ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: AZ92-377-I

CONSTRUCTION REPORT FOR ARIZONA'S SHRP SPS-4 EXPERIMENT

Construction Report

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16. Abstract

Nine joint sealants and five joint configurations were used on a newly constructed jointed plain concrete pavement (JPCP) along SR-360 (Superstition Freeway) in Mesa, Arizona. Twenty-four experimental transverse joint sections containing 25 to 38 joints in each section were used to evaluate sealed and unsealed joints.

Critical joint dimensions were obtained during construction on the transverse joints. Deflections at joints and at midslab between joints were measured by use of a Falling Weight Deflectometer (FWD).

The primary saw cut depth was generally less than the specified amount of one-third of the slab thickness. The majority of the measured saw cut widths were within the specified tolerances. Joint sealant depths were near the maximum for backer rods and for the tops of joints sealant depths. This resulted in shape factors often less than 1.0.

Load Transfer Efficiency (LTE) calculated from FWD data generally indicated full load transfer across joints. Uncracked joints generally demonstrated higher LTE than cracked joints.

This report consists of Volumes 1 and 2. Volume 1 contains the report, and Volume 2 contains the Appendices.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

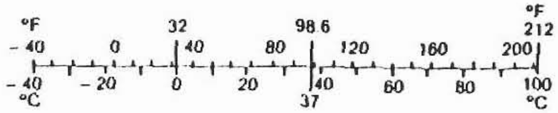
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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INTRODUCTION

Problem Statement

The cost effectiveness, performance and maintenance of joint sealants is important to local, state and federal agencies. Currently, research using various joint sealants is being conducted on new as well as existing pavements. The Strategic Highway Research Program (SHRP) has acknowledged the need for research in this area. SHRP SPS-4 (Maintenance Effectiveness Study of Concrete Pavements) has been developed to address problems with joint sealing.

The purpose of this Arizona Department of Transportation (ADOT) research program is to develop performance data for nine joint sealants and five joint configurations over a time period of ten years. The information obtained from this research project will be useful to ADOT and other state and federal agencies that construct portland cement concrete (PCC) pavements in a dry-nonfreeze climatic region.

Project Objectives

This research project was designed to evaluate nine joint sealants and five joint configurations over an extended period of time on a portion of recently constructed jointed plain concrete pavement (JPCP) along SR360 in Mesa, Arizona. Furthermore, the intent of this research is to relate these joint sealants to the cost of installation and load transfer properties determined by falling weight deflectometer (FWD) data. The following objectives were established for this project:

- Compare the performance between sealed and unsealed transverse joints. This is a SHRP SPS-4 experiment.

- Establish the cost effectiveness of the various types of joint sealants used in this experimental project. This information will be valuable not only for determining life cycle costs for new concrete pavement but also for establishing maintenance and rehabilitation strategies for existing concrete pavements as far as joint sealants are concerned.

- Develop relationships between joint evaluation criteria and pavement performance. This would include the collection of FWD data at transverse joint locations.

- Evaluate alternate joint sizes and details. Small joints provide for a quieter ride, and results in narrower joints after rehabilitation.

Project Location and Description

The project was located on a 2.15-mile segment of newly constructed PCC pavement on the Superstition Freeway (SR 360) between Power Road and Ellsworth Road in Mesa, Arizona. This segment of roadway was designed under ADOT Project No. F-028-1-311. The construction project location is shown in Figure 1. This project is approximately 25 miles east of Phoenix in central Arizona. The experimental portion of the project is located in the east part of Mesa, Arizona at a ground elevation varying from 1365 to 1465 ft. Mean annual precipitation is approximately 7 inches. Mean daily temperature is 75°F with yearly extremes from 30°F to 115°F.

The new roadway consists of a 6 lane divided highway section, with inside and outside shoulders, interchange ramps and overpass roadways. Mainline pavement lanes are 12 ft wide PCC with 11 ft wide inside concrete shoulders and 8.5 to 10 ft wide outside concrete shoulders. The pavement was designed for 2,891,700, 18 kip Equivalent Single Axle Loads (ESAL), and a 20 year design life.

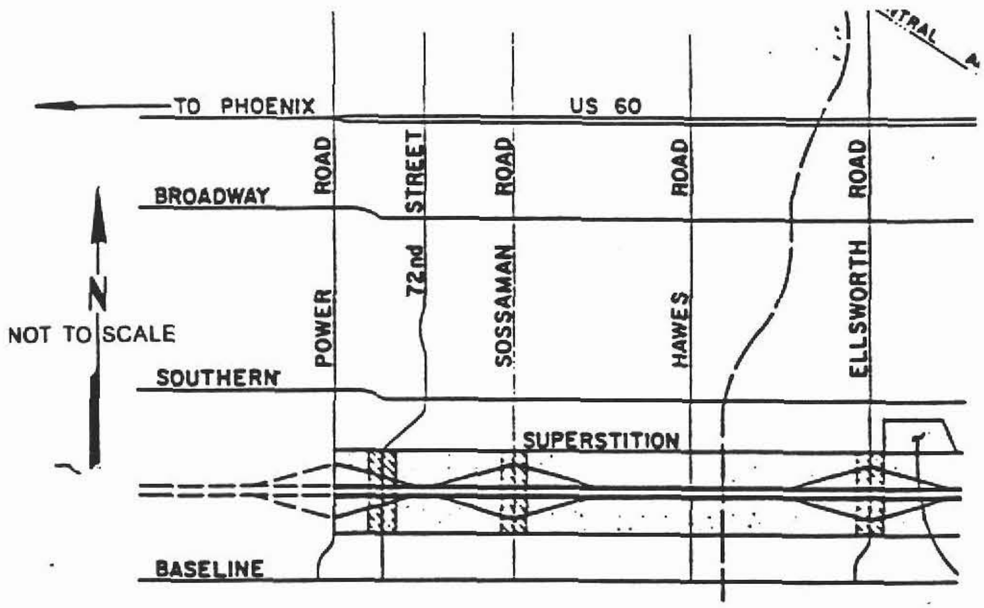

Figure 1 - Construction Project Location

Surface and Subsurface Soil Conditions

The predominant soils for this roadway alignment can be described as silty sand to sandy silt. These soils have been classified in accordance with the Unified Soil Classification System as SM to ML soil types.

The silty sand to sandy silt extends from the surface to the full depth of exploration (20 ft). Occasional layers of sandy gravel and gravelly sand are encountered below a depth of 10 ft.

In general the soils to a depth of 10 feet are medium dense to dense. Below a depth of 10 feet the soils are very dense as indicated by standard penetration test values.

The pavement section consisted of 13 inch thick jointed plain concrete pavement on 4 inches of compacted aggregate base placed on a compacted subgrade. The transverse joint spacing plan was established at staggered intervals of 13, 15, 17, 15 ft, and then continually repeated. The joints were skewed 2 on 12. The construction joints were not doweled.

Two experimental test zones were established on this project to evaluate nine different joint sealants. Experimental Zone No. 1 (Test Section Nos. 1 - 12) commences at Station 957+75 and extends to Station 1005+00. Experimental Zone No. 2 (Test Section Nos. 13 - 24) begins at Station 892+50 and extends to Station 939+25. The test sections were located in the eastbound travel lane, and are bounded by Power Road on the west and Ellsworth Road on the east.

Contract History

In 1990, the Arizona Department of Transportation awarded this project (Contract # F-028-1-514) to Ball, Ball and Brosamer, Inc. of Danville, California. The cost of the installation of the nine transverse joint sealants in the 24 test sections was included in Change Order No. 19. Joint sawing and sealant installation for this project were performed by Multiple Concrete Enterprises of Layton, Utah.

EXPERIMENTAL PLAN

General

This research experiment required in excess of two miles of newly constructed PCC pavement in one direction. Each sealant was tested in a test section located in each experimental test zone. Each test section included 25 continuous transverse joints, except for one SHRP test section located within each experimental test zone. Twenty joints in each test section are to be left undisturbed throughout the performance life of the sealant. This results in 50 joints per sealant product within the experiment. Nine different sealants products were used in this experiment.

Test Sections

Figure 2 shows the layout of Experimental Zones No. 1 and No. 2. This drawing provides the experimental field plan. Each test section was approximately 375 feet in length and contains 25 joints. Two control sections (Section Nos. 3 and 17) were unsealed, and approximately 600 feet in length. Section No. 3 was a SHRP unsealed test section. These two unsealed sections required only a primary saw cut. A secondary or reservoir cut was not required. Section No. 2 is a SHRP *section and was sealed using a silicone joint sealant.*

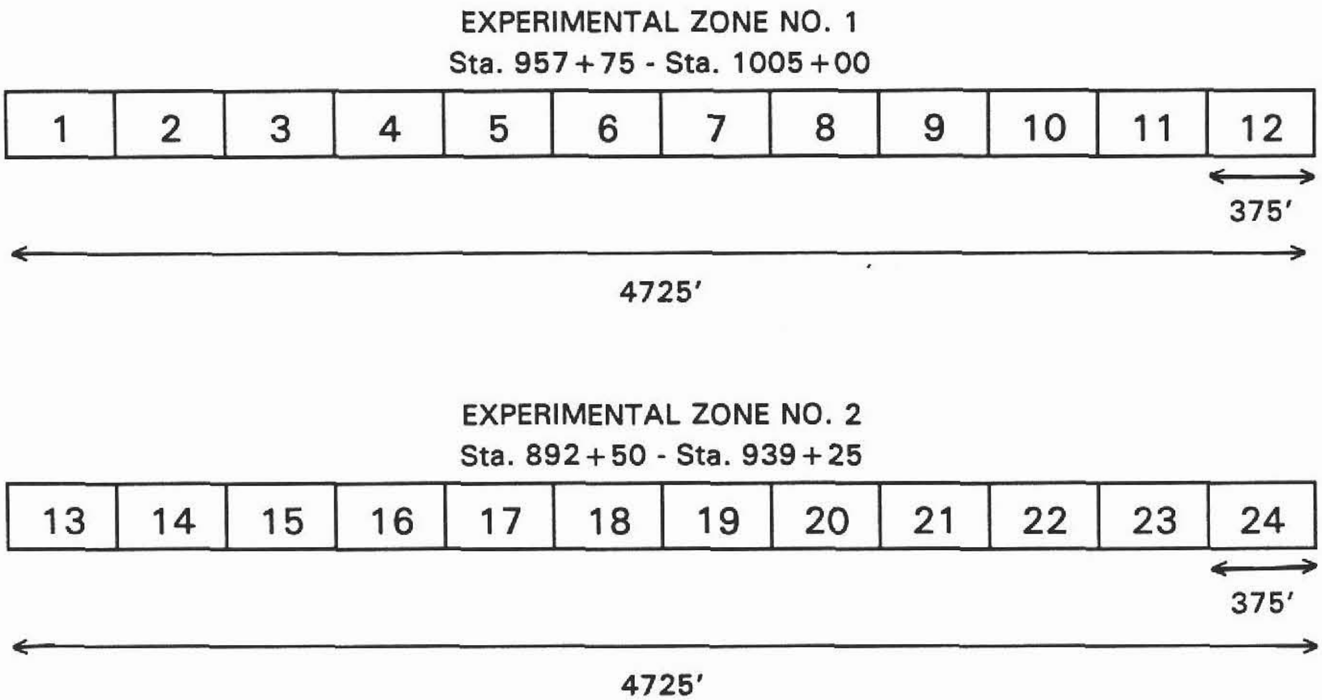

Figure 2 - Experimental Zones

Joint Sealants

Nine sealants representing four material classifications were used in this research project. These include compression seals, silicone, hot-pour, and silicone self leveling sealants. A product literature review was first conducted by Arizona Transportation Research Center (ATRC) to determine what joint sealant products were available and what sealants were currently being used in JPCP. This work was performed in conjunction with information available from ADOT and other federal and state agencies.

From the available information, nine joint sealants were recommended for use in this research project. The sealant installed at each test section along with the joint detail number is provided in Table No. 1. An Elastomer PV-687 compression seal was initially included as one of the sealants to be used for this project. Watson Bowman WB-687 and WB 812 sealants were used in lieu of the Elastomer PV-687 compression seal.

TABLE 1 - JOINT SEALANTS INSTALLED

	Test Section No.	Product Installed	Joint Detail
EXPERIMENTAL ZONE NO. 1	1	Delastic V-687 Comp. Seal	5
	2	Crafco Silicone S.L.	1
	3	Unsealed	2
	4	Dow 890 S.L.	3
	5	Watson Bowman WB-812	5
	6	Dow 888 S.L.	1
	7	Dow 888	1
	8	Crafco 444	1
	9	Dow 890 S.L.	4
	10	Mobay Baysilone S.L.	1
	11	Crafco 221	1
	12	Dow 890 S.L.	1
EXPERIMENTAL ZONE NO. 2	13	Dow 890 S.L.	4
	14	Delastic V-687 Comp. Seal	5
	15	Dow 888	1
	16	Mobay Basilone S.L.	1
	17	Unsealed	2
	18	Dow 890 S.L.	1
	19	Dow 888 S.L.	1
	20	Crafco Silicone S.L.	1
	21	Crafco 221	1
	22	Watson Bowman WB-687	5
	23	Crafco 444	1
	24	Dow 890 S.L.	3

Joint Configurations

Based upon the joint sealants selected for this project, joint configurations were determined from manufacturer's recommendations and various state and federal agency requirements. Information was obtained from the Arizona, Georgia, and Colorado Departments of Transportation. The American Association of State Highway and Transportation Officials (AASHTO) guidelines and Federal Highway Administration (FHWA) Technical Advisory 89-04 were also used to determine joint widths.

The primary cut for all joints was specified as the thickness of the slab (T) divided by three (T/3), with a width of 1/8 inches. The width and depth of the secondary cut was established specifically for each sealant. Five joint details were formulated to receive the various joint sealants. Detail 2 was used for the two unsealed test sections. Joint details are provided in Figure 3.

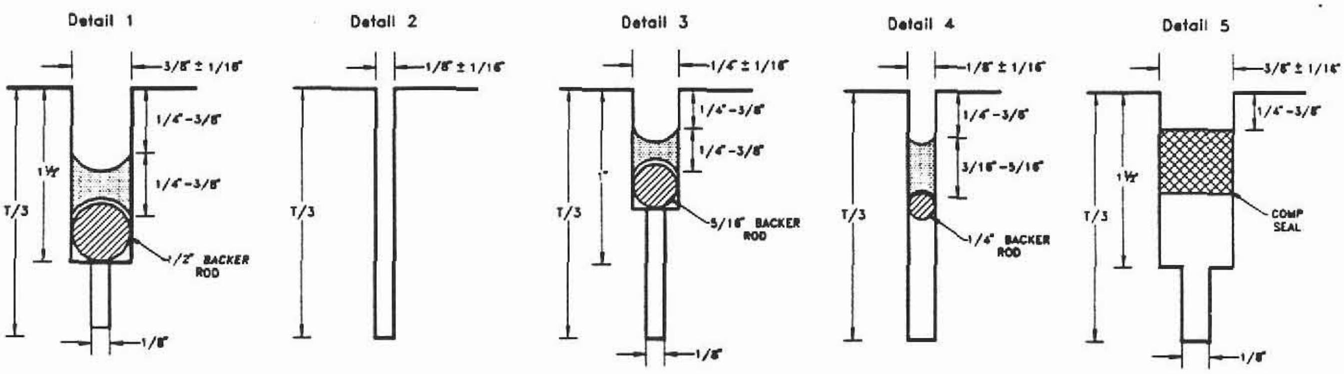

Figure 3 - Joint Details

Joint Specifications

Specifications from the Department of Transportation for the State of Georgia were reviewed, along with a specification written by Purdue University for SHRP for use in SPS-4 research projects. It was concluded that all transverse joints will be constructed in accordance with Section 401-3.06 of the 1990 ADOT Standard Specifications for Road and Bridge Construction.

This specification was used with the following additional requirements:

- The concrete shall cure a minimum of 7 days prior to sealant installation. In the event of rain, the time shall be extended an additional day for each day of rain.

- Sand blasting shall be performed in two passes (one for each joint face) with the nozzle directed at the joint face. Both passes shall be in the same direction.

- Just prior to sealant installation, the joint shall be blown out in one direction only.

- The nozzle used to install the sealant should be such that the joint is filled from the bottom up.

- Installation of the Crafco Hot Pour sealants will be performed in accordance with manufacturer's recommendations.

- Traffic will not be allowed on newly sealed joints for at least 3 days.

Except in the compression seal test sections, all joints, including both longitudinal and transverse joints will utilize the sealant indicated for that section. In the sections with compression seals, the longitudinal joints will be sealed with the sealant material currently available at the project.

All longitudinal joints will be sawn and sealed in accordance with project plans and specifications. The joint details refer only to the transverse joints.

Joint Measurements

The following joint measurements were obtained as part of the experimental plan for this research project. Since joint details varied depending on the sealant used, all of the following measurements were not necessarily obtained for each transverse joint.

- Joint location
- Joint width
- Depth (secondary cut)
- Primary joint depth
- Joint crack width
- Joint backer rod depth
- Sealant joint depth

Nondestructive testing (NDT) was conducted in accordance with SHRP Protocol: H30F Falling Weight Deflectometer Deflection Testing.

Testing was conducted using SHRP equipment at 10 transverse joint locations in each test section except for sections 5 and 22. ADOT FWD equipment was used to obtain test data at each joint for sections 5 and 22. Test data were used to develop relationships between joint evaluation criteria and pavement performance.

Changes In Experimental Plan

In the course of adopting the experimental plan to actual field construction, several changes had to be made. In March 1991, SHRP requested a 500-foot test section for testing a silicone joint sealant. In order to fulfill this request, the first nine joints of section 3 adjacent to section 2 in experimental zone no. 1 were cut according to joint detail 1. This increased the number of joints in section No. 2 from the existing 25 to 34. These transverse joints were sealed with Crafco Silicone S.L. Section No. 3 was approximately 567 feet long and contained 38 unsealed joints.

An Elastomer PV-687 Compression Seal was initially included as one of the two compression seals to be used in the experimental plan. A Watson Bowman WB-687 compression seal was used in lieu of the Elastomer PV-687. The Watson Bowman WB-687 was to be used in Sections 5 and 22, but a Watson Bowman WB-812 was used in Section 22.

Transverse joints were sawn 3/8 inches wide instead of 1/4 inch wide by the contractor at Section No. 4. There is an "extra" joint (#26) at the end of Section No. 8 because it was not sawn to typical dimensions for this section or the next section (No. 9). It was, however, sealed with a Crafco 444 sealant. A construction joint is included as one of the experimental joints in Section Nos. 12 and 24. There is a construction joint in Section No. 18 between joints Nos. 24 and 25. This joint was not included in the experimental plan.

The final section layout, test section numbering, and sealants used are provided in Figure 4.

A 5/16-inch diameter backer rod was specified for joint detail 3. A 3/8-inch diameter backer rod replaced the 5/16-inch diameter backer rod.

The experimental plan recommended that the JPCP be cured for a minimum period of 7 days prior to sealant installation. Ideally, all sealants were to be installed in a relatively short time period after the minimum cure time was achieved. Except for the Watson Bowman compression seals, all sealants were installed between March 18 and March 31, 1991. The Watson Bowman compression seals were installed on May 7, 1991, because the Elastomer PV-687 compression seal could not be purchased in a timely manner.

CONSTRUCTION

Construction Procedures

Sawing

The plain concrete pavement for this project was placed on February 13, 1991. The contractor began sawing the 4.333-inch (T/3) deep primary cut as soon as the concrete attained an age at which extensive raveling did not occur. Primary cutting was performed on February 13, and 14, 1991. Secondary cuts were sawn on February 15, 1991. All joints were cut using riding saws (Figure 5). The various sealant reservoirs were formed after all primary transverse joints were cut for a section.

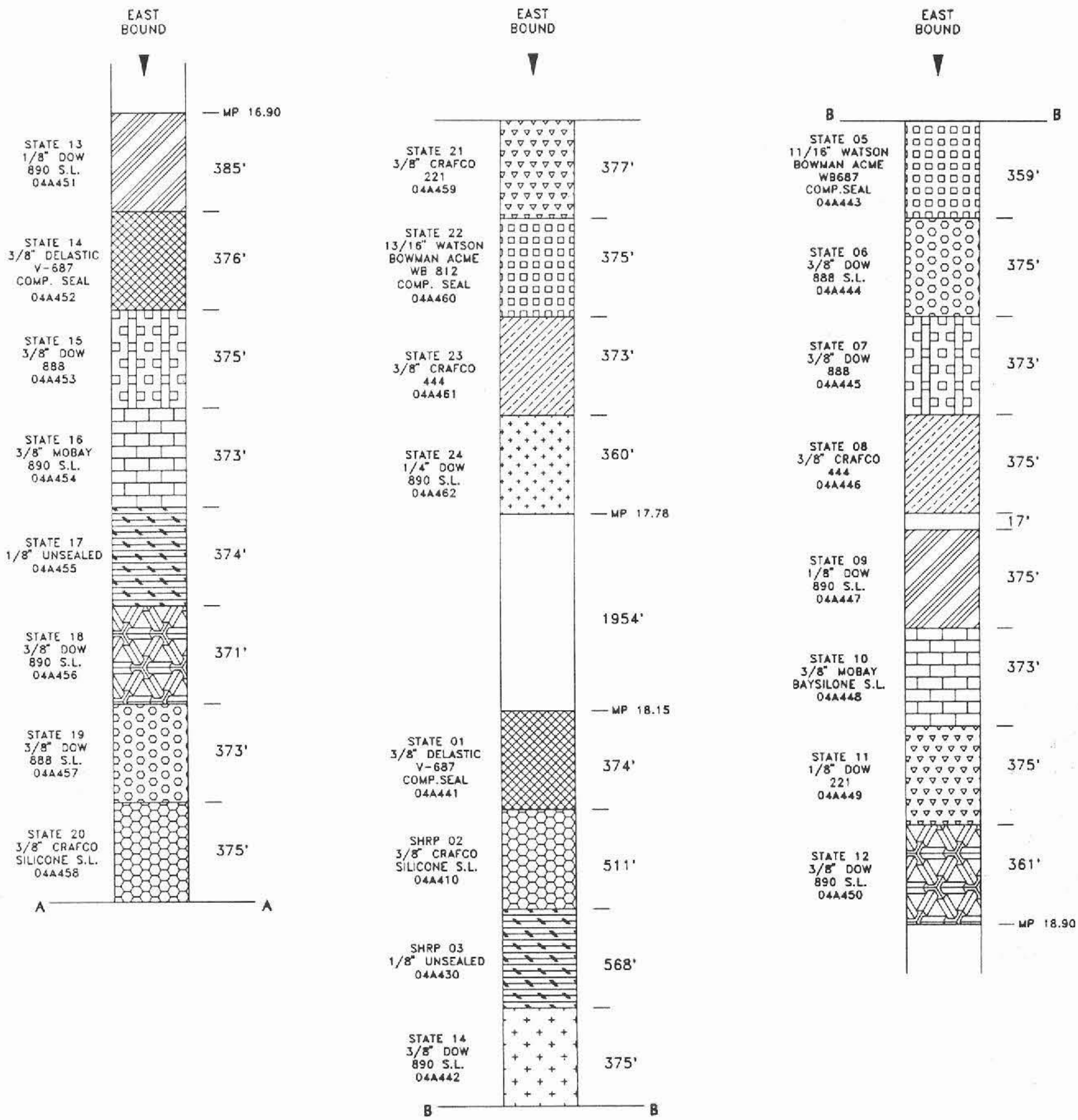

Figure 4 - Final Test Section Layout

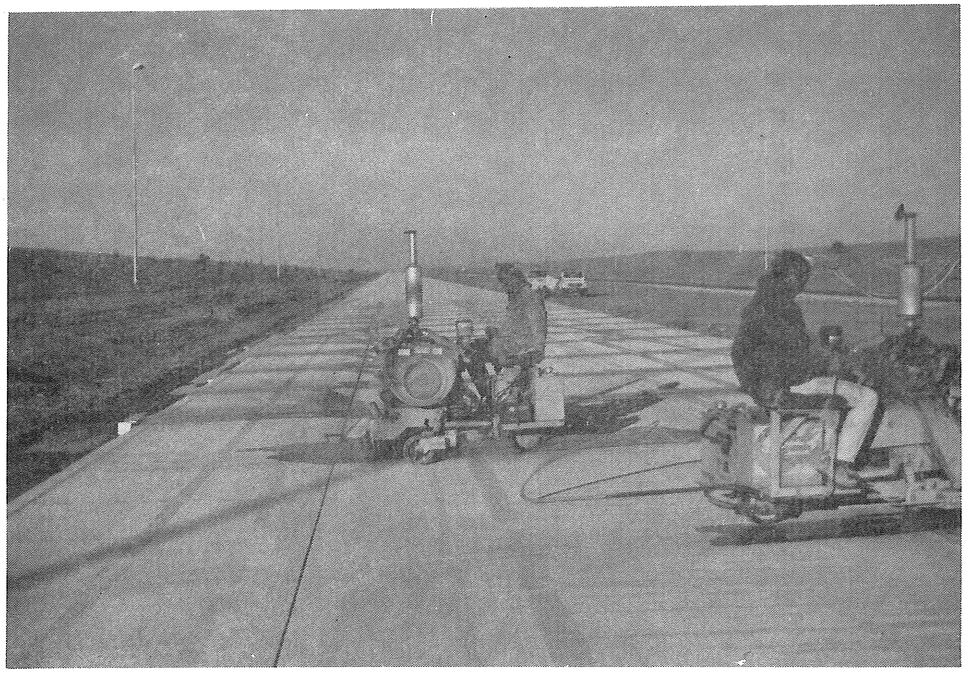

Figure 5 - Primary Saw Cutting Using Riding Saws

Joint Cleaning

After the joints were sawn, they were cleaned using air jetting methods having an air pressure of 120 psi. Air jetting did not usually remove all compressibles; therefore, the joints were dry sawn. After dry sawing, the joints were sand blasted in two passes (one pass for each joint face) with the nozzle directed at the joint face. Both passes were in the same direction. The joints were then air cleaned. Because of the accumulation of latency from the cutting operation and compressibles deposited by construction traffic, air jetting could not completely clean the joints. Therefore, water jetting was also used (Figure 6). All water from this operation was carried towards the shoulders. Approximately 1 to 1-1/2 gallons of water was used per joint. Where required, pieces of aggregate located in the joints were removed using a rock rake. Joints were again air jetted, prior to receiving sealant, using the hot pour tip.

Backer Material Placement

A backer rod was required for joint details 1, 3 and 4. Backer rods were installed after final joint cleaning and just prior to the application of the sealant. For joint detail 1, a 1/2-inch diameter closed-cell polyethylene rod was used. In joint detail 3, a 3/8-inch diameter backer rod replaced the specified 5/16-inch diameter backer rod. The contractor stated that a 5/16-inch diameter backer rod was not available. Joint detail 4 required a 1/4-inch diameter backer rod. The Contractor used backer rods produced by various manufacturers. The use of various backer rods should not be a cause of concern as long as they have the proper size. All backer rods were placed without any difficulty or tearing of the material, and were installed using a backer rod tool as shown in Figure 7.

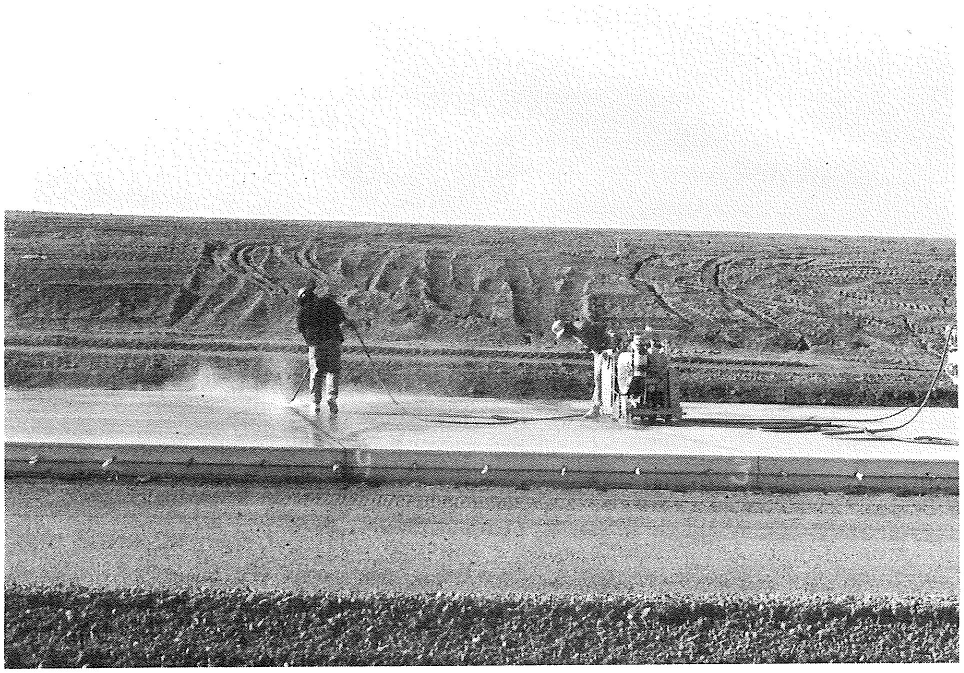

Figure 6 - Water Jetting and Dry Sawing Transverse Joints

Joint Sealing

Specifications for this research project required a minimum 7 day waiting period between concrete placement and sealant application. This requirement was met for each test section. All joint sealants within an experimental sections were installed from the west to the east.

The Crafco 221 and 444 (Lot No. 323), Figure 8, hot-poured sealants were placed using equipment and personnel from Crafco. The Crafco 444 was installed using a Crafco applicator (E-Z pour model) with a 200 gallon capacity (Figure 9). Because of equipment problems, Test Section No. 23 (Crafco 444) was placed by the contractor (Figure 10). The temperature of the Crafco 444 at time of placement varied from 255°F to 260°F, and the air temperature varied from 69°F to 79°F. The temperature of the Crafco 221 at time of placement varied from 400°F to 410°F, and the air temperature varied from 72°F to 74°F. A significant amount of bubbles was observed on the surface of the joints for both sealants at the time of placement.

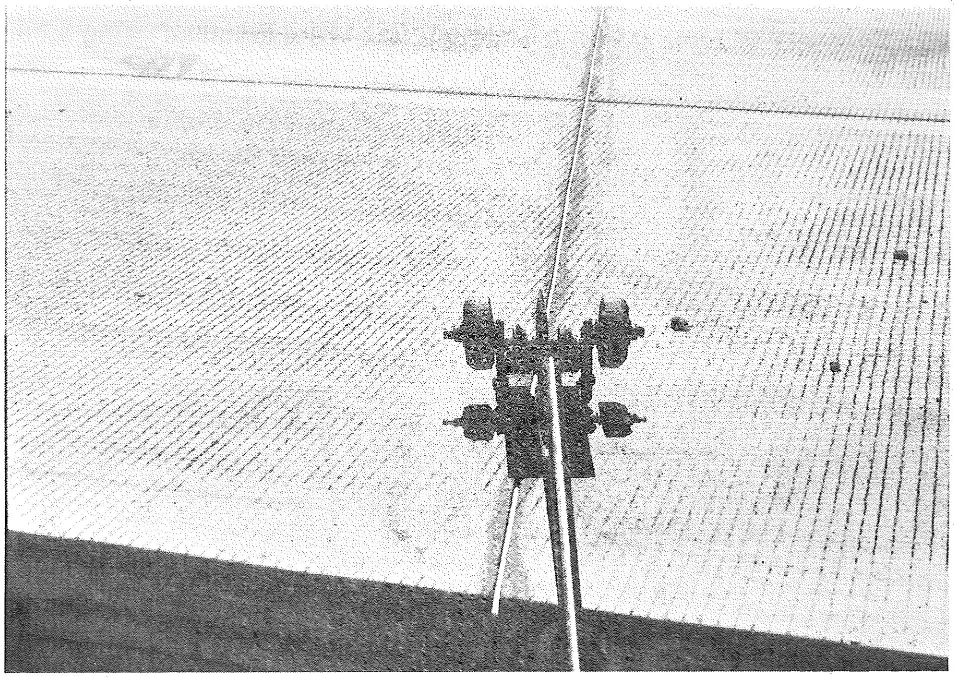

Figure 7 - Tool Used to Place Backer Rod

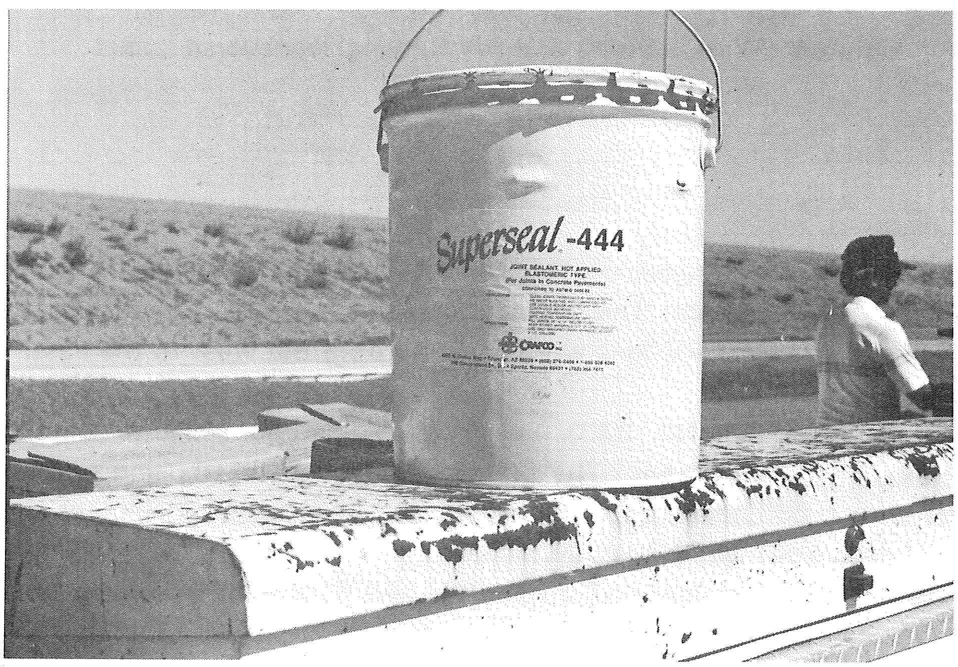

Figure 8 - Container of Crafco Superseal - 444 Joint Sealant.

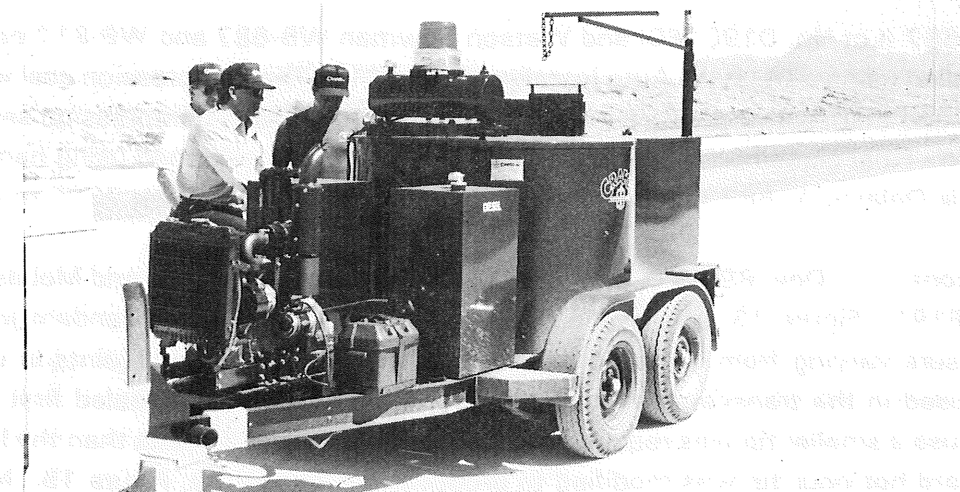

Figure 9 - Crafco Hot-Pour E-Z Pour Model Applicator

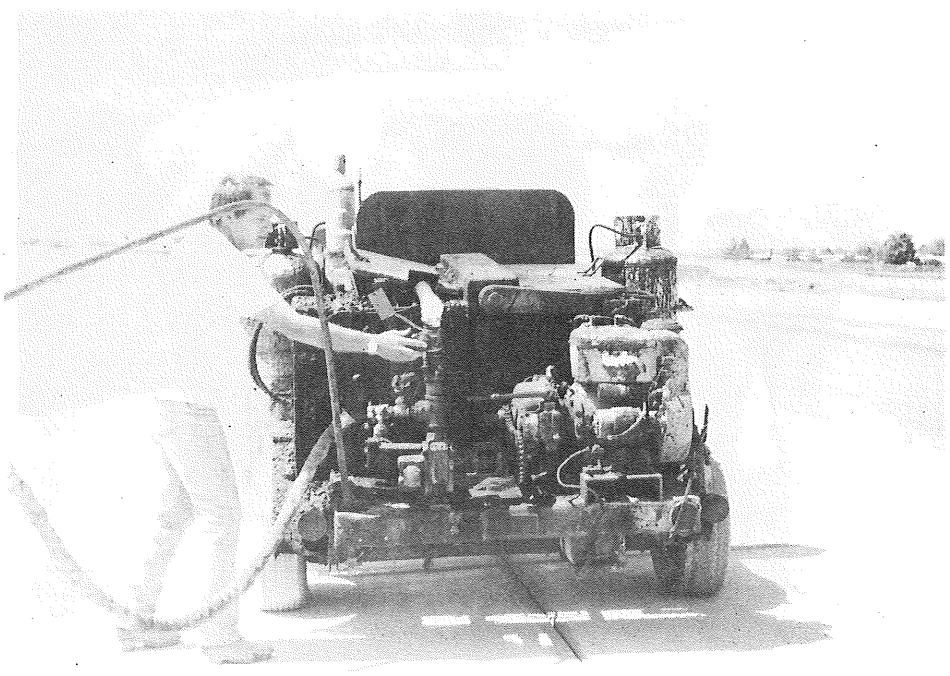

Figure 10 - Contractor's Hot-Pour Applicator

The Dow 888 (Lot No. ET08054) silicone joint sealer was placed with a standard brand joint sealant pump at a pressure of 65 psi. The joints were "tooled" to ensure good contact and adhesion as well as to control sealant depth and to provide a recessed surface. The air temperature at time of placement varied from 68°F to 78°F.

The Delastic V-687 (Lot No. 0190160) and Watson Bowman WB-687 and WB-812 compression seals were installed using a Delastall Auto Installer (Figure 11). The compression seal was initially started by hand and then installed with a machine. The last foot of the compression seal was also installed by hand. Final placement of the compression sealer was performed using hand methods (Figure 12). The Delastic V-687 was installed at air temperatures between 72°F to 81°F.

The Crafco Silicone S.L., Dow 890 S.L. (Lot No. ET110047), Dow 888 S.L., and Mobay Baysilone S.L. (Lot No. 56191), Figure 13, self-leveling sealants were placed with a standard joint sealant pump at a pressure varying from 60 to 75 psi, Figure 14. The longitudinal joints in which Dow 890 S.L. was used in the transverse joints (Joint Details 3 and 4) were sealed first. This was necessary because a smaller tip was required for sealing the transverse joints than the longitudinal joints. A standard hot-pour tip was modified to produce this smaller tip, Figure 15. No skinning of the surface of the longitudinal joints was observed before sealing of the transverse joints was completed. Air temperatures at the time of sealant application varied from 61°F to 73°F. A few bubbles were observed on the surfaces of the sealants in sections 6, 10, 16, 18, and 19.

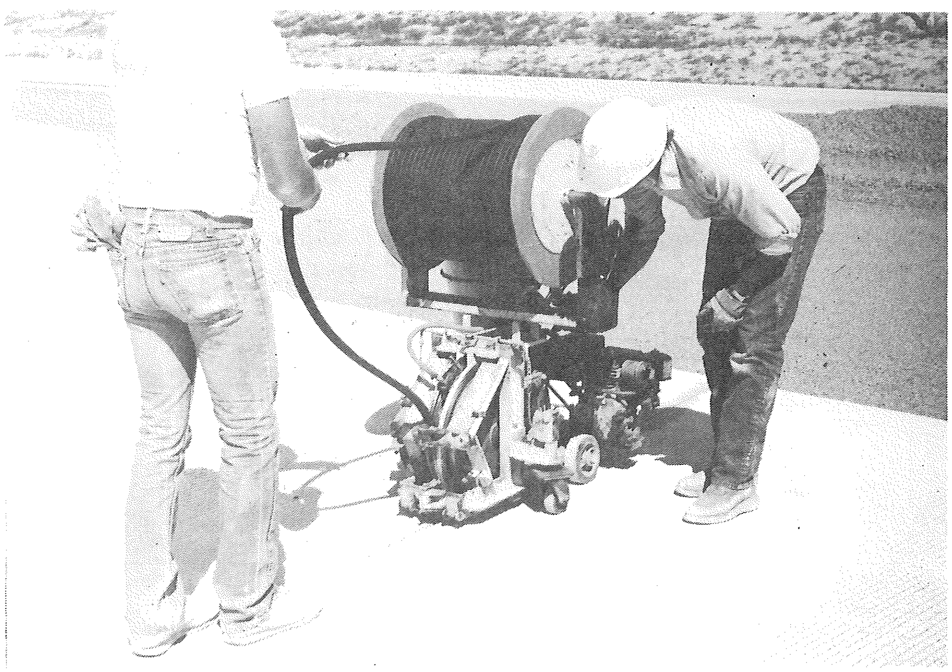

Figure 11 - Installation of Compression Seal Using A Delastall Auto Installer.

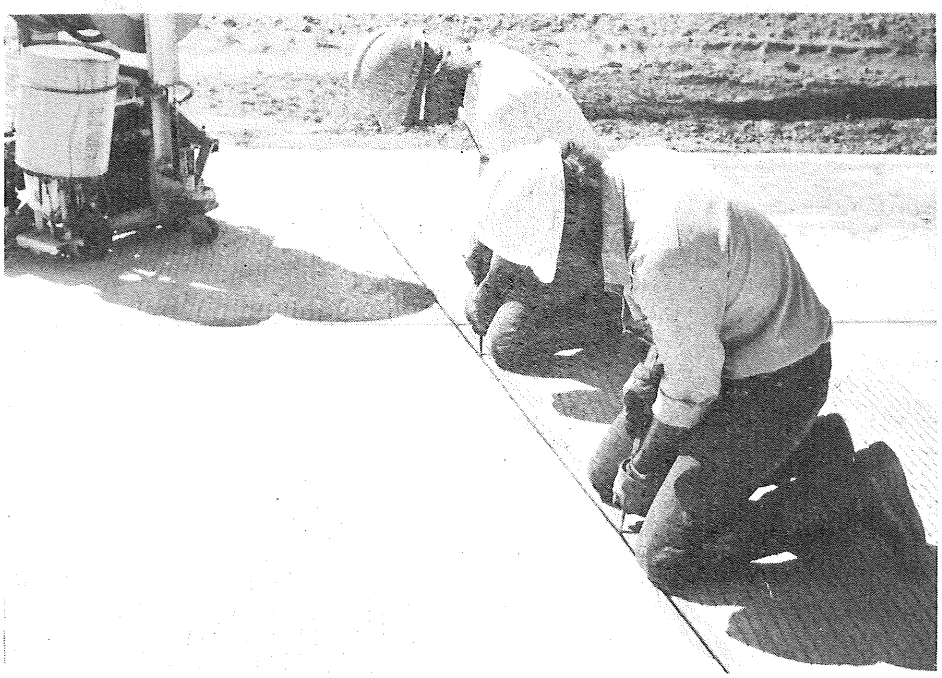

Figure 12 - Final Placement of Compression Seal

Figure 13 - Container of Mobay Baysilone 960 Joint Sealant

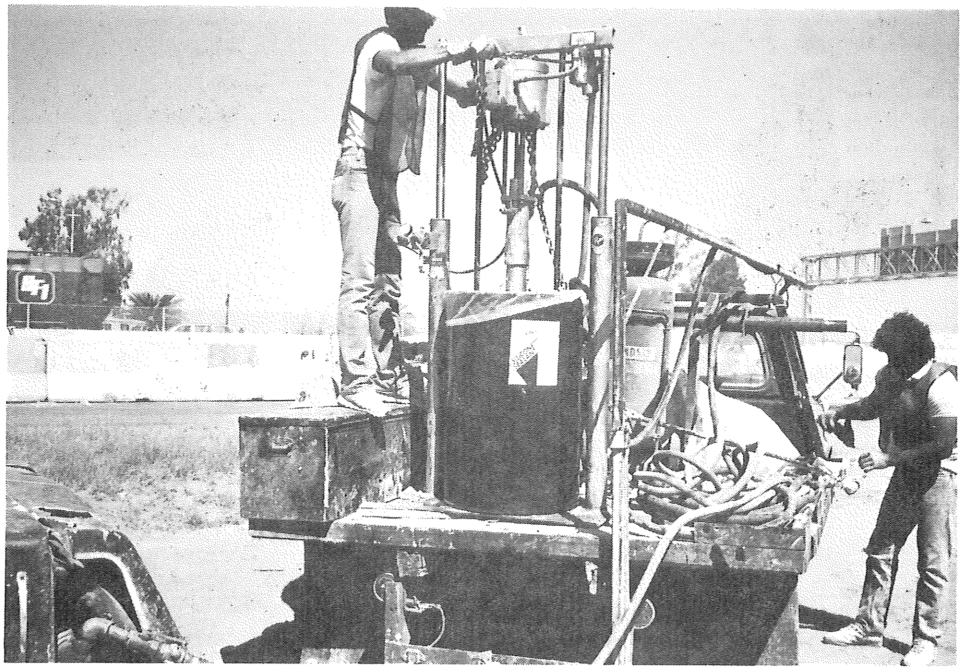

Figure 14 - Pumping Equipment for Installation of Sealants

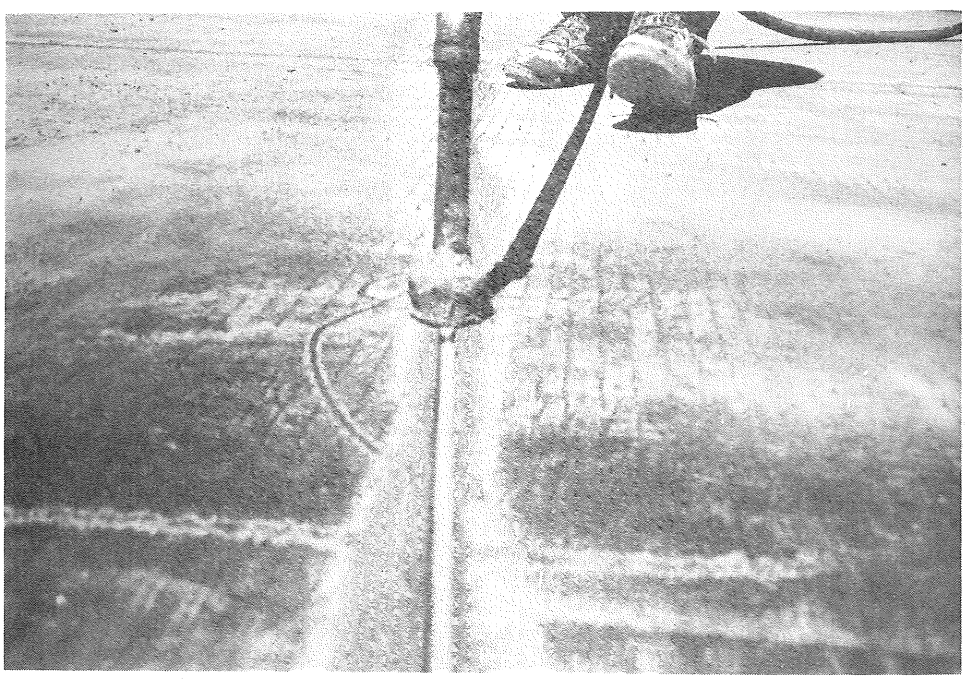

Figure 15 - Small Tip Wand Used for Sealant Application

The date each section was sealed is provided in Table 2.

TABLE 2 - JOINT SEALANT INSTALLATION DATA

Section Numbers	Product Installed	Date Installed
1, 14	Delastic V-687	3/31/91
2, 20	Crafco Silicone S.L.	3/30/91
3, 17	Unsealed	--
4, 9, 12, 13, 18, 24	Dow 890 S.L.	3/25/91
5,	Watson Bowman WB-687	5/7/91
22	Watson Bowman WB-812	5/7/91
6, 19	Dow 888 S.L.	3/29/91
7, 15	Dow 888	3/30/91, 3/31/91
8, 23	Crafco 444	3/18/91, 3/31/91
10, 16	Mobay Baysilone S.L.	3/27/91, 3/29/91
11, 21	Crafco 221	3/30/91

Construction Problems

The most paramount problems in the construction of the experimental sections were the changes in joint details, the acquisition of the various joint sealants, concrete cuttings in the joints, and the change over from one sealant to another sealant.

Joint Details

The first problem was highlighted in Section No. 4 when the transverse joints were sawn 3/8 inch wide instead of 1/4 inch wide. There is also an "extra" joint at the end of Section No. 8 because it was not sawn to the typical dimension for this section, or the next section (No. 9).

The location of construction joints in the experimental sections also became a problem. For Section Nos. 12 and 24 construction joints were included as experimental joints, in Section 18 the construction joint was not included.

Product Acquisition

Another major construction problem was acquiring the Elastomer PV-687 compression seal. All sealants were installed by late March of 1991, except for this compression seal. After this product could not be obtained, Watson Bowman WB-687 and WB-812 compression seals were used in lieu of the Elastomer PV-687 compression seal.

Compression Seals

The Watson Bowman WB-687 was to be used in place of the Elastomer PV-687 in Section Nos. 5 and 22. The Watson Bowman WB-687 was installed in Section No. 5, but was not installed in Section No. 22. Because of the lack of material, a Watson Bowman WB-812 was used in Section No. 22.

Hot-Poured Sealants

Crafco 444 is a hot-applied sealant that was used in Section Nos. 8 and 23. Personnel from Crafco Inc. applied this sealant to Section No. 8 on March 18, 1991. After completion of Section No. 8, the equipment was moved to Section No 23. The Crafco 444 sealant that was in the kettle could not be used because it had reached initial set. Multiple-Concrete Enterprises sealed Section No. 23, using Crafco 444 (same lot number), on March 31, 1991. Therefore, the material used for filling the last five or more joints in Section No. 8 may be defective due to the start of initial setting of the sealant.

Self-Leveling Sealants

A wave-like profile was produced on the top surface of all self-leveling sealants used in this experimental project. This condition was caused by the continuous surges in sealant from the pump. Surges of sealant produced higher areas that did not completely self-level. If low spots developed in a self-leveling sealant, additional material was added to produce an acceptable joint.

Contamination of one sealant by another sealant due to incomplete cleaning after application was a problem. This was especially noted when the Mobay Baysilone material was used. It appeared that this sealant was somewhat contaminated by the Dow 890 S.L. material.

The silicone sealant (Dow 888) that required tooling appeared to be more uniform and have better adhesion to the side of the concrete than the self leveling sealants.

Concrete Cuttings and Construction Traffic

Concrete cuttings from the joint sawing operations were removed from the joints by means of compressed air and dry sawing. During the time period when sealants were applied, several days of rain occurred. The rain washed cuttings back into the unsealed joints. Furthermore, compressibles from construction traffic became embedded into some unsealed joints. This material was wet and would not blow out. Therefore, the joints were again dry sawed and water jetted. A rock rake was used for removing large incompressibles. The joints were also air jetted prior to sealant placement. At some joint locations 1/8 to 3/8 inches of wet paste material remained at the bottom of the primary cut. It was decided that this condition would be acceptable for receiving the joint sealant.

Although specifications stated that the accumulation of latency from the sawing operation shall be swept with a throw broom, this operation was not performed. The reason given was that the latency particles would cause air pollution. Also, all construction traffic could not be controlled. Therefore, some light construction traffic used the sealed and unsealed joints prior to completion of the entire sealing operation.

Subbase Erosion

The PCC for this highway project was placed in widths less than full roadway. This placement method left the adjacent subgrade exposed to the environment (Figure 16). Normally, this is not a problem since the adjacent pavement will be placed after a short period of time. For this specific roadway, several storms occurred before the adjacent concrete was placed. The runoff water from the storms caused some undermining of the subgrade and aggregate base beneath the existing concrete pavement. This condition can be seen in Figure 17. Corrective action was taken by the Contractor to rehabilitate this erosion condition.

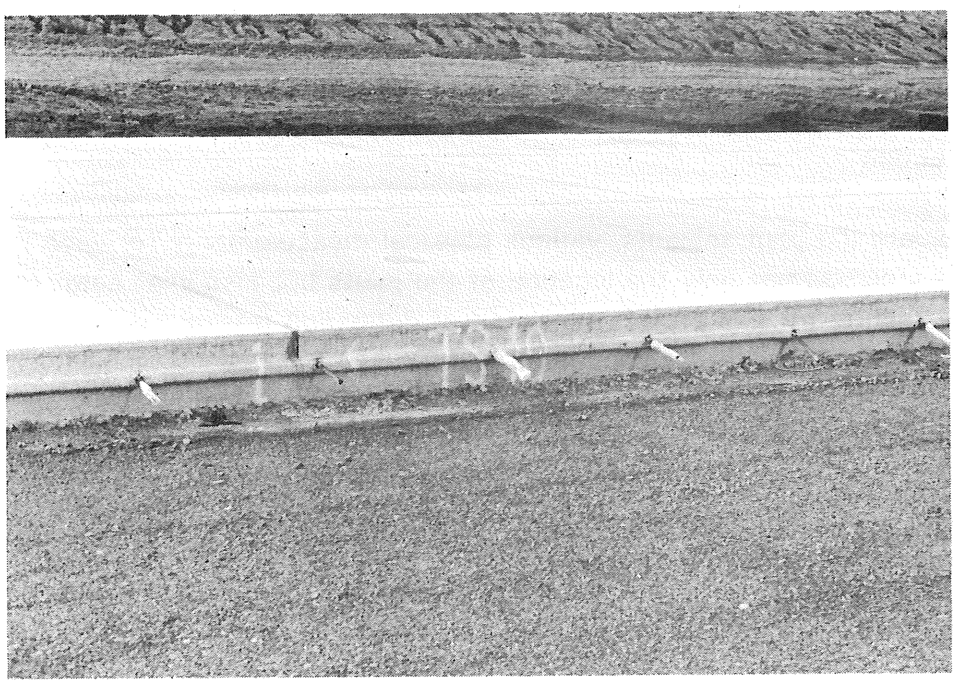

Figure 16 - Subgrade and Aggregate Base Prior to Storms

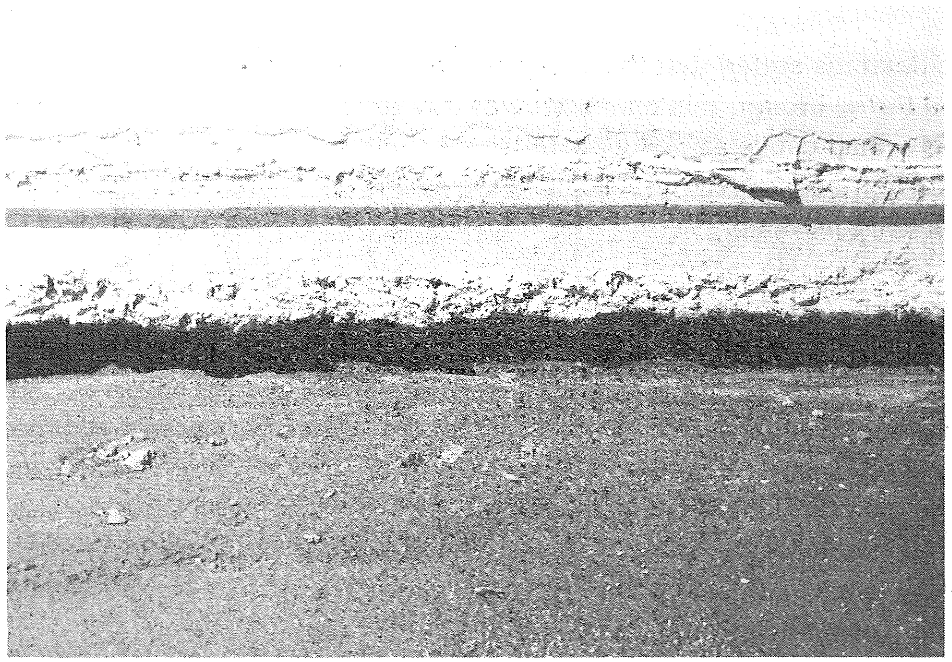

Figure 17 - Erosion Beneath PCC Pavement

Field Data Collection

In order to evaluate the joint sealants, various physical measurements for each joint had to be compiled. This included not only the location of the joints but also joint detail measurements. Nondestructive testing for this project consisted of deflection testing using a FWD at 10 joint locations for all sections except for sections 5 and 22.

Test Section Stationing

The test sections were numbered in the field. Beginning and ending stations were recorded as provided in Table 3.

Joint Locations

The transverse joint spacing plan was established at staggered intervals of 13, 15, 17, 15 ft, and then continually repeated. Actual joint location measurements are provided in Appendix E. These measurements varied as much a 6 inches from the required spacing. Joint locations were measured on February 19, 21, and 22, 1991.

TABLE 3 - TEST SECTION STATIONING

Section No.	Beginning Station	Ending Station	Length of Section*	No. of Joints
1	957+72' 6"	961+46' 10"	373.54'	25
2	961+46' 10"	966+58' 4"	511.38'	34
3	966+58' 4"	972+25' 3"	567.64'	38
4	972+25' 3"	976+00' 0"	375.10'	25
5	976+00' 0"	979+59' 3"	359.07'	25
6	979+59' 3"	983+33' 8"	375.01'	25
7	983+33' 8"	987+09' 9"	372.94'	25
8	987+09' 9"	990+81' 9"	374.70'	25**
9	990+81' 9"	994+73' 8"	393.24'	25
10	994+73' 8"	998+46' 5"	372.70'	25
11	998+46' 5"	1002+21' 5"	374.95'	25
12	1002+21' 5"	1005+82' 10"	361.31'	25***
13	892+39' 6"	896+40' 4"	384.62'	26
14	896+40' 4"	900+24' 1"	376.47'	25
15	900+24' 1"	903+98' 11"	375.06'	25
16	903+98' 11"	907+72' 0"	373.00'	25
17	907+72' 0"	911+46' 9"	374.94'	25
18	911+46' 9"	915+17' 8"	370.38'	25#
19	915+17' 8"	918+90' 5"	373.14'	25
20	918+90' 5"	922+65' 7"	374.90'	25
21	922+65' 7"	926+42' 7"	377.05'	25
22	926+42' 7"	930+17' 0"	374.50'	25
23	930+17' 0"	933+89' 10"	372.97'	25
24	933+89' 10"	937+49' 10"	359.79'	25##

Notes: * R.O.E. distance. All points are aluminum caps in E. B. roadway.
** Extra joint at end of test section; not included.
*** Joint No. 15 is a construction joint; is included.
# Construction joint between joint No. 24 and 25; not included.
Joint No. 17 is a construction joint; is included.

Transverse Joint Measurements

The following transverse joint measurements, if applicable, were obtained for each test section.

- Primary joint depth
- Joint width, and depth of secondary cut
- Backer rod depth
- Top of sealant depth

The primary transverse joint depth, joint width, and depth of secondary cut were measured shortly after the sawing operation was completed. If a delay occurred between when the joints were measured and when the sealant was actually placed, the joint width was again measured just before sealant application.

Only one measurement, for each dimension, was obtained from each joint. Measurement locations were spaced at staggered intervals consisting of near shoulder joint, middle of joint, and near longitudinal joint. This sequence of measurement locations was then repeated. The temperature of the concrete slabs varied from 56°F to 72°F, and the ambient temperature varied from 57°F to 79°F at the time measurements were recorded. Field measurements for all transverse joints are provided in Appendix D.

The depth to the top of the backer rod was measured at each joint in each section requiring the use of a backer rod. These measurements were obtained from March 18 through 25, 1991. These data are provided in Appendix E.

On April 1 and 2, 1991, the depth to the top of sealant in each joint was measured. These data are provided in Appendix E.

Nondestructive Testing

Nondestructive testing was conducted from April 4 through 7, 1991, by SHRP personnel. Deflection testing using a falling weight deflectometer was performed on all sections except for Sections 5 and 22. ADOT personnel performed FWD tests on these sections on August 7 and 8, 1991. All FWD data were obtained using SHRP Protocol: H30F. The FWD camera used to locate the transverse joints is shown in Figure 18, and Figure 19 shows the load being applied adjacent to a joint. FWD data are provided in Appendix F.

FWD testing was conducted at three load levels ranging from approximately 9,000 lbs to 17,000 lbs. Data were reduced by normalizing deflections to a 9,000-lb load. Load transfer efficiency was obtained by dividing the measured deflection across the joint from the load by the measured deflection at the load, and applying a bending correction obtained from midslab deflection testing.

SHRP deflection testing generally was conducted at the first joint in a section and at intervals of three joints following that. Ten joints were tested for each section. Tests were conducted on both sides of each joint selected. A midslab deflection, away from any joints, was performed for each joint tested. ADOT deflection testing was performed in a similar manner; however, all joints were tested for those two sections.

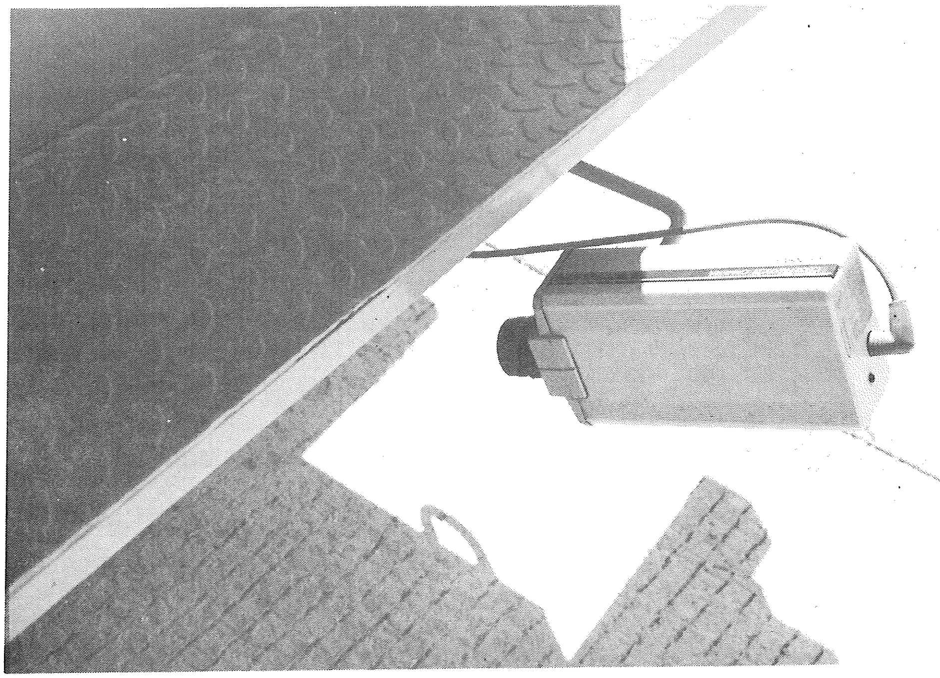

Figure 18 - Camera Used to Locate Transverse Joints

Construction Costs

It would be difficult, if not impossible, and not entirely fair or realistic, to determine the true cost of the total sealing operation for each joint sealant. The amount of time required to clean the joints varied depending on the weather conditions, specifically the amount of rainfall that occurred before the section was sealed. Time was required to change saw blades because of the various joint details, and to change sealants. Furthermore, no records were kept concerning the actual time, material used, and manpower required to clean and seal each section. In addition, personnel from Crafco installed one section at no cost to the Contractor.

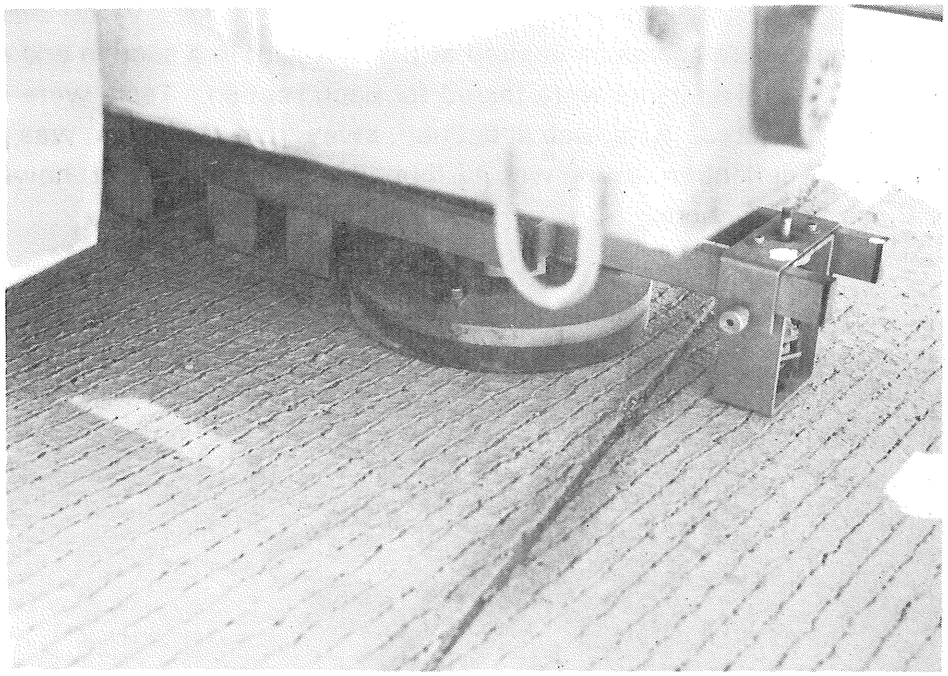

Figure 19 - FWD Load Applied Adjacent to Joint

Cutting, cleaning and sealing of the transverse joints in the sections were performed under Change Order No.19 for this project. A copy of the correspondence for this change order is provided in Appendix A. Ball, Ball and Brosamer submitted a revised cost of $14,011.52 on March 18, 1991, for the performance of this work. The cost of this change order included installation of 9 sealants in 24 test sections, material costs, additional labor, and additional equipment, and profit. It was estimated that 56,900 feet of transverse and longitudinal joints were included in Experimental Zones 1 and 2. Therefore, the cost per linear foot is $0.25.

The number of personnel required to perform the sealing operation depended upon the sealant being installed. Compression seals, self leveling sealants hot-pour and silicone sealants were installed using a 2 man crew. A 4 man crew was used to install sealants that required tooling. Therefore, there would be a cost saving in personnel for those sealants requiring only a 2 man installation crew.

The material costs in dollars for the available sealants, as provided in Change Order No. 19 prepared by Multiple Concrete Enterprises, and dated March 1, 1991, are provided in Table 4. Proposed costs include both longitudinal and transverse joints for corresponding sections.

TABLE 4 - MATERIAL COSTS

Sealant	Cost/ft
Watson Bowman Compression Seal Lubricant **Total**	*0.62 0.04 **0.66**
Elastomer PV-687 Compression Seal Lubricant **Total**	0.58 0.04 **0.62**
Crafco 221 Hot Pour Flush Oil **Total**	0.05 0.02 **0.07**
Crafco 444 Hot Pour Flush Oil **Total**	0.09 0.02 **0.11**
Dow 890 S.L.	0.50
Dow 888 S.L.	0.50
Mobay Baysilone S.L.	0.49
Dow 888	0.41
Crafco Silicone S.L.	0.41
* Used in place of Elastomer PV-687	

Laboratory Test Program

A laboratory test program was formulated by the Arizona Transportation Research Center (ATRC) for the testing of the various sealants used in this research project. Laboratory testing of the various joint sealants was performed by Western Technologies Inc. located in Phoenix, Arizona. Laboratory test results are provided in Appendix C, and product literature is provided in Appendix B.

Compression Seals

A sample of the Delastic V-687 compression seal was obtained by ATRC personnel on March 31, 1991. This sample was submitted to Western Technologies on September 18, 1991, for testing. This sealant met the required American Society For Testing and Materials (ASTM) specifications, except for ASTM D2628. Recovery at 70 hours for 212°F and 50 percent deflection did not meet the minimum value required in ASTM D2628.

Samples of the Watson Bowman WB-687 and WB-812 compression seals were obtained by ATRC personnel and submitted to Western Technologies on February 11, 1992. These compression seals met the required ASTM specifications, except of ASTM D2628. Recovery at 70 hours for 212°F and 50 percent deflection did not meet the minimum value required by ASTM D2628.

The Ozone Resistance (ASTM D1149-Modified) was not performed on any of the compression seals.

Hot Poured Sealants

Samples of Crafco 221 and Crafco 444 hot poured sealants were submitted to Western Technologies by ATRC personnel on March 21, 1991, and October 22, 1991, respectively. These sealants were tested in accordance with ASTM D3405-78 "Joint Sealant, Hot Poured, for Concrete and Asphalt Pavements." Test results indicate that both sealants met the physical requirements as listed in ASTM D3405-78. An artificial weathering test was not performed on either of the hot poured sealants.

Self Leveling Sealants

The self leveling silicone joint sealants were tested in accordance with SHRP protocol, which generally follows the State of Georgia Department of Transportation Method (GDT-106). A sample of each sealant was obtained from job site containers. Typical samples were obtained as shown in Figure 20.

A sample of Dow 890 S.L. sealant was obtained by ADOT personnel on March 25, 1991. This sample was submitted for testing on March 28, 1991. The Dow 890 S.L. sealant met GDT-106 specifications, except for Durometer Hardness (Shore A). A test value of 3 was obtained, which is less than the test requirement of 10 to 25.

A sample of Mobay Baysilone S.L. 960 sealant was also tested. Test results for this sealant did not meet GDT-106 specifications for movement capability and adhesion (10 cycles, +50%/0% at 0°F).

A sample of Dow 888 S.L. (Lot GA 110415) was obtained by ADOT personnel on March 29, 1991. This sample was submitted for testing on April 8, 1991. The Dow 888 S.L. sealant met GDT-106 specifications.

A sample of Crafco Silicone S.L. was obtained by ADOT personnel on March 30, 1991. This sample was submitted for testing on April 8, 1991. The Crafco Silicone S.L. met GDT-106 specifications, except for Durometer Hardness (Shore A) and Tack Free Time. A test value of 2 was obtained for Durometer Hardness, which is less than the test requirements of 10 to 25. The maximum tack free time of 90 minutes was exceeded by 45 minutes for this sealant.

Figure 20 - Typical Sampling of Self Leveling Joint Sealants

Silicone - Tooled Sealants

A sample of Dow 888 silicone sealant was obtained by ADOT personnel on March 30, 1991. This sample was submitted for testing on April 8, 1991. The Dow 888 silicone sealant met GDT-106 specifications.

ANALYSES

General

This research project was intended to collect data and develop findings over a period of at least ten years. As such, only limited analyses can be performed at this time. However, some of the data currently lends itself to analyses and conclusions.

Data have been collected relating to joint sawing, joint sealing and joint load transfer. These data have been examined and, where applicable, statistically analyzed. Much of the raw and reduced data are tabulated in Appendices D, E and F. Summaries of data pertinent to the analyses being performed are presented along with the analyses in some instances. When statistical analyses were performed, tests were conducted at a Type I error (α) of 0.05.

Joint Sawing

As described earlier in this report, primary saw cuts to control shrinkage cracking were made shortly after placement and finishing of the PCC pavement. Because all mainline concrete placed was to a specified depth of 13 inches, the required saw cut depth of T/3, given in the plans, was 4.333 inches. There were no tolerances for this requirement shown in the plans. The actual depths measured and reported were analyzed herein by treating the specified depth as a minimum, while considering whether the saw cut depth reached the specified depth. This approach was taken due to the importance of an adequate depth to control shrinkage cracking.

Table 5 is a comparison of the depths of primary saw cuts to the specified depth. It will be noted that only 6 of the 22 sections (7, 14, 15, 16, 25, and 23) for which data were available had mean depths greater than the requirement. The calculated mean depth for each section was increased by the value of that section's standard deviation. This would result in a depth which statistically is greater than approximately 84 percent of the actual depths for that section. Six sections (1, 8, 11, 12, 18 and 22) had depths, when computed in this manner, less than the specified depth.

The widths of the final saw cuts were compared to the specified ranges. Joints in the unsealed sections and 1/8 inch wide filled joints did not require a secondary saw cut, and the primary saw cut served as the final joint width. Only those joints that were recorded as uncracked were used for this analysis. The portion of the cracks outside the specified limits was computed using a normal distribution and the mean and standard deviation for each section. The results of this analysis are presented in Table 6. Table 7 is a comparison of the saw cut widths for the initial and final measurements where these had both been taken in a section. It was concluded that there was no significant difference between initial and final measurements. The data used in Table 5 are final measurements where they were taken, and initial measurements if there were no final measurements.

An examination of the portion of the crack width measurements beyond the specified limits indicates that the sections with 1/8 inch wide joints (9, 13 and 17) exceeded the upper limit a great deal of the time. The same can be concluded for the one section with 1/4 inch wide joints (24); although not to the extent of the 1/8 inch joints. Three of the sections with 3/8 inch wide joints (8, 18 and 20) statistically indicated more than one-third of the joints to be beyond the specified limits. The vast majority of the deviations from the specified limits was the result of crack widths greater than the upper limit.

Table 8 is a comparison of the mean widths of cracked and uncracked joints for each section for which data were available.

TABLE 5 - COMPARISON OF PRIMARY SAW CUT DEPTH TO SPECIFIED T/3

Section No.	No. of Joints	Depth, inches		Mean Depth + Std. Dev. (inches)	Mean Depth - Spec. Depth (inches)
		Mean	Std. Dev.		
1	25	4.030	0.189	4.219*	-0.303
2	34	4.204	0.216	4.420	-0.129
3	38	No Data, Unsealed Section			
4	25	4.058	0.369	4.427	-0.275
5	25	No Data			
6	25	4.138	0.221	4.359	-0.195
7	25	4.252	0.190	4.442	0.081
8	25	4.095	0.190	4.285*	-0.238
9	25	4.175	0.258	4.433	-0.158
10	25	4.215	0.149	4.364	-0.118
11	25	4.138	0.147	4.285*	-0.195
12	24	4.162	0.143	4.305*	-0.171
13	26	4.260	0.138	4.398	-0.073
14	25	4.485	0.063	4.548	0.152
15	25	4.472	0.156	4.628	0.139
16	25	4.468	0.094	4.562	0.135
17	25	No Data			
18	24	4.031	0.257	4.288*	-0.302
19	25	4.215	0.264	4.479	-0.118
20	25	4.152	0.191	4.343	-0.181
21	25	4.382	0.098	4.480	0.049
22	25	3.775	0.340	4.115*	-0.558
23	25	4.348	0.102	4.450	0.015
24	24	4.237	0.213	4.450	-0.096

* *Less than specified depth of T/3 (4.333 in.)*

TABLE 6 - COMPARISON OF SAW CUT WIDTHS TO SPECIFIED WIDTHS

Section No.	Saw Cut Width (inches)		Std Dev's to		Portion Beyond Specified Limits		
	Mean	Std Dev	UL	LL	LL	UL	Total
1	0.3789	0.0156	4.26	3.76	0.000	0.000	0.000
2	0.3864	0.0246	3.00	2.08	0.001	0.019	0.020
3	No Data, Unsealed Section						
4	0.3792	0.0161	4.14	3.62	0.000	0.000	0.000
5	0.3864	0.0253	2.92	2.02	0.002	0.022	0.024
6	0.3750	0	infinity	infinity	0.000	0.000	0.000
7	0.3787	0.0152	4.36	3.87	0.000	0.000	0.000
8	0.4091	0.0808	1.20	0.35	0.155	0.363	0.478
9	0.2031	0.0312	4.51	0.50	0.000	0.691	0.691
10	0.4028	0.0329	2.74	1.05	0.003	0.147	0.150
11	0.3792	0.0161	4.14	3.62	0.000	0.000	0.000
12	0.4375	0	infinity	infinity	0.000	0.000	0.000
13	0.1875	0.0361	3.46	0.00	0.000	0.500	0.500
14	0.3839	0.0227	3.15	2.36	0.001	0.009	0.010
15	0.3867	0.0369	2.01	1.38	0.023	0.084	0.107
16	0.3750	0	infinity	infinity	0.000	0.000	0.000
17	0.1641	0.0504	2.02	0.46	0.022	0.323	0.345
18	0.4081	0.0547	1.75	0.54	0.040	0.295	0.335
19	0.3984	0.0327	2.63	1.20	0.004	0.118	0.122
20	0.4208	0.0499	2.17	0.33	0.015	0.371	0.386
21	0.4042	0.0323	2.84	1.03	0.002	0.152	0.154
22	0.3906	0.0283	2.76	1.66	0.003	0.048	0.053
23	0.3906	0.0280	2.79	1.68	0.003	0.046	0.049
24	0.2812	0.0442	2.12	0.71	0.017	0.239	0.256

LL is Lower Limit, 1/16 inch for Section Nos. 9, 13 and 17; 3/16 inch for Section No. 24; and 5/16 inch for all other sections.

UL is Uppper Limit, 3/16 inch for Section Nos. 9, 13 and 17; 5/16 inch for Section No. 24; and 7/16 inch for all other sections.

TABLE 7 - COMPARISON OF SAW CUT WIDTHS FOR ALL JOINTS

Section No.	Mean Saw Width (inches)	
	Initial	Final
2	0.3897	0.3934
6	0.4200	0.3725
7	0.4375	0.3725
8	0.4350	0.3925
11	0.4250	0.3900
15	0.3900	0.4000
16	0.3775	0.4000
19	0.3900	0.4100
20	0.4075	0.4175
21	0.4000	0.3984
23	0.3925	0.3925
Mean	0.4056	0.3945
Std Dev	0.0205	0.0136

Pooled Std Dev = 0.0174
t(calc) = 1.496
t(table, n=20, α=0.05) = 1.725

Conclusion: There is no significant difference between the two means.

Again, the final measurements were used where they were available, and initial measurements used if final measurements were not available. Findings from this analysis had mixed results. Ten of the 23 sections for which data were available had mean widths for the cracked sections less than that for the uncracked sections. However, of these, only one section (7) was found to have a significant difference. Eight of the 13 sections with mean widths of the cracked joints greater than the uncracked joints, were found to have significantly different widths between cracked and uncracked joints.

TABLE 8 - COMPARISON OF MEAN WIDTHS FOR CRACKED AND UNCRACKED JOINTS

Section No.	Mean Width (inches)			Pooled Std. Dev.	t-Statistic		**
	Cracked	Uncracked	Difference		Calc	Table	
1	0.4306	0.3789	0.0517	0.0255	4.866	1.714	Y
2	0.4062	0.3864	0.0198	0.0317	1.740	1.694	Y
3	No Data, Unsealed Section						
4	0.4250	0.3792	0.0458	0.0333	3.369	1.714	Y
5	0.3839	0.3864	-0.0025	0.0301	0.206	1.714	N
6	0.3708	0.3750	-0.0042	0.0223	0.461	1.714	N
7	0.3594	0.3787	-0.0193	0.0204	2.207	1.714	Y*
8	0.3795	0.4091	-0.0296	0.0547	1.343	1.714	N
9	0.2292	0.2031	0.0261	0.0303	1.579	1.714	N
10	0.4180	0.4028	0.0152	0.0310	1.177	1.714	N
11	0.4062	0.3792	0.0270	0.0304	2.176	1.714	Y
12	0.4261	0.4375	-0.0114	0.0167	1.694	1.714	N
13	0.2537	0.1875	0.0662	0.0742	1.987	1.717	Y
14	0.4261	0.3839	0.0422	0.0302	3.468	1.714	Y
15	0.4236	0.3867	0.0369	0.0261	3.393	1.714	Y
16	0.4375	0.3750	0.0625	0.0484	1.667	1.812	N
17	0.1597	0.1641	-0.0044	0.0553	0.191	1.714	N
18	0.3750	0.4081	-0.0331	0.0456	1.693	1.714	N
19	0.4306	0.3984	0.0322	0.0383	2.018	1.714	Y
20	0.4028	0.4208	-0.0180	0.0483	0.884	1.725	N
21	0.3929	0.4042	-0.0113	0.0296	0.834	1.725	N
22	0.4062	0.3906	0.0156	0.0303	1.030	1.746	N
23	0.4097	0.3906	0.0191	0.0298	1.538	1.714	N
24	0.2688	0.2812	-0.0124	0.0319	0.502	1.812	N

* Indicates that uncracked joints are significantly wider than cracked joints.
**Y *indicates significant difference.*
N indicates no significant difference.

Joint Sealant

The depth to the top of the sealant for all sealed joints was specified to be between 1/4 and 3/8 inch. These two limits were compared to the depths measured to the top of the completed joint sealant. By using the means and standard deviations of this depth for each section and assuming a normal distribution, the proportion of the depths outside these limits was computed. The results of this analysis are shown on Table 9. There were no data available for Sections 5 and 22 which had joints sealed with Watson Bowman compression seals. Statistically, 10 of the 20 sections measured for this property had more than 50 percent of the depths outside the specified limits. The other 10 sections had from 18.8 to 49.5 percent of the depths outside the limits. By far, the majority of the depths outside the limits were less than the lower limit of 1/4 inch. The one exception to this was Section 14 where joints were sealed with Delastic V-687 compression seal.

The depth to the backer rod is not as closely defined, since its vertical position is specified according to the depth to the top of the sealant plus the depth of the sealant. Consequently, the backer rod could be as deep as 3/4 inch or as shallow as 1/2 inch and still comply with the plan detail. Table 10 is a summary of a statistical analysis comparing the depths to the backer rods to the required depth range by section, assuming a normal distribution of the data. The depths to the backer road for most of the sections have at least 85 percent within the specified range.

An important parameter for poured joints is the shape factor of the cross-section of the joint sealant. In particular, if the depth of the joint sealant is large compared to the width, large strains will be introduced into the joint sealant with only small movements of the joint. For the joint sealant details specified for this project, the shape factor would be the distance between the top of the backer rod and the top of the joint sealant divided into the width of the joint. The smallest shape factor that would comply with the specified joint detail would be the maximum depth of joint sealant and the minimum crack width, and would calculate to 0.83.

The shape factor was computed for each poured joint, and the mean and standard deviation for each section are summarized in Table 11. Seven of the 18 sections had a mean shape factor of less than 1.00, and 4 of these were less than 0.83. The remaining 11 sections had mean shape factors between 1.00 and 1.25.

Joint Load Transfer

Load transfer data were collected within all sections by use of a FWD. These data were collected by SHRP using their testing device for 22 of the 24 sections. Two of the sections (5 and 22) were not sealed at the time that SHRP performed their work, and were tested by ADOT using their test device at a later date. Data were collected by applying the FWD load near a joint and measuring the deflection at the load and at a point on the other side of the joint. This procedure was performed with the FWD load applied on both sides of the joint. Similar readings were taken at midslab, a significant distance from any joint, to allow for correction of the data for the distance between the load sensor and the sensor across the joint. This correction is necessary to allow for the reduced deflection away from the load even if there was not a crack or joint present.

TABLE 9 - COMPARISON OF DEPTHS TO TOP OF SEALANT TO SPECIFIED RANGE

Section No.	Depth to Top of Joint Sealant, inches		Std Dev's to		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
1	0.275	0.040	0.62	2.50	0.268	0.006	0.274
2	0.258	0.049	0.16	2.39	0.436	0.008	0.444
3	No Data, Unsealed Section						
4	0.292	0.080	0.52	1.04	0.302	0.149	0.451
5	No Data, Watson Bowman Compression Seal Section						
6	0.250	0.062	0.00	2.02	0.500	0.022	0.522
7	0.312	0.040	1.55	1.58	0.061	0.057	0.188
8	0.288	0.088	0.43	0.99	0.334	0.161	0.495
9	0.225	0.068	-0.37	2.21	0.644	0.014	0.658
10	0.298	0.052	0.92	1.48	0.179	0.069	0.248
11	0.165	0.054	-1.57	3.89	0.942	0.000	0.942
12	0.315	0.056	1.16	1.07	0.123	0.142	0.265
13	0.175	0.102	-0.74	1.96	0.770	0.025	0.795
14	0.368	0.066	1.79	0.11	0.037	0.456	0.493
15	0.315	0.039	1.67	0.94	0.047	0.174	0.221
16	0.240	0.064	-0.16	2.11	0.564	0.017	0.581
17	No Data, Unsealed Section						
18	0.278	0.067	0.55	1.45	0.291	0.074	0.365
19	0.238	0.051	-0.23	2.69	0.591	0.004	0.595
20	0.228	0.070	-0.31	2.10	0.622	0.018	0.640
21	0.185	0.049	-1.33	3.88	0.908	0.000	0.908
22	No Data, Watson Bowman Compression Seal Section						
23	0.182	0.065	-1.05	2.97	0.853	0.001	0.854
24	0.188	0.052	-2.54	4.94	0.994	0.000	0.994

LL is Lower Limit of 1/4 inch.
UL is Upper Limit of 3/8 inch.

TABLE 10 - COMPARISON OF DEPTHS TO BACKER ROD TO SPECIFIED RANGE

Section No.	Depth to Top of Backer Rod (inches)		Std Dev's to		Portion Beyond Specified Limits		
	Mean	Std Dev	LL	UL	LL	UL	Total
1	No Data, Compression Seal Section						
2	0.590	0.036	2.50	4.44	0.006	0.000	0.006
3	No Data, Unsealed Section						
4	0.705	0.038	5.39	1.18	0.000	0.119	0.119
5	No Data, Compression Seal Section						
6	0.612	0.040	2.80	3.45	0.003	0.000	0.003
7	0.620	0.025	4.80	5.2	0.000	0.000	0.000
8	0.668	0.047	3.57	1.74	0.000	0.041	0.041
9	0.635	0.071	1.90	1.62	0.029	0.053	0.082
10	0.660	0.044	3.75	1.93	0.000	0.027	0.027
11	0.595	0.048	1.98	3.23	0.024	0.001	0.025
12	0.735	0.033	7.12	0.45	0.000	0.326	0.326
13	0.605	0.080	1.31	1.81	0.095	0.035	0.130
14	No Data, Compression Seal Section						
15	0.667	0.035	4.77	2.37	0.000	0.009	0.009
16	0.608	0.038	2.84	3.74	0.002	0.000	0.002
17	No Data, Unsealed Section						
18	0.650	0.048	3.12	2.08	0.001	0.019	0.020
19	0.682	0.054	3.37	1.26	0.000	0.104	0.104
20	0.622	0.038	3.21	3.37	0.001	0.000	0.001
21	0.630	0.047	2.77	2.55	0.003	0.005	0.008
22	No Data, Compression Seal Section						
23	0.700	0.062	3.23	0.81	0.001	0.209	0.210
24	0.568	0.044	1.55	4.14	0.061	0.000	0.061

LL is Lower Limit of 1/2 inch
UL is Upper Limit of 3/4 inch

TABLE 11 - SUMMARY FOR SEALANT SHAPE FACTORS

Section No.	Shape Factor		Remarks
	Mean	Std. Dev.	
1	--	--	Compression Seal Section
2	1.24	0.21	
3	--	--	Unsealed Section
4	1.07	0.54	
5	--	--	Compression Seal Section
6	1.08	0.28	
7	1.25	0.26	
8	1.10	0.32	
9	0.58	0.16	
10	1.16	0.24	
11	0.93	0.16	
12	1.07	0.18	
13	0.62	0.32	
14	--	--	Compression Seal Section
15	1.17	0.23	
16	1.14	0.29	
17	--	--	Unsealed Section
18	1.13	0.32	
19	0.95	0.19	
20	1.08	0.20	
21	0.91	0.12	
22	--	--	Compression Seal Section
23	0.78	0.13	
24	0.61	0.08	

The Load Transfer Efficiency (LTE) was calculated by dividing the deflection at the FWD load into the deflection measured for the sensor on the other side of the joint. The factor was then multiplied by the midslab correction factor. A correction factor of 1.10 was used for the SHRP data, and a factor of 1.22 was used for the ADOT data.

The LTE was determined for each joint tested for both sides of the joint. The mean and standard deviation for the LTE for each section was determined separately for cracked and uncracked joints. A linear regression analysis was performed using the depth of the primary saw cut as the independent variable and the mean LTE for both sides of the joint as the dependent variable.

The results of the linear regression analysis by section are shown in Table 12. The very low coefficient of determination (r^2) of 0.033 indicates poor correlation between saw cut depth and LTE at this time. The regression coefficient does have a negative sign indicating that LTE would be reduced with increase in saw cut depth, as would be expected. Since the vast majority of the LTE values are near 1.00, indicating complete load transfer at this time, a strong correlation to any other variables would not be expected. It is expected that with time and usage, the LTE will be reduced and a stronger correlation with other factors may develop.

A similar regression analysis was performed using the mean saw cut depth and LTE for each section as variables. This included the mean LTE for both cracked and uncracked joints in the same test section. The results of the linear regression analysis by section are shown in Table 13.

SUMMARY

This research project was constructed to evaluate the performance of various types of joint sealant and joint configurations for portland cement concrete pavement. Nine types of joint sealant, two sections of unsealed joints and three joint configurations were included in the work. Joint sealant materials studied included preformed compression seals, hot poured sealant, tooled silicone sealant and silicone self leveling sealant. Most sealants were placed in 3/8 inch wide joints; however, some 1/8 and 1/4 inch wide sealed joints were constructed. Joints in the unsealed section consisted of only the 1/8 inch wide primary saw cut.

Cost for the work was negotiated with the paving contractor as a change order. Proposed sealants were laboratory tested for specification compliance. The primary saw cut for transverse joints was detailed in the plans to be 1/8 inch wide and to a depth of one-third the thickness of the 13 inch thick portland cement concrete slab. Secondary saw cuts were made to widen the joints to 1/4 or 3/8 inch, where required.

Joint sawing took place during February, 1991, and joints were sealed during March, 1991, except for two sections with compression seals that were sealed during May, 1991.

TABLE 12 - COMPARISON OF LTE TO PRIMARY SAW CUT DEPTH BY SECTIONS

Section No.	No. of Joints	Mean LTE	Mean Sawcut Depth (inches)
1	9	0.82	4.0625
2	12	1.00	4.1979
3	13	1.01	No Data
4	9	0.91	4.0625
5	24	1.02	No Data
6	9	1.01	4.2222
7	9	1.01	4.3264
8	8	1.00	4.0703
9	9	0.95	4.1597
10	9	1.00	4.2153
11	9	1.01	4.1458
12	9	1.01	4.1458
13	9	1.02	4.2708
14	9	0.82	4.4792
15	9	0.93	4.3958
16	9	1.00	4.4931
17	9	1.00	No Data
18	8	1.01	3.9453
19	9	1.01	4.1944
20	9	1.01	4.1875
21	9	1.01	4.3750
22	25	1.01	3.7750
23	9	0.93	4.3542
24	6	0.97	4.1354

Linear regression using 21 points:
LTE = 1.243 - 0.0638d, d is sawcut depth
$r^2 = 0.033$

TABLE 13 - SUMMARY OF LOAD TRANSFER EFFICIENCY DATA

Section No.	Mean LTE		Linear Regression LTE vs. Saw Cut Depth		
	Cracked	Uncracked	A	B	r^2
1	0.64	0.98	3.37	-0.6277	0.328
2	1.02	1.00	1.00	0.0787	0.082
3	1.02	1.02	No Saw Cut Data		
4	0.70	1.00	1.24	-0.0818	0.045
5	1.02	1.02	No Saw Cut Data		
6	1.00	1.02	1.03	-0.0045	0.019
7	1.00	1.02	0.91	0.0225	0.088
8	1.00	1.02	0.91	0.0242	0.056
9	0.94	1.02	1.47	-0.1249	0.054
10	0.99	1.02	0.92	0.0200	0.031
11	1.01	1.01	1.09	-0.0190	0.056
12	1.01	1.02	0.73	0.0681	0.408
13	1.02	1.02	0.98	0.0067	0.006
14	0.72	1.00	0.95	-0.0305	0.000
15	0.80	0.99	1.38	-0.1039	0.023
16	1.00	0.99	0.78	0.0483	0.108
17	1.01	1.00	No Saw Cut Data		
18	1.03	1.00	1.15	-0.0357	0.350
19	0.98	1.02	1.14	-0.0381	0.134
20	1.02	1.01	1.26	-0.0605	0.272
21	1.00	1.01	0.97	0.0094	0.012
22	0.98	1.00	0.90	0.0293	0.060
23	1.00	0.90	0.63	0.0689	0.003
24	1.00	--	1.14	-0.0417	0.057

During construction of the experimental work, the dimensions and condition of the sawed joints were recorded. The vertical positions for joint sealant materials were measured. Following the completion of joint sealing, falling weight deflectometer data were taken at selected transverse joints in all sections to study the joint's load transfer ability. FWD data were obtained by SHRP for all but two of the sections during April, 1991. ADOT obtained the FWD data for the other two sections during August, 1991.

Data collected from joint sawing were examined. Generally, the primary saw cut depth was less than the specified amount of one-third the slab thickness. An appreciable proportion of the widths of uncracked final saw cuts exceeded the specified maximum width; however, the majority of the widths measured were within specified tolerances. Very few of the final saw cut widths were less than the lower limit of the specified range.

The tops of the joint sealant materials were above the specified range for a large portion of the joints. The vertical positions of the backer rods, where they were required, were generally within the allowable range. The combination of correct crack width, correct backer rod placement and higher than specified top of joint sealant, where it occurred, resulted in thicker than intended joint sealant applications. The result of this was shape factors of depth compared to width smaller than expected for some sections.

Load transfer efficiency calculated from FWD data generally indicated full load transfer across the joints at this early age. Consequently, the correlation with other factors such as depth of primary saw cut is not good. Generally, the joints observed to be uncracked, demonstrated better load transfer than the cracked joints. Specifically, four sections had LTE for cracked joints equal to or less than 0.80, while the uncracked joints in those sections were near 1.0.

Future studies of the performance of these joints are intended. It is expected that these later observations will provide additional information on joint configuration and joint sealant performances.