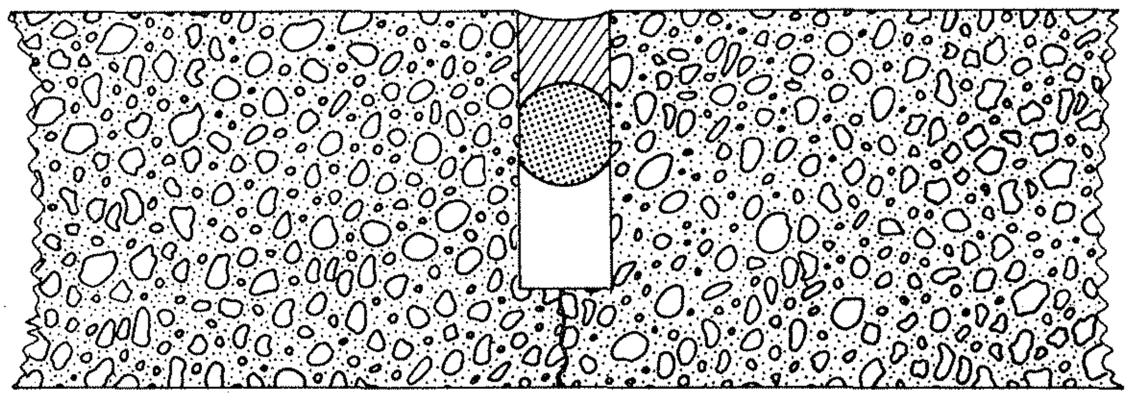
Final Report
for
Iowa Highway Research Board
Project HR 203

Transverse Joint Sealing with Various Sealants



Highway Division
September 1983
in cooperation with
Dallas County
Secondary Road Department

Iowa Department of Transportation

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FINAL REPORT
FOR
IOWA HIGHWAY RESEARCH BOARD
PROJECT HR-203

TRANSVERSE JOINT SEALING
WITH
VARIOUS SEALANTS

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IN COOPERATION WITH
THE DALLAS COUNTY
SECONDARY ROAD DEPARTMENT

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TRANSVERSE JOINT SEALING WITH VARIOUS SEALANTS

INTRODUCTION

Iowa's first portland cement concrete pavement was constructed in 1904 in the City of LeMars. A portion of that pavement served traffic until 1974 at which time it was resurfaced. The first rural Iowa pcc pavement (16' wide, 6" to 7" thick) was constructed under the direction of the Iowa State Highway Commission in 1913. Some of Iowa's early pavements had transverse joints at 25-foot spacings. At that time, joint spacings across the nation ranged from 24 to 100 ft.[1] There have been many changes in joint design over the years with some pavements being constructed without transverse joints.

Joint spacing on Iowa primary pavements has generally remained around 20 feet with this spacing having been adopted as an Iowa standard in 1954. Until 1978 it was common to specify a 40-foot joint spacing on secondary pavements.

The performance of the pavements with joint spacings greater than 20 feet, and in some cases no contraction joints, generated a 1955 research project on joint spacing.[2] This project was 16 miles long containing sections without contraction joints and sections with joints sawed at intervals of 20, 50 and 80 feet. Approximately half of the sawed joints were left unsealed. The results of this research supported the 20-foot spacing, but were inconclusive regarding the benefits of sealing.

One of the desired characteristics of joint sealing material is that it should act as a moisture barrier and prevent the intrusion of surface water. It was generally accepted from past experience that the hot poured type joint seals did not provide this effective moisture barrier.

In an effort to identify an effective joint sealing system, research project HR-125 was initiated in 1966 to evaluate the use of preformed neoprene joints. The neoprene joints have provided substantially better performance than the standard hot poured blend of recycled rubber and asphalt cement used in 1966. Due to the additional cost, preformed neoprene joints were never specified on Iowa projects.

Over the years, Iowa has maintained a standard practice of sealing joints on new PCC pavement construction. The standards have required hot poured bituminous materials. Prior to 1948, the materials were unmodified asphalt cements. From 1948 through 1964, the sealant material was an asphalt cement product with a mineral filler. A blend of recycled rubber and asphalt cement was used from 1964 through 1977. From 1977 through 1982 a specification was adopted requiring a blend of virgin rubber and asphalt cement meeting Federal Standard Specification SS-S-1401.

The present specification, adopted in 1982, requires the material to have greater elongation characteristics as:

4136. JOINT FILLERS AND SEALERS.

DELETE all of Paragraph 4136.02A and add the following new Paragraph A in lieu thereof.

A. ***Poured Joint Sealer.*** Hot-poured joint sealer shall be composed of petropolymers and shall be supplied in solid form. The sealer shall meet requirements of ASTM D 3405 with the following modifications:

Penetration at 77F (25C)	110-150
Bond at -20F (-29C), standard specimen, 3 cycles, 100% extension	Passes
Bond at -20F (-29C), modified specimen (Note 1) 1 cycle, 300% extension	Passes

There shall be no loss of adhesion, at room temperature, after 24 hours, when a modified specimen (Note 1) is blocked open at an extension of 200%.

Note 1: Specimen dimensions modified to 1/4 inch by 2 inches by 2 inches.

Cold-applied sealers meeting the above physical requirements may also be approved by the engineer.

Backer rope used in conjunction with this sealer shall be made of cellulose, cotton, or plastic foam. When used with hot-poured sealers, the rope must withstand, without damage, the high temperatures inherent to these sealers. The rope shall be of a size that compression is required for installation in the joint so that it maintains its position during the filling operation.

DELETE the last sentence of 4136.03A and add the following in lieu thereof:

Sealer used with these fillers shall meet requirements of 4136.02A or shall be a two-component, synthetic polymer type meeting requirements of ASTM D 1850. Other resilient fillers may be approved by the engineer.

Some transverse joints in Iowa have been formed utilizing parting strips, but for the most part have been imparted by sawing. Prior to 1982, standards required a minimum width of 1/8" and a minimum depth of one fourth the slab thickness. The minimum width of saw cut is now 1/4 inch. In recent years the common practice has been to make that saw cut with a 3/16" or 7/32" abrasive blade.

There is no record of the use of backing material beneath the hot poured sealant on any Iowa project prior to 1978.

Highway engineers over the years have been concerned with joint sealing materials and procedures. A small experimental study utilizing a one component, polyvinyl chloride coal tar elastomeric type, hot poured sealer was incorporated into a U.S. 30 project at the southwest corner of Ames in 1972. The sealant reservoir was cut one-half inch wide and cleaned by sandblasting prior to hot pour sealing. These joints have performed very well.

PROBLEM

Deterioration of joints and joint related distress of pcc pavements continues to be a major maintenance problem. These joints are constructed to control cracking and provide for movement due to variation in temperature. The difficulty of maintaining these joints in a sealed condition is primarily caused by the opening and closing of the joint, but movement produced by traffic is a contributing factor. Unfortunately, the poured sealants and present joint design and construction practices have not been able to adequately provide for this movement. Even under ideal conditions, the life of most poured sealants rarely exceeds three years.[1] The bond between the sealant and the concrete fails and allows the joint to leak (figure 1).

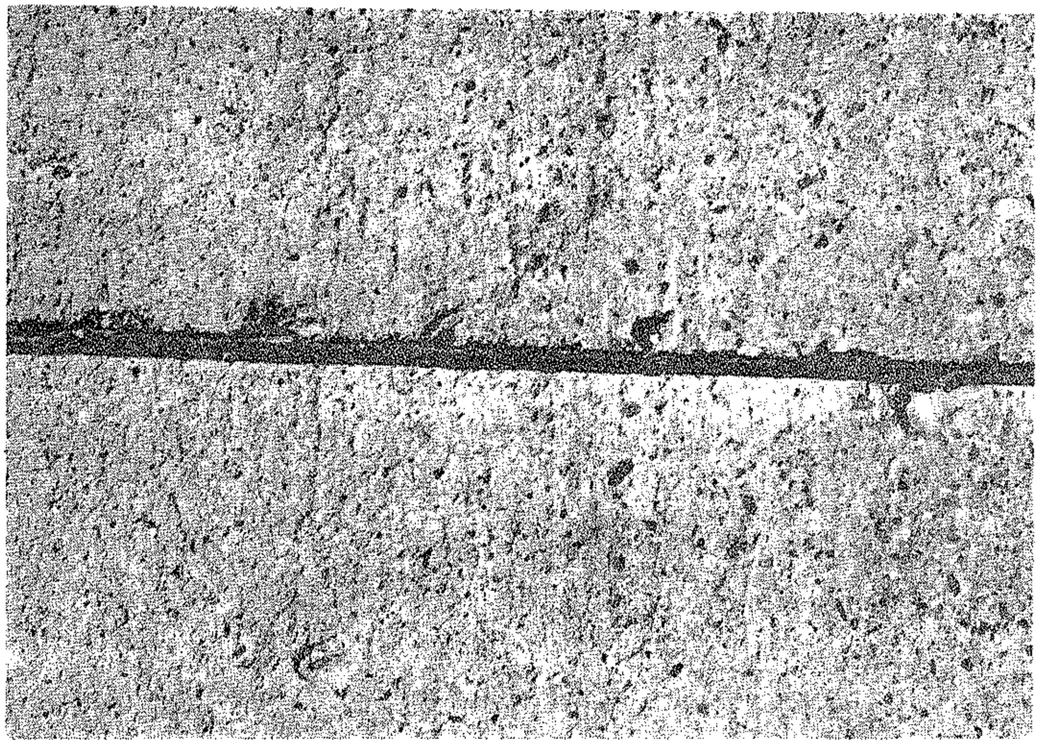

Figure 1 - Bond Failure of Sealant Material

Failure of the joint seal results in additional problems. Surface water is allowed to enter the joint. This additional water detracts from the stability of the base material. It further causes erosion of the base both from gravity and by pumping. The freezing of this concentration of water during winter months causes joint heaving resulting in poor riding quality.

Blowups are the most dramatic of the joint failures. The generally accepted major contributing factor to blowups is incompressibles deposited in the joints (figure 2) during the winter months.

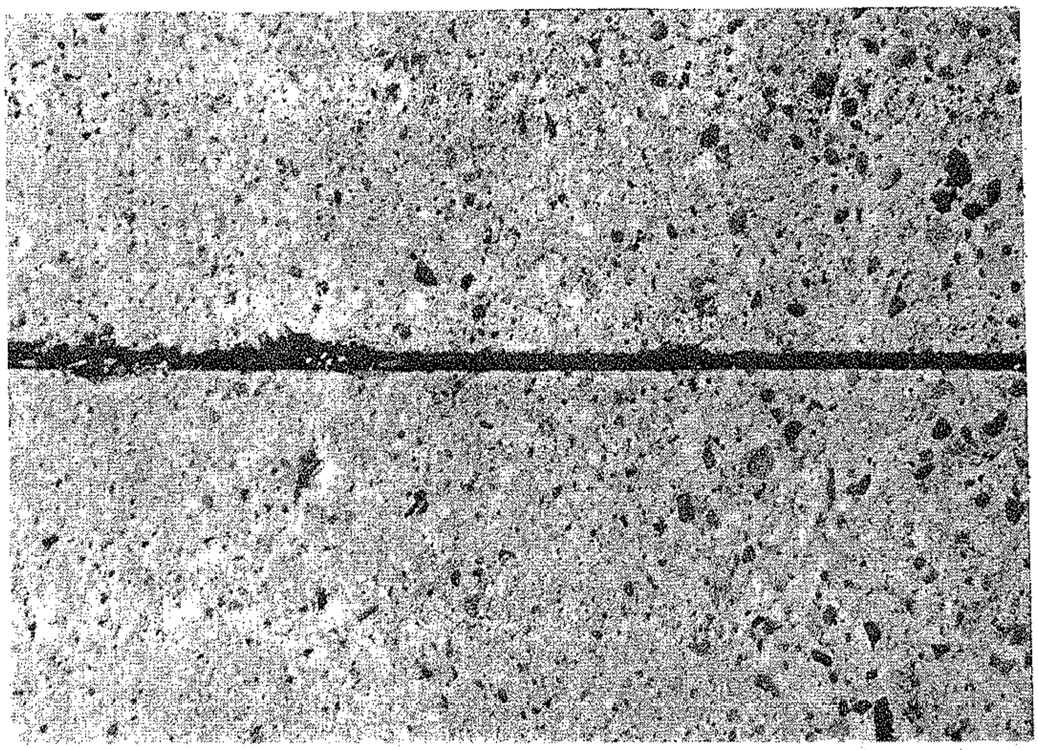

Figure 2 - Incompressibles in Transverse Joint

A combination of thermal expansion during the hot summer months, high moisture conditions and joints plugged with incompressibles results in numerous blowups. To alleviate this problem, the Iowa DOT initiated an extensive program of cutting pressure relief joints. The four inch wide cuts were placed at 1,000-foot intervals. It has been typical for these pressure relief joints to close up rapidly. The four inches have closed to less than one inch within two years in many instances.

There has been substantial research on joint sealing. The New York State Department of Public Works has researched preformed neoprene and a variety of poured sealants.[3] Their results from this 1955 to 1963 research demonstrated the short effective life of poured sealants and supported the superior performance of preformed neoprene. Economics, labor requirements and joint restrictions have continued to be a detriment to the use of preformed neoprenes.

A recent HRIS literature search (5-10-78) cited many abstracts on joint sealing. The Pennsylvania DOT has an active project in the use of various sealant materials with various sealant reservoirs. The Wisconsin DOT has a current project comparing sealed versus unsealed, sealant type and joint spacing.

OBJECTIVE

The objective of this research is to evaluate the performance of pcc pavement contraction joints utilizing a variety of sealants and joint preparations and to identify an effective sealant system. The variables to be evaluated are:

1. Sealant material
2. Joint Preparation
3. Size of Saw Cut (sealant reservoir)
4. The Use of Backing Material

PROJECT SELECTION AND LOCATION

The decision to pursue joint sealant research was made in March of 1978. By that time, most pcc paving projects were either let or in the process of being let. As joint seal performance requires a long term evaluation (minimum of three years) and the winter period presents the severe test condition, it was considered desirable to incorporate the research into 1978 construction. Joint movement is greater on pavement with 40 foot spacing and was, therefore, one of the selection criteria to subject the joint seal to the most severe condition. This immediately eliminated primary roadways with a 20-foot spacing, so Dallas County project FM-25(2)--55-25 designed with a 40-foot spacing was selected. The project on secondary road R-30 begins 1-1/4 miles west of Granger and extends southerly approximately 8-1/2 miles.

PAVING DESIGN

The paving was 22 feet wide and 6 inches thick using Iowa DOT Standard Specifications B-6 mix proportions. It had a 2-inch crown and the only reinforcing was 3-foot long #4 tie bars across the centerline at 48-inch centers.

CONTRACTOR AND PERSONNEL

The successful bidder on this paving project was Central Paving Corporation. Their project superintendent on this project was Mack Capper. The jobber for most of the Central Paving Corporation miscellaneous supplies at that time was Pittsburg-Des Moines Steel. The jobber cooperated with the research in providing all sealant and backer materials at invoiced cost and providing the cost information.

PAVING MATERIALS

The materials and proportions of the Standard Specification B-6 mix used for this paving were:

B-6 Mix Proportion

Materials	Absolute Volume	Batch Quantities pounds per cu. yd.
Cement	0.098936	523
Fine Agg.	0.404409	1819
Coarse Agg.	0.269606	1204
Water	0.176049	297
Air	0.060000	

The cement was a Type I from the Penn-Dixie Cement Company of West Des Moines, Iowa.

The fine aggregate (Sp. Gr. = 2.67) was produced at the Hallett Construction Company sand pit in West Des Moines (Polk County 7 & 8-79-24).

The coarse aggregate was a crushed limestone (100% passing 1-1/2" screen) from the Hallett Construction Company quarry near Gilmore City, Iowa (Pocahontas County NE 1/4 36-92-31).

The air entraining agent was CSC from Contractor Steel Corporation of Des Moines, Iowa and the white pigmented curing compound was produced by Carter-Waters Corporation of Kansas City, Missouri.

JOINT SEALING MATERIALS

Sealants

Six different sealant materials were used in the contraction joints included in this research.

A. W. R. Meadows "Hi-Spec" - This was one of two brands of hot applied, rubber asphalt meeting the 1978 Iowa Standard Specification 4136. It was an upgraded rubber asphalt product utilizing virgin rubber to meet Federal Standard Specification SS-S-1401B.

B. Lion Oil Division "Lion D-200" - Lion D-200 was a pourable, two component, cold applied formulation of asphalt and urethane.

C. W. R. Meadows "Gardox" - Gardox was a pourable, two component, cold applied liquid neoprene sealant.

D. W. R. Meadows "Poly-Jet Highway" - This sealant was a one component, hot applied polyvinyl chloride coal tar.

E. Dow Corning "Dow Corning 888" - This sealant was a cold applied, one component, low modulus silicone rubber.

F. W. R. Grace "Para Plastic" - Para Plastic is the other brand of hot applied, rubber asphalt meeting the 1978 Iowa Standard Specification 4136 (FSS-SS-S-1403) utilizing virgin rubber.

Backing Materials

Backing material was one of the variables to be evaluated in the research. Its purpose was to restrict the sealant and provide the desired depth of sealant reservoir. One type of backing material used in this research was fiber reinforced adhesive tape. The tape was used in the 1/2" deep step joints of both widths.

The other backing materials were round, commercially available products. These come in a variety of diameters with the normal recommendation of a diameter of 1/8" greater than the width of saw cut. All backer materials used in this research were purchased from W. R. Meadows, Inc. Two types of backer were used. The "Backer Rod" was a closed cell polyethylene foam for use with cold applied materials. "Backer Rope" was a nonravelling, fiber product for use with hot applied sealants.

CONSTRUCTION OPERATION

The construction project was paved from 09-07-78 to 09-26-78. Several shutdowns were caused by frequent rain during this time. There was a cement shortage and the cement producer put Central Paving Corporation on allocation and limited hours. Due to a lack of contractor's personnel for the special research activities, some joint sealing operations were performed by Iowa DOT personnel.

The paving operation was typical with the concrete being batched and mixed in a central plant. The concrete was placed with a slip form paver. A transverse tine texture was imparted into the surface just prior to the application of the liquid curing compound.

JOINT LAYOUT AND IDENTIFICATION

The research proposal was developed to place groups of five joints with the same combination of variables. A repetitive group of five joints with the same combination of variables was to be placed at another location. The joint sealing variables to be considered were:

TABLE 1

Sealant Materials

A - W. R. Meadows, "Hi-Spec" (Iowa Standard Specification 4136)
B - Lion Oil Division, "Lion D-200" (Two Comp. Urethane)
C - W. R. Meadows, "Gardox" (Two Comp. Neoprene)
D - W. R. Meadows, "Poly-Jet Highway" (Polyvinyl Chloride)
E - Dow Corning, "888" (Silicone Rubber)
F - W. R. Grace, "Para Plastic" (Iowa Standard Specification 4136)

Cleaning	Saw Cut
1. Air Jet	1. Nominal 1/8"
2. Sand Blast	2. Nominal 1/4"
3. Water Blast	3. Nominal 3/8" x 1/2" deep
	4. Nominal 3/8" x 1" deep
	5. Nominal 1/2" x 1/2" deep
	6. Nominal 1/2" x 1-1/4" deep

Backing Materials	Size of Backing
N - No Backing Materials	3 - 3/8"
T - Tape	4 - 1/2"
BH - Backer Rope (Hot Material)	5 - 5/8"
BC - Backer Rod (Cold Material)	

An installation code designation was established for ease of documentation. The variables for 560 (numbered through 581) joints were tabulated and are included in Appendix A. The research was to include at least ten joints of each possible combination of the variables previously noted. Some alterations in placement were necessary to be compatible with the contractor's operation. Limitation of material or equipment reduced or eliminated the use of some combinations. No nominal 1/8" wide joints were used.

JOINT SAWING

The initial cutting was a typical operation of cutting joints 1-1/2" deep (1/4 of slab thickness) using a 3/16" thick carborundum blade to prevent random cracking. The required depth and width for each group of five joints were spray painted on the pavement. Dual 3/16" blades were used to obtain the 3/8" wide joints. Dual 1/4" blades were used for the 1/2" wide joints.

JOINT PREPARATION

Many engineers have the opinion that one major factor in the failure of joint seals is inadequate cleaning. Three types of cleaning were utilized for this research. The standard for years has been air jet removal of the cutting dust.

The second method of cleaning was sand blasting. For this operation, the contractor rented a small Clemco Mighty-mite Sandblaster (figure 3) and used bagged silica sand. A specially designed wand would have improved this operation. To effectively sand blast the joint, the operator had to hold the short metal section with the nozzle very close to the pavement.

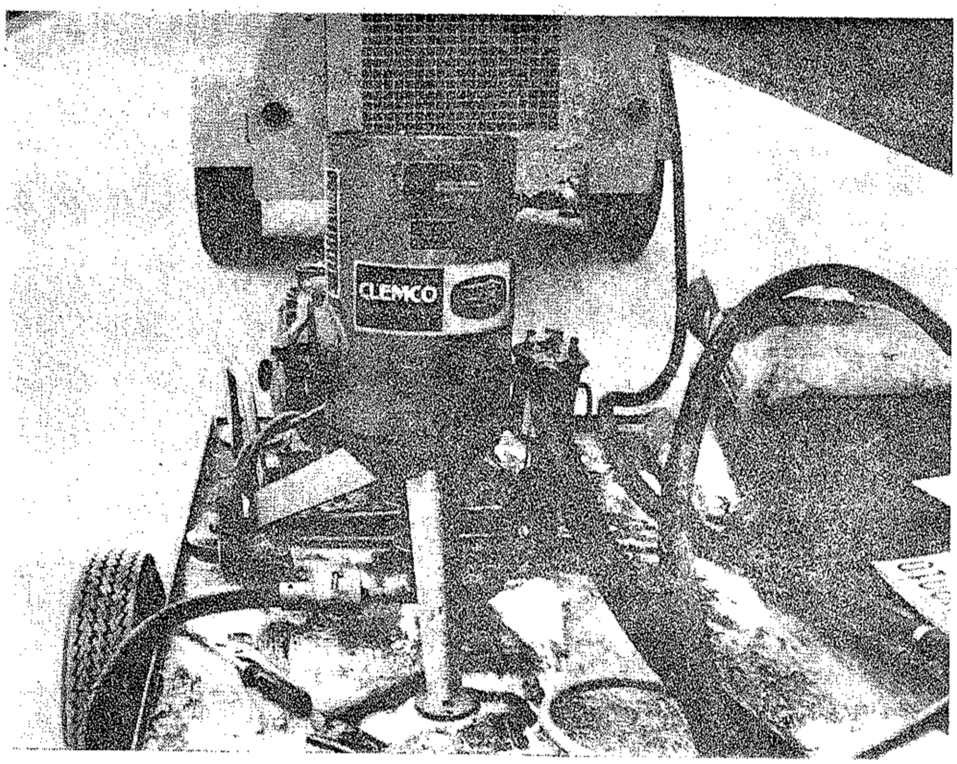

Figure 3 - Sand Blast Equipment

A portable car wash unit (figure 4) that would supply about 500 psi of pressure was used for water blast removal of dust and dirt. This unit was operated from the roadway shoulder and, therefore, could not be used when the rainy weather produced impassible conditions.

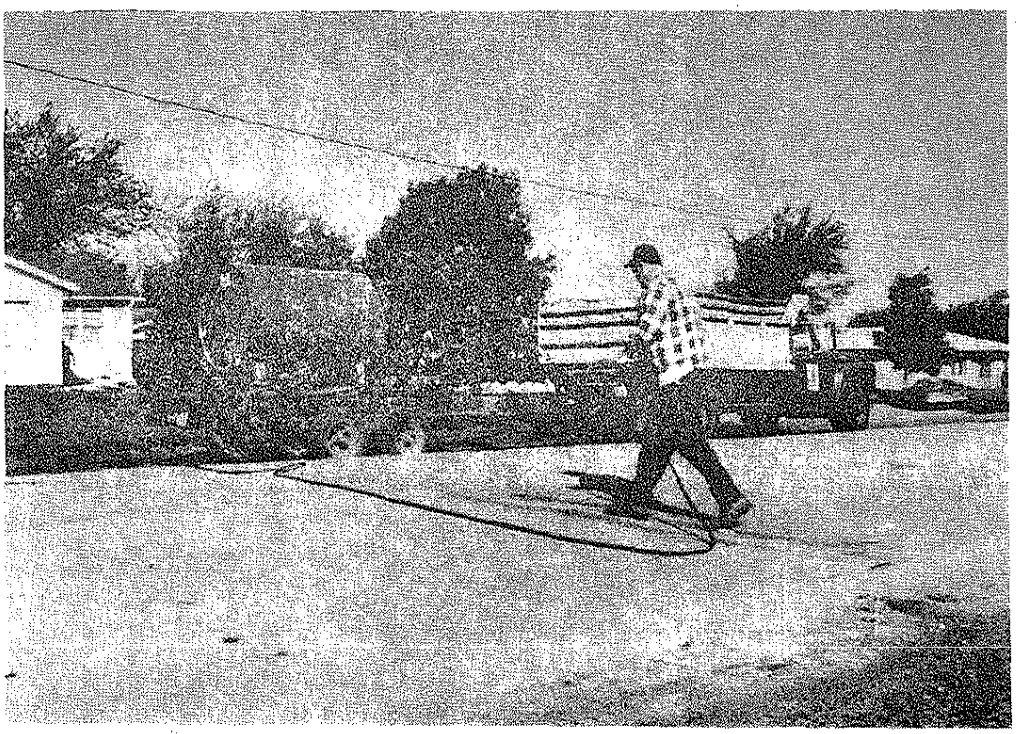

Figure 4 - Water Blast Equipment

INSERTING BACKING MATERIAL

Standard Iowa DOT joint sealing procedures do not include backing material. A number of the research joints were sealed without backing material. The most inexpensive type of backing material utilized in this research was tape. Another economical feature was that it required less depth on the step joints. The fiber backing tape requires only 1/2" of depth and the backer rod or backer rope requires 1" to 1-1/4" depending on the diameter. Proper placement of the fiber reinforced tape was very difficult.

The shoulders of the step joint were generally not equally distributed or wear of the carborundum blade did not produce distinct shoulders for a bearing surface (figure 5).

Due to difficulty in tape placement, the 1/2" deep step joints were soon discontinued.

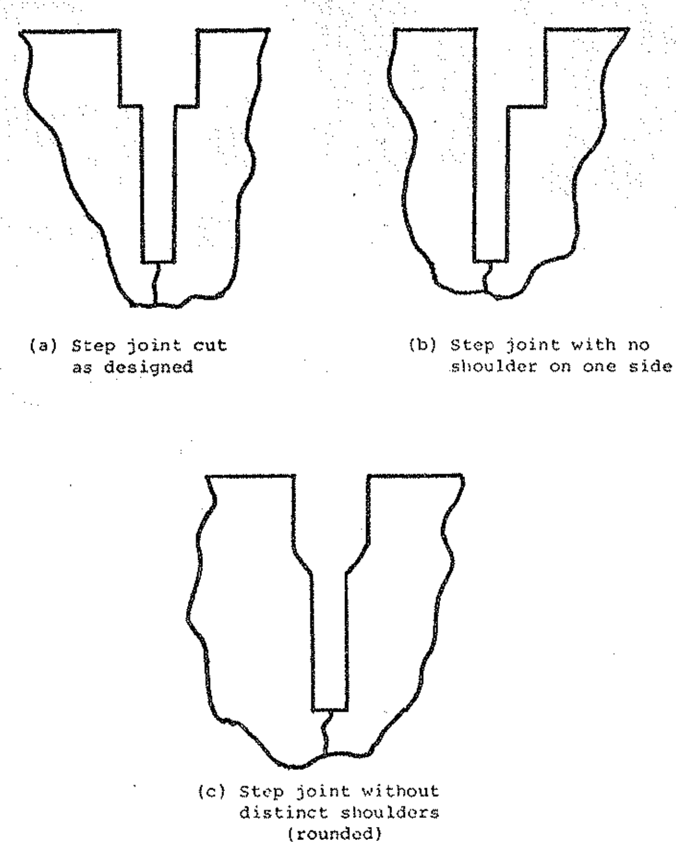

Figure 5 - Step Joints for Tape Backing

The backer rod material (figure 6) comes in three sizes (3/8", 1/2" and 5/8" diameter) that are matched to joint widths. It must be properly centered over the joint and rolled to the proper depth with a special tool (figure 7). To obtain the desired 1/2" reservoir for the sealant, the knife edge on the roller had to be 5/8" deep for the 1/2" and 5/8" diameter backer rod while a 1/2" knife edge depth was sufficient to place the 3/8" diameter backer rod.

The 3/8", 1/2" and 5/8" diameter sizes of backer rope, for use with the hot applied sealants, were installed with the same special tool.

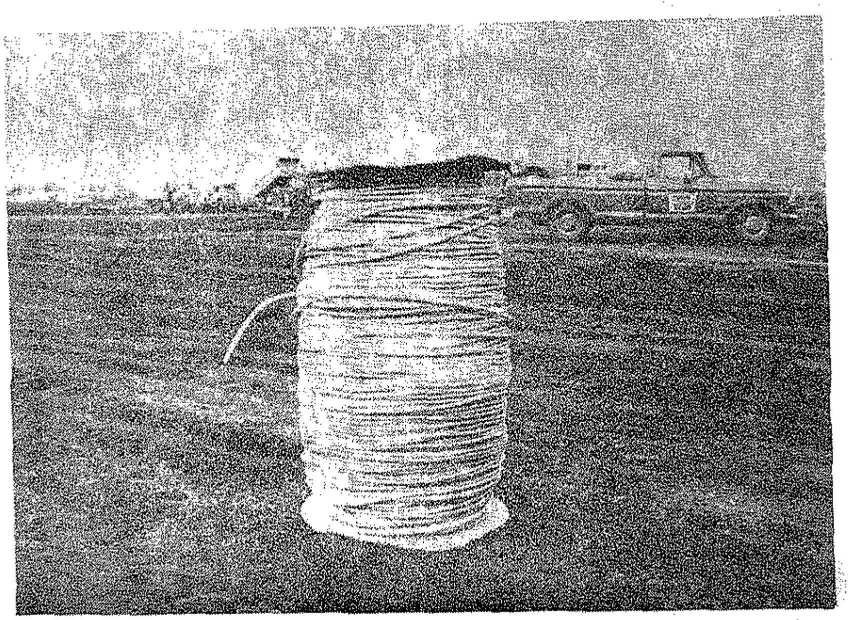

Figure 6 - Backer Rod Material

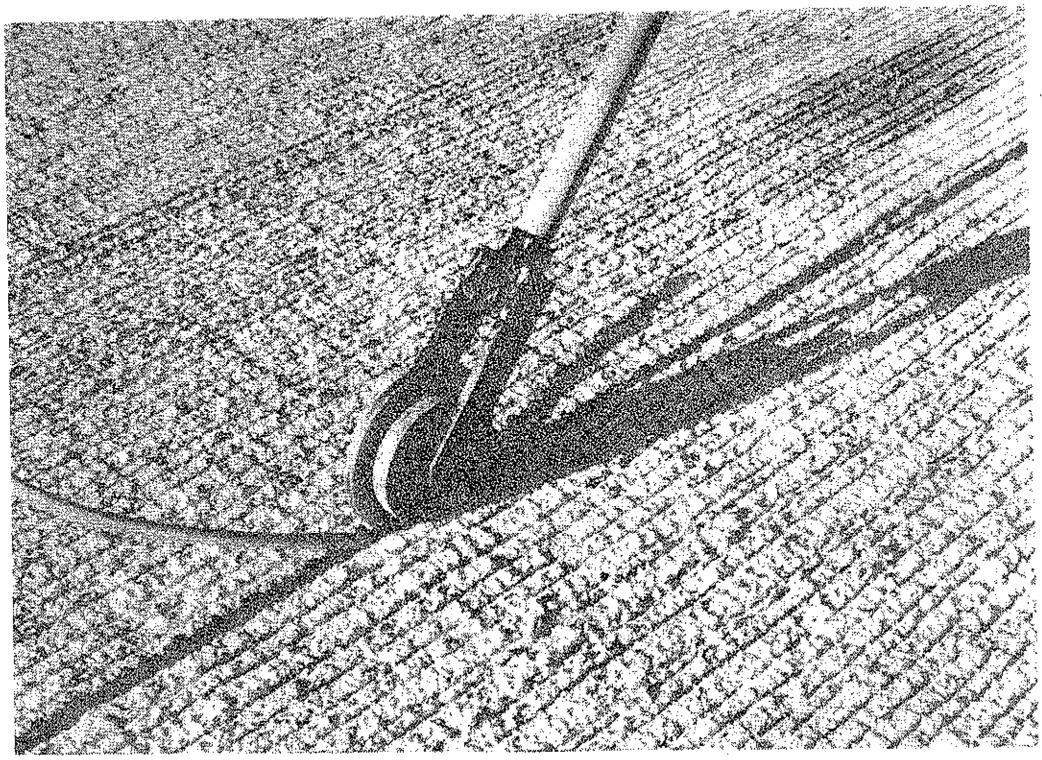

Figure 7 - Inserting Backer Rod Material

JOINT SEALING OPERATION

A. W. R. Meadows "Hi-Spec"

The contractor's standard operation includes a specially constructed hydraulically driven joint sealing unit (figure 8) that spans the slab for ease in applying the standard sealant material. It was equipped to heat the sealant to the recommended pouring temperature of 390^{o}F. The material was pumped through a wand with a special applicator tip.

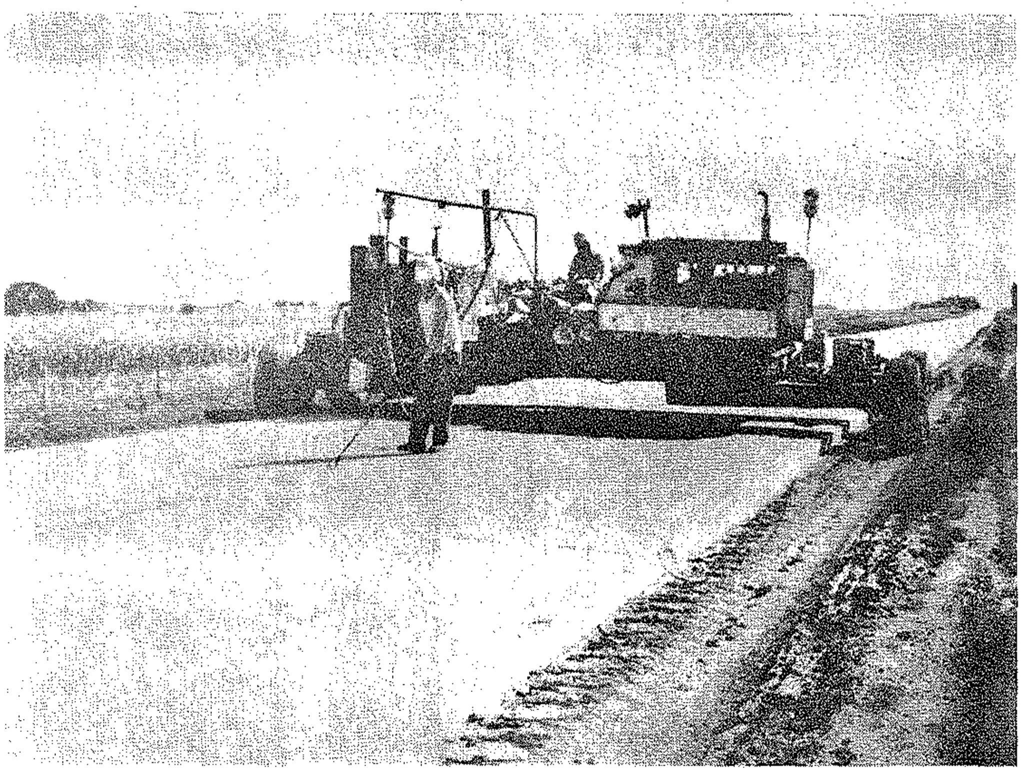

Figure 8 - Contractor's Joint Sealing Unit

B. Lion Oil Company "Lion D-200"

The two component material was mixed per the manufacturer's instruction. The contractor made a mixing agitator by welding a 6" hinge onto 1/4" diameter round stock. After component two was poured into component one, the contractor's personnel mixed the material thoroughly for 3 to 5 minutes. The viscosity of this material would not allow it to flow through the small orifice of an Iowa DOT crack sealing pot. All joints were hand poured using a five gallon bucket with one side bent to form a pouring spout (figure 9).

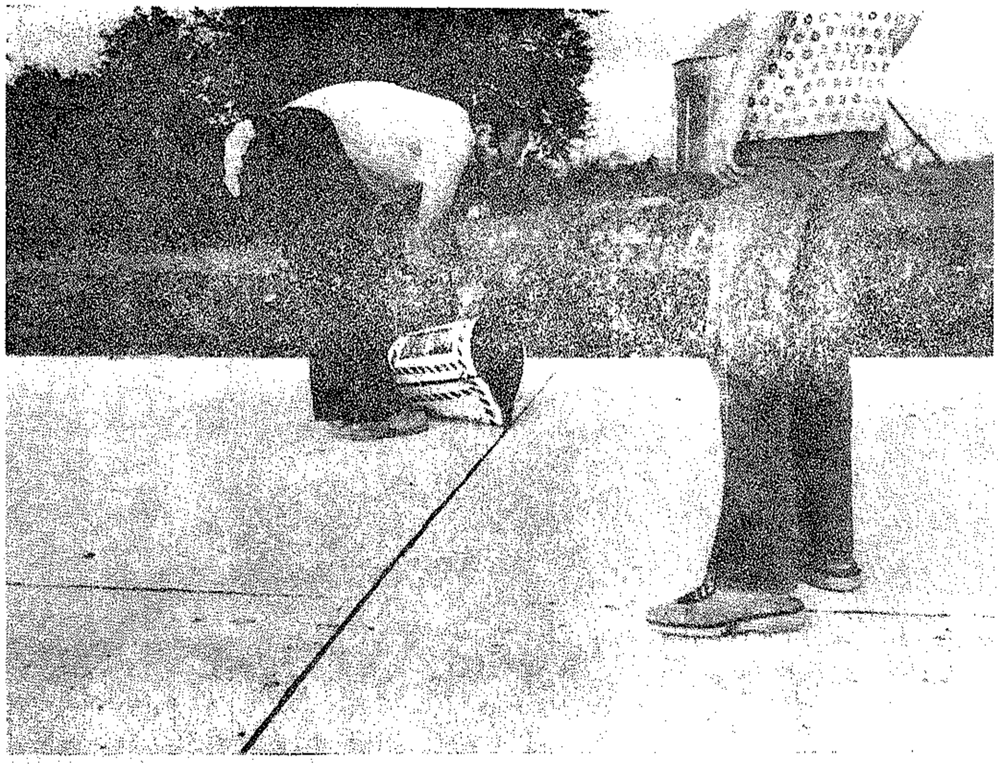

Figure 9 - Manual Pouring of Joint Sealant

Operator experience and technique are very important in obtaining properly filled joints. The pot life of this sealant was one to two hours. Better joints were obtained if the sealant was used soon after mixing while very fluid. If only the right amount of sealant was added to the pouring bucket to complete one joint at a time, a better sealing job was obtained. The operator must proceed at a speed that is coordinated with the viscosity of the sealant. With hand operation, it was very difficult and near impossible to under fill the joint 1/8" as desired. With some operator experience, reasonably neat appearing joints were obtained. Production type equipment could be developed to improve this sealing procedure and make it compatible with the contractor's operation.

C. W. R. Meadows "Gardox"

Mixing and applying this two component material was very similar to product "B" above. The mixing time was normally in excess of five minutes. The viscosity and pouring techniques were very similar to the Lion D-200. The manufacturer claims a pot life of 2 to 3 hours, but it exhibits far better pouring characteristics immediately after mixing. The length of time after mixing is directly related to the adverse pouring characteristics.

D. W. R. Meadows "Poly-Jet Highway"

This hot pour material was applied with the contractor's normal sealing equipment. Even though the application of this material is very similar to that for the Standard Specification rubber asphalts, there are some additional limitations and precautions. This polyvinyl chloride coal tar is not compatible with the rubber asphalt, therefore, it was necessary to completely clean the sealing equipment before and after using Poly-Jet Highway. Furthermore, the materials cannot be used in contact with each other in the joints, so when the transverse joints were Poly-Jet Highway, the longitudinal joint was also Poly-Jet Highway.

Poly-Jet Highway cannot be reheated, as it gels after heating. Any material remaining in the kettle at the end of the day must be discarded. Personnel must avoid the vapor produced while heating as it can cause irritation to the skin. The control of the heat must be precise with a recommended pouring temperature of 280°F and a maximum safe temperature of 300°F. Overheating causes the material to gel and additional heating will assure gelation.

The contractor was made aware of these precautions and the Poly-Jet Highway was installed without problems.

E. Dow Corning "888"

A representative of the Dow Corning Corporation supplied the sealant and application equipment in addition to supervising the installation. The sealant for this research was supplied in 4.5-gallon pails and 11-ounce caulking tube samples. The "888" sealant is to be tooled in and, therefore, the manufacturer recommends the use of backer materials. A few of the 1/4" wide joints were sealed using the caulking gun (figure 10). Most of the research joints were sealed using the air operated bucket pump supplied by Dow Corning (figure 11). The "888" sealant does not flow readily and must be "tooled" into the joint. This tooling was done immediately after depositing the sealant. Round steel rods compatible with the width of joints were used in much the same manner as one would "strike" the joints of a concrete block wall.

This was the first paving project where the Dow Corning personnel had assisted in the field application. It was a relatively slow process and the Dow Corning representative recognized that equipment modifications would improve the operation. A more efficient sealing system can be developed to increase the speed of application.

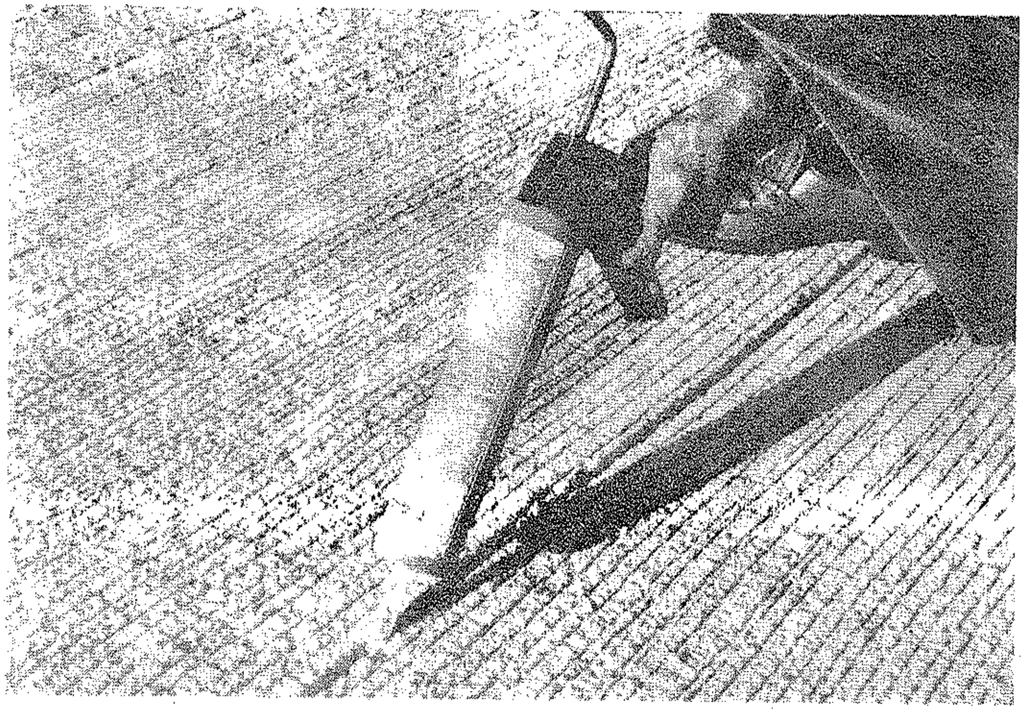

Figure 10 - Dow Corning 888 Sealing with a Caulking Gun

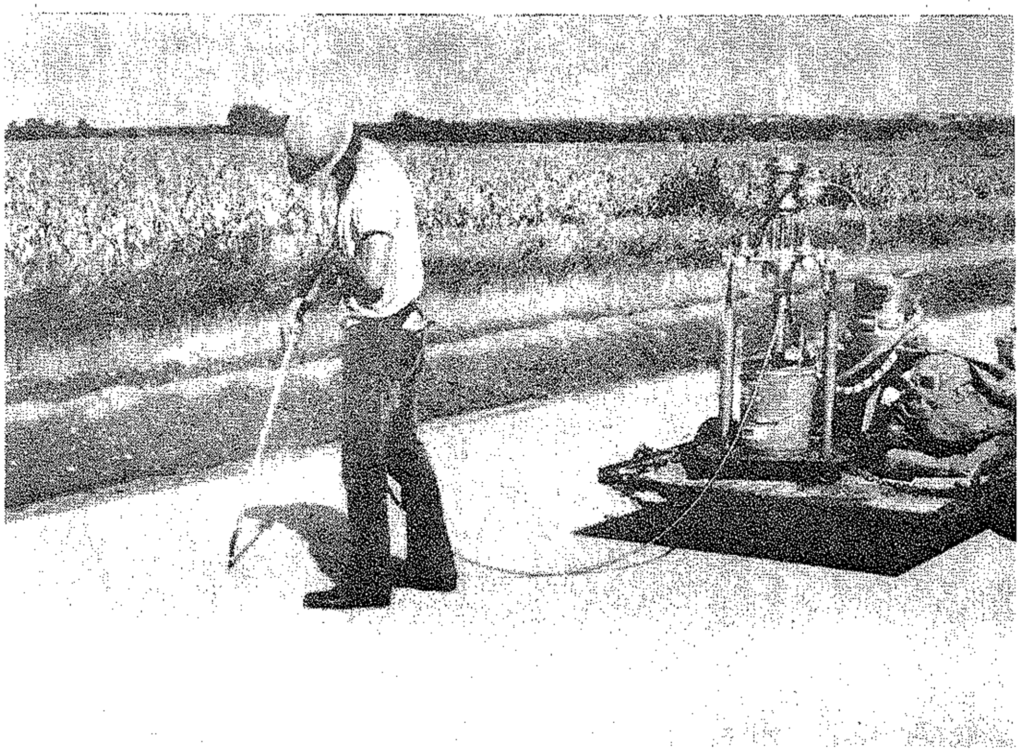

Figure 11 - Dow Corning 888 Sealing with Bucket Pump

F. <u>W. R. Grace "Para Plastic"</u>

The contractor used his normal sealing equipment for this Standard Specification rubber asphalt sealant. There were no problems and the application was exactly the same as for the W. R. Meadows "Hi-Spec" sealant.

COST COMPARISON

It would be difficult, if not impossible, and not entirely fair or realistic to try to determine the true cost of the total sealing operation for each sealant from the research. Some sealants were applied with readily available equipment while others were applied by crude hand equipment or equipment in the developmental stage.

The costs presented for comparison will be the contractor's cost of materials only (Table I & Table II).

Table I

Backer Rod	- 3/8" diam.	= $0.015/lin. ft.
	- 1/2" diam.	= 0.021/lin. ft.
	- 5/8" diam.	= 0.030/lin. ft.
Backer Rope	- 3/8" diam.	= $0.04 /lin. ft.*
	- 1/2" diam.	= 0.029/lin. ft.
	- 5/8" diam.	= 0.033/lin. ft.

*Purchased from another company on a small lot basis.

Sealant cost (Table II) presented is estimated for a 1/4" wide and 1/2" deep joint. This joint is selected to provide a definite volume for the cost comparison.

Table II

Sealant	Contractor's Cost Per/lb.	Per/gal.	Quantity for 1/4" x 1/2" joint	Price Per Lineal Ft.
Hi-Spec	$0.2415	$ 2.16	5.85 lb per 100 lineal feet	$0.015
Lion D-200	0.8211	7.80	154 lineal feet per gallon	0.051
Gardox	1.8907	19.38	0.7 gallon per 100 lin. ft.	0.136
Poly-Jet Hwy	0.5558**	5.89	6.888 lb/100 lin. ft.	0.038
Dow Corning 888	----	23.00	154 lineal ft. per gallon	0.149
Para Plastic	0.2415	2.16	5.85 lb. per 100 lin. ft.	0.015

** Includes cost of flushing oil.

PERFORMANCE EVALUATION

Three evaluation criteria were proposed when the project was initiated in 1978. They were:

1. A visual inspection and rating of the joints.
2. A rating of the joint heave during the winter period.
3. Core drilling and testing.

On previous projects, Dallas County had encountered severe problems with joint heave approximately three years after paving. Based upon this history, it was believed that an evaluation of joint heave for each joint series would be an excellent rating of the performance of the particular joint sealant system. Fortunately, for the public using the roadway, the joint heave problem has not occurred. The best evaluation of the performance of the road was obtained from a visual inspection and rating of each test section.

Visual Inspection

Visual evaluations of all joints listed in Appendix A were conducted four times during the project. The first visual review was conducted in

February and April of 1979. At that time, all joints appeared to be tight and sealed. Inspection of some joints was difficult due to a large amount of sand from winter ice control remaining on top of the sealant. From this first evaluation, it appeared that the visual evaluation should be conducted during a period of cold temperature to open the joints to their maximum. It would also be desirable to select an evaluation time substantially after the last application of sand for ice control.

The visual evaluations conducted in 1980, 1981 and 1983 are shown in Appendix A. The second evaluation conducted on February 27, 1980, was very revealing as many of the joints were broken. A visual rating scale was established as:

1 = good
2 = 3' or less of broken seal
3 = 3' or more of broken seal

If the joint to had failed when rated a 3, having 3' or more of broken seal, then at a time of 17 months after construction, 215 of the 560 joints evaluated had failed. This amounted to 38% failure at only 17 months. From this first visual evaluation, it was readily apparent as shown in Appendix A that the success or failure of a joint was primarily due to the joint sealant material. Some joint sealant materials exhibited no failures, while other joint sealant materials exhibited predominant failure. There did not seem to be a significant relationship to the type of cleaning that was used nor did there seem to be significant influence of the sealant reservoir or saw cut.

On the third evaluation conducted on February 26, 1981, only those joints that had not been rated as a 3 on the previous evaluation were evaluated. As of this date, 29 months after construction, 281 of the 560 joints (50%) being evaluated had failed. Again the failure seemed to relate more to the sealant material than to any other factor. One sealant material was performing very well, one sealant material was performing very poorly and the others were doing reasonably poorly. Even in this evaluation, the type of cleaning, the size of saw cut or sealant reservoir seemed to have insignificant bearing on the failures.

The final visual evaluation was made on March 16, 1983, 53 months after construction. At this time, 492 of the 560 joints (88%) had failed. This data was evaluated and grouped according to the installation code designations for particular joints. The results of this tabulation are given in Appendix A, Pages A-11 and 12. Utilizing the rating of 1 being equal to no visable seal failure, 2 being equal to 3' or less of broken seal, and 3 being equal to more than 3' of broken seal, a weighted numeric value was determined for each joint type. This data was used in a "Summary of Visual Evaluation Rating" given on page A-12. The summary is an effort to isolate and evaluate various different joint variables. The joint sealant materials are listed across the top of the summary. Joint sealant material E, the Dow Corning 888, received the best rating over all of 1.16. The sealant material B, Lyon D 200, exhibited the poorest performance on this project, with an overall rating of 2.93. All other sealant materials performed poorly ranging from 2.68 to 2.79.

A set of basic joint variables was utilized with sealant materials A, B, C and D. These basic joints were utilized to evaluate cleaning variables and saw cut variables. Joint sealant materials E and F were not included, as all types of joints were not placed with these sealant materials. Using the data from sealants A, B, C and D, the three different types of cleaning were compared. Air jet cleaning averaged a rating of 2.87 while sand blast cleaning averaged a rating of 2.64 and water blast cleaning yielded a rating of 2.84. From this data, it would appear that sand blast cleaning is slightly better than air or water blast cleaning on this project.

The X-X-2BX3 average of 2.81 represents the nominal 1/4" joints. The nominal 3/8" joints represented by the X-X-4 yielded 2.68 while the nominal 1/2" joints yielded a 2.82 rating. From this data, we would conclude that the saw cut on this project was not a determining factor in the performance of the joint systems.

Most joint materials were placed utilizing a backing material. Much research has indicated that a shallower joint seal utilizing a backing material would yield better performance. On pages A-11, it may be noted that a substantial number of joints utilizing sealant A and sealant F were placed without a backing material. Using the data given for sealant A and F the joints without backing material performed better than the comparative joint with backing material.

Joint seal failure was normally due to the loss of bond between the sealant material and the face of the saw cut. This may be an explanation as to why the joints without backing material performed better than those with backing material as in these joints there was a greater bonding area as the sealant material was placed to a greater depth.

Joint Heave

The riding quality of the pavement was determined using the Bureau of Public Roads Type Roughometer (BPR). Testing of both lanes soon after construction (11-30-78) resulted in an average of 71" per mile. The 25' profilometer was used to determine the degree of heaving of the various joints on the project. The first survey was conducted in February

1979. This profile trace exhibited no joint heave and served as original data for comparison with subsequent profiles.

Surveys of the entire length of the project were made using the 25' profilometer in February 1980, and March 1983. Joint heaving was not identified at any joint.

Core Drilling and Testing

The data obtained from core drilling and testing is given in Appendix B. Cores were drilled on April 16, 1979, February 27, 1980, and May 20, 1983.

In 1979 one interesting and significant feature was noted while drilling. The cores were drilled with an Acker Drill which supplies cooling and flushing water through a Moyno pump. When drilling the Dow Corning 888 joints, the water was pumped to both edges of the slab where it spurted up in a small stream. This emphasized the tight seal of this joint. This type of spurting was not noted on joints with other types of sealants.

In 1979 all cores were drilled between the wheel paths of the northbound lane. The intent was to center the core over the transverse joint, yielding a 4" length of joint seal for inspection and testing. The cores taken in 1979 were visually inspected and rated on the basis of their condition after drilling. Cores were classified as: 1. no visible failure - the bond was apparently tight on both interfaces for the entire 4" length, 2. partial seal failure - there was a loss of bond on one interface for even a short length, and 3. broken seal - the bond had completely failed on one interface and the core was no longer held together. Using this criteria, the cores were rated and summarized in respect to sealant material, cleaning and saw cut (B-4). Upon this 1979 evaluation, considering the sealant and disregarding other variables, the Poly-Jet Highway and the Dow Corning 888 exhibited no visible failures. The visual rating with respect to cleaning did not yield results that would favor any one procedure. The water blast cleaning exhibited the poorest results. The 1/2" deep joints with taped backing had no visible failures in the saw cut summary.

The cores were grouped by sealant type and color slide photographs were taken (figure 12).

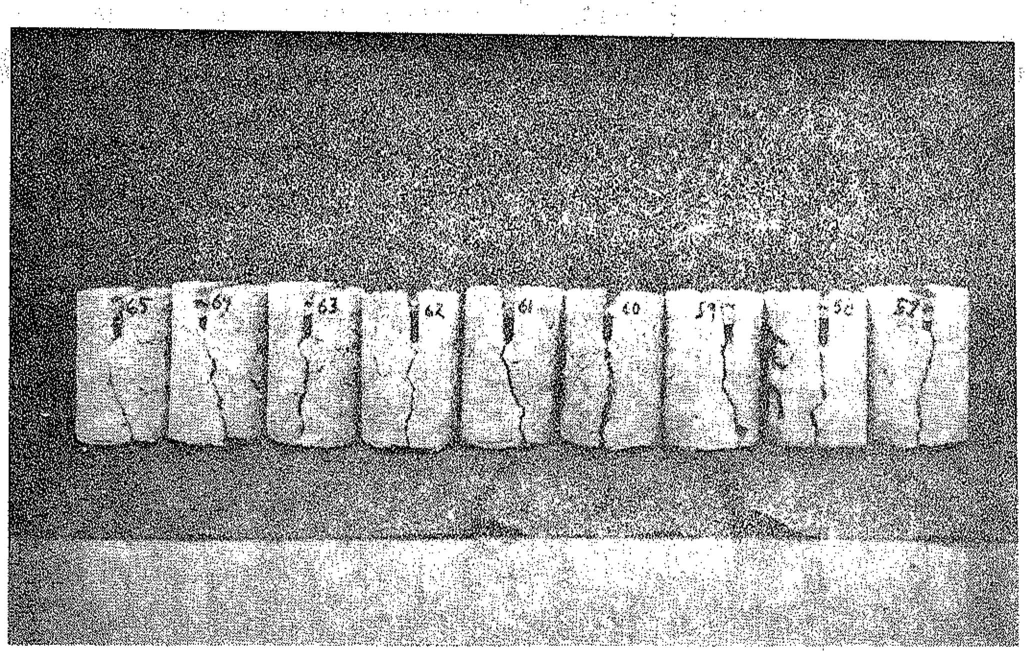

Figure 12 - Cores from Dow Corning 888 Joints

The top portion (approximately 2") of the cores, including the joint seal, was cut off for the final test of the cores. Two C clamps were fitted with pull rods to be used in a Tinius Ohlsen Testing Machine (figure 13). The C clamps were secured to the rods so they were not free to rotate. The rods were free to move for alignment. All cores that were bonded sufficiently to transmit load were tested. Even some that were rated partial seal failure yielded a significant maximum load at failure. The load was applied at the rate of 0.3" per minute. The maximum load, elongation at maximum load (not available for all cores) and elongation at failure are tabulated in Appendix B.

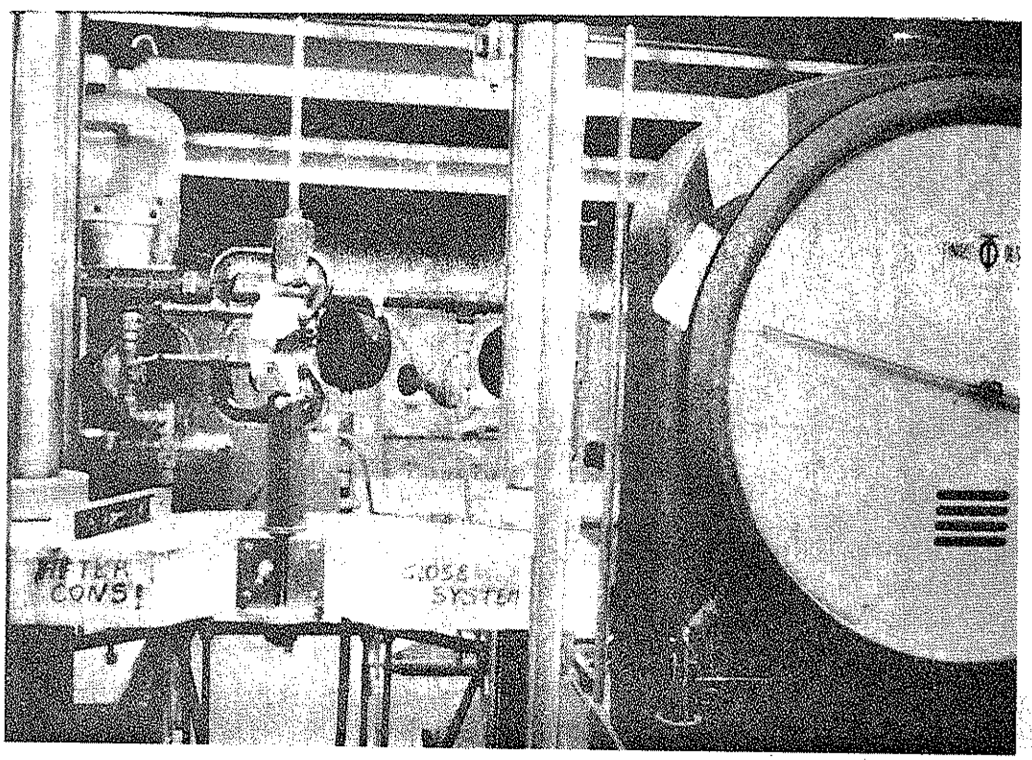

Figure 13 - Joint Seal Testing Apparatus

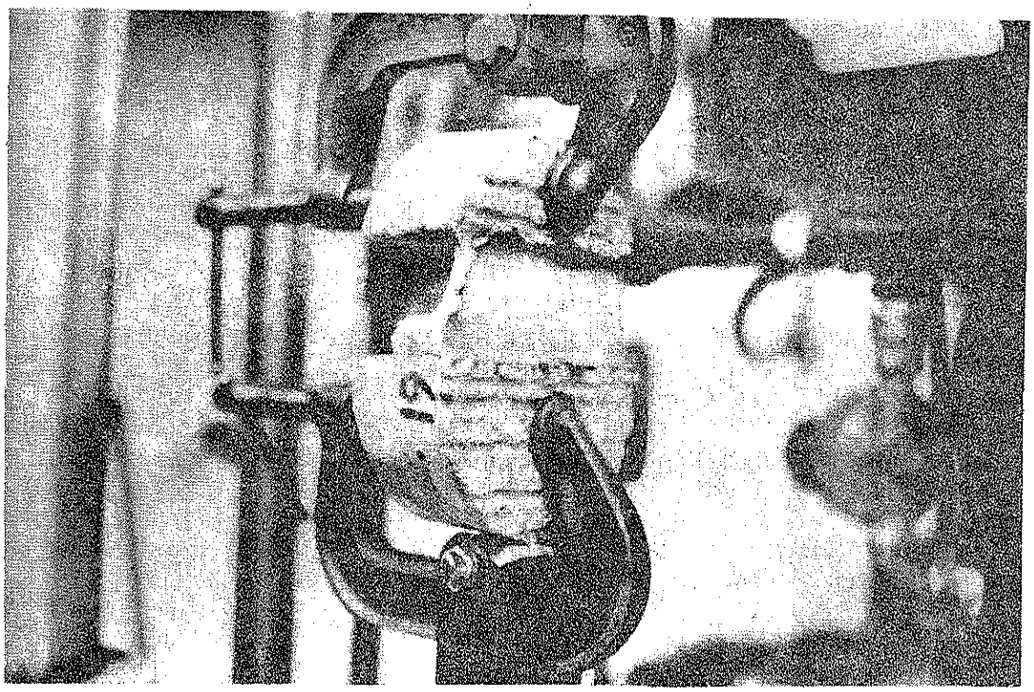

Figure 14 - Elongation of Dow Corning 888

The Dow Corning 888 material exhibited outstanding elongation (figure 14). Some Paraplastic joints had a very deep seal that resulted in a high maximum load (figure 15). A maximum load of 89.5 lbs. was obtained on a Paraplastic joint. The point of failure was somewhat arbitrary but certain criteria were established for this determination. First, if the bond was destroyed on 80% of the 4" length on either interface it had failed. Second, it failed if a load greater than 20 lbs. had been obtained followed by reduction below 10 lbs. The maximum loads and maximum elongations were summarized with respect to the same variables as the visual rating on page B-4. This testing exhibited poor strength and elongation for the Lyon D 200 and High Spec sealants. There was no significant difference due to the cleaning procedure. As expected, the 1/4" saw cut yielded the poorest elongation capabilities.

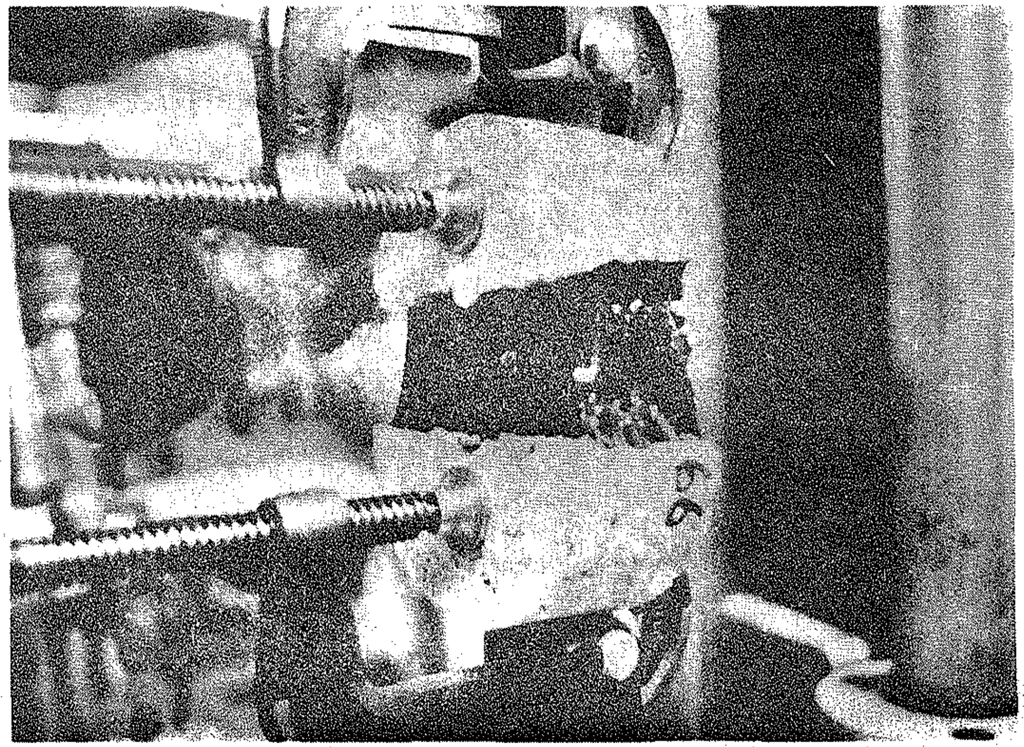

Figure 15 - Deep Seal of a Para Plastic Joint

The cores drilled on February 27, 1980, were tested in the same manner as the first set of cores. This data is given in Appendix B-5 and B-6. The maximum load and the elongations from the various sealant materials is very similar to the original core testing of 1979.

Testing of cores drilled on May 20, 1983 yielded maximum loads and maximum elongations very similar to the initial testing in 1979 (Appendix B-7). This seemed to indicate that if the material remained bonded to the faces of the saw cut the material would still perform as intended. The modulus or flexibility of the sealant material apparently had not changed to any great degree.

DISCUSSION

This project was initiated in answer to a growing concern by Iowa Department of Transportation Engineers for the rapid deterioration of portland cement concrete joints. There was a need that improved joint sealant procedures be identified and incorporated in portland cement concrete pavement projects. An Iowa DOT portland cement concrete joint task force was established in 1980. This task force was charged with bringing recommendations for improved portland cement concrete joints. Their recommendations resulted in:

1. The elimination of 1/8" wide saw cuts for contraction joints.
2. A specification for improved joint sealant material.

A new relatively inexpensive joint sealant material was introduced to the market after the inception of this research project. This new joint sealant material exhibits improved elongation characteristics and retains these desirable characteristics at cold temperatures. This new product and the Dow Corning 888 sealant material used in this project both meet present Iowa DOT specifications.

CONCLUSIONS

From this research it can be concluded that:

1. The type of cleaning of the transverse saw cut had very little bearing on the performance of the joint sealant system. The sandblast cleaning, however, exhibited a slightly better performance than did air jet or water blast cleaning.
2. The performance of the joint sealant material, was not significantly affected by the width of saw cut.

3. The performance of the joint depended primarily upon the joint sealant material. The Dow Corning 888 sealant material provided excellent performance. All other sealant material exhibited predominate failure.

ACKNOWLEDGEMENTS

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Hossein Foadian of the Iowa Department of Transportation contributed much to the success of the research by providing direction, inspection and documentation.

REFERENCES

1. "Joint-Related Distress in P.C.C. Pavement Cause, Prevention and Rehabilitation" NCHRP Synthesis 56 (January 1979) 36 pp.

2. DeYoung, Clarence "Spacing of Undoweled Joints in Plain Concrete Pavement" Highway Research Record No. 112 (1966) pp 46-54.

3. Grapham, M.C. et al "New York State Experience with Concrete Pavement Joint Sealers" Highway Research Record No. 80 (1965) pp 42-48.

APPENDIX A:

JOINT VARIABLE TABULATION

and

VISUAL EVALUATION

HR-203, "Joint Sealing with Various Sealants"

Installation Code Designations

A- 3- 5- B 3

- A- Material
- 3- Cleaning
- 5- Saw Cut
- B - Backing Materials
- 3 - Size of Backing

Sealant Materials

A- W. R. Meadows, "Hi-Spec" (Iowa Standard Specification 4136)
B- Lion Oil Division,"Lion D-200" (Two Comp. Urethane)
C- W. R. Meadows, "Gardox" (Two Comp. Neoprene)
D- W. R. Meadows, "Poly-Jet Highway" (Polyvinyl Chloride)
E- Dow Corning, "Dow Corning 888" (Silicone Rubber)
F- W. R. Grace, "Para Plastic" (Iowa Standard Spec. 4136)

Cleaning

1. Air Jet
2. Sand Blast
3. Water Blast

Saw Cut

1. Nominal 1/8"
2. Nominal 1/4"
3. Nominal 3/8" x 1/2" deep
4. Nominal 3/8" x 1" deep
5. Nominal 1/2" x 1/2" deep
6. Nominal 1/2" x 1-1/4" deep

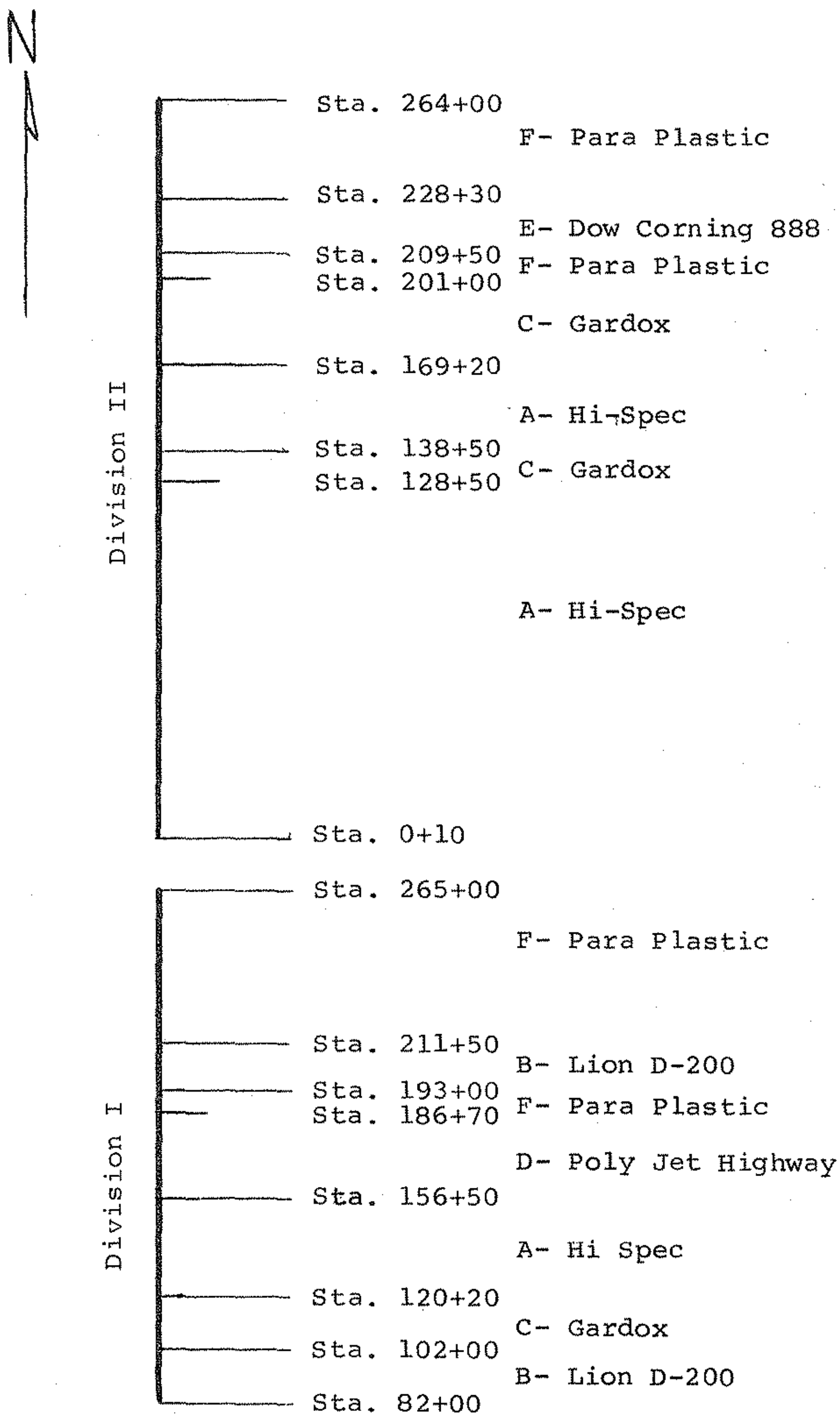
Backing Material

N- No Backing Materials
T- Tape
BH- Backer Rope (Hot Sealant)
BC- Backer Rod (Cold Sealant)

Size of Backing

3- 3/8"
4- 1/2"
5- 5/8"

SCHEMATIC JOINT SEALANT LAYOUT



APPENDIX A

JOINT VARIABLE TABULATION AND VISUAL EVALUATION

All stations were determined by pacing and, therefore, are approximate

Joint Number	Station	Installation Code Designation	Visual Evaluation** 80	81	83*
1	82+52	B-3-2-BC3	3		
2	82+88	"	3		
3	83+25	"	3		
4	83+70	"	3		
5	84+02	"	3		
	84+50	Broken	3		
6	84+85	B-3-4-BC4	3		
7	85+34	"	3		
8	85+70	"	3		
9	86+15	"	3		
10	86+56	"	3		
11	86+88	B-3-6-BC5	3		
12	87+35	"	3		
13	87+75	"	3		
14	88+20	"	3		
15	88+62	"	1	2	2
16	88+98	B-1-2-BC3	3		
17	89+50	"	3		
18	89+85	"	2	3	
19	90+35	"	3		
20	90+70	"	1	2	3
21	91+96	B-1-4-BC4	2	3	
22	91+52	"	1	1	1
23	91+85	"	3		
24	92+35	"	1	2	3
25	92+70	"	3		
26	93+15	B-1-6-BC5	1	1	3
27	93+55	"	2	2	3
28	93+88	"	2	3	
29	94+34	"	1	3	
30	94+67	"	2	3	
31	95+00	B-2-2-BC3	2	3	
32	95+45	"	3		
	95+85	Broken	3		
33	96+15	B-2-2-BC3	2	3	
34	96+62	"	3		
35	96+97	"	2	3	
	97+40	Broken	3		
36	97+80	B-2-4-BC4	1	1	1
37	98+23	"	1	1	2
38	98+65	B-2-4-BC4	2	2	3
39	99+09	"	1	1	3
40	99+49	"	2	3	
41	99+90	B-2-6-BC5	1	1	3
42	100+30	"	2	2	3
43	100+75	"	2	3	
44	101+35	Not functioning			
45	101+65	B-2-6-BC5	1	2	3
46	102+02	C-3-2-BC3	3		
47	102+45	"	3		
48	102+90	"	3		
49	103+40	"	3		
50	103+85	"	3		
51	104+25	C-3-4-BC4	3		
52	104+75	"	3		
53	105+25	"	1	1	3
54	105+65	"	2	3	
55	105+94	"	3		
56	106+45	C-3-6-BC5	3		
57	106+85	"	2	3	
58	107+20	"	3		
59	107+60	"	3		
60	108+01	"	3		
61	108+37	C-1-2-BC3	3		
62	108+79	"	3		
63	109+25	"	3		
64	109+60	"	1	2	3
65	110+10	"	3		
66	110+55	C-1-4-BC4	1	2	3
67	110+90	"	3		
68	111+42	"	3		
69	111+75	"	1	1	2
70	112+10	"	3		
71	112+58	C-1-6-BC5	1	1	3
72	112+88	"	1	1	2
73	113+33	C-1-6-BC5	3		
74	113+72	"	3		
75	114+03	"	2	3	
76	114+51	C-2-2-BC3	1	3	
77	114+85	"	3		

* Visual Rating: 1 = Good, 2 = 3' or less broken seal, 3 = 3' or more broken seal

** Visual Evaluation: Dates of inspection = 2-27-80, 2-26-81, 3-16-83

APPENDIX A Cont.

Joint Number	Station	Installation Code Designation	Visual Evaluation ** 80	81	83 *
78	115+27	C-2-2-BC3	1	2	3
79	115+69	"	3		
80	116+03	"	1	1	3
81	116+36	C-2-4-BC4	3		
82	116+78	"	1	2	3
83	117+15	"	3		
84	117+55	"	1	3	
85	118+02	"	3		
86	118+40	C-2-6-BC5	1	1	2
87	118+90	"	3		
88	119+28	"	1	1	2
89	119+60	"	3		
90	120+05	"	1	1	1
91	120+40	A-3-2-N	3		
92	120+80	"	1	1	2
93	121+22	"	3		
94	121+62	"	1	1	2
95	121+98	"	3		
96	122+33	A-3-4-BH3	3		
97	122+80	"	1	1	2
98	123+25	"	3		
99	123+60	"	3		
100	124+00	"	3		
101	124+36	A-3-6-BH5	3		
102	124+78	"	3		
103	125+20	"	3		
104	125+55	"	3		
105	126+00	"	3		
106	126+40	A-1-2-N	3		
107	126+80	"	3		
108	127+20	"	3		
109	127+60	"	3		
110	127+96	"	3		
111	128+45	A-1-4-BH3	3		
112	128+90	"	1	2	3
113	129+30	"	3		
114	129+72	"	1	1	2
115	130+18	"	3		
116	130+70	A-1-6-BH5	3		
117	131+00	"	1	2	3
118	131+66	A-1-6-BH5	1	2	2
119	132+05	"	3		
120	132+50	"	2	3	
121	132+90	A-2-2-N	3		
122	133+30	"	3		
123	133+75	"	3		
124	134+20	"	3		
125	134+58	"	3		
126	134+97	A-2-4-BH3	1	1	2
127	135+38	"	3		
128	135+75	"	1	2	3
129	136+15	"	3		
130	136+50	"	2	2	3
131	136+90	A-2-6-BH5	3		
132	137+30	"	1	1	1
133	137+70	"	3		
134	138+10	"	1	1	2
135	138+45	"	3		
136	138+85	Not functioning			
137	139+30	"	3		
138	139+70	"	3		
139	140+00	"	2	2	2
140	140+35	"	2	2	3
141	140+80	A-3-4-BH3	3		
142	141+15	"	3		
143	141+60	"	3		
144	141+97	"	3		
145	142+30	"	3		
146	142+65	A-3-6-BH5	3		
147	143+10	"	3		
148	143+43	"	3		
149	143+82	"	3		
150	144+20	"	3		
151	144+60	A-1-2-N	2	3	
152	145+05	"	2	3	
153	145+45	"	1	3	
154	145+78	"	1	1	2
155	146+20	"	3		
156	146+65	A-1-4-BH3	3		
157	147+00	"	3		
158	147+40	"	2	3	
159	147+80	"	3		
160	148+20	"	2	3	
161	148+60	A-1-6-BH5	3		
162	148+95	"	3		
163	149+35	A-1-6-BH5	3		
164	149+70	"	3		
165	150+10	"	3		
166	150+50	A-2-2-N	3		
167	150+90	"	3		
168	151+30	"	1	2	2
169	152+03	"	1	1	2
170	152+48	"	3		
171	152+83	A-2-4-BH3	3		
172	153+25	"	3		
173	153+65	"	3		

APPENDIX A Cont.

Joint Number	Station	Installation Code Designation	Visual Evaluation** 80	81	83*
174	154+00	A-2-4-BH3	3		
175	154+40	"	3		
176	154+80	A-2-6-BH5	1	1	3
177	155+20	"	3		
178	155+60	"	2	2	3
179	155+91	"	3		
180	156+30	"	3		
181	156+70	D-3-2-BH3	3		
182	157+10	"	3		
183	157+50	"	2	3	
184	157+90	"	1	3	
185	158+30	"	1	2	3
186	158+70	D-3-4-BH4	1	2	3
187	159+05	"	1	1	3
188	159+43	"	1	1	3
189	159+80	"	1	2	3
190	160+20	"	1	1	3
191	160+60	D-3-6-BH5	1	1	2
192	161+00	"	1	2	3
193	161+40	"	1	1	3
194	161+75	"	1	3	
195	162+15	"	1	2	3
196	162+55	D-3-2-BH3	2	3	
197	162+93	"	2	3	
198	163+30	"	1	3	
199	163+70	"	2	3	
200	164+10	"	1	3	
201	164+50	D-3-4-BH4	1	1	3
202	164+85	"	1	1	2
203	165+30	"	1	1	2
204	165+70	"	1	1	2
205	166+06	"	1	2	3
206	166+46	D-3-6-BH5	1	1	3
207	166+86	D-3-6-BH5	1	2	3
208	167+25	"	1	1	3
209	167+67	"	1	2	3
210	168+10	"	1	3	
211	168+50	D-2-2-BH3	1	1	1
212	168+92	"	1	1	3
213	169+30	"	1	2	3
214	169+70	"	1	2	3
215	170+15	"	2	2	3
216	170+55	D-2-4-BH4	1	1	3
217	170+95	"	1	1	3
218	171+35	"	1	2	3
219	171+75	"	1	1	3
220	172+20	"	1	1	3
221	172+60	D-2-6-BH5	1	1	2
222	173+04	D-2-6-BH5	2	3	
223	173+45	"	2	3	
224	173+85	"	1	2	3
225	174+35	"	1	1	2
226	174+75	D-2-2-BH3	1	1	1
227	175+18	"	2	2	2
228	175+63	"	1	2	2
229	176+08	"	2	2	2
230	176+50	"	1	2	2
231	176+88	D-2-4-BH4	1	1	2
232	177+30	"	1	1	1
233	177+70	"	1	1	1
234	178+10	"	1	1	2
235	178+50	"	1	1	1
236	178+94	D-2-6-BH5	1	2	3
237	179+35	"	1	1	2
238	179+75	"	1	3	
239	180+10	"	1	1	2
240	180+50	"	1	1	3
241	180+90	D-1-2-BH3	1	1	2
242	181 30	"	2	3	
243	181+70	"	1	2	3
244	182+10	"	2	2	3
245	182+50	"	1	3	
246	182+85	D-1-4-BH4	1	2	3
247	183+25	"	1	1	3
248	183+65	"	1	2	3
249	184+10	"	1	3	
250	184+50	"	1	3	
251	184+90	D-1-6-BH5	3		
252	185+25	"	3		
253	185+65	"	2	3	
254	186+10	"	1	2	3
255	186+50	"	2	3	
256	186+88	F-1-2-BH3	3		
257	187+30	"	2	3	
248	187+70	"	3		
259	188+08	"	3		
260	188+48	"	3		
261	188+88	F-1-4-BH4	3		
262	189+30	"	3		
263	189+70	"	3		
264	190+10	"	3		
265	190+50	"	3		
266	191+10	F-1-6-BH5	3		
267	191+50	"	3		
268	191+95	"	3		
269	192+40	"	3		

APPENDIX A Contd.

Joint Number	Station	Installation Code Designation	Visual Evaluation ** 80	81	83 *
270	192+80	F-1-6-BH5	2	3	
271	193+28	B-3-2-BC3	3		
272	193+70	"	3		
273	194+20	"	3		
274	194+75	"	3		
275	195+08	"	3		
276	195+48	B-3-4-BC4	1	3	
277	195+88	"	3		
278	196+30	"	1	3	
279	196+70	"	3		
280	197+12	"	2	3	
281	197+52	B-3-6-BC5	2	3	
282	197+95	"	2	3	
283	198+35	"	1	3	
284	198+80	"	1	3	
285	199+25	"	2	3	
286	199+70	B-2-2-BC3	3		
287	200+15	"	3		
288	200+60	"	3		
289	201+03	"	3		
290	201+40	"	3		
291	201+80	B-2-4-BC4	3		
292	202+20	"	2	3	
293	202+60	"	2	3	
294	203+00	"	2	3	
295	203+40	"	3		
296	203+80	B-2-6-BC5	2	2	3
297	204+20	"	2	3	
298	204+60	"	1	2	3
299	204+98	"	1	1	3
300	205+38	"	1	2	3
301	205+75	B-1-2-BC3	3		
302	206+12	"	3		
303	206+53	"	3		
304	206+94	"	3		
305	207+32	"	3		
306	207+68	B-1-4-BC4	3		
307	208+09	"	3		
308	208+50	"	3		
309	208+88	"	3		
310	209+25	"	2	3	
311	209+65	B-1-6-BC5	2	2	3
312	210+03	"	2	2	3
313	210+43	"	1	2	3
314	210+85	"	1	1	3
315	211+20	"	3		
316	211+67	F-1-2-BH3	3		
317	212+07	"	3		

Joint Number	Station	Installation Code Designation	Visual Evaluation ** 80	81	83 *
318	212+47	F-1-2-BH3	3		
319	212+86	"	3		
320	213+25	"	3		

From Sta. 213+25 to Hwy 44, all the joints are under the following code:
F-1-2-N. The longitudinal joint material is "F".

From Hwy. 44 to Sta. 128+65 all the joints including the longitudinal joint up to Sta. 201+36 are under the following code: A-1-2-N

Joint Number	Station	Installation Code Designation	Visual Evaluation ** 80	81	83 *
321	128+65	C-1-3-BC3	3		
322	129+05	"	1	1	3
323	129+45	"	3		
324	129+85	"	1	1	3
325	130+25	"	2	3	
326	130+65	C-1-4-BC4	1	2	3
327	131+09	"	3		
328	131+40	"	2	2	3
329	131+75	"	1	3	
330	132+25	"	3		
331	132+65	C-1-5-BC4	3		
332	133+06	"	2	2	3
333	133+40	"	2	3	
334	133+75	"	3		
335	134+30	"	3		
336	134+65	C-1-6-BC5	1	1	3
337	134+65	"	1	1	3
338	135+48	"	3		
339	135+90	"	3		
340	136+35	"	3		
341	136+70	C-1-2-BC3	3		
342	137+09	"	2	2	3
343	137+44	"	3		
344	137+80	"	2	3	
345	138+25	"	3		
346	138+60	A-1-3-N	1	1	1
347	139+00	"	1	1	2
348	139+36	"	1	1	1
349	139+70	"	1	1	1
350	140+15	"	1	1	1
351	140+60	A-1-4-N	1	1	1
352	141+30	"	1	1	1
353	141+70		1	1	3
354	142+22	"	2	2	1

APPENDIX A Cont.

Joint Number	Station	Installation Cost Designation	Visual Evaluation 80	81	83
355	142+60	A-1-4-N	1	1	1
356	143+09	A-1-5-N	1	1	1
357	143+45	"	1	1	1
358	143+90	"	1	1	2
359	144+35	"	1	1	2
360	144+75	"	1	1	2
361	145+10	A-1-6-BH5	3		
362	145+52	"	Not functioning		
363	145+88	"	3		
364	146+30	"	2	3	
365	146+65	"	1	1	3
366	147+00	A-1-2-N	3		
367	147+45	"	3		
368	147+80	"	3		
369	148+30	"	3		
370	148+60	"	3		
371	148+99	A-1-3-N	2	2	3
372	149+40	"	1	1	1
373	149+75	"	2	2	3
374	150+25	"	1	1	2
375	150+60	"	1	1	3
376	150+90	"	1	1	1
377	151+30	"	2	2	3
378	151+70	"	1	1	1
379	152+10	"	2	2	2
380	152+55	"	2	2	2
381	152+80	A-1-5-N	1	1	2
382	153+12	"	1	2	3
383	153+45	"	1	1	2
384	153+90	"	1	1	1
385	154+35	"	1	1	3
386	154+75	A-1-6-N	1	1	3
387	155+20	"	1	1	1
388	155+60	"	1	1	2
389	156+00	"	1	1	1
400	156+35	"	1	1	1
401	156+75	A-1-2-N	2	2	2
402	157+30	"	2	2	2
403	157+70	"	1	1	2
404	158+20	"	2	2	2
405	158+50	"	3		
406	158+90	A-1-3-N	1	1	1
407	159+30	"	1	1	3
408	159+75	"	2	2	3
409	160+20	"	1	1	3
410	160+60	"	1	1	2
411	161+03	A-1-4-N	1	1	3
412	161+40	"	1	1	3

Joint Number	Station	Installation Code Designation	Visual Evaluation 80	81	83
413	161+83	A-1-4-N	2	2	3
414	162+30	"	1	1	2
415	162+70	"	1	1	2
416	163+10	A-1-5-N	1	1	3
417	163+55	"	1	1	3
418	163+95	"	1	1	3
419	164+40	"	1	1	3
420	164+83	"	1	1	2
421	165+20	A-1-6-N	1	1	2
422	165+65	"	1	1	2
423	166+01	"	1	2	2
424	166+39	"	2	2	3
425	166+77	"	1	1	3
426	167+35	A-1-2-N	1	1	1
427	167+75	"	2	3	3
428	168+15	"	2	2	3
429	168+65	"	3		
430	169+02	"	1	1	2
431	169+40	C-1-3-BC3	3		
432	169+85	"	1	1	1
433	170+25	"	1	1	1
434	170+75	"	3		
435	171+09	"	2	2	2
436	171+60	C-1-4-BC4	1	1	1
437	171+96	"	3		
438	172+43	"	1	1	2
439	172+80	"	1	2	2
440	173+25	"	2	2	3
441	173+65	C-1-5-BC4	2	3	
442	174+02	"		Faulted	
443	174+38	"	1	2	2
444	174+75	"	2	2	2
445	175+20	"	3		
446	175+73	C-1-6-BC5	2	2	2
447	176+15	"	3		
448	176+58	"	1	2	2
449	176+91	"	3		
450	177+30	"	2	2	2
451	177+80	C-1-2-BC3	3		
452	178+17	"	1	2	2
453	178+65	"	2	2	3
454	179+04	"	3		
455	179+50	"	1	1	2
456	179+94	C-2-3-BC3	2	2	3
457	180+35	"	3		
458	180+75	"	2	3	
459	181+17	"	3		
460	181+60	"	2	2	2

APPENDIX A Cont.

Joint Number	Station	Installation Cost Designation	Visual Evaluation 80	81	83
461	181+99	C-2-4-BC4	3		
462	182+40	"	1	2	2
463	182+80	"	3		
464	183+30	"	1	1	2
465	183+70	"	1	2	2
466	184+42	C-2-5-BC4	2	2	3
467	184+80	"	3		
468	185+20	"	1	2	2
469	185+60	"	1	1	1
470	186+10	"	3		
471	186+55	C-2-6-BC5	2	2	2
472	186+94	"	2	2	2
473	187+35	"	3		
474	187+75	"	2	2	2
475	188+20	"	1	1	1
476	188+60	C-2-2-BC3	3		
477	189+09	"	1	1	1
478	189+40	"	3		
479	189+85		Missing		
480	190+35		Missing		
481	190+76	C-3-3-BC4	3		
482	191+16	"	3		
483	191+56	"	1	2	3
484	192+01	"	3		
485	192+43	"	1	1	2
486	192+90	C-3-4-BC4	1	1	3
487	193+30	"	1	1	1
488	193+70	"	3		
489	194+15	"	1	2	2
490	194+55	"	1	1	1
491	194+96	C-3-5-BC4	1	2	2
492	195+40	"	3		
493	195+80	"	3		
494	196+22	"	3		
495	196+62		Missing		
496	197+04	C-3-6-BC5	3		
497	197+44	"	3		
498	197+82	"	3		
499	198+30	"	3		
500	198+75	"	3		
501	199+25	C-3-2-BC3	1	1	1
502	199+70	"	3		
503	200+09	"	3		
504	200+50	"	3		
505	200+97	"	3		
506	201+36	F-3-3-N	1	2	2
507	201+80	"	1	1	2
508	202+20	"	1	1	2
509	202+60	F-3-3-N	1	1	2
510	203+06	"	2	2	2
511	203+46	F-3-4-N	1	1	1
512	203+86	"	3		
513	204+33	"	2	2	2
514	204+73	"	1	2	3
515	205+17	"	1	1	2
516	205+56	F-3-5-N	1	1	3
517	206+02	"	1	1	3
518	206+42	"	1	2	3
519	206+82	"	1	2	3
520	207+22	"	1	2	3
521	207+62	F-3-6-N	1	3	
522	208+05	"	1	1	3
523	208+45	"	1	1	2
524	208+85	"	1	2	3
525	209+36	"	1	2	2
526	209+67	E-3-2-BC3	1	1	1
527	210+08	"	1	1	1
528	210+60	"	1	1	1
529	211+03	"	1	1	1
530	211+43	"	1	2	3
531	211+90	F-1-2-N	1	1	2
532	212+36	E-1-2-BC3	1	2	2
533	212+73	"	1	1	1
534	213+20	"	1	1	1
535	213+62	"	1	1	1
536	214+03	"	1	1	1
537	214+42	E-1-6-BC5	1	1	1
538	214+85	"	1	1	1
539	215+26	"	1	1	1
540	215+67	"	1	1	1
541	216+06	"	1	1	1
542	216+46	E-1-5-T	2	2	2
543	217+05	"	1	2	2
544	217+42	"	1	1	1
545	217+82	"	1	1	1
546	218+25	"	1	1	1
547	218+63	E-1-4-BC4	1	1	1
548	219+03	"	1	1	1
549	219+36	"	1	1	1
550	219+78	"	1	1	1
551	220+21	"	1	1	1
552	220+55	E-1-3-T	1	2	2
553	220+95	"	1	1	1
554	221+40	"	1	1	1
555	221+82	"	1	1	1
556	222+13	"	1	1	1

APPENDIX A Cont.

Joint Number	Station	Installation Cost Designation	Visual Evaluation** 80	81	83*
557	222+58	E-2-2-BC3	1	1	1
558	222+88	"	1	1	1
559	223+30	"	1	1	1
560	223+70	"	1	1	1
561	224+09	"	1	1	1
562	224+50	E-2-6-BC5	1	1	1
563	224+82	"	1	1	1
564	225+24	"	1	1	1
565	225+64	"	1	1	1
566	226+00	"	1	1	1
567	226+40	E-2-5-T	1	1	1
568	226+80	"	2	2	2
569	227+20	"	1	1	1
570	227+60	"	1	1	1
571	228+10	"	1	1	1
572	228+50	F-1-4-N	1	1	2
573	228+90	"	1	2	3
574	229+30	"	1	1	1
575	229+70	"	1	1	2
576	230+10	"	1	1	1
577	230+50	F-1-3-N	1	1	2
578	230+90	"	1	1	1
579	231+33	"	1	1	3
580	231+72	"	1	1	1
581	232+15	"	1	1	1

**Visual Evaluation: Dates of inspection =

2-27-80, 2-26-81, 3-16-83

*Visual Rating: 1 = Good, 2 = 3' or less broken seal,

3 = 3' or more broken seal

Remarks:

From Sta. 82+00 to Sta. 156+30 the longitudinal joint material is "A"

From Sta. 156+30 to Sta. 186+50 the longitudinal joint material is "D"

From Sta. 186+50 to Sta. 213+25 the longitudinal joint material is "F"

From Hwy. 44 to Sta. 201+36 the longitudinal joint material is "A"

From Sta. 201+36 to F-31 the longitudinal joint material is "F"

From Sta. 232+15 to F-31 all the joints including the longitudinal joint are under the following code F-1-2-N

SUMMARY TABULATION OF JOINT VARIABLES AND THEIR RATINGS

A-1-2-N 25 @ 2.68
A-1-3-N 15 @ 2.00
A-1-4-N 15 @ 2.00
A-1-4-BH3 10 @ 2.20
A-1-5-N 15 @ 2.20
A-1-6-N 10 @ 2.00
A-1-6-BH5 14 @ 2.93
A-2-2-N 10 @ 2.80
A-2-4-BH3 10 @ 2.90
A-2-6-BH5 10 @ 2.70
A-3-2-N 9 @ 2.40
A-3-4-BH3 10 @ 2.90
A-3-6-BH5 10 @ 3.00

B-1-2-BC3 10 @ 3.00
B-1-4-BC4 10 @ 2.80
B-1-6-BC5 10 @ 3.00
B-2-2-BC3 10 @ 3.00
B-2-4-BC4 10 @ 2.70
B-2-6-BC5 9 @ 3.00
B-3-2-BC3 10 @ 3.00
B-3-4-BC4 10 @ 3.00
B-3-6-BC5 10 @ 2.90

C-1-2-BC3 15 @ 2.87
C-1-3-BC3 10 @ 2.50
C-1-4-BC4 15 @ 2.67
C-1-5-BC4 10 @ 2.80
C-1-6-BC5 15 @ 2.73
C-2-2-BC3 8 @ 2.75
C-2-3-BC3 5 @ 2.80
C-2-4-BC4 10 @ 2.70
C-2-5-BC4 5 @ 2.40
C-2-6-BC5 10 @ 2.10
C-3-2-BC3 10 @ 2.80
C-3-3-BC4 5 @ 2.80
C-3-4-BC4 10 @ 2.50
C-3-5-BC4 4 @ 2.75
C-3-6-BC5 10 @ 3.00

D-1-2-BH3 5 @ 2.80
D-1-4-BH4 5 @ 3.00
D-1-6-BG5 5 @ 3.00
D-2-2-BH3 10 @ 2.20
D-2-4-BH4 10 @ 2.20
D-2-6-BH5 10 @ 2.60
D-3-2-BH3 10 @ 3.00
D-3-4-BH4 10 @ 2.70
D-3-6-BH5 10 @ 2.90

E-1-2-BC3 5 @ 1.20
E-1-3-T 5 @ 1.20
E-1-4-BC4 5 @ 1.00
E-1-5-T 5 @ 1.40
E-1-6-BC5 5 @ 1.00
E-2-2-BC3 5 @ 1.00
E-2-5-T 5 @ 1.20
E-2-6-BC5 5 @ 1.00
E-3-2-BC3 5 @ 1.40

F-1-2-N 1 @ 1.00
F-1-2-BH3 10 @ 3.00
F-1-3-N 5 @ 1.60
F-1-4-N 5 @ 1.80
F-1-4-BH4 5 @ 3.00
F-1-6-BH5 5 @ 3.00
F-3-3-N 5 @ 2.00
F-3-4-N 5 @ 2.20
F-3-5-N 5 @ 3.00
F-3-6-N 5 @ 2.60

SUMMARY OF VISUAL EVALUATION RATING
3-16-83 Survey

Joint Variables	Material A-"Hi-Spec."	B-Lion D-200	C-Gardox	D-Poly Jet Highway	Averages (A,B,C,D)	E-Dow Corning 888	F-Para Plastic
X-1-2-BX-3	25 @ 2.68[a]	10 @ 3.00	15 @ 2.87	5 @ 2.80	2.84	5 @ 1.20	10 @ 3.00
X-1-4-BX-4	10 @ 2.90	10 @ 2.80	15 @ 2.67	5 @ 3.00	2.84	5 @ 1.00	5 @ 3.00
X-1-6-BX-5	14 @ 2.93	10 @ 3.00	15 @ 2.73	5 @ 3.00	2.92	5 @ 1.00	5 @ 3.00
Airjet	49 @ 2.80	30 @ 2.93	45 @ 2.76	15 @ 2.93	2.87	15 @ 1.07	20 @ 3.00
X-2-2-BX-3	10 @ 2.80	10 @ 3.00	8 @ 2.75	10 @ 2.20	2.69	5 @ 1.00	N.P.
X-2-4-BX-4	10 @ 2.90	10 @ 2.70	10 @ 2.70	10 @ 2.20	2.63	N.P.	N.P.
X-2-6-BX-5	10 @ 2.70	9 @ 3.00	10 @ 2.10	10 @ 2.60	2.60	5 @ 1.00	N.P.
Sandblast	30 @ 2.80	29 @ 2.90	28 @ 2.59	39 @ 2.33	2.64	10 @ 1.00	N.P.
X-3-2-BX-3	9 @ 2.40	10 @ 3.00	10 @ 2.80	10 @ 3.00	2.80	5 @ 1.40	N.P.
X-3-4-BX-4	10 @ 2.90	10 @ 3.00	10 @ 2.50	10 @ 2.70	2.78	N.P.	5 @ 2.20
X-3-6-BX-5	10 @ 3.00	10 @ 2.90	10 @ 3.00	10 @ 2.90	2.95	N.P.	5 @ 2.60
Waterblast	29 @ 2.78	30 @ 2.97	30 @ 2.77	30 @ 2.87	2.84	5 @ 1.40	10 @ 2.40
Average	2.79	2.93	2.68	2.72		1.16	2.70

X-X-2-BX3 (Avg) = 2.81
X-X-4-BX4 (Avg) = 2.68
X-X-6-BX5 (Avg) = 2.82

1. No Visable Seal Failure
2. 3 Feet or Less of Broken Seal
3. More Than 3-Feet of Broken Seal

N.P. - None Placed
X - Inserted to Indicate Variable
a - No Backing Material

APPENDIX B:

CORE DRILLING

and

TESTING TABULATION

APPENDIX B - CORE DRILLING AND TESTING TABULATION

(From cores drilled 4-16-79)

Core No.	Station	Installation Code Designation	Visual Rating *	CORE TESTING Maximum Load	Elongation at Maximum Load	Elongation at Failure
1	139+70	A-3-2-N	P	4.0	---	0.19
2	141+60	A-3-4-BH3	B	0.0		
3	143+43	A-3-6-BH5	B	4.3	---	0.19
4	147+40	A-1-4-BH3	N	19.3	0.64	1.34
5	151+30	A-2-2-N	N	10.0	0.45	0.55
6	153+65	A-2-4-BH3	B	0.0		
7	155+60	A-2-6-BH5	N	13.2	0.83	1.21
8	163+30	D-3-2-BH3	N	11.6	0.38	0.50
9	165+30	D-3-4-BH4	N	26.1	0.71	2.00
10	167+25	D-3-6-BH5	N	--	---	
11	175+63	D-2-2-BH3	N	15.1	0.50	0.70
12	177+70	D-2-4-BH4	N	24.1	---	1.45
13	179+75	D-2-6-BH5	N	20.3	---	1.32
14	181+70	D-1-2-BH3	N	15.5	0.51	0.71
15	183+65	D-1-4-BH4	N	11.9	0.51	0.79
16	185+65	D-1-6-BH5	N	20.2	0.72	1.59
17	187+70	F-1-2-BH3	N	0.0		
18	189+70	F-1-4-BH4	P	3.7	0.83	0.91
19	191+95	F-1-6-BH5	N	2.3	0.57	0.60
20	194+20	B-3-2-BC3	P	0.0		
21	196+75	B-3-4-BC4	P	6.1		0.56
22	198+35	B-3-6-BC5	N	12.2	0.93	1.31
23	200+60	B-2-2-BC3	B	0.0		
24	203+00	B-2-4-BC4	N	21.6	---	1.24
25	204+60	B-2-6-BC5	N	9.3	0.89	1.57
26	206+53	B-1-2-BC3	P	2.3	---	0.13
27	208+50	B-1-4-BC4	N	14.2	---	0.89
28	210+43	B-1-6-BC5	N	18.9	1.74	1.97
29	212+47	F-1-2-BH3	B	0.0		
30	145+88	A-1-6-BH5	B	0.0		
31	147+80	A-1-2-N	N	7.4	0.55	0.73
32	149+75	A-1-3-N	N	35.6	0.36	1.45
33	151+70	A-1-4-N	N	48.4	1.40	2.17
34	153+45	A-1-5-N	N	13.5	1.77	2.12

*N-No Visible failure; P- Partial Seal Failure; B- Broken Seal

APPENDIX B
Continued

CORE TESTING

ore No.	Station	Installation Code Designation	Visual Rating *	Maximum Load	Elongation At Maximum Load	Elongation at Failure
35	166+01	A-1-6-N	N	7.8	0.64	3.10
36	168+15	A-1-2-N	N	14.9	0.92	1.28
37	170+25	C-1-3-BC3	N	60.8	0.62	1.19
38	172+43	C-1-4-BC4	N	82.0	0.57	18.2
39	174+38	C-1-5-BC4	N	25.4	---	0.80
40	176+58	C-1-6-BC5	N	38.0	0.47	0.99
41	178+65	C-1-2-BC3	N	27.2	0.57	1.04
42	180+75	C-2-3-BC3	N	63.0		2.36
43	182+80	C-2-4-BC4	P	9.9	0.47	0.61
44	185+20	C-2-5-BC4	N	27.0	---	1.02
45	187+35	C-2-6-BC5	P	11.2	0.38	0.65
46	189+09	C-2-2-BC3	N	43.0	1.11	1.56
47	189+85	C-2-2-N	N	41.7	0.42	0.89
48	191+56	C-3-3-BC4	N	77.0	0.73	1.94
49	193+70	C-3-4-BC4	P	16.9	0.58	1.47
50	195+80	C-3-5-BC4	N	41.2	0.45	0.80
51	197+82	C-3-6-BC5	P	2.7		0.22
52	200+09	C-3-2-BC3	P	52.5	0.91	1.21
53	202+20	F-3-3-N	N	22.6	1.37	1.72
54	204+33	F-3-4-N	N	24.6	1.58	1.94
55	206+42	F-3-5-N	N	35.2	0.93	1.92
56	208+45	F-3-6-N	N	40.9	1.50	2.91
57	210+60	E-3-2-BC3	N	43.3	1.21	1.97
58	213+20	E-1-2-BC3	N	24.2	1.01	1.72
59	215+26	E-1-6-BC5	N	14.9	0.79	1.22
60	217+42	E-1-5-T	N	44.5	1.95	2.18
61	219+36	E-1-4-BC4	N	30.1		2.44
62	221+40	E-1-3-T	N	28.0	1.82	2.10
63	223+30	E-2-2-BC3	N	19.3	---	1.05
64	225+24	E-2-6-BC5	N	25.3	---	1.71
65	227+20	E-2-5-T	N	22.9	---	1.50
66	229+30	F-1-4-N	N	73.3	1.54	1.78
67	231+33	F-1-3-N	N	89.5	1.32	2.13
68	242+03	F-1-2-N	N	57.7	1.41	2.70

* N- No Visible failure; P- Partial Seal Failure; B- Broken Seal

APPENDIX B - CORE DRILLING AND TESTING TABULATION

(From cores drilled 4-16-79)

	Visual Rating			Core Testing Summary	
Sealant Material	No Visible Failure	Partial Seal Failure	Broken Seal	Average Maximum Load, pounds	Average Maximum elongation, inches
A. W. R. Meadows "Hi-Spec"	9	1	4	12.7	1.0
B. "Lion D-200"	5	3	1	9.4	0.9
C. W. R. Meadows "Gardox"	11	5	0	38.7	1.2
D. W. R. Meadows "Poly-Jet Highway"	9	0	0	18.1	1.1
E. "Dow Corning 888"	9	0	0	28.1	1.8
F. W. R. Grace "Para Plastic"	9	1	1	31.8	1.5
Cleaning					
1. Air Jet	27	2	2	26.8	1.4
2. Sand Blast	14	2	2	20.9	1.1
3. Water Blast	11	6	2	23.4	1.2
Saw Cut					
2. Nominal 1/4"	14	4	2	19.5	0.8
3. Nominal 3/8" x 1/2" deep	7	0	0	43.2	1.8
4. Nominal 3/8" x 1" deep	11	4	2	24.2	1.3
5. Nominal ½" x ½" deep	7	0	0	30.0	1.5
6. Nominal ½" x 1¼" deep	13	2	2	15.1	1.3

APPENDIX B
Continued

Cores Drilled 2-27-80

CORE TESTING

Core No.	Station	Installation Code Designation	Visual Rating *	Maximum Load	Elongation At Maximum Load	Elongation at Failure
1A	139+30	A-3-2-N	3 N	40.7	0.98	1.34
2A	141+15	A-3-4-BH3	3 N	14.6	0.60	0.72
5A	151+30	A-2-2-N	1 N	21.2	0.40	0.64
8A	162+93	D-3-2-BH3	2 P			
9A	164+85	D-3-4-BH4	1 N	32.6	0.44	0.70
10A	166+86	D-3-6-BH5	1 P	20.6	0.48	0.76
11A	175+18	D-2-2-BH3	2 P	11.0	0.20	0.52
12A	177+30	D-2-4-BH4	1 N	28.0	0.56	0.72
13A	179+35	D-2-6-BH5	1 P	13.8	0.42	0.88
14A	181+30	D-1-2-BH3	2 P			
15A	183+25	D-1-4-BH4	1 P	20.5	0.28	0.38
16A	185+10	D-1-6-BH5	3 P			
21A	196+30	B-3-4-BC4	1 N	21.7	0.50	.77
22A	197+95	B-3-6-BC5	2 B			
24A	202+60	B-2-4-BC4	2 P	6.4	0.33	
25A	204+20	B-2-6-BC5	2 P	11.7	0.85	1.18
28A	210+03	B-1-6-BC5	2 N	23.1	0.54	0.77
30A	145+10	A-1-6-BH5	3 P			
32A	149+40	A-1-3-N	1	80.5	1.10	1.58
33A	151+30	A-1-4-N	2 N			
34A	153+30	A-1-5-N	1 P			
35A	165+65	A-1-6-N	1 N	60.7	1.18	1.54
36A	167+75	A-1-2-N	2 N	41.4	1.02	1.38
37A	169+85	C-1-3-BC3	1 N	49.1	0.66	0.88
38A	171+96	C-1-4-BC4	3 P			
39A	173+65	C-1-5-BC4	2 P			
40A	176+15	C-1-6-BC5	3 P	21.2	0.48	0.58
41A	178+17	C-1-2-BC3	1 N	53.1	0.72	1.10
42A	180+35	C-2-3-BC3	3 P			
43A	182+40	C-2-4-BC4	1 N	47.4	0.66	0.82
44A	184+80	C-2-5-BC4	3 P			
45A	186+94	C-2-6-BC5	2 N	45.7	0.72	0.94
46A	189+09	C-2-2-BC3	1 N	59.3	0.78	1.12
48A	191+16	C-3-3-BC4	3 P	15.0	0.14	
49A	193+30	C-3-4-BC4	1 N	78.0	0.60	0.86
53A	201+80	F-3-3-N	1 N	36.6	0.84	1.34
54A	203+86	F-3-4-N	3 P	18.6	0.92	1.34
55A	206+02	F-3-5-N	1 N	48.8	0.68	1.36
56A	208+05	F-3-6-N	1 N	20.3	0.74	0.90
57A	210+08	E-3-2-BC3	1 N	29.5	0.98	1.82
58A	212+73	E-1-2-BC3	1 N			

APPENDIX B
Continued

Cores Drilled 2-27-80 Continued — CORE TESTING

Core No.	Station	Installation Code Designation	Visual Rating *		Maximum Load	Elongation At Maximum Load	Elongation at Failure
59A	214+85	E-1-6-BC5	1	N	19.4	0.90	1.34
60A	217+05	E-1-5-T	1	N	28.1	1.56	2.24
61A	219+03	E-1-4-BC4	1	N	16.5	2.14	2.10
62A	220+95	E-1-3-T	1	N	23.9	1.22	1.76
63A	222+88	E-2-2-BC3	1	N	25.6	1.24	1.84
64A	224+82	E-2-6-BC5	1	N	31.4	3.10	4.04
65A	226+80	E-2-5-T	2	N	25.9	0.54	1.10
66A	228+90	F-1-4-N	1	N	55.4	1.04	1.34
67A	230+90	F-1-3-N	1	N	62.0	0.96	1.31
68A	241+63	F-1-2-N		N	59.4	1.26	1.69

APPENDIX B
Continued

Cores Drilled 5-20-83

CORE TESTING

ore No.	Station	Installation Code Designation	Visual Rating *	Maximum Load	Elongation At Maximum Load	Elongation at Failure
1	91+52	B-1-4-BC4	N	17.8	.51	.86
2	97+80	B-2-4-BC4	N	29.3	.18	.30
3	137+30	A-2-6-BH5	N	17.1	.90	1.18
11B	174+75	D-2-2-BH3	N	32.2	.21	.46
12B	177+70	D-2-4-BH4	P	2.2		.09
4	140+60	A-1-4-N	N	8.6		.12
5	143+09	A-1-5-N	N	6.59	.97	1.20
6	156+00	A-1-6-N	N	43.8	.95	1.20
37B	169+85	C-1-3-BC3	P	23.2	.32	.42
45B	188+20	C-2-6-BC5	N	43.4	.57	.70
49B	194+55	C-3-4-BC4	N	64.4	.52	.72
52B	199+25	C-3-2-BC3	N	60.8	.50	.97
57B	210+60	E-3-2-BC3	N	32.4	1.70	1.98
58B	213+62	E-1-2-BC3	N	37.6	1.20	1.75
61B	219+03	E-1-4-BC4	N	23.1	1.45	1.70
63B	223+30	E-2-2-BC3	N	14.4	0.42	0.75
64B	225+24	E-2-6-BC5	N	18.5	1.90	2.42
65B	277+60	E-2-5-T	N	8.9	0.63	0.98
66B	229+30	F-1-4-N	N	50.6	0.90	1.33
67B	232+15	F-1-3-N	P	27.0	0.75	1.20