percent solids) glue. In both cases, the glue appears as thin streaks on the seal and seems to offer only the slightest resistance when removing a two year old compression seal installation. In the case where the joint opened in excess of 80 percent of the seals's nominal width but less than the nominal width itself, the adhesive was not successful in preventing sand intrusion.

One manufacturer used a "high solids" (75 percent solids) lubricant-adhesive, which was a moisture-cured polyurethane. In one instance on another project, the maximum joint opening equaled the seal's nominal width, yet incompressible infiltration did not occur, and it did not appear that the glue line was broken. Considerable force was required in removing a two year old compression seal installation which utilized this glue.

Thus, when application is correct, the lubricant-adhesive does aid the seal's performance.

Sealing Transverse Pavement Joints

The movements of transverse portland cement concrete pavement joints are not nearly as severe as the movements of bridge joints. Bridge joint movements include racking motions and sharp, rapid movements as well as other factors such as non-uniform joint widths, skew, etc. Pavement joint movements on the other hand are relatively one dimensional; however, even pavement joint movements are non-uniform and jerky. Because pavement slabs warp and curl due to temperature and moisture changes, there is some slight vertical movement exerted on the sealant causing a rotational force on the sealant material about its longitudinal axis. Giordano and Pachuta (7) showed that this force is slight, but for certain materials sensitive to this type movement, this small force constantly repeated because of vehicle traffic presents a potential source of fatigue failure.

Giordano and Pachuta (7) also reported that the major movement, that of thermal expansion and contraction, occurred in a slip-stick fashion, Cook and Lewis (1, p.17) reasoned that: "The temperature change builds up stresses in the slab. Under some conditions, this buildup continues until the stresses exceed the frictional force between slab and subgrade. At this point, a short incremental movement of slab begins." Thus the Bostik Tester, upon which much of our original testing effort was developed, closely simulates actual conditions since its movements occur in a slip-stick fashion in an enclosed environmental chamber. This device and its results are discussed in more detail in the Laboratory Testing portion of this report.

Louisiana's Pavement Design:

The location of the concrete pavement used for the experimental test is shown in Figure 37. The particular pavement used for the evaluation is detailed in the "Methodology".

At the time of the evaluation, Louisiana had two basic types of pavement design. High traffic count facilities were 10 inches thick, reinforced, with 58 1/2 feet between joints. This was the type used for the evaluation. The theoretical joint movement was 3/8 inch. Lower traffic count roads were eight or nine inches thick, unreinforced, with 20 feet between joints. The theoretical joint movement was 1/8 inch. For both designs the joints were 3/8 inches wide and 2 1/2 inches deep.

In evaluating pavement performance across the state, several reoccurring distress patterns were noted to be associated with the 58 1/2 foot reinforced slabs. These signs of distress were:

(1) Pavement growth - all of the projects "grew," that is, developed pavement thrust very quickly.

(2) Spalling - after approximately eight to ten years of service, major joint spalling was prevalent.

(3) Uncontrolled cracking - midpoint and third-point cracking commonly occurred between joints.

Because of these problems, this type design is no longer used, and though the thickness may vary according to projected usage, the slab lengths are 20 feet long and unreinforced. Even though the early Present Serviceability Indices* may be less than those for the longer slab lengths because of the increased joints, it is felt that the Present Serviceability Indicies over the total design life will be improved and that the aforementioned problems will be less frequent. The shorter slab length design is recommended by PCA and the Federal Highway Administration (M. F. Maloney's FHWA Notice of March 10, 1971).

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*Note: Present Serviceability Index is an AASHO Road Test developed concept for rating a pavement's performance based upon slope variance and certain signs of distress.

During one design phase when the 58 1/2 foot slabs were used, the concrete pavement was placed on top of a one inch sand asphalt blanket which rested upon a stabilized base. Other designs of this period have the pavement resting directly atop a stabilized base course or an aggregate base course and do not use the sand blanket. Although an insufficient amount of time for proper performance comparison has passed, it appears that the design containing the one inch asphalt sand blanket has less intermediate slab cracking, no faulting and less spalling than the other designs which place the pavement directly on top of the base course. It is expected that less spalling will occur with the asphalt sand blanket design since fines infiltration from beneath the joint can be equal to the incompressible infiltration from above. The sand blanket appears to minimize the fines intrusion from beneath. At times when replacement construction requires the removal of old concrete slabs, it has been noted that the joint spalling at the bottom of the slab can be as prevalent as the spalls at the top of the slab. Spellman (6) showed the magnitude of the problem of fines infiltration originating from beneath or beside the slab.

Pavement Joint Design:

The 58 1/2 foot pavement slabs having a 3/8 inch wide joint and a theoretical maximum movement of 3/8 inch have a 100 percent movement at the joint. Most of the available sealant materials on the market at the time of the evaluation claimed movement capabilities of 60 percent. Hiss and Brewster (8) showed that, within certain limits, joint widths had little effect on roughness and noise. Therefore, for the joint evaluation portion of the test project, the joints were widened to 5/8 inch, thus reducing the theoretical joint movement to 60 percent.

Scribes (Figure 45) were designed and placed within the pavement joints to record the maximum joint movements in the experimental section. Many of the scribes were rendered inoperative because of an inferior glue; however, those that did remain recorded movements less than the theoretical movements. The experimental joints were also measured during temperature extremes and the data was projected to those joints with inoperative scribes. Table 6 in Appendix B lists the average joint movement that existed during the life of the material. The average joint movement was about 40 percent of the theoretical width. There are three reasons the percent movement has not equaled the theoretical percent movement.

(1) The actual temperature differential has not equaled the designed temperature differential.

(2) Frictional restraint exists between the slab and the base course, where the theoretical design assumes an unrestrained slab.

(3) Most of the slabs had two intermediate cracks between joints. These joints were observed to open slightly, accounting for some of the movement despite the steel reinforcement. McCarty, Brewster and Hiss (9) also noted thermally-related movements in longitudinal joints tied together with steel.

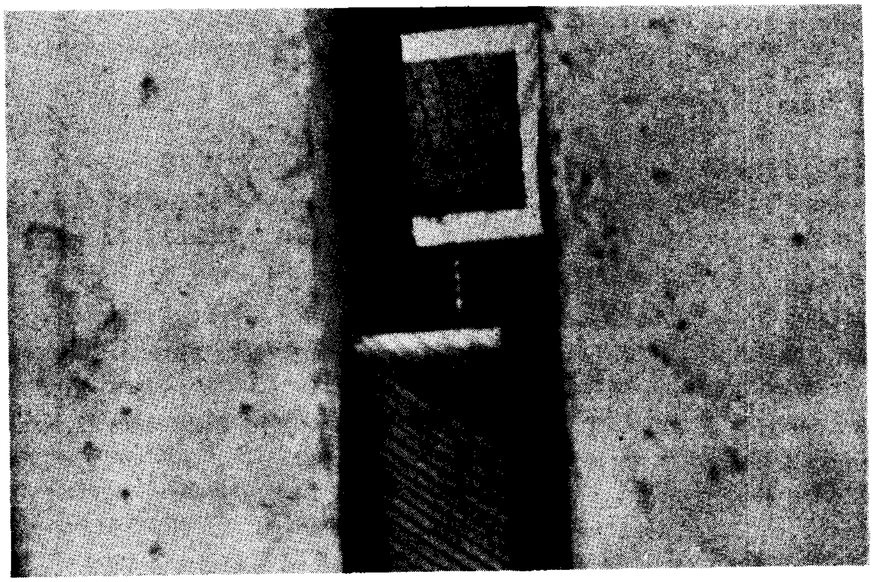

FIGURE 45

Pavement Joint Movement Scribe

Louisiana pavements are constructed with an extremely hard chert gravel. This aggregate precludes the sawing of joints because of its hardness. Therefore, the typical joint formation in Louisiana is by fiber board inserts later sawed out with abrasive or diamond blades. This type of joint formation has several problems associated with it which are as follows: (1) the tendency for a joint to taper in depth, (2) variation in joint widths according to how well the saw follows the insert, (3) increased joint edge spalling or raveling, (4) insufficient depth removal of insert because of blade wear, (5) insufficient removal of insert fibers from joint wall faces because the faces were not cleaned well.

Because of Louisiana's unique problem several innovations are being closely examined, one of which is a removable metal insert which will form perpendicular joint sidewalls. Other trials include the usage of a diamond blade saw with varying blade designs, and a permanent insert with a bonded neoprene cover (Sealinsert from the R. J. Company, Figure 46).

Several corrective measures have subsequently been developed concerning joint formation when using the sawed insert method.

(1) The insert itself should be asphalt free, since the blade friction heats the asphaltic material thereby depositing a thin asphaltic film along the joint walls which is difficult to remove.

(2) The insert should be removed in one saw pass since additional saw passages create increased joint width variations. Reducing the slab length has reduced the preformed compression seal size thereby reducing the necessary removal depth of the insert.

(3) Some allowance must be tolerated in joint width variations. An overall width variation of 1/8 inch is allowed as the seal itself is capable of accomodating an average variation of 3/16 inch, or 1/4 inch for a short distance. This pertains to the Department's current 7/16 inch wide joint with the 13/16 inch compression seal for the 20 foot slab length pavements.

(4) The concrete pavement should be allowed sufficient curing time prior to removal of the insert (a minimum of five curing days). This produces more immediate but less ultimate raveling and minor spalling. The spalling that does occur can be corrected prior to installation of the joint sealant.

(5) Sandblasting the joint sidewalls is required for complete removal of the insert's fibers from the sidewalls.

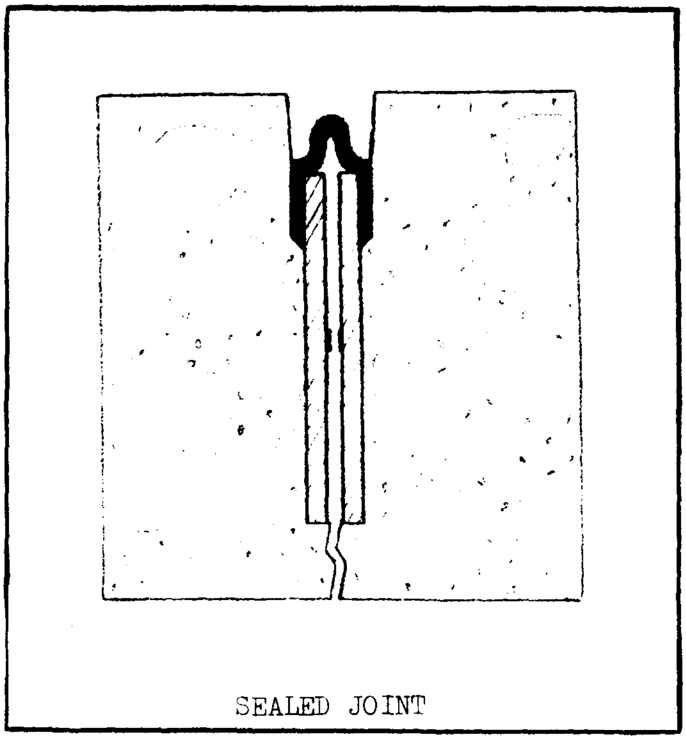

FIGURE 46
Sealinsert, Experimental Trial

Raveling and Minor Spalling:

The compression seals and most of the catalyzed liquid-poured sealants lasted at least one year, whereas the asphaltic based materials failed after the first sharp temperature drop. The one obvious trend associated with the sealed joints that were performing successfully after one year was the increased spalling during the first year of observation. The liquid-poured materials depend upon adhesion to the pavement for success; therefore, during pavement contraction, some tensile stresses are exerted upon the concrete, the amount dependent upon the stiffness of the sealant. Some of the catalyzed materials exerted considerable stress; naturally, these joints had the most minor spalling and raveling (Figure 47). However, even joints filled with compression seals showed some minor spalling.

A close investigation of the joints filled with asphalt based material revealed no edge raveling or minor spalling during the first year.

FIGURE 47

It was suspected that the joint formation creates flaws in the concrete edge. Successfully sealing the joint places more stress upon the edge; **whereas**, the asphaltic materials, which extrude slightly during warm weather, helped cushion the edge during the initial months. It is expected that these flaws would also show up in the joints filled with asphalt, but at a later date. However, it was impossible to actually show this, since the failing sealants had to be removed prior to project acceptance.

To determine if successfully sealed joints caused more edge spalling over a five year period, another approach was used. After the concrete was a year old, 10 joints adjacent to the evaluation section were cleaned out, resawed with diamond edge blades and filled with a liquid-poured, catalyzed material. A recent examination after one year of service revealed no spalling or raveling. Adjacent joints filled with rubberized asphalt showed (after two years service) some minor spalling and raveling, as well as adhesion and cohesion failure of the sealant. Therefore, the increased spalling of the successfully sealed joints was probably caused by flaws implanted during construction. The increased spalling was only an initial increase, after five years service it is expected the reverse will be true. As the poorly sealed joints fill with debris, stresses will be exerted on the pavement edge thus causing the poorly sealed joints to spall the most.

Most spalling (Figure 48) initially known to begin after approximately five years service on the asphaltic (poorly sealed) joints should be reduced or hopefully eliminated with well sealed joints.

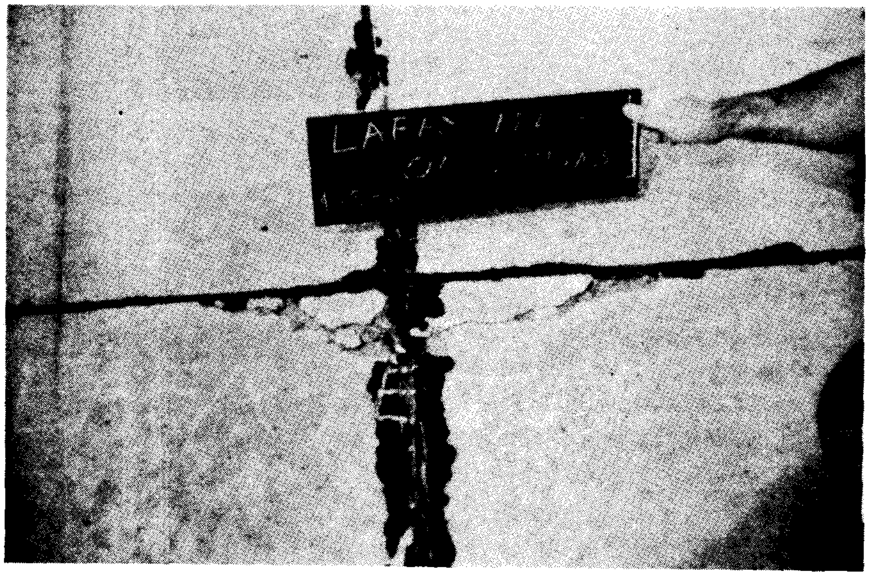

FIGURE 48

Most concrete pavement projects take two years to construct. Some of the most damaging infiltration can occur during this period (Figure 49). The specification language and actual inspection must scrupulously prevent this damage. Ideally, the joint sealants should be placed just prior to job acceptance provided the joints could be adequately protected from incompressible infiltration (water leakage could be tolerated). This would permit the concrete edge to sufficiently strengthen and the flaws to expose themselves and be easily repaired. In addition, the sealant would not be subjected to the ravages of the atmosphere. One solution may be to create the joint and protect it with a temporary sealant such as the backup rod of polyethylene until just prior to job acceptance. The backup rod could then be removed and discarded and the joint thoroughly cleaned and sealed. Some of the backup rod could possibly be reused if a liquid-poured sealant was used. This process would increase the joint sealing costs by approximately seven cents per foot, but may prove worthwhile on the basis of successful service life.

FIGURE 49

Pavement Joint Materials Used

Table 6 of Appendix B summarizes the evaluation results after 30 months of service. Twenty two different materials were evaluated. These materials are classified as liquid-poured and preformed.

Liquid Poured, Asphaltic Type:

The asphalt cement with mineral filler, the material widely used by maintenance forces for resealing joints, exhibited the poorest performance. This material failed in cohesion during the first seasonal cool weather. Remaining tacky, it trapped incompressibles like fly paper traps flies. In addition, it readily extruded from the joint (Figure 50). Upon failure the material was replaced, and the material's width-depth ratio was controlled. The replacement also failed rapidly.

Two types of catalytically blown asphalt were also used. Both materials were tough, did not track under traffic or excessively extrude. Both gradually began to show signs of roping failure from the beginning. After the passage of the first cold front, both materials had completely failed.

Rubberized asphalt conforming to AASHO M-173-60 was used. It failed within four months in cohesion, with entrapment and embedment of gravel also being noted. Removal prior to reinstallation clearly indicated particle entrapment (Figure 51). Sealant thickness was controlled during reinstallation but failure again occurred within four months. Slight material extrusion from the joint was also noted.

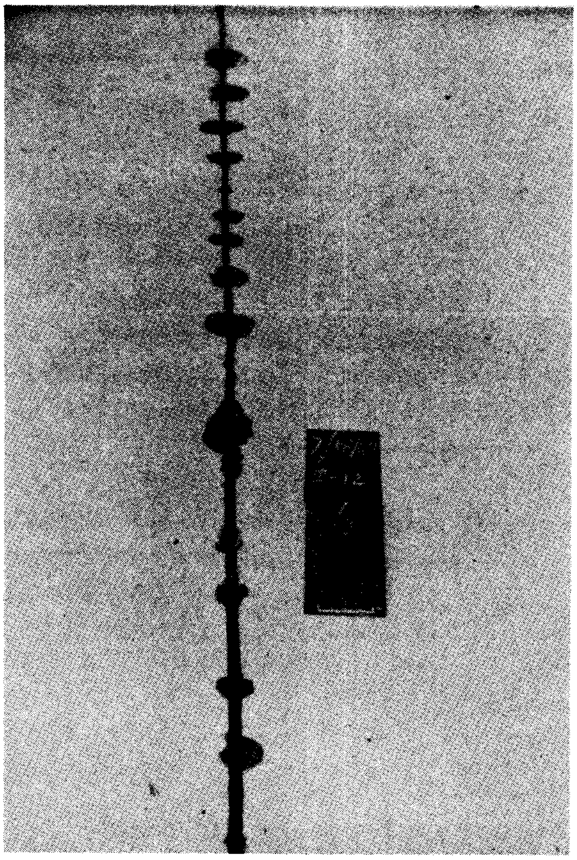

FIGURE 50

FIGURE 51

An improved rubberized asphalt containing synthetic rubber and conforming to ASTM D 1854-61T and Federal Specification SS-S-167b was also used. While its characteristics seemed more rubberlike and appeared less susceptible to temperature extremes, it too failed (mostly in adhesion) within four months. Upon removal and prior to reinstallation, material embedment and excessive wetness were noted. The reinstallation failed within four months.

Both rubberized asphalts were exceptionally difficult to completely remove from the joint, a factor which must be considered for maintenance of all joint materials.

Based upon these observations and reinforced by subsequent observations on other projects, it was concluded that asphaltic materials do not work in a concrete paving joint subject to movement. In addition, these materials do not prevent incompressible material infiltration. In a joint whose movement is restricted by steel and where incompressible infiltration is not a major problem, the rubberized asphalts are, for the most part, successful in preventing water leakage and do not objectionably extrude from the joint. The asphalt cement with mineral filler, however, does extrude objectionably in addition to tracking badly under traffic.

Liquid-Poured, Catalyzed Polymers:

The catalyzed polymers can be grouped into four main classes: polysulfide, liquid neoprene, polyurethane and polyvinyl chloride. The groupings are in the most liberal terms imaginable, and just as "toothpaste" does not distinguish between Superwhite and Brand X, all catalyzed polymers should not be judged according to the ones evaluated here.

Each material contains a base material (which may differ from another base material with the same name) extended with a less expensive filler material. Unlike the rubberized asphalts, each material changes to a solid, rubber-like material upon reaction with moisture or heat, or a catalyzing agent.

Each sealant, being a solid material, is directly affected by its depth-width ratio. As Tons (10) showed, this solid material cannot change in volume as joint movement occurs but must instead change its shape. The sealer curves in equally from the top and bottom of the joints upon extension of the joint. Strain determinations along the sealant surface at different thicknesses showed that the optimum depth of the sealant should be one-half of its width to reduce the strain to a minimum. In practice, this thickness should not be less than 1/2 inch; therefore, with the joints of this project being 5/8 inches wide, this ratio was approximately 5:4 rather than 2:1.

Several of the installations lasted over one year and a few served well for approximately two years. One material, Superseal 444, is still functioning well after 20 months; however this material was placed at a much later date than the other products, with the critical time for most of the installations being the winter of the second year. One polyurethane, P.R.C., exhibits five joints still functioning after approximately 20 months. However, 20 other joints with this material now exhibit failures. As discussed later in the laboratory testing portion of this report, several other polyurethanes possess properties equivalent to P.R.C.; however, one definite advantage of machine-mixed P.R.C. is the swift curing time. The Superseal 444 also cures quickly upon cooling.

A pavement joint in the field does not remain still as do blocks in the laboratory, waiting until final cure of the sealant before moving. Then too, in the field, the wind blows dust, the temperature varies in wide extremes, and unexpected showers or a heavy dew may occur. For these reasons, it would seem vitally important that the sealant self-cure within an hour, or better yet, within minutes.

Disadvantages of the two component system are the ease at which variations in proportions can occur (proper proporations are vital) and the ease at which insufficient mixing can occur (attainment of sufficient shear during mixing is necessary). Improper priming of the joint walls is also a source of failure. Proper joint and sealant protection must be maintained during installation and cure, and good conditions during cure must exist for success.

Suppliers manufacturing rubber products in controlled conditions in a shop can produce inadequate materials (witness the many physical test property failures that occur on neoprene bridge pads or compression seals). Therefore, if manufacturing problems can occur under controlled conditions, then surely they will occur under uncontrolled field conditions. This undesirable feature would not in itself be completely detrimental provided the flawed installations would immediately expose themselves for correction. However, just the opposite is true, as inadequate installations can last a month to twelve months before they reveal themselves. Thus, the consumer has no evidence the installations are adequate. Strict inspection during installation may help, but again offers no assurance of success.

Nevertheless, some of these polymers possess sufficient physical properties for successful performance. Materials, properly mixed, cured and installed in the laboratory perform well. The blocks in Figure 52 can be twisted 180°F without material failure. The material can withstand weatherometer exposures equivalent to five years. The material can withstand relatively rapid extension-compression cycles in a controlled environment of temperature extremes. In the field, despite numerous adjacent failures, some of the installations perform as hoped. Thus, because of the laboratory success and the few field successes, it is felt these materials can work if the reasons for field failure can be discovered.

However, when the decision must be reached concerning day-to-day usage in a construction or maintenance atmosphere, the disadvantages, at this time, outweigh acceptance. In short, the consumers want a product that will work or can be corrected to work prior to job acceptance. Attempts are being made to devise field tests or field acceptance procedures that will ensure successful application. Without doubt, a liquid-poured sealer is definitely needed in cases of varied joint widths or ragged joint walls. However, at this time, these materials are not being specified in Louisiana.

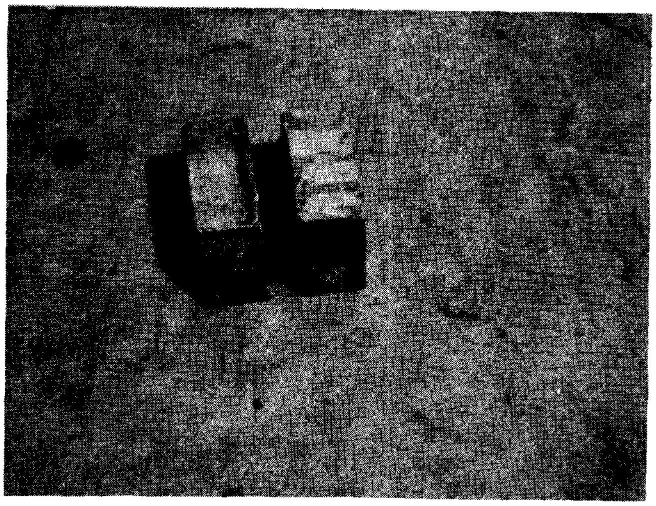

FIGURE 52
Sample Ready for Bostik Test

Compression Seals:

All of the compression seals are still functioning effectively. One of the seals, possessing ears or lips at the top, has curled slightly away from the joint edge at the top. Some fines infiltration has begun; however, as yet, they have not penetrated past the upper layer of the steel.

Williams (2) noted that standing water finally soaks past the seal. However, upon close observation during wet conditions, it appears that water penetration past the seal in a pavement which has an adequate tangent crown is very slight. However, at the longitudinal joint between the pavement and the shoulder considerable leakage did occur, making it impossible to actually determine the seal's water tightness.

Since Louisiana uses stabilized bases beneath concrete pavements and since deicing salts are not used, the slight amount of water seepage that does occur at transverse joints would not detrimentally affect the pavement's performance. However, more adequate sealing techniques must be found for sealing the joint between the shoulder and pavement since this is where the largest amount of water entrance occurs. Several different trials were made at sealing this shoulder pavement joint, none really completely effective.

Because of the effectiveness of the installations, Louisiana now specifies only compression seals for use in transverse contraction joints in concrete pavements. Hopefully, because of the need and also for competition's sake, a liquid-poured polymeric sealant can be accepted in the future. One important characteristic of both the compression seals and the liquid-poured polymeric sealants must not be overlooked: that is, even upon failure these materials are partially effective, for the solid, flexible material acts as a buffer for the incompressible materials that wedge into the adhesion or cohesion failures. These materials effectively reject the larger debris without becoming displaced as easily as asphaltic materials.

The desirable material properties of a pavement compression seal parallel those of the bridge compression seals discussed earlier. Again, a minimum pressure is necessary for success, three psi at 80 percent nominal width being selected.

One advantage inherent in pavement compression seals over bridge compression seals is the relative uniformity of joint size. Because of this uniformity, desirable characterics should be easier to control. While a minimum pressure limit at the widest opening is necessary, a maximum pressure limit at the narrowest opening is highly desirable since extreme pressures accelerate the breakdown of rubber. Thus, a "low stress" seal would seem to offer advantages. Because of the closeness in size, the pavement seals were examined as a group, and a maximum pressure of 25 psi at 50 percent nominal width was selected. This was determined by examining the "Z" value characteristics of the seals. ("Z" value can be defined as the limit of safe compressibility and is the compressed width of the seal at that point at which unobstructed closure of the air voids has ceased and compression of the solids, or extrusion, is initiated. This point is defined on the pressure-deflection curve by a rapid and considerable increase in pressure).

The single most important test which seems closest related to observed field difficulties appears to be the high temperature recovery test. A seal that passes this test (the specifying agency should actually run this test and not accept a certification alone) will be at least partially effective in the field provided, of course, joint formation and installation procedures are adequate.

As with the bridge seal evaluation, the most effective lubricant-adhesive used with the compression seals was the high solids type. However, because regulations are less stringently enforced (most of the lubricant-adhesive is wiped off during installation) and because performance conditions are less severe in pavements, the 25 percent solids type lubricant-adhesive conforming to AASHO requirements for pavement seals seems adequate for pavement sealing purposes.

In most cases, inadequate compression seal installations rapidly manifest deficiencies that are obvious upon close inspection. This allows correction prior to job acceptance. Adequate performance for five years is expected of these seals, with ten years life hoped for and under ideal conditions, attainable. No doubt, as knowledge in this relatively new field is gained, more extended performance life will be possible.

A Trial Pavement Anchorage Attempt:

As described earlier, pavement thrust upon structures is a very real and serious phenomena. In many instances, the problem is not relieved until after the damage is done. Transfer of this problem back to the pavement with the resulting spalling or blow-ups would seem to be the lesser of two evils.

Therefore, if the pavement could be anchored next to a structure, the structure would not be damaged and the pavement damage, immediately noticeable, could be immediately corrected. It is theorized that keeping the joints free of incompressibles 1000 feet to 2000 feet adjacent to the structure would provide sufficient pavement weight and friction to resist pavement growth and creep.

In order to observe pavement thrust, areas exhibiting thrust adjacent to four structures were selected. A measurement system was devised, and periodic measurements are regularly being taken at several joints within each area. One section is a control section, and its joints are to be cleaned and repoured according to the regular maintenance schedule. Sections of 500 feet, 1000 feet and 1500 feet respectively have been selected for the area adjacent to the other three bridges. In each respective area, the joints have been completely cleaned of asphalt and debris and resealed with compression seals. (It is interesting to note the joints had enlarged from the original 3/8 inches to an average of 5/8 inch.) The four inch wide pressure relief joints have also been cleaned, rewidened to a four inch width and sealed with a compression seal.

It will be several years before an adequate determination can be made. The installations were made in September, 1969. A recent examination revealed no closure of the relief joints where the compression seals were installed. A very slight closure may have occurred on the uncorrected control section. The closure is so slight it is not significant at this time for the measurements must be compared during the same time of year and at the same approximate temperature.

THE LABORATORY TEST PROGRAM

Poured Joint Sealer

The test results of liquid cold pour concrete joint sealers are listed in Table 8 of Appendix C. There were 15 joint materials studied in this laboratory phase of the project. Some of the results in Table 8 are incomplete due to equipment difficulties, the materials' short shelf life and the time at which the materials were received.

Physical Testing:

Detailed in Table 8 are 10 tests conducted on each material. These tests were Bostik Cycles, Percent Recover at 39°F and 122°F, Color, Ductility at 39°F and 77°F, Ozone, Shrinkage, Hardness or Penetration at 39°F and 77°F, Time of Set or Tack Free, and Weatherometer Exposure. Procedures for all tests except the Bostik are covered in ASTM specifications. The relative merits of each may be defined as follows:

(1) Bostik Cycles - These are the number of complete cycles, expansion and contraction, that the sealant endured without failure. The procedure was to prepare the sealant in accordance with the manufacturer's instruction, pour the sealant to a controlled 1/2 inch thickness between two 2 inch x 2 inch concrete blocks (Figure 52) to a width of 1/2 inch and a length of two inches. The sealant was allowed to cure seven days. The blocks were placed in the Bostik Environmental Cycling Chamber. A cycle consisted of gradually cooling and elongating the sealant to an ultimate elongation of 65 percent at 0°F, then gradually heating and compressing the sealant to an ultimate compression of 35 percent at 160°F. Each cycle took 24 hours. After various trials of cycle ratios and number of cycles, a test was considered to pass after 40 cycles without failure. The failures were listed under two rather broad descriptions, adhesion failure or cohesion failure (Reference 11). Adhesion failure is a failure between the joint material and the concrete surface, usually caused by either no primer (the primer was a low solid rubber-solvent mixture which was applied 30-60 minutes prior to application of joint material) or an ineffective primer. Cohesion failure is a failure within the material itself caused by an inability of the joint material to withstand the movement and/or the environmental changes.

(2) Percent Recovery - This test determines the ability of the material to regain or recover from prolonged cycles of compression at both 39°F and 122°F. It examines a material's stress relaxation properties as well as flexibility properties.

(3) Color - This test merely indicates the color of the joint material and gives some inclination as to the type of extender present.

(4) Ductility - This test is one of elongation only and gives some insight as to the amount of elongation that a material may undergo. It is conducted at two temperatures, 39°F and 77°F. It could give some indication as to whether material may or may not "rope." Roping occurs when a material undergoes a large amount of elongation and during this expansion cycle, fatigues beyond the point of recovery.

(5) Ozone - This test is a visual evaluation of a material's ability to withstand ozone exposure. The material is examined prior to placement in the ozone cabinet. After placement in the ozone cabinet, the material is subjected to ozone gas for a given period of time then re-examined for oxidation reactions which are evidenced by cracking in the surface of the material. This laboratory test could possibly give some indication of the serviceability of the material due to weather conditions.

(6) Shrinkage - The results of the test indicate the shrinkage of the material upon curing. Ideally, when the material cures it should not shrink, as shrinkage will cause internal stresses which could result in premature adhesion and/or cohesion failures.

(7) Hardness or Penetration - This test is indictative of the hardness of a material. Thus an evaluation may be made of a material's ability to undergo expansion and contraction movements, and also of the material's ability to prevent foreign material from penetrating its surface. The test is conducted at two temperatures, 39°F and 77°F. In two component materials, the rate of catalysis is dependent upon the amount and efficiency of the activator. When complete activation is not achieved, the material does not attain the correct hardness, and intrusion of aggregate into the joint is evident.

(8) Tack Free (Hours) - This is the time required for a material to surface cure and not attract aggregate due to its tacky condition.

(9) Weatherometer Exposure - This test is subjective and gives some indication as to the weathering characteristics of a material when exposed to high frequency ultra-light waves. Quite often, a material may cycle adequately but weather very poorly. This test is correlated to field conditions and allows an evaluation of a material's weathering properties under laboratory conditions.

(10) Infra-Red - Infra-red curves are run on each base resin as well as each activator for indentification purposes to insure that a material's chemical formulation is not changed without being noticed.

Correlation of laboratory tests to field performance is one of this project's most important objects. After a literature review of the available tests and after trials using the previously mentioned tests, a rather informal list of requirements was adopted for judgement purposes. Since this was done before the correlation has been completed, the validity of the predicted performance by the sealant are in no way definite.

Table 8 of Appendix C lists the results of the tests run. The tests considered most significant were the Bostik cycling, Percent Recovery, Ozone, Shrinkage, and Weatherometer.

The tentative requirement limits adopted were:

(1) Bostik cycles - pass the 40 cycles as described in the test description with no evidence of failure.
(2) Percent recovery - have minimum percent recoveries of 75% at 39°F and 122°F.
(3) Ozone - pass the test as described in ASTM D 1194-64.
(4) Shrinkage - the material should not shrink.
(5) Weatherometer - pass the test as described in ASTM D 750-68.

It may also be noted that these liquid-poured materials appear to have valuable properties, but it is very difficult to obtain these properties in the field due to improper mixing and improper application; whereas, obtaining adequate mixing and application in the laboratory is relatively simple. This observation seems to be the basis for the field program being unsuccessful. In other words, quite a few of these materials should be considered suitable for use, based on laboratory findings, but they do not perform satisfactorily in the field since many failures occur within six months after installation.

Preformed Joint Materials

The second phase of the laboratory study included evaluation of a different type of joint material. The type of joint material was called preformed neoprene compression seal. This material was composed basically of neoprene rubber with different designs in the cross-sections which, according to the manufacturer, tend to prevent fatigue or overstressing of the neoprene. The prevention of fatigue in this type of joint sealant is extremely important because the joint material is retained in the joint only by the sidewall force of the preformed joint material against the concrete joint wall. The sidewall force is proportional to the design of the inter-web or "shape-factor" of the preformed neoprene joint material. A lubricant-adhesive solution is used to ease the material installation, and upon curing, actually serves as an adhesive. However, much of this adhesive is wiped off during installation.

These types of joint materials are larger than the joint to be sealed, and are preformed. During installation they are squeezed closed, slipped into the joint, and then released. Upon release, the sidewall pressure of the preformed material against the walls of the joint actually holds the material inplace. Based on this concept, sidewall pressure and fatigue prevention of the joint-sealer design appear to be most important to successful performance.

Compression- Pressure Properties:

Figure 53 illustrates the wall pressure exerted by one inter-web design as it is compressed through various percentages of its nominal width. There is a significant difference in the wall pressure exerted by both different designs and different size of preformed materials. In addition, there appears to be a large difference in wall pressure at various stages of compression between various companies. This is illustrated in Figures 53, 54 and 55. This material is subjected to three cycles of compression and release with the readings taken on the third cycle.

Table 9 of the Appendix C lists the various preformed neoprene suppliers. Also included in this table are the various size of the preformed material supplied to the Department for study. The wall pressures exerted by the various preformed materials are listed also. As in the aforementioned paragraph, a large difference in wall pressure can be observed as the joint material is compressed. Table 9 is the numerical tabulation of the wall pressures. The wall forces are exerted on the original materials before any type of exposure. After exposure of these preformed materials, it is surmised that any reduction in wall pressure will have a significant bearing on field performance.

Table 10 of the Appendix C applies to compression test data of preformed joint materials before exposure, after several months of field installation and after weatherometer exposure on the original materials. The weatherometer exposure was conducted to determine, if possible, if a relationship exists between hours of accelerated exposure and months of field exposure. The numerical values of Table 10 indicate that in some instances the wall pressure of the preformed neoprene materials both decrease and increase from the original materials after field exposure. In addition, the accelerated exposures in the weatherometer do not tend to correlate with any field exposures regarding an increase or decrease in wall pressures. Based on Table 10, it does not appear that any type of correlation between field exposure and weatherometer exposure is feasible.

A new concept in wall pressure decrease is evident. Work has begun on obtaining wall pressure fatigue using the Bostik Cycling Environmental Chamber. The new concept involves reading wall pressure for a given shape of a preformed neoprene joint material. Once these wall pressures have been determined, the preformed joint material is then subjected to Bostik cycling and temperature control. After a given number of cycles, the preformed material is removed and wall pressures are redetermined. Tab le 11 of Appendix C is a sample from one source. It is apparent from this table that fatigue in wall pressure does occur with cycling. However, it has not been ascertained, at this point, if wall pressure fatigue occurs in the field at the same rate. In other words, if a preformed material can withstand 40 cycles of expansion and contraction, and if this material is unaffected by high intensity ultra-voilet light, it follows that this preformed material could possibly withstand 15 years of field exposure assuming two cycles of expansion and contraction per year in the field.

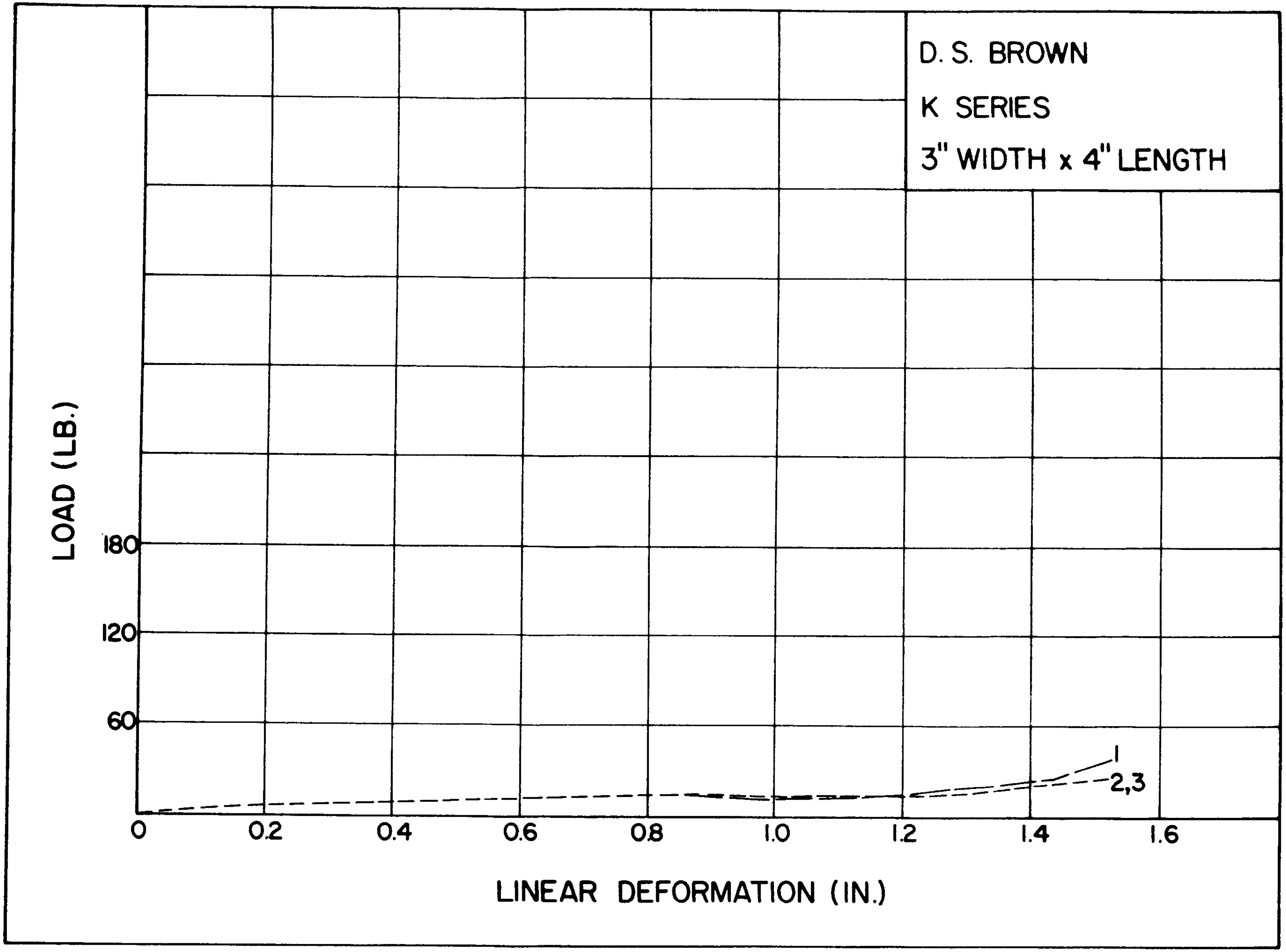

FIGURE 53
Typical Compression-Pressure Curve

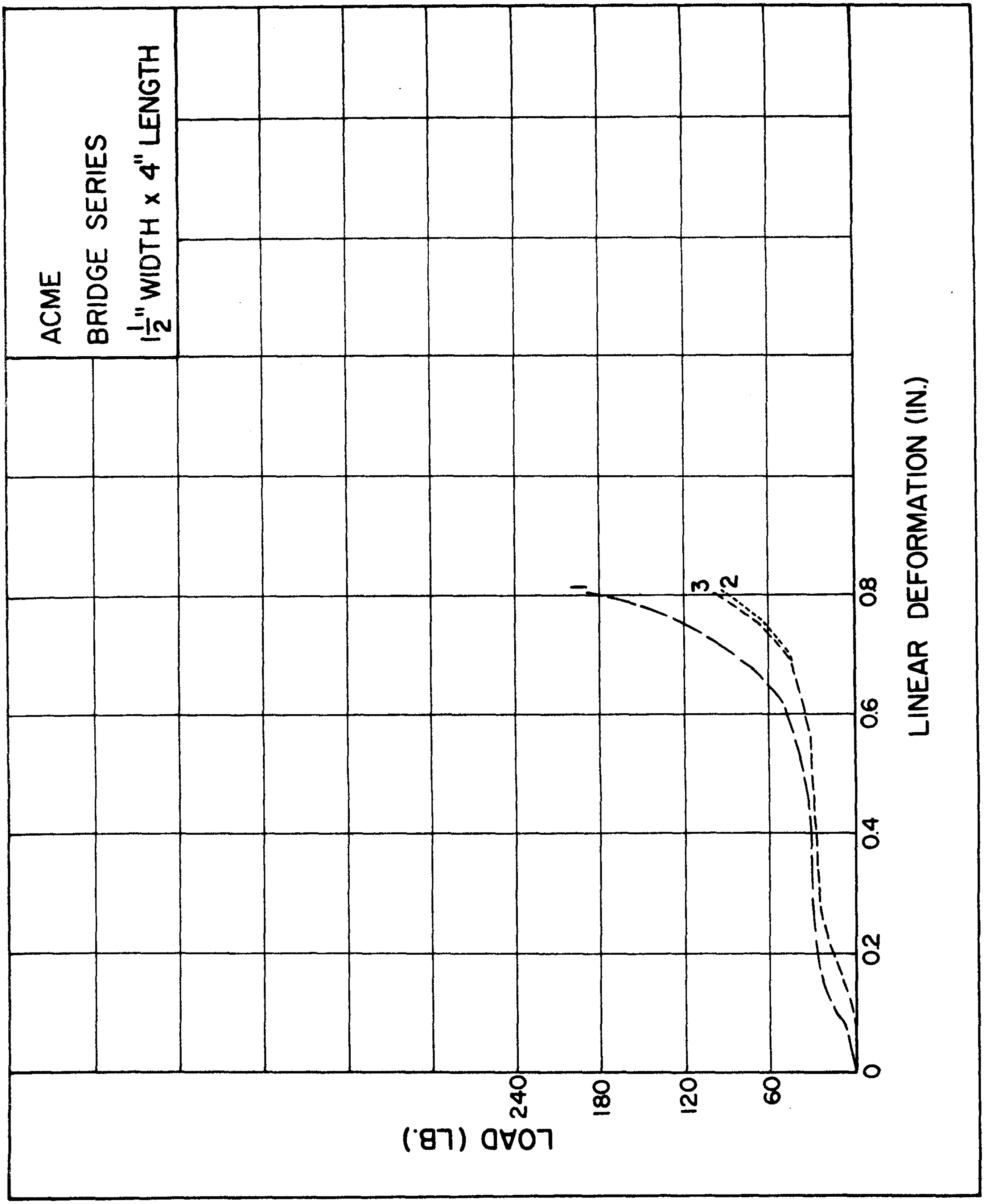

FIGURE 54
Typical Compression-Pressure Curve

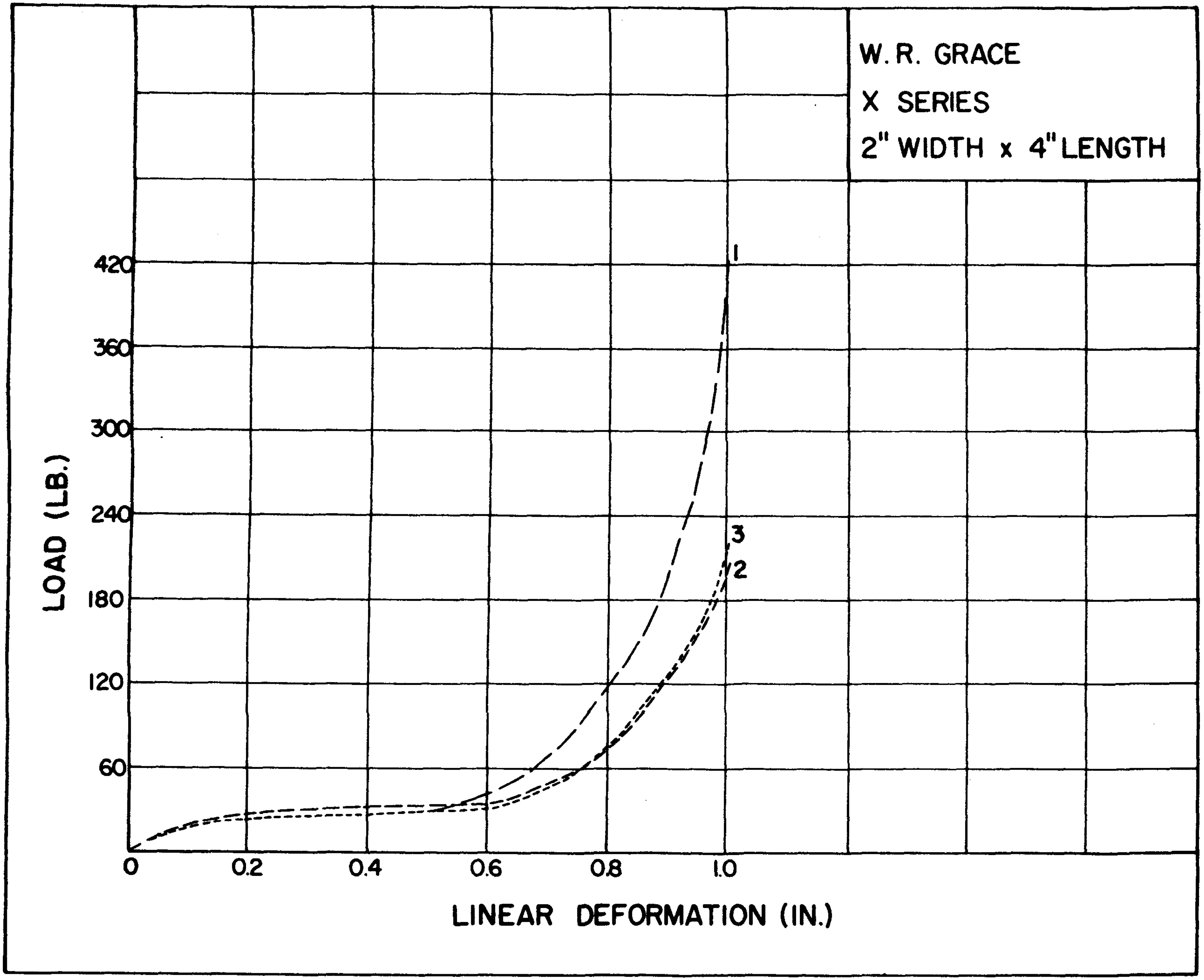

FIGURE 55
Typical Compression-Pressure Curve

CONCLUSIONS

1. All joints in concrete, whether pavement or structures, are more effective (sometimes effective only) when adequately sealed.

2. The most effective joint sealant was found to be the neoprene compression seals. On the other hand, the asphaltic based materials were especially deficient. A few of the polymeric sealants show promise for sealing pavement joints; however, with one exception, the installation procedures appear too sensitive for field use.

3. Adequate joint design must be based upon practical knowledge of available construction techniques and actual movement expectations. This practical knowledge includes recognizing and compensating for the variations present in the construction techniques together with figuring the actual movement expectations based on panel length. In short, the joint must be considered as a total system, rather than a hodge-podge of related parts.

4. Extended performance life appears possible using neoprene compression seals as more knowledge is gained through field performance, and the related critical areas are improved through materials design, formulation and use. Specification requirements and tests are currently going through a rapid transition period toward more realistic and more directly applicable tests and requirements.

5. The use of lubricant-adhesives is beneficial to the performance of neoprene compression seals. Some improvements in lubricant-adhesives have been realized. Further improvements in lubricant-adhesives and in the application and installation techniques are very possible and hopefully will be forthcoming in the very near future.

RECOMMENDATIONS

Almost all of the recommendations have already been implemented (see Implementation) and are too numerous to list in detail. In regards to the joint materials only, the major recommendations are:

1. Neoprene compression seals offer the best present solution to sealing concrete bridge and pavement joints and are being specified.

2. Several of the polymeric sealants show promise as a pavement sealant; however, the vast majority possess critically sensitive installation and application requirements. These liquid poured sealants are vitally needed, and if inspection procedures or tests can be developed to expose the flawed installations for replacement, several of these sealants could be used.

3. The asphaltic based materials are ineffective in sealing a joint exhibiting movement and they should not be used under these circumstances. Weatherometer tests also expose the inferior weathering characteristics of these materials.

4. Since neoprene compression seals exhibit loss of sidewall pressure upon use, some minimum initial pressure should be specified. Three psi at 80 percent nominal width is currently the Department's minimum requirement.

5. Continued research is needed in the improvement of existing materials, in the most efficient use of existing joint sealant systems, and in the development of new joint sealants systems. Meaningful evaluation techniques need to be developed which better predict field performance.

REFERENCES

1. John P. Cook and Russell M. Lewis, *Evaluation of Pavement Joint and Crack Sealing Materials and Practices*, National Cooperative Highway Research Program Report No. 38 (Washington: Highway Research Board, 1967), 40 pp.

2. Dennis L. Williaman, *Investigation of Use of Preformed, Compressed Neoprene Seals in Joints of Concrete Bridge Decks*, Kentucky Department of Highways Research Report (Lexington: Division of Research, 1968), 77 pp.

3. Stewart C. Watson, "Reconstruction and Effective Resealing of Joints on Existing Bridges and Structures," for presentation to the Committee on Maintenance of Structures, Highway Research Board, January 1970.

4. Robert L. Henry, *Final Report on a Study of Control of Pavement Movements Adjacent to Structures* (University of Mississippi, School of Engineering, 1968), 137 pp.

5. D. C. Gordinier and William P. Chamberlin, *Pressure Relief Joints for Rigid Pavements*, Interim Report on Research Project 245 (Albany: Engineering Research and Development Bureau, New York State Department of Transportation Agency, Division of Highways, 1970), 12pp.

6. J. J. Giordano and J. M. Pachuta, *Concrete Pavement Joints*, A Special Report delivered at the Symposium Elastoplastics in Commercial and Governmental Application; American Hotel, New York, June 3, 1968 (Thiokol Chemical Co., 1968), 39 pp.

7. D. L. Spellman, *California Pavement Faulting Study*, Interim Report on Research Project No. 635167 (Sacramento: State of California Transportation Agency, Division of Highways, 1970), 67 pp.

8. J. G. Hiss, Jr. and David R. Brewster, *The Influence of Joint Widths and Spacings on Pavement Riding Qualities*, Report on a Special Study under Physical Research Project 926 (Albany: Bureau of Physical Research, New York State Department of Transportation, 1968), 17 pp.

9. William M. McCarty, David R. Brewster, J. G. Fred Hiss, Jr., *Sealers for Longitudinal Joints*, Final Report on Research Project 39-1 (Albany: Engineering Research and Development Bureau, New York State Department of Transportation, 1971), 31 pp.

10. Egons Tons, "A Theoretical Approach to Design of a Road Joint Seal," Concrete Pavement: Subbase and Joint Construction, Highway Research Board Bulletin 229 (National Academy of Sciences, National Research Council, Publication 689), pp. 20-53.

11. Committee on Sealants and Fillers for Joints and Cracks in Pavements, HRB, Joint Sealing, A Glossary: Highway Research Board Special Report 112, 30 pp.

APPENDIX A

SEALANT INFORMATION

TABLE 1

PAVEMENT SEALS MATERIALS INFORMATION

I. Acme
  A. S-545
    1. A neoprene compression seal.
    2. The joints were sawed and sandblasted. The seal was installed by hand using a high solids (75%) glue lubricant E.P. Prima-Lub. (No. 1009). The seal was installed at least 1/4 inch below the top of the joint.

II. American Metaseal
  A. 355
    1. A black two part polysulfide.
    2. The joints were sawed, sandblasted and primed with S.P.I.D. The two components were drill mixed and hand poured onto a closed cell polyethelene backup material that controlled the depth of 1/2 inch at 1/4 inch below the top of the joint.

  B. 220
    1. A black two component polyurethane.
    2. The joints were sawed, sandblasted and primed with SP 30. The two components were drill mixed and hand poured onto a closed cell polyethelene backup material that controlled the thickness to 1/2 inch at 1/4 inch below the top of the joint.

III. ByWater
  A. ByWater Road Seal
    1. A two part polysulfide.
    2. The joint was sawed, sandblasted and primed with Byco seal primer, The two components were mixed and poured by hand onto a closed cell polyethelene foam backup material that controlled the depth to 1/2 inch at 1/4 inch below the top of the joint.

IV. Continental Products
  A. J.C. 26
    1. A two part polyurethane.
    2. The joints were sawed, sandblasted and primed. The two components were hand mixed and applied with a caulking gun onto a closed cell polyethelene backup material that controlled the thickness to 1/2 inch at 1/4 inch below the top of the joint.

TABLE 1

V. D. S. Brown

A. A and E 1250

1. Both are neoprene compression seals.
2. The joints were sawed and air blasted. The seals were installed and the glue was placed with a machine. The depth of installation was controlled by the machine at 1/4 inch below the surface. A low solids (25%) glue was used.

VI. DuPont

A. Imron

1. A black one part polyurethane with a 24 hour curing time..
2. The joint was sawed, sandblasted, air blasted and primed with V.M 5881. The material was in cartridges and was placed by using a hand caulking gun. The backup material was a closed cell polyethelene that controlled the depth to 1/2 inch at 1/4 inch below the top of the joint.

VII. Edoco

A. Code 3093

1. A two component polyurethane with a curing time of two hours.
2. The joints were sawed, sandblasted and primed with Edoco 3203 primer. The two components were hand mixed and applied onto a closed cell polyethelene foam backup material that controlled the thickness of 1/2 inch at 1/4 inch below the top of the joint.

VIII. Essex

A. Beta Seal 260

1. A two part polyurethane with a 3-4 hour cure.
2. The joints were sawed, sandblasted and primed with primer 435.6. The two materials were drill mixed and applied with a caulking gun onto a closed cell polyethelene backup material that controlled the the depth of 1/2 inch at 1/4 inch below the joint surface.

B. Beta Seal 250

1. A two part coal tar extended polyurethane with a 2-3 hour curing time.
2. The joints were sawed, sandblasted and primed with primer 435.6. The two components were drill-mixed and applied with a caulking gun onto a closed cell polyethelene backup material that controlled the depth of 1/2 inch at 1/4 inch below the surface of the joint.

TABLE 1

IX. Gulf States Asphalt

A. 621 X Soft
1. A catalytically blown asphalt.
2. The joints were sawed and sandblasted. The material was heated in a kettle and applied by hand at 425°F.

B. 622 Y Medium
1. A catalytically blown asphalt.
2. The joints were sawed and sandblasted. The material was heated in a kettle and applied by hand at 425°F.

X. Products Research Chemical Comporation, Inc.

A. P.R.C. 3105
1. A black two component polyurethane with a 6 minute curing time.
2. The joint was sawed, sandblasted and primed with primer number 14. The two components were machine mixed and applied over a closed cell polyethelene backup rod that controlled the depth of the seal to 1/2 inch at 1/8 inch below the top of the joint.

XI. Sandell

A. Polytite
1. A polyurethane impregnated foam.
2. The joints were sawed and sandblasted and the material was installed by hand after being compressed by being stepped on.

XII. Sika

A. T-68
1. A black two component modified polyurethane with a three hour curing time.
2. The joints were sawed, sandblasted, and primed with colma sol clear. The two components were hand mixed and poured onto a closed cell polyethelene foam backup material that controlled the depth to 1/2 inch flush with the surface of the joint.

XIII. Slip-Pruf Service Corporation

A. Kractite
1. A two part polyurethane.
2. The original joints were sawed, sandblasted and primed with Kractite Primer. The two components were hand mixed and applied with a caulking gun onto a closed cell polyethelene foam backup material.

The later joints were sawed, sandblasted and not primed. The two components were drill mixed and applied with a caulking gun onto the backup material.

XIV. Sonneborn

A. Sonolastic Paving Joint Sealant
1. A two part polyurethane.
2. The joints were sawed, sandblasted and primed with 733 primer. The two components were hand mixed and poured onto a closed cell polyethlene foam backup material that controlled the depth to 1/2 inch beginning at the surface of the joint.

XV. Superior Products

A. Superseal 444
1. A polyvinyl polymer -
2. The joints were sawed and sandblasted. The material was heated in a kettle at 275°F and poured by hose onto a rope backup material that controlled the 1/2 inch thickness at 1/4 inch from the top of the joint.

XVI. Tee Juana

A. Tee Juana
1. Asphalt and mineral filler.
2. The joints were sawed and sandblasted. The material was heated in a kettle and poured using hand pouring pots. The joint was filled.

XVII. Thiokol

A. 701
1. A two component extended coal tar polysulfide.
2. The joints were sawed and sandblasted. The two components were machine mixed and applied with pump and nozzle onto a closed cell polyethelene backup that controlled the thickness at 1/4 inch from the top of the joint.

XVIII. U.S. Rubber Reclaiming

A. Flow-Mix
1. Asphalt and 20 percent reclaimed rubber.
2. The joint was sawed and sandblasted. Ground rubber was used as a backup and controlled the depth of 1/2 inch at 1/4 inch below the top of the joint. The materials were heated and mixed in a kettle with an agitator and poured by hand.

XIX. W. R. Grace

A. Daraseal U
1. A black two component polyurethane with a 2-4 hour curing time.
2. The joint was sawed, sandblasted and primed with Daraseal U-2C. The two components were mixed with a drill and hand poured over a closed cell polyethelene backup rod which controlled the thickness of 1/2 inch. The joint was filled to the top.

B. 2350 Improved Paraplastic
1. A rubberized asphalt poured at 400°F.
2. The joint was sawed, sandblasted and a cane fiber backup material was used. The material was heated in a double boiler kettle and poured by hand to the top of the joint.

C. Bondtite
1. A black two component polysulfide with a 2-4 hour curing time.
2. The joint was sawed and sandblasted. No primer was used. The two components were mixed and poured by hand onto a closed cell polyethelene backup rod to control the thickness to 1/2 inch at 1/4 inch below the top of the joint.

D. Type II
1. Neoprene Compression Seal.
2. The joint was sawed and sandblasted. A low solids (24%) glue lubricant was used in conjunction with a rolling disc to seat the neoprene at 1/4 inch below the top of the joint.

E. 416 M Developmental Paraplastic
1. A rubberized asphalt.
2. The joints were sawed and sandblasted. The material was heated in a kettle to 400°F and poured by hand onto a celotex backup rod that controlled a depth of 1/2 inch.

XX. W. R. Meadows

A. Gardox
1. A two component liquid neoprene .
2. The joints were sawed, sandblasted and airblasted. No primer was used. The two components were hand mixed and poured onto a closed cell polyethelene backup material that controlled the thickness of 1/2 inch at 1/4 inch from the top of the joint.

TABLE 2

BRIDGE SEALS MATERIAL INFORMATION

I. Acme

  A. Regular shape
    1. Neoprene compression seal.
    2. The joint faces were sandblasted to a white metal finish and primed. The neoprene was installed using prima-lub glue lubricant to within 1/4 inch of the top of the joint.
    3. The prima-lub used as a glue lubricant is a high solids (74%) polyurethane base glue.

II. D. S. Brown

  A. B Series
    1. Neoprene compression seal.
    2. The joint was not sandblasted. Supporting lugs were welded to the joint faces.
    3. A lubricant-adhesive containing 24 percent solids was used.

  B. CV Series
    1. Neoprene compression seal.
    2. The joint was not sandblasted. Supporting lugs were welded to the joint faces.
    3. A lubricant-adhesive containing 24 percent solids was used.

  C. H Series
    1. Neoprene compression seal.
    2. Joint was not sandblasted. Supporting lugs were welded to the joint face.
    3. A lubricant-adhesive containing 24 percent solids was used.

  D. K Series
    1. Neoprene compression seal.
    2. Some joints were sandblasted to a white metal finish. One joint had lugs welded to the joint faces.
    3. Delasti bond glue was used in some joints. Other seals were installed with soap and water only.

III. Dow Corning

  A. Terraseal 100
    1. A one component polyurethane with a time of six to eight hours for curing.

2. The joint faces were sandblasted to a white metal finish and were primed with Primer G. The polyurethane came in cartridge form and was placed by hand using a caulking gun. Round closed cell polyethelene backup rods were used to control thickness to 1/2 inch at 1/4 inch below the top of the joint.

IV. Products Research Chemical Corporation

A. P.R.C.

1. A black two part component polyurethane with a 3 to 6 minute curing time.
2. The joint faces were sandblasted to a white metal finish and primed with primer numbers 14 for concrete and 15 for steel. The two components were mixed and placed using a machine. A closed cell polyethelene foam backup rod was used to control thickness to 1/2 inch at 1/4 inch below the surface of the joint.

V. Sika

A. T-68

1. A two component black polyurethane with a three hour curing time.
2. The joint faces were sandblasted to a white metal finish and primed. The two components were mixed with a drill and hand poured on top of a closed cell polyethelene backup rod placed at a depth in the joint to give a 1/2 inch thickness to the seal at 1/4 inch below the top of the joint.

B. Colma Seal

1. A two component black polysulfide with a four hour curing time.
2. The joint faces were sandblasted to a white metal finish and primed. The two components were mixed with a drill and poured by hand. The backup rod of closed cell polyethelene was glued in place to give the seal a depth of 1/2 inch at 1/4 inch below the top of the joint.

VI. Slip-Pruf Service

A. Kractite

1. A white two component polyurethane.
2. The two components were drill mixed and applied with a caulking gun. The joint was sandblasted to a white metal finish and not primed. Bead board styrene was used to control thickness to 1/2 inch at 1/8 inch from the top of the joint.

VII. Thiokol

A. BD-3

TABLE 2

1. A black two component polysulfide with a six minute curing time.
2. The joint faces were sandblasted to a white metal finish and primed with TPR 410 and the components were mixed and installed with a machine. A closed cell polyethelene was placed to give a sealant depth of 1/2 inch at 1/4 inch below the top of the joint.

VIII. W. R. Grace

A. Type II
   1. Neoprene compression seal.
   2. The joint faces were sandblasted to a white finish and the neoprene was installed using a glue lubricant.
   3. The glue lubricant used meets the Michigan Specifications of July 1968.

B. Bondtite
   1. A black two component polysulfide with a curing time of 2-4 hours.
   2. The joint faces were sandblasted to a white metal finish and were not primed. The two components were mixed and poured by hand onto a closed cell polyethelene backup rod which was placed to maintain a thickness of 1/2 inch at 1/4 inch below the top of the joint.

APPENDIX B

FIELD INVESTIGATION

TABLE 3

BRIDGE JOINT MOVEMENT STUDY

Name of Bridge	Route	Bridge Type	Designed Joint Opening	Measurement Average Actual Opening (inches)	Movement (inches) Theo.	Movement (inches) Actual Ave.
Perkins Road Overpass	450-10-06 I-10	Steel girders and concrete slabs	1 1/4"	1.68	.42 .63	.37
Evangeline St. Overpass	450-33-45 I-110	Prestressed concrete girders 66' 6" and 72' 6"	1 1/4"	1.60	.32	.43
Calcasieu River	3-30-03 I-10	Steel girders and concrete slabs	1" 2"	1.22 2.01	.44 1.08	.31 .85
Atchafalaya Floodway	913-214 4814-3 U.S. 190	41' concrete slab and girders	1"	1.06	.19	.32
Bonnet Carre Spillway	450-14-07 I-10	65' precast prestressed concrete girders	1 1/4"	0.73	0.66	.75
Moss Bluff	24-1-16 24-2 U.S. 171	65' precast prestressed concrete girders	1 1/4"	1.34	0.98	.47

TABLE 4

BRIDGE SEALANT EVALUATION
INSTALLATION AND PERFORMANCE INFORMATION

Joint Number	Company Name	Trade Name	Material	Date Installed	Minimum Jt. Opening (inches)	Maximum Jt. Opening (inches)	%Movement at the time of failure	Distress First Noticed	Remarks First Failure	Complete Failure
3	Thiokol	BD-3	Two part polysulfide	7/68	0.73	1.43	32	8/68	A few adhesion failures	11/68
5	Products Research Corp.	PRC 3105	Two part polyurethane	7/68	1.77	2.51	-	-	-	-
7	Thiokol	BD-3	Two part polysulfide	7/68	0.81	1.46	30	8/68	A few adhesion failures	8/69
9	Sika	-	Two part polysulfide	8/68	1.50	2.26	23	10/68	All material fell through joint	10/68
11	Thiokol	BD-3	Two part Polysulfide	7/68	1.37	1.95	17	8/68	A few adhesion failures	1/70
15	Sika	T-68	Two part polyurethane	8/68	1.36	1.95	19	8/68	A few adhesion failures	1/70
17	Thiokol		Two part polysulfide	7/68	1.38	1.92	20	8/68	A few adhesion failures	1/70
19	Thiokol		Two part polysulfide	7/68	1.07	2.07	61	8/68	A few adhesion failures	8/69
25	D.S. Brown	B-1625	Neoprene	10/68	0.95	1.55	-	-	-	-
47	D.S. Brown	CV-2000	Neoprene	10/68	0.94	1.61	-	-	-	-
51	D.S. Brown	B-1625 replaced B-2500	Neoprene	10/68	1.23	2.09	57	2/69	Joint wider than the seal (B-1625)	2/69
53	D.S. Brown	B-2000	Neoprene	10/68	1.30	1.83	-	-	-	-

TABLE 4

BRIDGE SEALANT EVALUATION
INSTALLATION AND PERFORMANCE INFORMATION

Number	Company Name	Trade Name	Material	Date Installed	Minimum Jt. Opening (inches)	Maximum Jt. Opening (inches)	% Movement at the time of failure	Distress First Noticed	Remarks First Failure	Complete Failure
57	D.S. Brown	K-2000 replaced K-3000	Neoprene	10/68	1.00	1.87	60	2/69	-	-
59	D.S. Brown	K-2000	Neoprene	10/68	0.95	1.41	44	2/69	-	-
65	D.S. Brown	H-1625	Neoprene	10/68	0.68	1.57	87	1/70	Separation	-
69	D.S. Brown	H-1625	Neoprene	10/68	0.78	1.10		-	-	-
75	Acme	-	Neoprene	8/68	0.35	0.68	-	-	-	-
87	Sika	-	Two part polysulfide	7/68	0.93	1.27	13	8/68	One adhesion failure	10/68
89	Sika	-	Two part polysulfide	7/68	0.57	0.93	15	8/68	One adhesion failure	11/68
95	Sika	-	Two part polysulfide	7/68	0.81	1.07	12	8/68	Bubbles	10/68
109	Acme	-	Neoprene	8/68	0.96	1.71	-	-	-	-
119	Sika	T-68	Two part polyurethane	8/68	0.62	1.72	60	10/68	One adhesion failure	8/69
121	Sika	T-68	Two part polyurethane	8/68	1.23	1.70	11	10/68	A few adhesion failures	11/68
123	Sika	T-68	Two part polyurethane	8/68	1.36	2.37	37	10/68	Cohesion failures on 1/2 the joint	11/68
133	Dow Corning	Terraseal 100	One part polyurethane	7/68	1.16	2.01	43	4/69	A small adhesion failure	12/70
139	Dow Corning	Terraseal 100	One part polyurethane	7/68	1.28	2.21	40	11/68	A 1" adhesion failure	12/70
141	Acme	-	Neoprene	7/68	1.06	2.06	-	-	-	-
143	Acme	-	Neoprene	7/68	0.94	1.34	-	-	-	-
145	Acme	-	Neoprene	7/68	0.97	1.95	-	-	-	-
147	Products Research Corporation	PRC	Two part polyurethane	7/68	0.99	1.35	-	-	-	-
151	Products Research Corporation	PRC	Two part polyurethane	7/68	1.06	1.72	-	-	-	-

TABLE 4

BRIDGE SEALANT EVALUATION
INSTALLATION AND PERFORMANCE INFORMATION

Joint Number	Company Name	Trade Name	Material	Date Installed	Minimum Jt. Opening (inches)	Maximum Jt. Opening (inches)	% Movement at the time of failure	Distress First Noticed	Remarks First Failure	Complete Failure
155	Products Research Corp.	PRC 3105	Two part polyurethane	7/68	0.87	1.27	-	-	-	-
163	W.R. Grace	Type II 1 5/8"	Neoprene	7/68	0.97	1.71	82	4/69	Joint opening wider than seal	-
165	W.R. Grace	Bondtite	Two part polysulfide	8/68	1.19	1.61	30	1/70	Nine 5" cohesion failures	12/70
169	W.R. Grace	Type II 1 5/8"	Neoprene	7/68	0.98	1.84	69	11/68	Joint opening wider than seal	-
171	W.R. Grace	Bondtite	Two part polysulfide	8/68	0.94	1.31	31	4/69	A few small cohesion failures	7/70
173	W.R. Grace	Type II 2"	Neoprene	7/68	1.02	2.00	53	1/69	Joint opening as wide as the seal	-
175	W.R. Grace	Bondtite	Two part polysulfide	8/68	1.03	2.02	66	4/69	A few small cohesion failures	8/69
179	Thiokol	BD-3	Two part polysulfide	10/68	1.06	1.90	66	11/68	One 3" cohesion failure	1/70
181	Thiokol	BD-3	Two part polysulfide	10/68	1.06	1.73	54	11/68	One 3" cohesion failure	1/70
229	Sika	T-68	Two part polyurethane	4/69	0.82	1.79	41	7/69	Numerous adhesion failures	1/70
233	Sika	T-68	Two part polyurethane	4/69	1.22	1.74	42	7/69	Adhesion failures three cohesion failures	1/70
241	Thiokol	BD-3	Two part polysulfide	10/68	1.08	1.82	49	11/68	One 3" cohesion failure	1/70
245	Thiokol	BD-3	Two part polysulfide	10/68	1.31	2.01	54	11/68	Nine cohesion failures from 1" to 18"	1/70
249	Thiokol	BD-3	Two part polysulfide	10/68	1.11	2.06	43	11/68	One 1" cohesion failure	1/70
253	Thiokol	BD-3	Two part polysulfide	10/68	0.81	1.91	59	11/68	16 cohesion failures from 1" to 18"	4/69

TABLE 4

BRIDGE SEALANT EVALUATION
INSTALLATION AND PERFORMANCE INFORMATION

Joint Number	Company Name	Trade Name	Material	Date Installed	Minimum Jt. Opening (inches)	Maximum Jt. Opening (inches)	% Movement at failure of failure	Distress First Noticed	Remarks First Failure	Complete Failure
257	Sika	T-68	Two part polyurethane	4/69	0.85	1.76	67	8/69	One 3" cohesion failure	12/70
259	Slip-Pruf Service	Karctite	Two part polyurethane	1/70	1.39	2.16	30	12/70	Three cohesion failure one adhesion failure	
261	Slip-Pruf Service	Karctite	Two part polyurethane	1/70	1.37	2.04	42	12/70	Three adhesion failures; crimping	5/71
263	D.S. Brown	K-3000	Neoprene	5/70	1.15	1.99	41	12/70	Foreign material intrusion	-
265	D.S. Brown	K-3000	Neoprene	5/70	1. 18	1.80	33	-	- -	
267	D.S. Brown	K-3000	Neoprene	5/70	1.01	1.85	63	12/70	Some intrusion	-
269	D.S. Brown	K 3000	Neoprene	5/70	1.30	1.82	33	12/70	Some intrusion	-
271	D.S. Brown	K-3000	Neoprene	5/70	0.98	1.60	52	5/71	General intrusion	5/71
273	D.S. Brown	K-3000	Neoprene	5/70	1.08	1.44	27	7/70	General intrusion	5/71

TABLE 5

COMPRESSION SEAL SIDEWALL PRESSURE CHANGE DUE TO AGING

Joint	Manufacturer	Series	Pressure (PSI) 80% Nominal Width		
			Original PSI	Aged PSI	Age (Months)
Oct. 68 25	D. S. Brown	B-1625	5.6	3.3	31
47	D. S. Brown	CY2000	9.0	7.2	31
51	D. S. Brown	B-1625	5.5	3.8	31
53	D. S. Brown	B-2000	6.4	6.5	31
May 70 57	D. S. Brown	K-3000	1.2	1.0	11
Oct. 68 59	D. S. Brown	K-2000	1.2	0.7	31
May 70 65	D. S. Brown	B-2000	3.9	3.2	11
Oct. 68 69	D. S. Brown	H-1625	4.5	1.6	31
Aug. 68 75	Acme	-	3.0	0.9	33
July 68 145	Acme	-	3.0	1.2	34
163	W. R. Grace	Type II 1 5/8"	3.0	1.3	34
173	W. R. Grace	Type II 2"	1.5	1.2	34

Average Pressure Loss at 31 months = 35%

TABLE 6
PAVEMENT SEALANT EVALUATION

SUMMARY OF PERFORMANCE INFORMATION

Supplier	Type	Name	Distress First Noticed	Complete Failure	Average Percent Movement from °F to Maximum Temp.	Remarks
Products Research Corporation, Inc.	Two part Polyurethane	PRC 3105	1 Mo.	-	43	An installation of five joints is good after two years
W. R. Grace	Two part Polyurethane	Bondtite	12 Mo.	16 Mo.	30	Many adhesion and cohesion failures
W. R. Grace	Two part Polyurethane	Daraseal	1 Mo.	22 Mo.	27	One joint failed immediately in cohesion
W. R. Grace	Rubberized Asphalt	Paraplastic	1 Mo.	3 Mo.	36	Joints accepted incompressibles
W. R. Grace	Neoprene	1 1/4"	-	-	33	The top does not appear to be supported when under compression
Tee Juana	Asphalt & Mineral filler	Tee Juana	Immed.	Same	37	Flowed thru joint, accepted incompressibles
U.S. Rubber Reclaiming	Asphalt & Reclaimed Rubber	Flo-Mix	Immed.	Same	41	Accepted incompressibles
D. S. Brown	Neoprene	A	-	-	29	OK
D. S. Brown	Neoprene	E	-	-	36	OK
DuPont	One part Polyurethane	Imron	3 Mo.	7 Mo.	14	Cohesion and adhesion failures
ByWater	Two part Polysulfide	-	5 Mo.	5 Mo.	22	Complete adhesion failure
Acme	Neoprene	S-545	-	-	45	

TABLE 6
PAVEMENT SEALANT EVALUATION

SUMMARY OF PERFORMANCE INFORMATION

Supplier	Type	Name	Distress First Noticed	Complete Failure	Average Percent Movement from °F to Maximum Temp.	Remarks
Sonneborn	Two part Polyurethane	-	11 Mo.	16 Mo.		Average of two cohesion failures first observed
Sika	Two part poly.	T-68	5 Mo.	5 Mo.		Complete adhesion failure
Sanddell	Polyurethane Impregnated foam	-	Immed.	Same		Would not reject incompressibles; migrated down in joint
Slip-Pruf Service	Two part Polyurethane	Kractite	8 Mo.	11 Mo.		Small cohesion failures at first
W. R. Meadows	Liquid Neoprene	Gardox	3 Mo.	16 Mo.		Adhesion failures at top of seal
American Metaseal	Two part Polysulfide		6 Mo.	9 Mo.		Cohesion failures
American Metaseal	Two part Polyurethane		6 Mo.	-		Five inch(average) adhesion failure
Continental	Two part Polyurethane	J.C. 26	3 Mo.	3 Mo.		Complete adhesion and cohesion failures
Superior Products	Polyvinyl with Fillers	Superseal 444	-	-		OK
Thiokol	Two part Polysulfide	701	3 Mo.	14 Mo.		Small adhesion failures

APPENDIX C

LABORATORY TESTING

TABLE 7

TEST PROCEDURES

The following test procedures were used in the laboratory for both liquid cold pour joint sealants and preformed neoprene compression seals.

ASTM D395-67 "Compression Set of Vulcanized Rubber"

ASTM D1194-64 "Accelerated Ozone Cracking of Vulcanized Rubber"

ASTM D750-68 "Operating Light-Weather-Exposure Apparatus (Carbon-Arc- Type) for Artificial Weathering Testing of Rubber Compounds"

ASTM D113-44 "Test for Ductility of Bituminous Materials"

Federal Specifications TT-S-00-227E "Sealing Compressed, Elastomeric Type, Multi-Component" (COM-NBS), November 4, 1969

Federal Specifications TT-S-00-230B "Sealing Compressed, Elastomeric Type, Single Component" (COM-NBS), May 5, 1967

TABLE 8

TEST AND RESULTS ON POURED CONCRETE JOINT SEALERS

Source	Bostik Cycles	% Recovery 39°F	% Recovery 122°F	Color	Ductility 77°F	Ductility 39°F	Ozone	Shrinkage	Hardness Penetration 77°F	Hardness Penetration 39°F	Tack Free	Weatherometer Exposure
Sealinsert	53 Pass											
Sikaflex T-68	53 Pass											
Colma	40 Fail	63	55	Lt. Grey	---	---	Pass	None	10	15	-	-
W. R. Meadows	35 Pass			Dark Brown								
Bondtite	40 Pass	88	44	Black	11	16	Pass	Nil	2	3	24 hours	50 Fail Elongated
PRC 3105	42 Pass	97	75	Black	10	17	Pass	None	12	15	24 hours	650 Good
Kractite (Slipproof)	40 Pass	76	54	Grey	20	20	Pass	None	17	20	24 hours	650 hours Good to Fair
Dupont	3 Fail											
Superseal 444	40 Pass											
Edoco (3200-3201)	40 Pass	87	75	Black	52	60	Pass	None	0	0	48 hours	

TABLE 8 (CONTINUED)

TEST AND RESULTS ON POURED CONCRETE JOINT SEALERS

Source	Bostik Cycles	% Recovery		Color	Ductility		Ozone	Shrinkage	Hardness Penetration		Tack Free	Weatherometer Exposure
		39°F	122°F		77°F	39°F			77°F	39°F		
Meta Seal 355	15 Fail			Black								
Daraseal (U)	10 Fail	99	89	Alum. Grey	-	-	Pass	Slight	25	27	24 hours	650 Fair to Poor
Sonneborn	-	99	92	Lime Stone	48	48	Pass	None	18	25	48 hours	150 Fail
ByWater	-	85	55	Light Grey	5.7	7.0	Pass	Nil	7	8	48 hours	650 Fair
Essex	-	90	80	Grey	52.7	51.5	Pass	None	5	5	48 hours	150 Fail
Thiokol	-	72	72	Black	20	19	Pass	None	-	-	45 min.	

TABLE 9

COMPRESSION TESTS (PSI) ON ORIGINAL PREFORMED JOINT MATERIALS

No.	Size	Source	% Compression	Original Samples
S-16	1 1/8" x 3 3/16"	D. S. Brown Model K	9.3	0.7
			18.6	1.6
			27.9	2.1
			37.2	2.9
			50.0	5.1
S-17	3.0" x 2 3/4"	D. S. Brown Model K	6.4	1.2
			12.9	1.7
			19.5	1.4
			25.7	1.9
			50.0	2.5
S-18	2 3/8 x 2.0"	D. S. Brown Type CV	9.3	2.8
			18.6	4.7
			27.9	5.4
			37.2	5.4
			50.0	8.8
P-3	2.0" x 2.0"	Type A Acme	9.8	4.4
			19.7	5.6
			29.5	6.6
			39.4	7.1
			50.0	23.5
P-4	1 1/4" x 1 1/4"	Acme	15.8	2.1
			31.5	2.5
			47.3	3.4
			-	-
			50.0	3.4

TABLE 9 (CONTINUED)

COMPRESSION TESTS (PSI) ON ORIGINAL PREFORMED JOINT MATERIALS

No.	Size	Source	% Compression	Original Sample
P-5	7/16" x 3/4"	Acme	45.0	51.4
			50.0	51.4
P-6	3/4" x 1 1/8"	Acme	22.5	3.8
			45.0	6.8
			-	-
			50.0	6.8
P-2	2.0" x 2.0"	W. R. Grace	9.8	4.1
		Type X	19.7	5.4
			29.5	5.6
			39.4	7.5
			50.0	18.0
S-14	2.0" x 2.0"	W. R. Grace	9.8	4.1
		Type X	19.7	5.4
			29.5	5.8
			39.4	7.7
			50.0	24.6
S-15	1 7/16" x 1 3/8"	W. R. Grace	14.9	2.9
		Type III	29.8	3.6
			44.7	4.9
			50.0	6.8
S-19	1 5/8" x 1 1/4"	W. R. Grace	11.2	4.8
		Type Y	22.5	5.1
			33.7	5.5
			45.0	7.5
			50.0	7.5

TABLE 9 (CONTINUED)

COMPRESSION TESTS (PSI) ON ORIGINAL PREFORMED JOINT MATERIALS

No.	Size	Source	% Compression	Original Samples
S-20	7/8" x 7/8"	W. R. Grace	22.5	4.1
		Type Y	45.0	6.8
			50.0	8.7

TABLE 10

COMPRESSION TESTS (PSI) OF FIELD EXPOSED, ORIGINAL AND WEATHEROMETER EXPOSED PREFORMED JOINT MATERIALS

Size	Source	Joint Number	% Compression	Original Samples (PSI)	Field Exposed (PSI)	111 hrs. in Weath. (PSI)	376 hrs. in Weath. (PSI)	611 hrs. in Weath. (PSI)	915 hrs. in Weath. (PSI)
B 1625	D. S. Brown	25	15	5.2	2.8	5.1	5.6	4.6	6.8
			30	6.2	4.4	6.0	6.2	5.4	7.0
			50	16.8	11.3	22.6	23.8	18.5	13.0
B 1625	D. S. Brown	51	15	5.2	3.4	5.1	5.6	4.6	6.8
			30	6.2	5.0	6.0	6.2	5.4	7.0
			50	16.8	13.2	22.6	23.8	18.5	13.0
H 1625	D. S. Brown	65	15	4.2	2.2	5.4	5.5	5.0	5.6
			30	5.1	3.5	6.6	6.6	6.9	6.3
			50	8.2	34.9	11.6	11.0	11.0	10.5
H 1625	D. S. Brown	69	15	4.2	1.4	5.4	5.5	5.0	5.6
			30	5.1	2.3	6.6	6.6	6.9	6.3
			50	8.2	4.8	11.6	11.0	11.0	10.5
CV 2000	D. S. Brown	47	15	9.0	6.2	7.5	7.1	11.4	7.8
			30	9.0	8.8	10.0	8.7	12.4	9.1
			50	21.9	44.1	33.0	60.0	31.7	15.8
K 2000	D. S. Brown	57	15	0.9	0.8	1.0	0.7	1.7	0.8
			30	1.7	1.5	1.6	1.8	3.1	1.9
			50	4.4	5.1	3.2	3.8	4.6	3.6
K 2000 D.	D. S. Brown	59	15	0.9	0.5	1.0	0.7	1.7	0.8
			30	1.7	1.5	1.6	1.8	3.1	1.9
			50	4.4	6.2	3.2	3.8	4.6	3.6

TABLE 10 (CONTINUED)

COMPRESSION TESTS (PSI) OF FIELD EXPOSED, ORIGINAL AND WEATHEROMETER EXPOSED PREFORMED JOINT MATERIALS

Size	Source	Joint Number	% Compression	Original Samples (PSI)	Field Exposed (PSI)	111 hrs. in Weath. (PSI)	376 hrs. in Weath. (PSI)	611 hrs. in Weath. (PSI)	915 hrs. in Weath. (PSI)
B 2000	D. S. Brown	53	15	4.7	5.5	6.8	6.1	4.8	5.3
			30	6.4	8.8	7.7	7.8	7.8	8.8
			50	7.7	42.0	14.1	17.8	17.3	14.6
K 3000	D. S. Brown	263	15	-	0.4	-	-	-	-
			30	-	1.0	-	-	-	-
			50	-	2.1	-	-	-	-
2.00	Acme	75	15	2.6	0.9	4.6	5.2	0.8	3.4
			30	3.5	0.9	5.3	5.9	2.3	4.0
			50	8.6	6.0	8.5	11.2	7.7	9.7
2.00	Acme	141	15	2.8	0.4	3.0	2.6	4.2	3.1
			30	3.0	0.8	4.7	4.1	4.8	3.9
			50	11.2	8.5	11.6	12.9	15.8	9.0
2.00	Acme	143	15	2.8	1.0	3.0	2.5	4.2	3.1
			30	3.0	3.3	4.7	4.1	4.8	3.9
			50	11.2	18.0	11.6	12.9	15.8	9.0
2.00	Acme	145	15	2.8	1.0	3.0	2.5	4.2	3.1
			30	3.0	1.8	4.7	4.1	4.8	3.9
			50	11.2	9.3	11.6	12.9	15.8	9.0
1625	W. R. Grace	163	15	2.8	1.1	4.0	4.0	4.0	3.4
			30	3.5	1.7	4.0	4.2	5.0	3.9
			50	4.0	4.9	5.2	5.7	7.4	4.7

TABLE 10 (CONTINUED)

COMPRESSION TESTS (PSI) OF FIELD EXPOSED, ORIGINAL AND WEATHEROMETER EXPOSED PREFORMED JOINT MATERIALS

Size	Source	Joint Number	% Compression	Original Samples (PSI)	Field Exposed (PSI)	111 hrs. in Weath. (PSI)	376 hrs. in Weath. (PSI)	611 hrs. in Weath. (PSI)	915 hrs. in Weath. (PSI)
1.625	W. R. Grace	169	15	2.8	0.5	4.0	4.0	4.0	3.4
			30	3.5	1.1	4.0	4.2	5.0	3.9
			50	4.0	5.4	5.2	5.7	7.4	4.7
2.00	W. R. Grace	173	15	1.5	0.7	2.7	2.9	0.9	3.0
			30	1.5	2.2	3.4	3.2	1.4	3.9
			50	2.0	3.4	3.9	4.4	2.4	3.9

TABLE 11

COMPRESSION TESTS (PSI) AFTER BOSTIK CYCLING FOR PREFORMED JOINT SEALERS

Source	Lab. No.	Cycles	Size	Nominal Groove Width	Min. Groove Width	Original Percent Compression	Lbs/Sq. In.	Lbs/Sq.in. Bostik	Weatherometer
D. S. Brown K-3000	88991	58	3"x2 3/4"	2 3/8" (80%)	1 1/2" (50%)	6.25	0.75	0.44	
						12.60	1.19	0.75	
						18.90	1.79	0.90	
						25.20	1.94	1.04	
						50.00	2.69	1.94	