STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

EVALUATION OF DESIGN CHANGES AND EXPERIMENTAL PCC CONSTRUCTION FEATURES

F8

Study Made by ..... Pavement Branch

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16. ABSTRACT

This report is divided into four parts. Part I deals with a continuously reinforced concrete pavement (CRCP) and other experimental features intended as design improvements to reduce pavement maintenance costs. Part II covers field trials with four different types of joint sealant materials. It also reports on the first edge drain installation in California for the purpose of removing surface infiltrated water. Part III concerns experimental shoulder treatments, the prime variable being PCC shoulders. Part IV deals with other experimental features incorporated into construction projects under the FHWA Construction-Evaluated Research Program. These features include: (1) bridge approach slabs containing accelerated-set concrete mixtures, (2) the use of asphalt treated permeable base (ATPB) as both a drainage layer and a base for PCC pavement, and (3) the use of a cement treated permeable base (CTPB) in a highway roadbed structural section as a drainage layer for ground water control.

Although firm conclusions are not warranted by the limited data from some projects, the findings from certain experimental construction has led to further installations and, in some cases, the adoption of those practices for current projects. For example, the use of edge drains, along with ATPB or CTPB, is now required on new pavement construction.

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic years (yd^3)	3.785 .02832 .7646	litre (l) cubic metres (m^3) cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s	28.317	litres per second l/s)
	gallons per minute (gal/min)	.06309	litres per second (1/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G) (ft/s^2)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) (1000 lbs) kips	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British termal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (in-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi) pounds per square foot (psf)	6895 47.88	pascals (Pa) pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi$\sqrt{in}$)	1.0988	mega pascals$\sqrt{metre}$ (MPa$\sqrt{m}$)
	pounds per square inch square root inch (psi$\sqrt{in}$)	1.0988	kilo pascals$\sqrt{metre}$ (KPa$\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{+F - 32}{1.8} = +C$	degrees celsius (°C)

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INTRODUCTION

When the performance of portland cement concrete pavements (PCCP) is deemed less than desirable, the solution may be a change in design or construction procedure. Over the years, California has constructed numerous experimental features in paving projects representing various proposed changes. The research described in this report was initiated to evaluate some of those experiments and provide background for implementation purposes.

This report is divided into four parts. Part I deals with a continuously reinforced concrete pavement (CRCP) and other experimental features intended as design improvements to reduce pavement maintenance costs.

Part II covers trials with four different types of joint sealant materials. It also reports on the first edge drain installation in California for the purpose of removing infiltrated surface water.

Part III reports on experimental shoulder treatments, the prime variable being PCC shoulders.

Part IV deals with other experimental features incorporated into construction projects under the FHWA Construction-Evaluated Research Program (formerly Category 2 projects). These features include:

1. Bridge approach slabs constructed (during pavement rehabilitation) with various accelerated-set concrete mixtures.

2. The use of asphalt treated permeable base (ATPB) as both a drainage layer and a base for PCC pavement.

3. The use of a cement treated permeable base (CTPB) in a highway roadbed structural section as a drainage layer for ground water control.

Previous Reports Related To This Project

Two previous reports concerning Part I have been published. The first, "Recent Experimental PCC Pavements in California," was published in 1973 and covered construction details which began in May 1971, and early performance through November 1972. The second, "Performance of Experimental PCC Pavement Sections," was published in September 1978 and covered performance from 1971 to 1978. Some details from these reports are presented here to provide a better understanding of the project.

The purpose of the study was primarily to evaluate continuously reinforced concrete pavement (CRCP) but four other experimental designs were included for comparisons of performance and cost. Some 9 miles of CRCP was placed, with about 1 mile sections of the other four variables. Approximately one half of each variable was placed in each travel direction. The CRCP was further broken down into 3 types of reinforcement. Section 1-A contained longitudinal bars only, Section 1-B had both longitudinal and transverse reinforcement, and Section 1-C contained welded wire fabric in the form of mats approximately 8x40 ft in size.

The CRCP was placed during the period May 19 through June 19, 1971. Low temperatures during paving ranged from 45 to 55°F. High temperatures were from 68 to 90°F. Daily

temperature variations of 20 to 40°F were considered conducive to early thermal cracking. Yearly temperatures in the area range from about 20 to 115°F. There were afternoon rain showers on two days while paving Section 1-C southbound, but not enough to disrupt the paving operation. Rainfall in the area averages only about 10 to 15 in. per year with approximately 80% occurring between November and March. Winds were normally calm in the mornings but increasing to 10 to 15 mph in the afternoon. On one day while paving Section 1-B southbound, the wind was measured at 18 mph in the morning and 35 mph in the afternoon.

In Section 1-A, the longitudinal bars were placed on the base ahead of the paving machine, lapped 20 in., and tied. The tied laps were at staggered intervals across the roadbed. Bars were fed through tubes on a frame designed to place the steel at the proper depth. Measurements on cores taken through the hardened concrete over the steel indicated most of the bars ended up lower than planned, an average depth of 0.46 ft. This resulted in less cracking (but slightly wider cracks) than in the other reinforced sections where the depth of reinforcement was within the prescribed limits.

The steel in Section 1-B was set on chairs, so no problems were encountered in obtaining the proper depth.

In Section 1-C, the wire mats were lifted by crane onto the freshly placed concrete in staggered intervals (about 4 ft), tied together at 16 in. laps longitudinally and 8 in. transversely, then depressed to the proper depth by a machine following the paver. On occasion, the depressor bars would catch on the steel mats and pull them forward, breaking the ties and displacing one or more mats. When

detected, these were corrected immediately, but later, wide cracks were found to be caused by lap failures. Before the contract was accepted, a total of 57 such lap failures were located and repaired. A few more were subsequently found but were not as serious and have never been repaired.

A series of lug type terminal anchors were used at the ends of the CRCP sections at bridge approaches. The lugs were intended to restrain the movements of the slab ends and prevent excessive pressure on the structure abutments due to thermal expansion. No problems have occurred at the approaches so the anchors are deemed to have been successful.

Tests for strength of the concrete entering the project gave results as follows:

	28 Day Comp. Str. PSI	7 Day Flex. Str. PSI
Control	3850	670
CRCP	3850	655
High Strength	4500	810
Concrete Base	3050	580

Tests for Modulus of Elasticity were not made. Construction cost data was collected with the cooperation of the Contractor. Indirect costs such as those involved in maintaining haul roads for batch trucks, are included. Overtime salaries were reduced to straight time for comparison purposes, and included fringe benefits payable by the Contractor.

Unit costs of the concrete pavement include charges for aggregate and hauling to the batch plant, cement, batch

plant operation, hauling concrete to the grade, paving, finishing, curing, installing the insert for the longitudinal weakened plane joint, and sawing transverse weakened plane joints (where applicable), including all men and equipment. In the CRCP sections, charges for excavating terminal anchor lugs are included as well as the costs of reinforcement, material, shipping and placing. A summary of the cost comparisons is shown in the following table. The base for cost comparisons is the control portion of the project within experimental limits. Since some of the experimental sections were at the longest haul distance, average haul lengths were used in cost computations, both for nonreinforced and reinforced sections.

PAVEMENT	AREA, SQ.YD.	COST (% OF CONTROL)
Control	85,390	100
Short Joint Spacing	16,170	102
7.5 Sacks Cement	16,130	114
0.95 Feet Thickness	13,570	134
Longitudinal Bars Only	27,700	158
Longitudinal and Transverse	51,520	159
Welded Wire Fabric	51,250	183

There were no significant performance developments during the early years of traffic service.

A report concerning Part II, "Performance of PCC Pavements in California," was published in February 1978. Subjects covered in the report included (1) longitudinal and transverse weakened plane joints with a discussion of construction by sawing and by plastic insert, and effects on performance; (2) rating of pavements by use of the Roadmeter; and (3) various joint treatments and sealants. The latter subject is the only one connected with the present project.

Normal practice in California was to seal joints only in mountain areas where pavement sanding for ice control is expected. In 1974, at the urging of Contractors and joint seal material suppliers, a construction project in the San Francisco Bay region was modified to include 1000 ft sections (4 lanes wide) of various joint seal materials and certain variations of installation procedures such as resawing old plastic insert joints and sealing sawed joints without resawing for proper shape factor. Since it was the State's contention that joint seals would not be effective in preventing water from getting under the pavement (which is considered to lead to pavement deterioration), a 1000 ft length section of plastic pipe edge drain was also installed, complete with outlets every 100 feet.

Although there was the usual problem of maintaining the proper depth of the liquid sealants, a more serious problem was created by the wind blowing dust and sand onto freshly cleaned and primed joint faces or on newly placed sealant at the intersections of transverse and longitudinal joints where more sealant was to be placed and bonded to the older material.

After 3 years, there were no detectable differences in performance. Not surprisingly, however, in light of the blowing sand and dust, a number of adhesion (bond to concrete) failures were found, although only a few cohesion failures. The edge drains were found to be quite effective in removing water from the pavement, with outflow from the drains measuring 60 gals/hr or more during a rain but with flow stopping within minutes after the rain stopped.

CONCLUSIONS

Part I - CRCP and Other Variables

After 14 years of service, the sections showing the best performance, based on subjective evaluation, are 1) 0.70-foot thick CRCP with both longitudinal and transverse steel; 2) nonreinforced pavement with very short slabs; and 3) 0.95 foot thick nonreinforced pavement. Other nonreinforced sections show evidence of pumping which usually leads to pavement and shoulder deterioration. Based on roadmeter roughness measurements only, the standard pavement with a concrete base gives the best performance.

Part II - Joint Seals and Edge Drains

There were numerous failures in adhesion and some in cohesion with all three of the poured sealants on the project. Water is moving through the transverse joints as well as through the longitudinal shoulder joint. The preformed neoprene seals also have many adhesion failures, and pumping is occurring through them as well.

The edge drain installation performed well in removing water from the pavement during the first three years of service, but became ineffective when the outlet pipes were inadvertently destroyed by landscaping crews.

Part III - Concrete Shoulders

The concrete shoulders and adjacent pavement are performing satisfactorily. The sections with the shoulder tied to the mainline pavement and having all pavement and shoulder joints sealed are considered to be performing best. The

full depth asphalt concrete (AC) shoulder is also performing well. The standard 0.3 foot thick AC shoulder is satisfactory in some areas, but in others is deteriorating due to the pumping action of the adjacent pavement.

Part IV - Construction-Evaluated Projects

Bridge approach slabs constructed with epoxy coated reinforcing steel and concrete containing calcium chloride are performing satisfactorily after six years service. The nonreinforced slabs with calcium chloride concrete are also performing well, but have received no truck traffic. Concrete slabs made with calcium aluminate cement are not considered satisfactory due to the presence of 2 or 3 cracks per slab.

Concrete pavement constructed over ATPB is performing well after five years. Cracking is occurring in the shoulders in contiguous control areas, but not in those adjacent to the ATPB.

CTPB placed in 1980 is performing well as a drainage blanket under the PCC pavement (see Performance Update section of this report).

IMPLEMENTATION

Edge drain construction has been adopted by the California Department of Transportation (Caltrans) as standard practice on new highways as well as on many rehabilitation projects. The use of treated permeable material with asphalt or cement binder also has been adopted as a drainage layer and as a base for PCC pavement. Specifications in the form of special provisions have been written for use in projects where a permeable material is needed.

A closer joint spacing has also been adopted, although not as close as those constructed experimentally on this project. Current plans now specify repetitive spacings of 12, 15, 13, and 14 feet.

PART I - CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

Engineers have long looked for pavement designs and materials that would result in high performance, low cost, and low maintenance pavements. Leaders in the steel industry believe that CRCP provides the answer. Thus, in 1971, several sections of CRCP were constructed as part of a Caltrans paving contract. Four other experimental designs were also selected as possible alternatives to steel reinforcement for improving performance and serviceability.

Location of the project is on Interstate 5 in San Joaquin County, east of Tracy and just north of the I-5/I-580 Interchange. I-5 consists of two 12-foot lanes in each direction. All variables were placed in both the northbound and southbound lanes to avoid possible performance differences should traffic in one direction be different from the other. See Figure I-1 for the layout of all the test sections.

A portion of the project was the California standard (at the time) unreinforced concrete pavement design which was used as the "control" when evaluating the performance of the experimental sections. The structural section for these control sections consisted of 0.70 foot PCC over 0.45 foot Class A cement treated base (CTB), all over layers of aggregate subbase. The CTB was plant-mixed and placed with a slipform paver. With this procedure, no trimming or excessive manipulation of the CTB was required. It was believed that the surface of this layer would be more durable and erosion resistant than that of CTB mixed in place on the grade, spread and compacted, then trimmed to grade.

(1) Control Section -
Standard Transverse Joint
Spacing: Repeating Sequence
of 13'-19'-18'-12'

(1-A) Longitudinal Bars Only
CRCP

(1-B) Longitudinal & Transverse Bars
CRCP

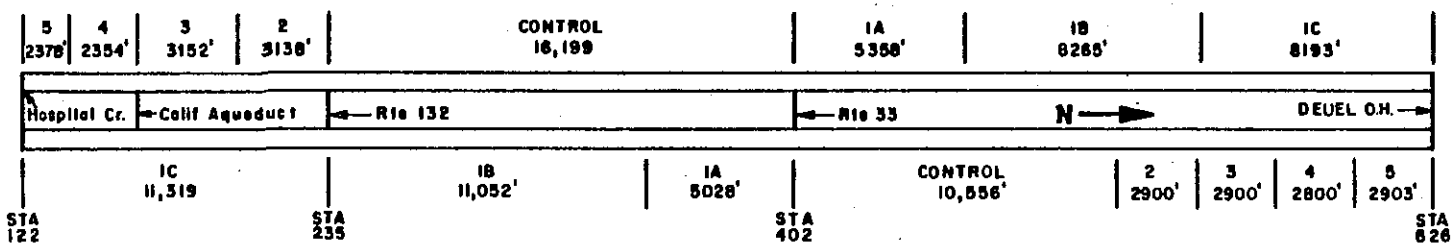
(1-C) Welded Wire Fabric
CRCP

(2) Short Transverse Joint
Spacing: Repeating Sequence
of 8'-11'-7'-5'

(3) Higher Cement Content
Increase Cement to 7.5
Sks./C.Y. from 5.5 Sks.

(4) Extra Thickness
From 0.70' to 0.95'

(5) Lean Concrete Base



Note: 1 foot = 0.3048 m

LAYOUT OF TEST SECTIONS
Figure I-1

Continuously Reinforced Concrete Pavement (CRCP), Section 1

The thickness designated for CRCP was 0.70 foot, the same as that used in the control area. Longitudinal reinforcement was 0.56% of the theoretical cross-sectional area and was to be located 0.25 to 0.35 foot from the top surface. Three different types of reinforcement were used - longitudinal bars only (Section 1-A), both longitudinal and transverse bars (Section 1-B), and welded wire fabric made from deformed bars (Section 1-C).

In Section 1-A, there were 44 No. 5 round deformed bars spaced at 6-1/2 in. in the 24-ft width. Longitudinal reinforcement was the same in Section 1-B, but also had No. 4 bars placed transversely at 60-in. centers measured longitudinally. Transverse bars were set to proper grade on metal chairs with the longitudinal bars tied on top. The specified minimum yield strength of the longitudinal reinforcing bars was 60,000 psi.

The wire fabric section was made of D-19 (0.19 sq in. cross-section) longitudinal bars spaced at 4 in. welded to D-6 (0.06 sq in. cross-section) transverse wires spaced at 6 in. The specified minimum yield strength of the steel making up the fabric was 70,000 psi.

A longitudinal insert type weakened plane joint material was placed between the 12-foot lanes but no transverse joints were formed in the reinforced sections. Where contact joints were necessary, such as at the end of a day's paving, additional steel was used to provide twice the normal reinforcement across the joint.

Short Slabs, Section 2

For this section, repetitive intervals of a series of 8, 11, 7, and 5 feet (total 31 feet) were used, compared to the then standard intervals of 13, 19, 18, and 12 feet (total 62 feet). All joints were skewed counterclockwise 2 feet in 12. It was reasoned that if these weakened plane joints could be made to crack through the slab, the resultant tighter cracks should provide better aggregate interlock and load transfer as well as higher resistance to intrusion of foreign material.

Higher Cement Content, Section 3

The cement content of the pavement concrete was increased to 7.5 sacks per cubic yard from the 5.5 sacks used in the concrete for the remainder of the project. The purpose was to provide higher concrete strength, thereby reducing the bending stress ratios (ratio of stress induced by loading to flexural strength of the concrete) and increasing fatigue life. The greater stiffness of the higher strength slabs was also expected to reduce load deflections and tendencies to pump.

Extra Thickness Pavement, Section 4

This section of pavement was built to a thickness of 0.95 foot compared to the 0.70 foot used for the remainder of the project. This was also placed on 0.45 foot CTB. Decreased deflection and resultant pumping action beneath the slab was expected. It was designed to be a "no fatigue" section since calculated stress ratios, even at the highest expected loadings, would not greatly exceed 0.5.

Lean Concrete Base (LCB), Section 5

Lean concrete base (LCB), in lieu of CTB, was placed 0.45 foot thick using a 4-sack concrete mix. Transverse joints were cut at 30 foot intervals to relieve tensile stresses and prevent random cracking. Since LCB is more rigid than CTB and has greater abrasion resistance, it was expected to be more effective in reducing the tendency of joints to fault.

For construction details and early performance of these four sections, see References (1) and (2) for this Part I.

CONDITION SURVEY OF EXPERIMENTAL SECTIONS

The most recent survey of this project was made when the pavement was almost 14 years of age. Crack counts were made on sections of the CRCP, rideability was measured with a Roadmeter, the overall condition was noted, and photographs were taken. Periodic faulting measurements have been made on the jointed pavements.

Sections 1-A, 1-B, and 1-C

The number of cracks has not changed significantly in the past eight years. In the sections with longitudinal steel only, the average distance between cracks was about 4.3 feet; with longitudinal and transverse steel, it was 3.0 feet; and in the wire fabric sections, the average distance was 2.3 feet. The wire fabric sections appear to have developed more map crakcing (closely spaced, tight, interconnected cracks) than was noted previously (see Photos 1 and 2). Photo 3 shows the repaired areas of two of the 57 mesh lap failures detected soon after construction. Repairs are performing well. Photo 4 showes a wide crack typical of a lap failure.

Photo 5 shows typical cracking in the sections with both longitudinal and transverse steel. Photo 6 shows a station number that was stamped into the fresh concrete to aid in locating specific areas during surveys.

Photo 7 shows typical cracking in the southbound lane section with longitudinal steel only. The wider crack with spalling is attributed to the steel being inadvertently placed too low for much of the southbound lane, actually

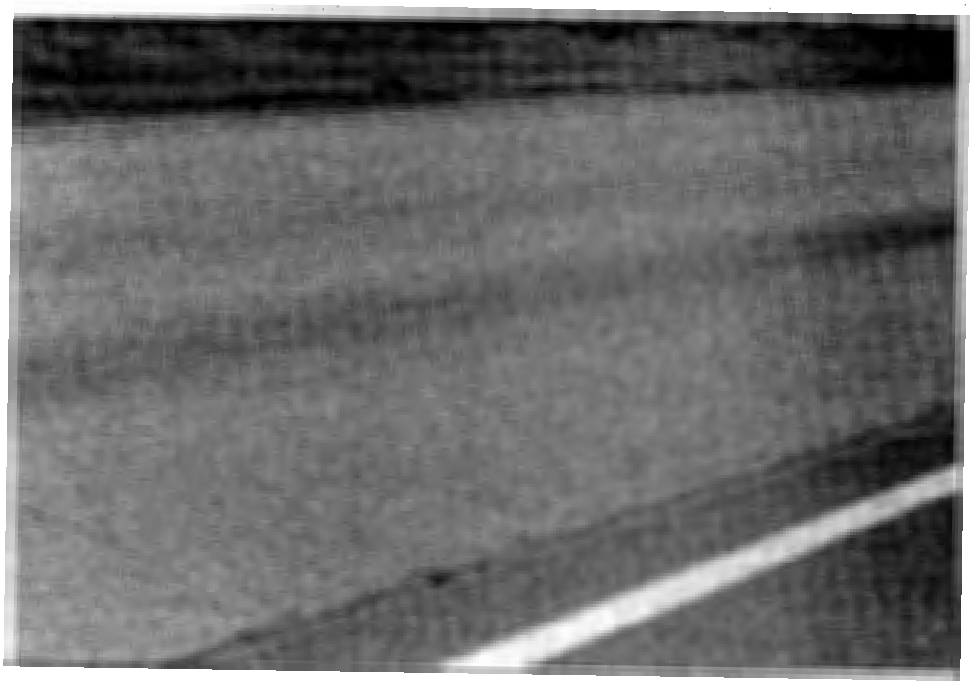


Photo I-1. Typical cracking in the section with wire fabric reinforcement.

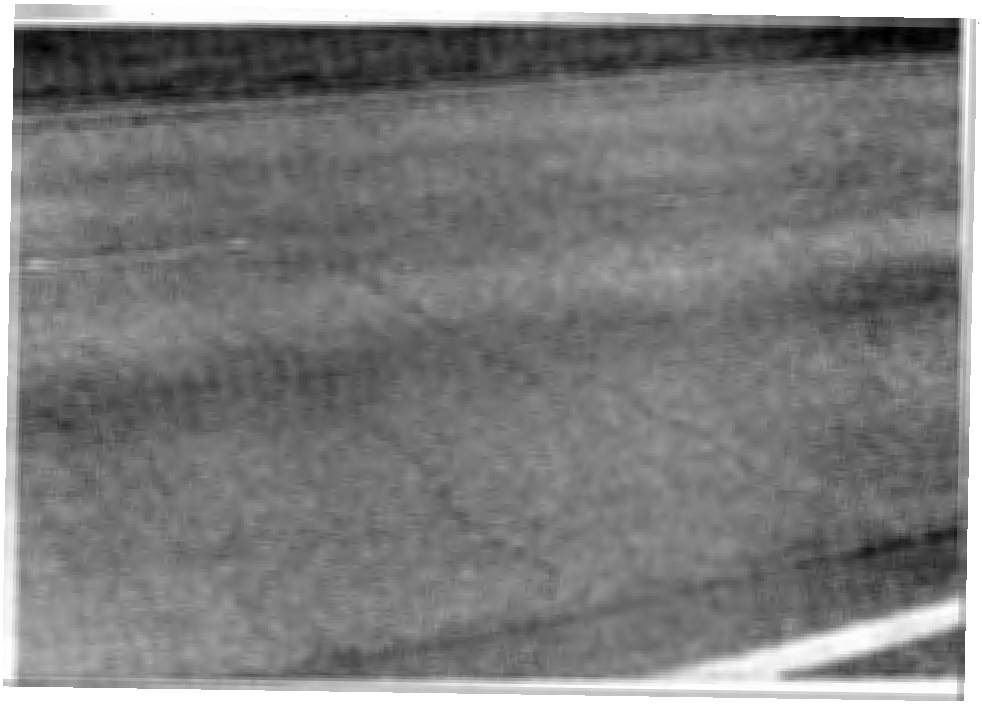


Photo I-2. Typical cracking in the section with wire fabric reinforcement. Note also width of crack at left center.

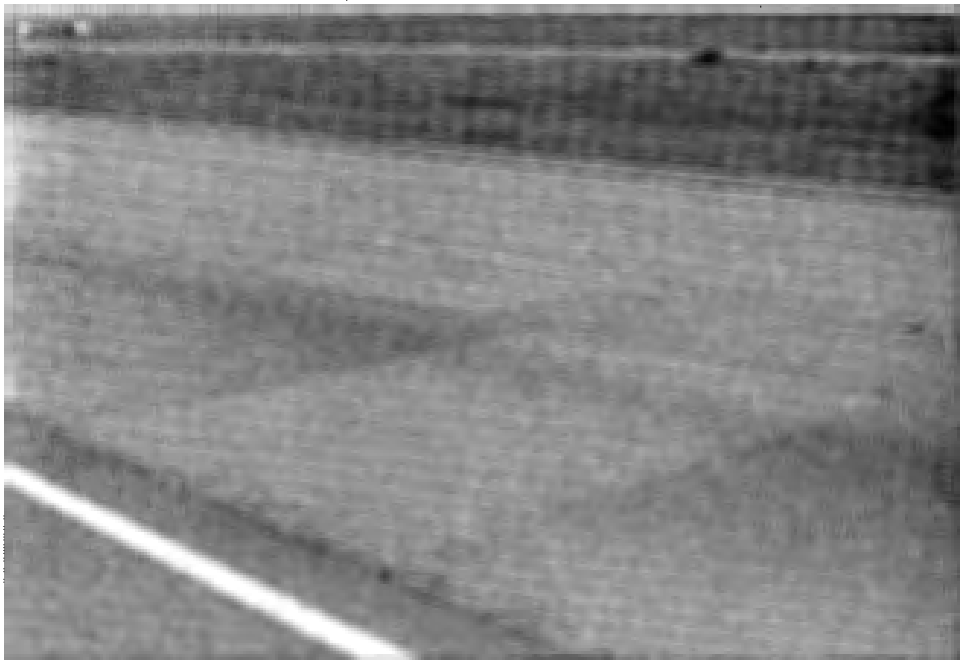


Photo I-3. Repaired areas where two lap failures occurred in wire fabric sections.

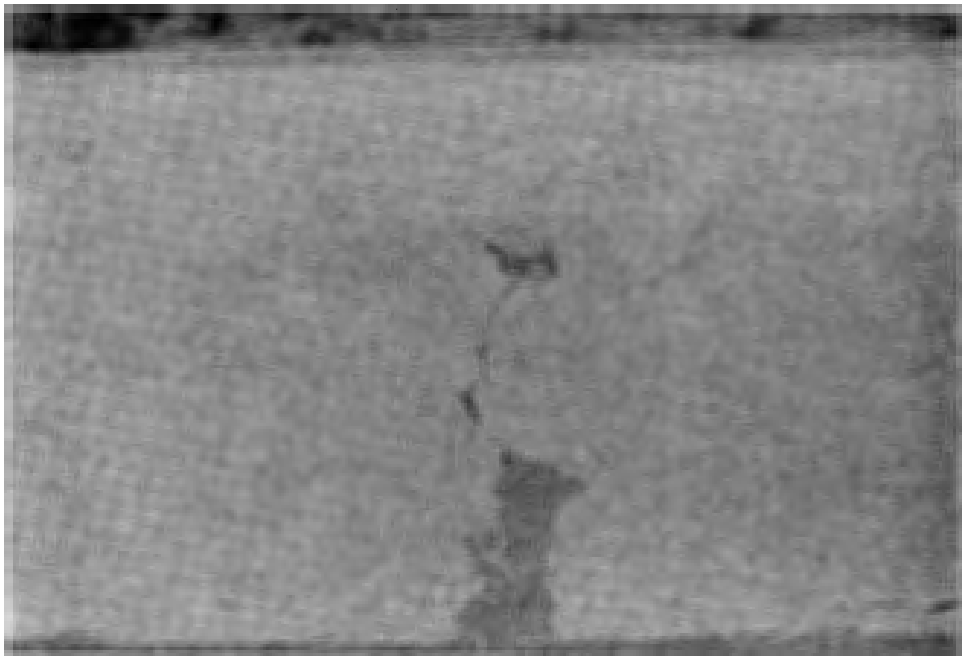


Photo I-4. Wide Crack typical of lap failure.

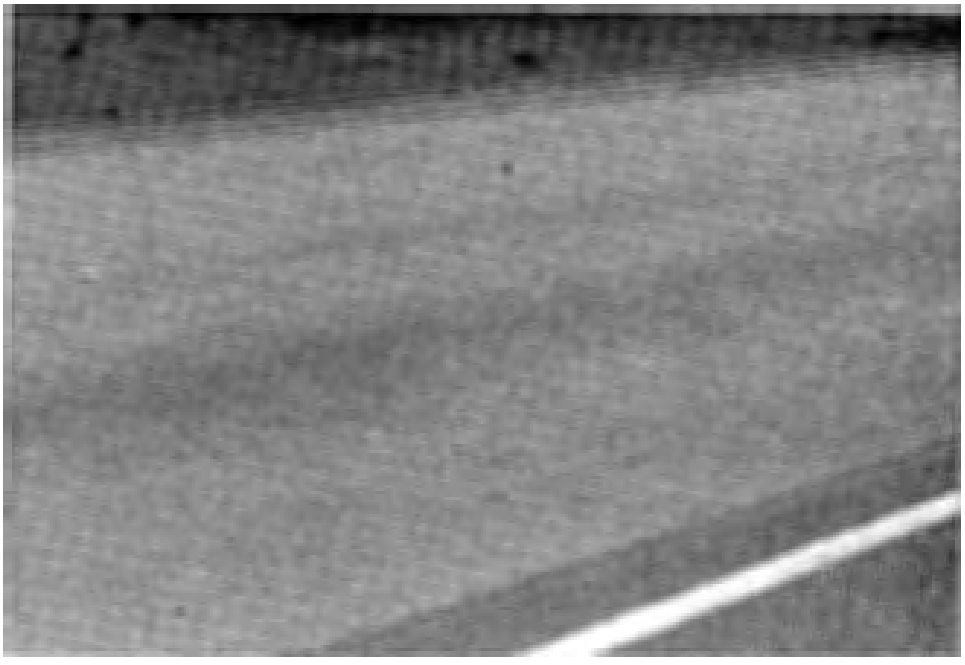


Photo I-5. Typical cracking pattern in section with longitudinal and transverse reinforcement.

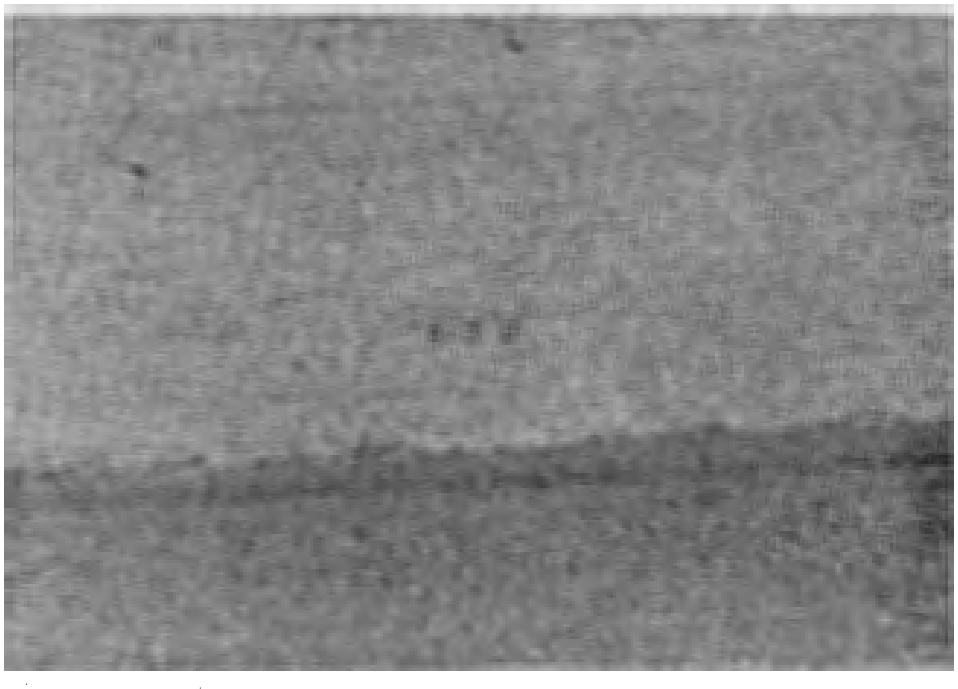


Photo I-6. Station number stamped into the concrete when fresh to provide a reference for future surveys.

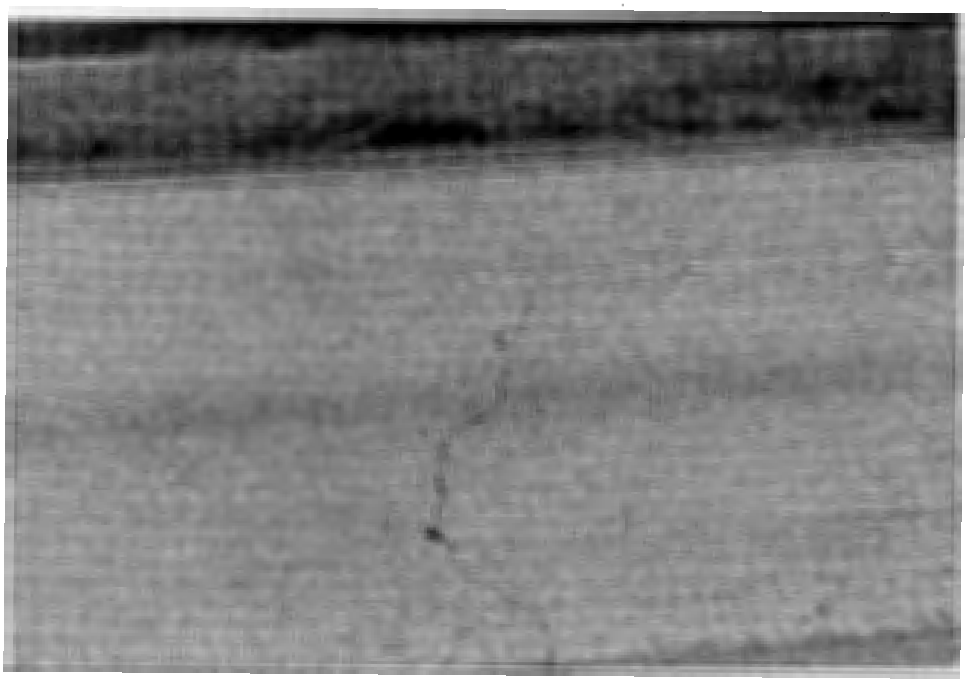


Photo I-7. Typical cracking in section with longitudinal steel only, with steel placed below the center of pavement.

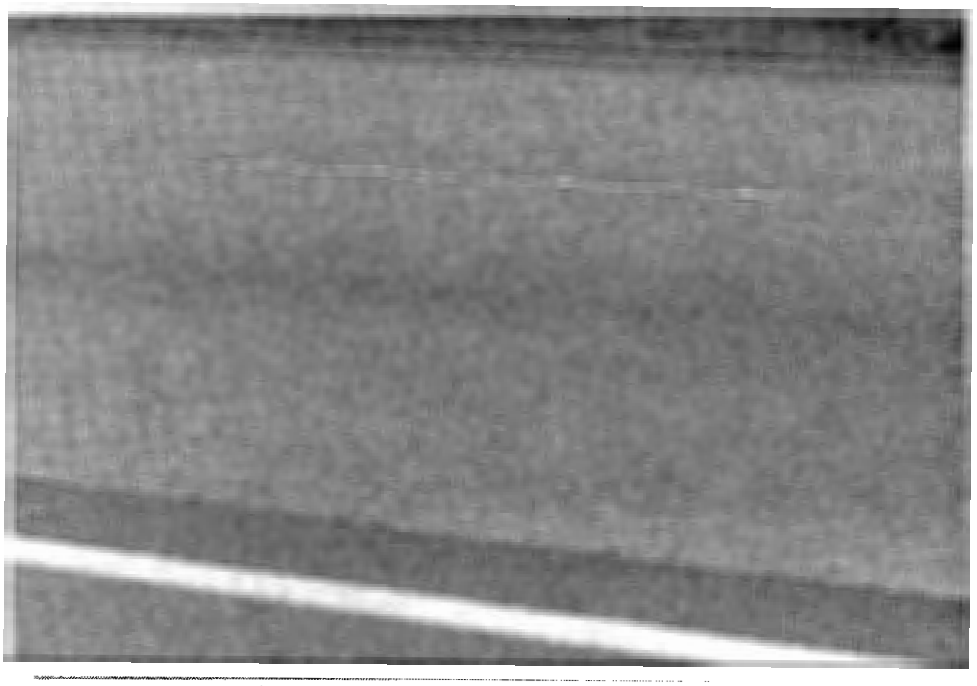


Photo I-8. Typical crack when steel was placed at proper depth, just above pavement mid-depth.

below the center of the slab for much of the distance. Photo 8 is also of a crack in a section with longitudinal steel only, but in the northbound lane. Steel placement techniques had been improved when these lanes were paved.

Control Section

Although the jointed pavement with standard joint spacing is performing adequately, pumping is taking place that can accelerate deterioration. Photo 9 shows evidence of pumping with staining of the shoulder and depressions at the joints. Photo 10 is a close-up of a depression, and also shows that the shoulder has already been patched once.

Section 2

The condition of the sections with short slabs is considered excellent. There is no evidence of pumping such as settling of the shoulder or stains. Photos 11 and 12 show the typical condition of the sections.

Section 3

The sections with concrete containing 7.5 sacks of cement per cubic yard also have a large amount of pumping evident. This can readily be seen in Photos 13 and 14. Measurements reported in Reference (1) indicated this pavement was curled upward at the joints which would allow more deflection and resultant pumping. With the exception of Section 2, with the short slabs, all of the nonreinforced sections were found to be curled to some degree, but not quite as much as in this Section 3. The reason for the difference in curling is probably due to the higher modulus of elasticity of the 7.5 sack concrete compared to the 5.5 sack concrete.

Photo I-9. Depressed shoulder at joints in the control section due to pumping and loss of fines from the shoulder base.

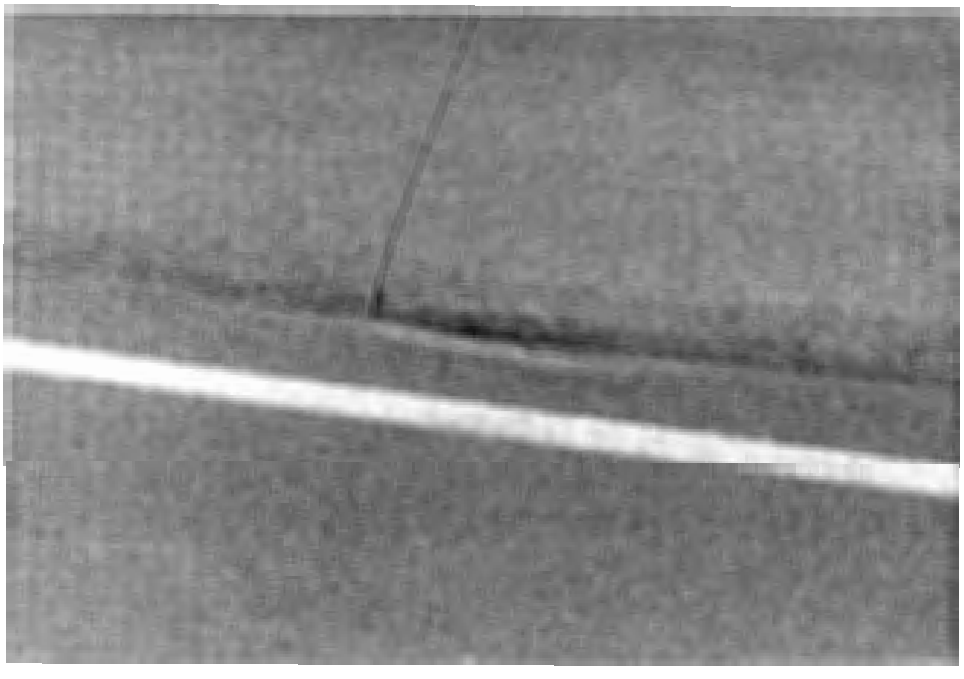


Photo I-10. Close-up of depressed shoulder.

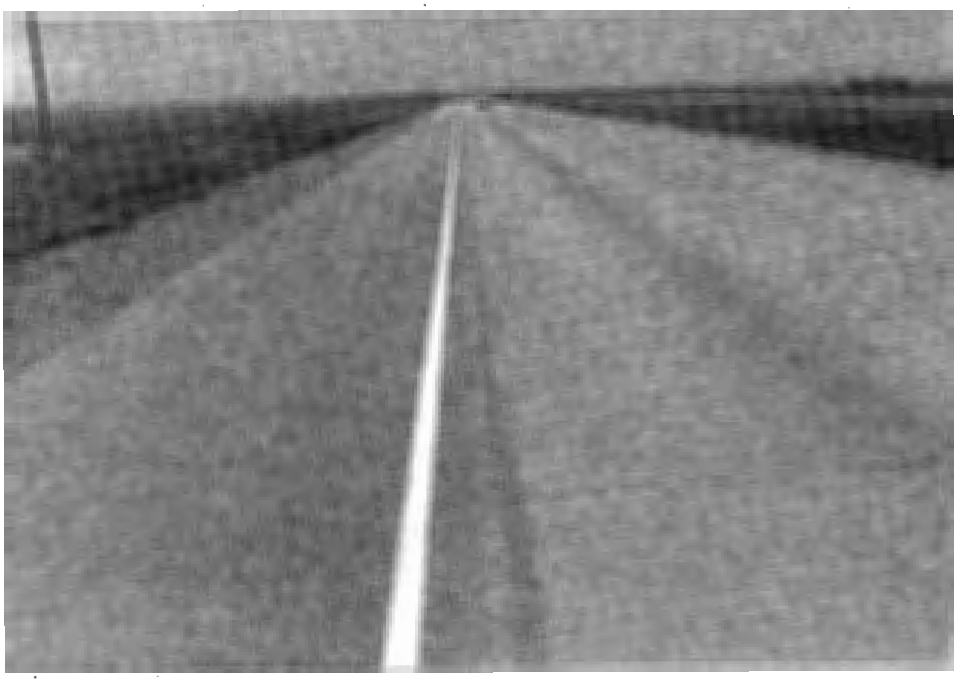


Photo I-11. Short slab length section. No evidence of pumping.

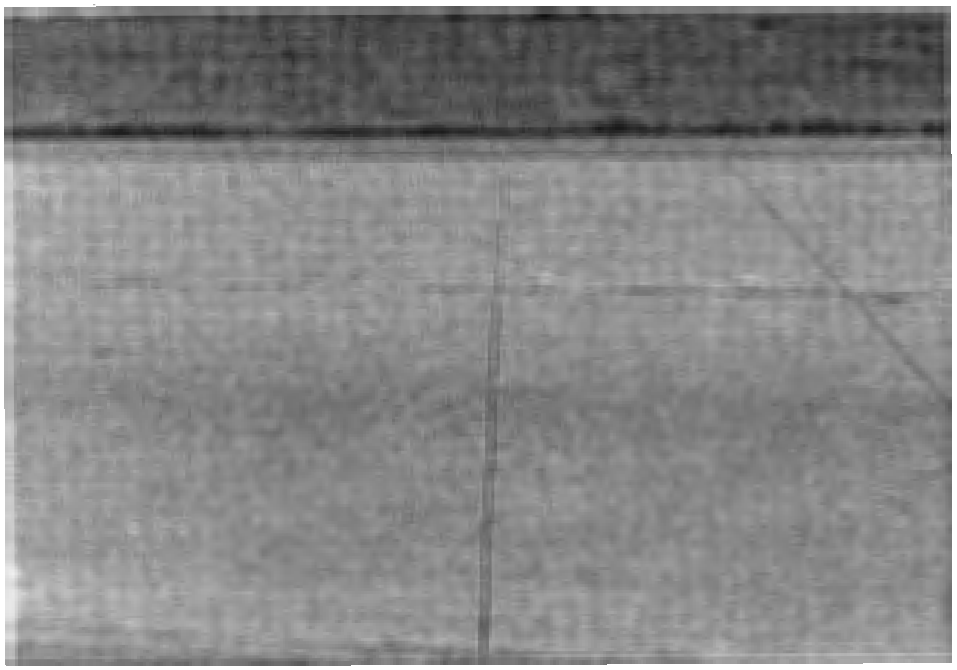


Photo I-12. Transverse joints remain in good condition.

Photo I-13. Note evidence of pumping and depressed shoulder in section with extra rich concrete.

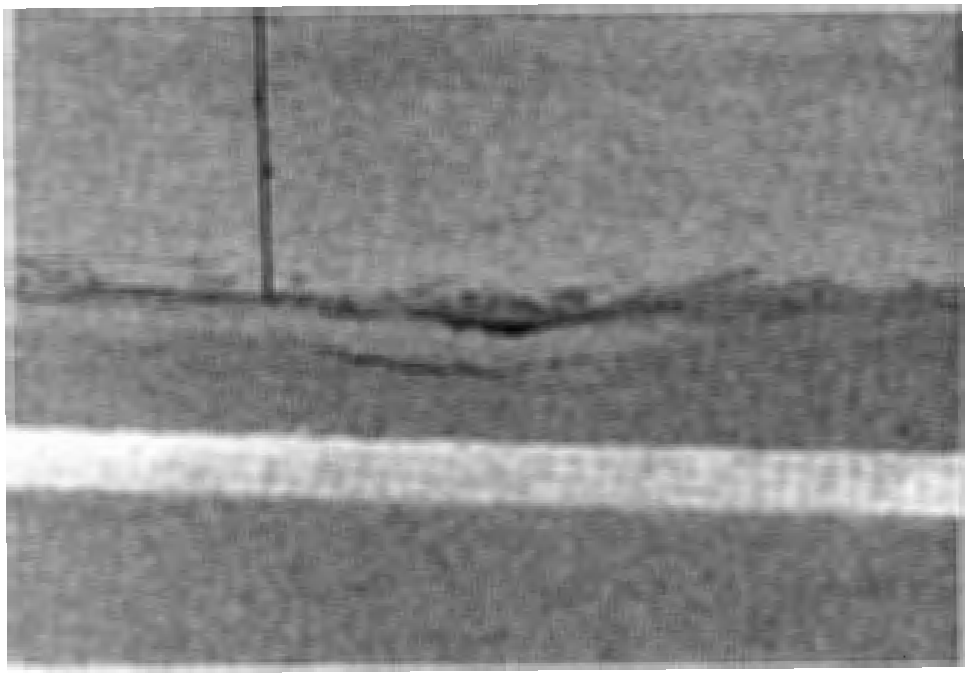


Photo I-14. Typical depression at joint.

Section 4

The extra pavement thickness appears to be working as planned. The sections are performing well with no evidence of pumping (see Photos 15 and 16).

Section 5

Like the control sections, the lean concrete base (LCB) sections are performing adequately, but as seen in Photos 17 and 18, pumping is quite evident.

Roadmeter Measurements

Rideability for the 1985 survey was measured with a Caltrans Division of Highway Maintenance Roadmeter which is used in biannual surveys of all California state highways. Previous measurements were made with the Transportation Laboratory Roadmeter which, unfortunately, was taken out of service without a calibration reference to the maintenance equipment. For comparison with roughness of previous tests, present serviceability index (PSI, see Reference I-1) calculations, based on ride only, were made from the same curve established for the previous measurements at six years of age. Results are shown in Table I-1.

While the values do not appear to fit in all cases when compared to the previous measurements, they are considered to provide relative roughness values. Southbound Section 3, with 7.5 sacks of cement per cubic yard, had the roughest ride of all the sections. The surprises, based on expectations from the subjective evaluation, were the southbound section of short slabs and both extra thick pavement sections. These had been considered to be the best performers.

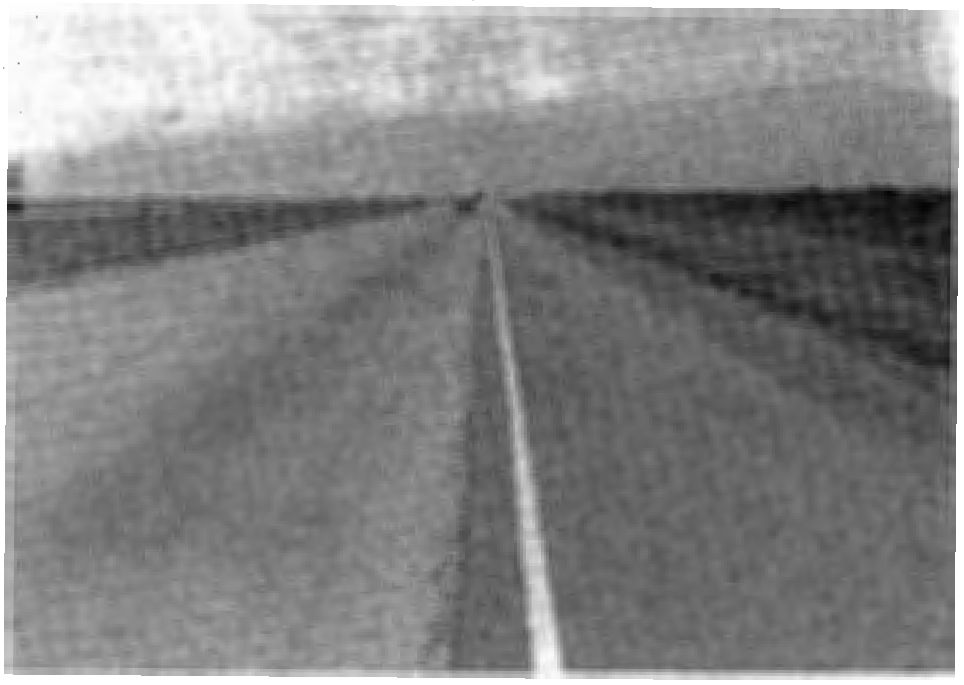


Photo I-15. Extra thick pavement - no evidence of pumping.

Photo I-16. Similar to I-15.

TABLE I-1

Present Serviceability Index (PSI) from Roadmeter*

		Age			
		6 mos	3 yrs	6 yrs	14 yrs*
Control	SB	4.60	3.80	3.45	3.65
	NB	4.50	3.75	3.50	3.70
1-A Longitudinal Bars Only	SB	4.15	3.55	3.35	3.50
	NB	4.60	4.05	4.05	4.00
1-B Longitudinal and Transverse Bars	SB	4.65	4.05	4.10	4.05
	NB	4.65	4.10	3.85	3.60
1-C Welded Wire Fabric	SB	4.55	4.00	3.95	3.55
	NB	4.45	3.85	3.55	3.35
2 Short Slabs	SB	4.55	4.15	3.45	3.25
	NB	4.60	4.10	4.00	4.00
3 Higher Cement Content	SB	4.55	3.75	3.45	3.10
	NB	4.60	4.00	3.85	3.90
4 Extra Thickness Pavement	SB	4.55	3.90	3.60	3.30
	NB	4.60	4.05	3.90	3.35
5 Std. Pavement with Lean Concrete Base	SB	4.55	4.35	4.15	4.25
	NB	4.60	3.95	3.85	4.00

*The Roadmeter and vehicle used for the 14 year measurements are different from those used for the previous tests. The PSI was calculated from the same curve used for the 6 year tests. Though the validity of the actual numbers may be questioned, the relative values are considered accurate.

Section 5, with the lean concrete base, is shown to have the least roughness, even though considerable pumping is taking place.

Traffic

The latest available traffic information (1983) for this project indicates that the 2-way average annual daily traffic is about 9,000 vehicles a day with 1,800 trucks. This is considerably less than had been anticipated.

Faulting

Faulting of the jointed pavements is relatively minor in all sections, with maximum measurements ranging from 0.06 inch to 0.09 inch. However, the maximum for the short slab sections is about 0.03 inch, a significantly lesser amount. Since there are twice as many joints in these sections as in the standard spaced sections, the total faulting in inches per mile would probably be about the same, but riding quality would be expected to be much better with the shorter slabs.

Maintenance

Routine maintenance has included mud jacking to raise depressed slabs at culverts and bridge approaches. Two longer depressed sections were smoothed with AC overlays. A few sections which appeared to be spalled due to fabric lap failures were patched with AC. Shoulder areas where voids had occurred due to pumping were filled with asphalt concrete.

Summary

Because of the low traffic volume, it is difficult to make an accurate evaluation of the individual experiments. Since all sections are performing adequately, it would not seem advisable to use reinforcement which adds some 60 to 80% to the cost of the pavement (based on construction cost figures). The short slab proposal might be considered worthwhile since 1) figures indicated only about a 2% increase in cost, 2) the joints stay tighter and, therefore, let less debris into the joint, and 3) less severe faulting occurred where the short slabs were used. The lean concrete base is considered to have performed well but, alone, cannot prevent faulting. The untreated shoulder still provides a source of fines that eventually leads to a buildup under the approach side of the joint and thereby results in faulting.

REFERENCES

I-1. Recent Experimental PCC Pavements in California. A Transportation Laboratory report, CA-HY-MR-5180-1-73-01.

I-2. Performance of Experimental Pavement Sections. A Transportation Laboratory report, FHWA-CA-TL-78-29.

PERFORMANCE UPDATE

Because interior corner breaks were noted while traveling in the area, a new survey was made of the project in the spring of 1987.

Sections 1-A and 1-B

No apparent change since the last survey. No pumping is evident.

Section 1-C (Wire Reinforcement)

Southbound Direction

At one location, a section of pavement approximately 12 ft by 12 ft had been removed and replaced with AC (see Photo IA-1). The reason for the failure is not known, but is probably associated with the lap failures which occurred during construction. No pumping is evident.

Northbound Direction

No apparent change since the last survey. No pumping is evident.

Control

This section still shows signs of extensive pumping evidenced by stains on the shoulder in the joint area. A few interior corner breaks are now occurring, and one crack was found on the obtuse angle rather than the acute angle where they are usually found (see Photos 1A-2, 3, 4). About half of the 18 and 19 ft slabs have transverse cracks,

Photo IA-1. Pavement portion replaced with AC. Wire Fabric Section

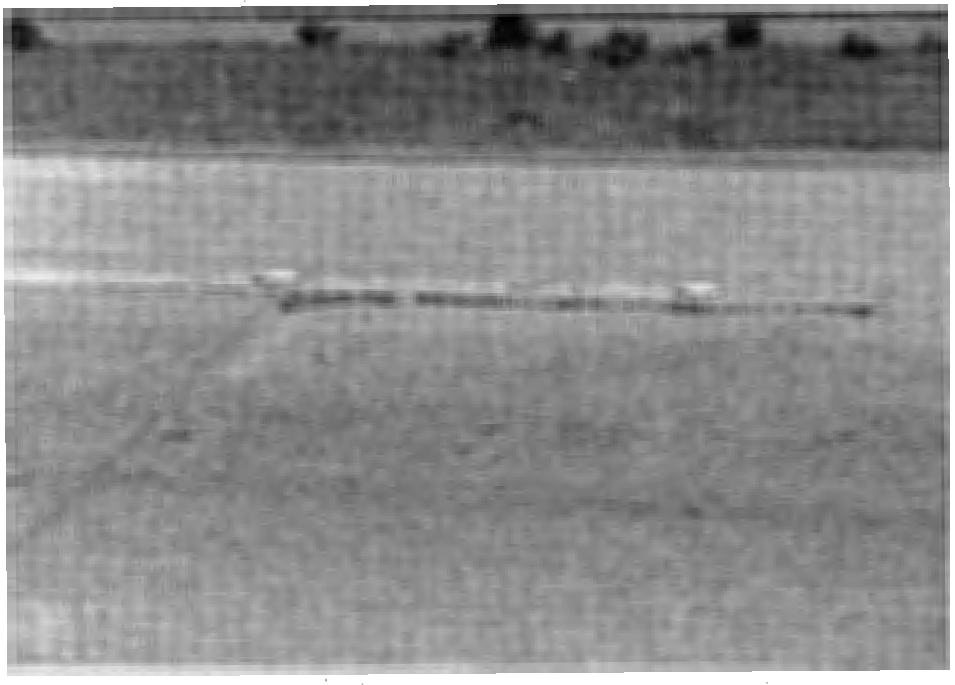


Photo IA-2. Typical corner break. Control Section

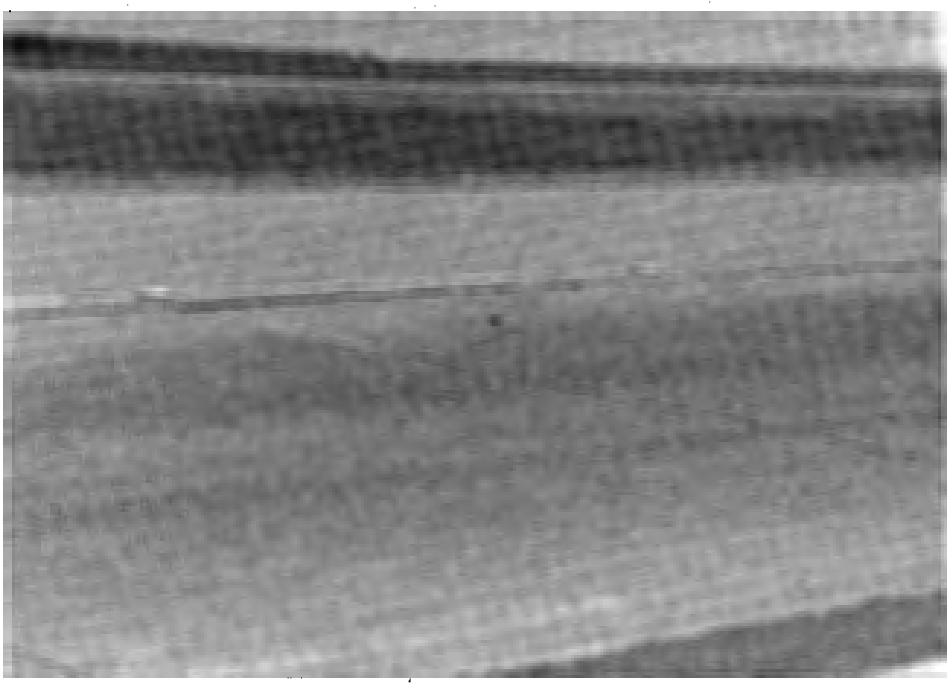


Photo IA-3. Typical corner break.
Control Section

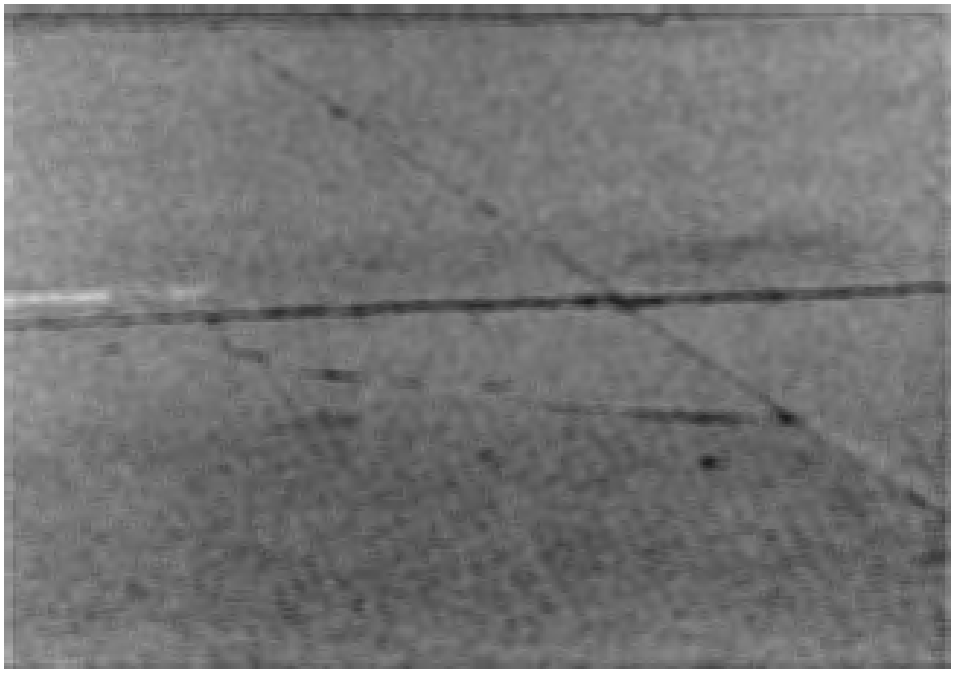


Photo IA-4. Obtuse angle corner break.
Control Section

mainly near the midpoint of the slab. These occurred early in the life of the pavement, but have generally been ignored or accepted as inevitable. One portion approximately 100 ft long has been overlaid with AC.

Section 2 (Short Slabs)

Southbound

While this section was considered to be in excellent condition during the previous survey, drastic changes have occurred since that time. There is evidence of extensive pumping and some 40 interior corner breaks were found in the 3150 ft section, all in the 11 ft slabs. That is approximately 40% of all the slabs of that length. In addition, there are a number of incipient cracks that will eventually break completely through (see Photos 1A-5, 6, 7, 8).

Northbound

No corner breaks were found and pumping is relatively slight.

Section 3 (7.5 sk cement)

Southbound

The most significant change apparent was the finding of 26 interior corner breaks in the 3150 ft section. Most of the 18 and 19 ft slabs have cracked transversely at midslab (63 cracks in 2000 ft).

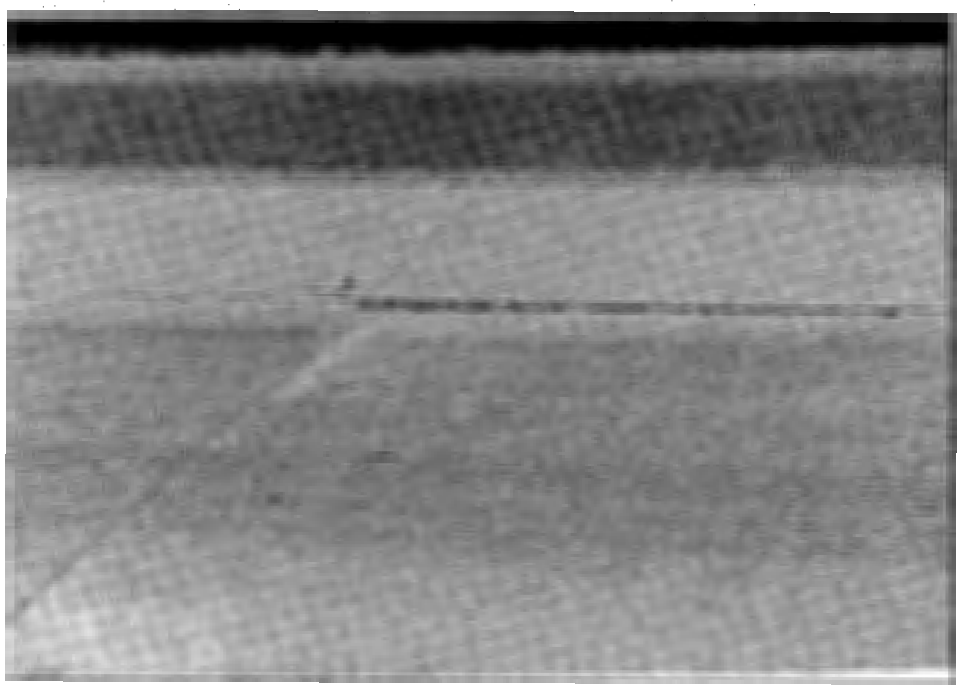
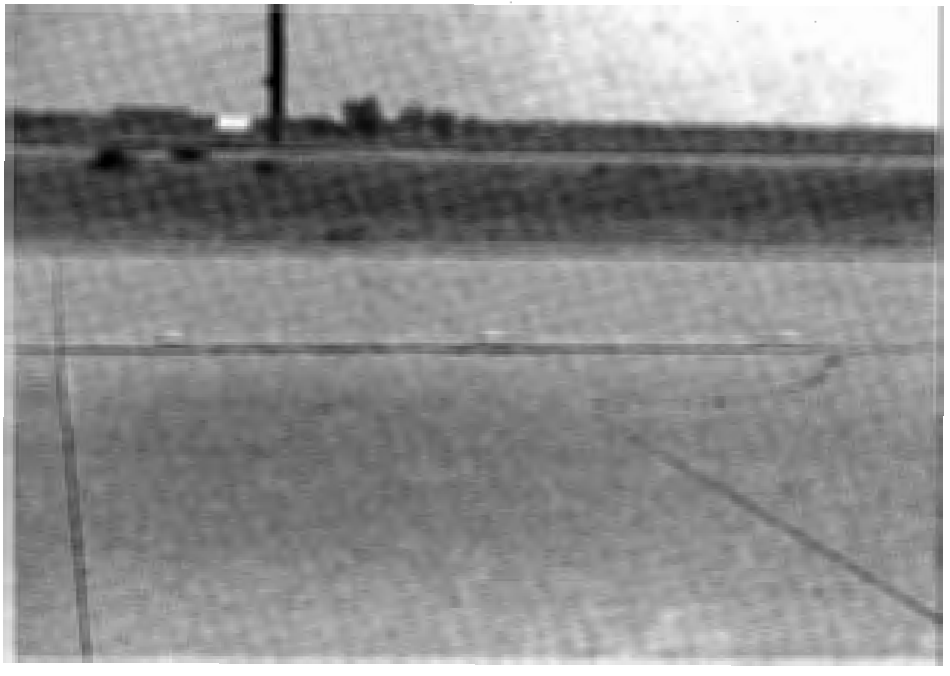


Photo IA-5. Corner break in short slab section.
Note depression of slab.



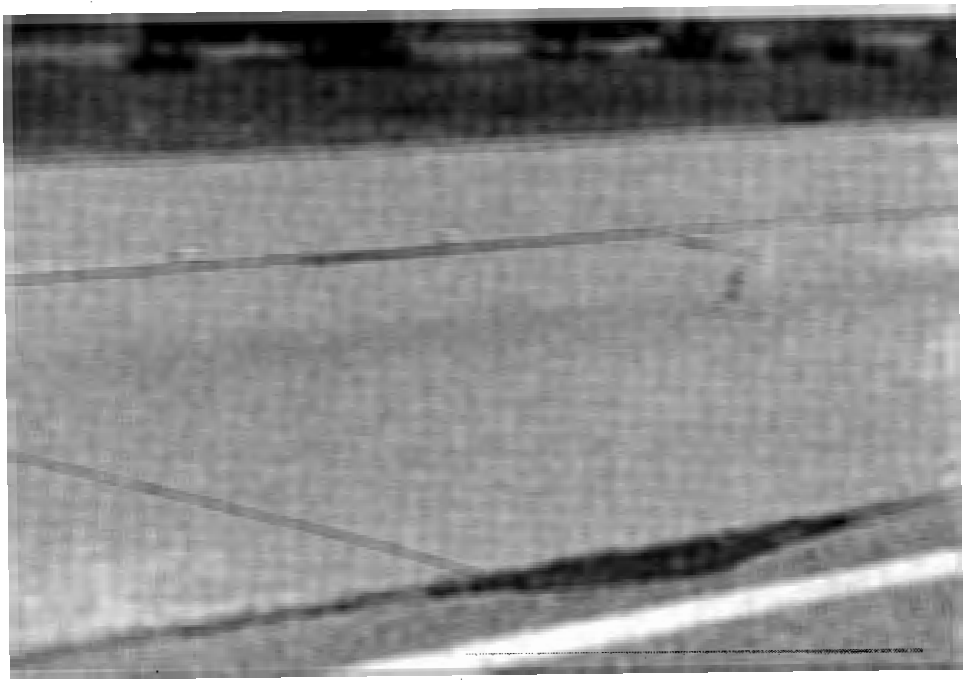


Photo IA-7. Corner break and shoulder depression.
Short Slab Section

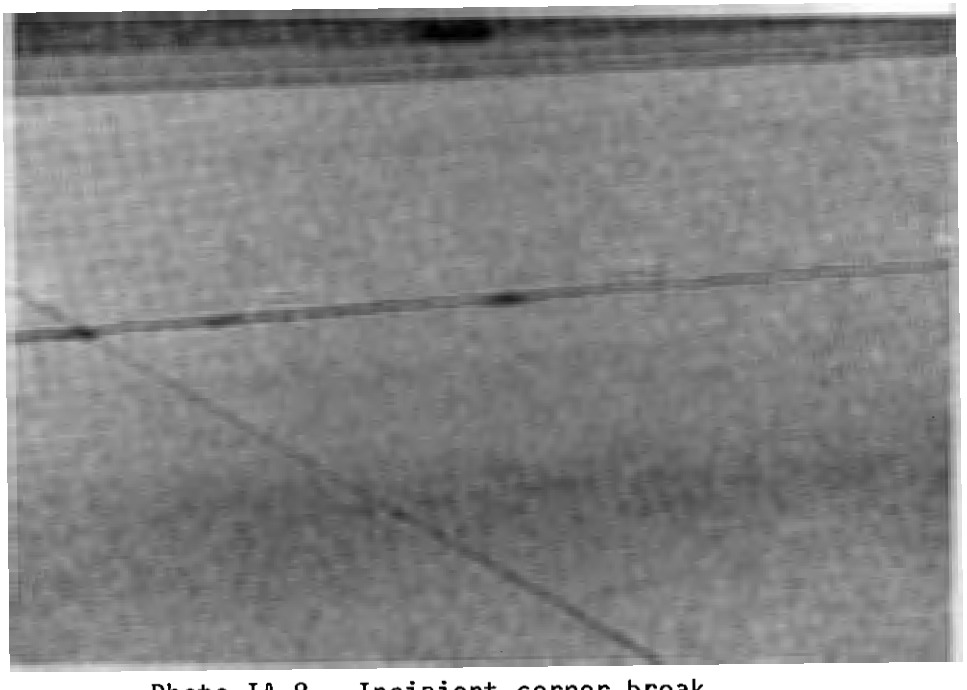


Photo IA-8. Incipient corner break.
Short Slab Section

Section 4 (0.95 ft thickness)

Southbound

This section still looks very good. A slight amount of pumping can be detected, however. A total of 14 transverse cracks were counted in this 2350 ft section.

Northbound

The section looks good with no pumping evident. No transverse cracks were found.

Section 5 (Concrete Base)

Southbound

Considerable pumping is evident. A total of 53 transverse cracks were counted in this 2350 ft section.

Northbound

Condition is similar to above. There were also 53 transverse cracks in this 2900 ft section.

Traffic

Traffic is increasing each year but is still relatively light. Data for 1985 shows 11,000 2-way ADT with 2090 trucks. This would be equal to about 1.6 million equivalent single axle load (ESAL's) per year. Total loading from 1971 through 1985 is approximately 12 million ESAL's.

Faulting

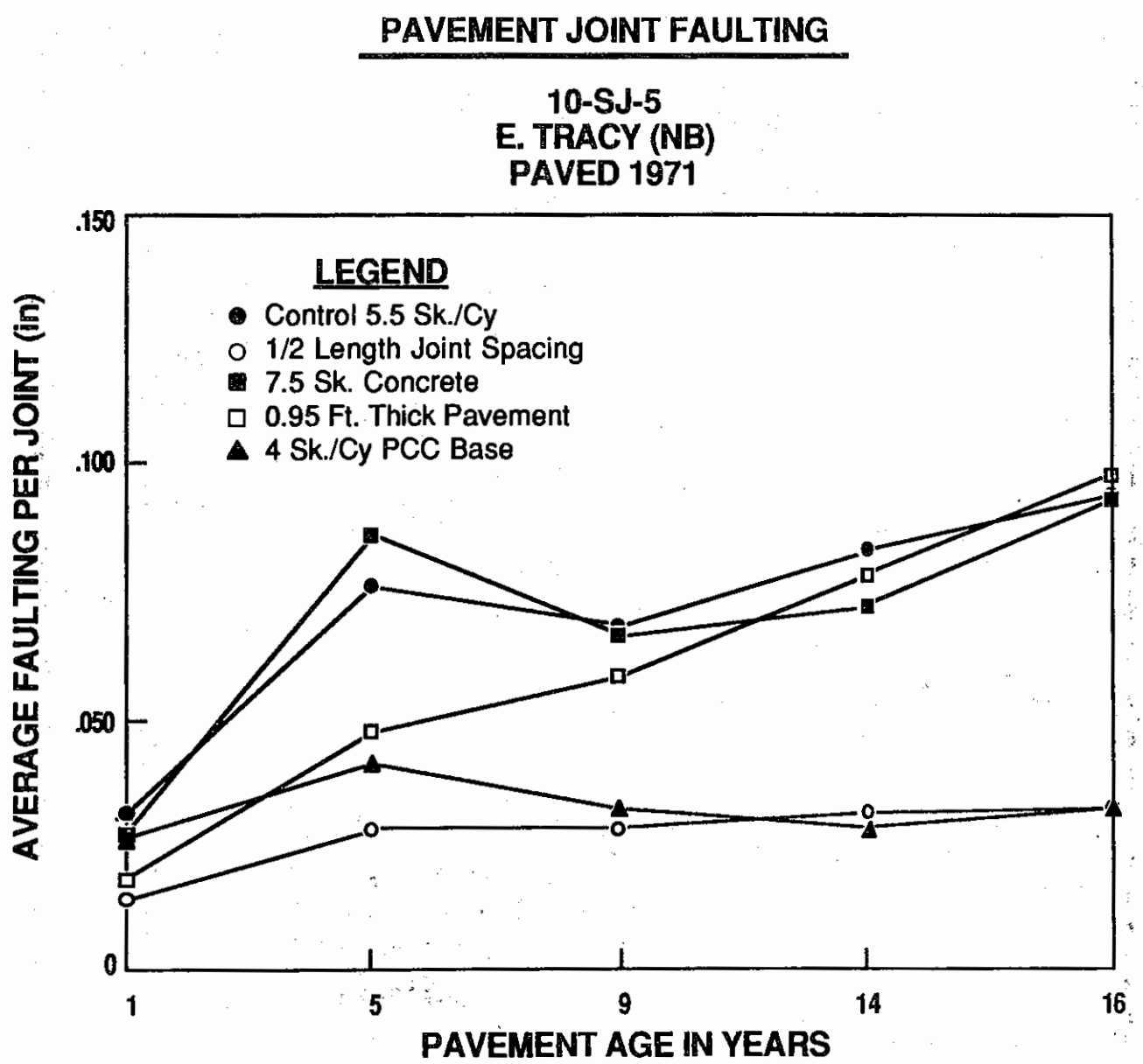
Faulting is still slight on all the nonreinforced sections. Only two of the test sections (control and 7.5 sk cement sections in the southbound lanes) have reached 0.12 inch stepoff which is considered to be approximately the level that is noticeable to motorists. None of the other experimental sections have faulting exceeding 0.10 inch. The concrete base and short slab sections are still the best performers with faulting not exceeding 0.05 inch (see Figures I-2, 3).

Roadmeter Results

The Maintenance Division's biannual pavement condition survey was completed on this highway portion in April 1987. However, the four short sections in each direction were not run individually with the Roadmeter so the results cannot be fully evaluated. It does not appear that there were any significant changes in the roughness of these sections from the 14-year results. Neither were there any significant changes in the reinforced sections or the northbound control. The southbound control section had a PSI of 3.40 compared to 3.65 at 14 years. The lower value is probably a result of the numerous corner breaks now present.

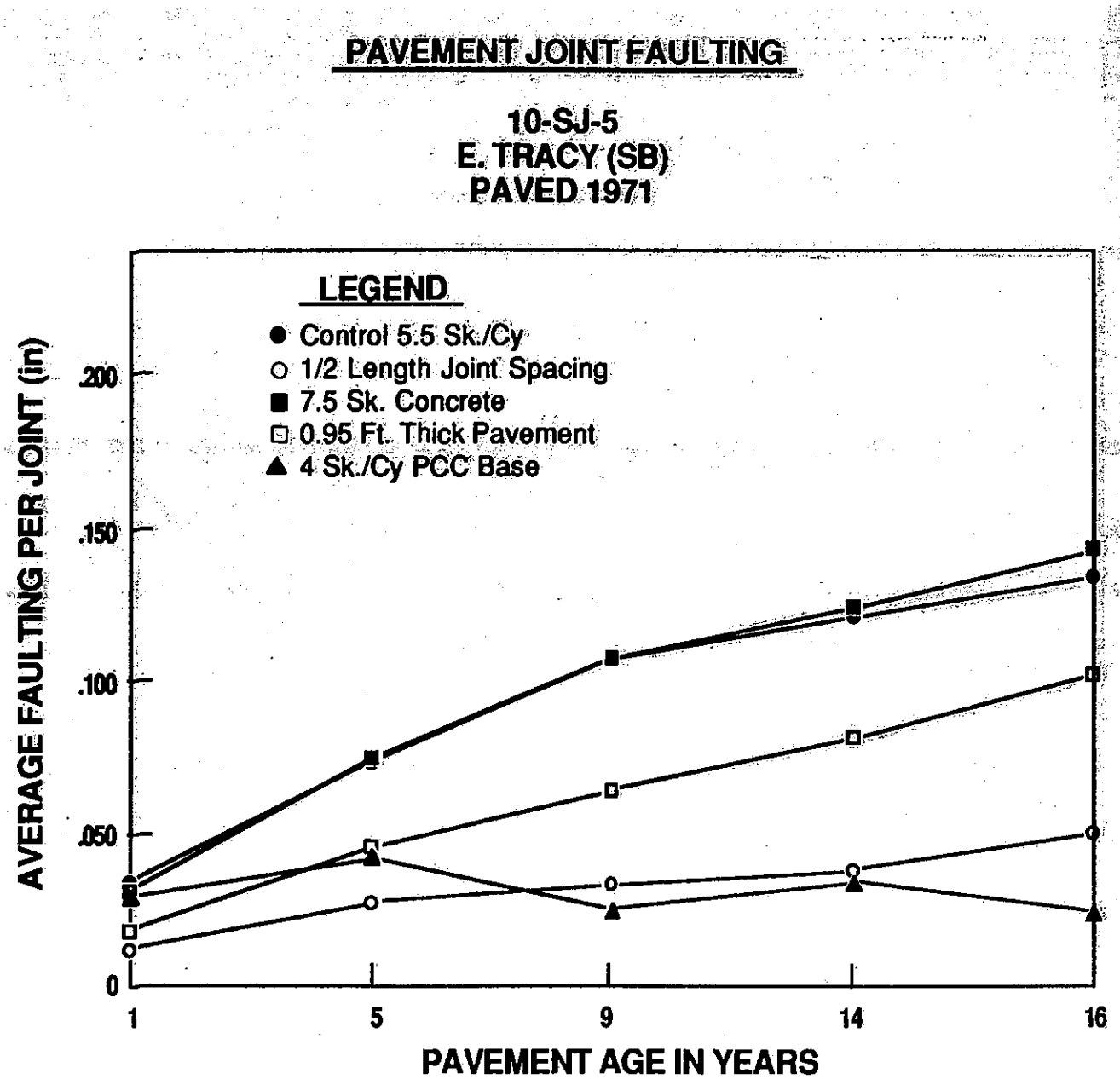
Summary

The deterioration in performance of the short slab sections in the southbound direction had evidently started before the survey of 1985 as indicated by the low PSI value (Table I-1), even though there was no visible evidence. However, for such drastic changes to have taken place during the past two years suggests a major change in some condition which



FAULTING TREND LINE

Figure I-2



FAULTING TREND LINE

Figure I-3

affects performance. The most likely cause is the extremely wet season of 1985-86 in which rainfall was about double that of normal. The nonreinforced sections in the southbound lanes are at the southern end of the project where the westerly lanes are more low-lying and likely to be slower draining than those on the opposite roadway at the north end of the project (see Photos IA9, 10). For the broken portions of slabs at interior corner breaks to settle as much as they have, it would seem that considerable pumping and removal of material has had to take place. Broken slab removals at other locations have shown that there is no significant loss of surface of the cement treated base. This suggests that some of the subbase has been removed, but this aspect has not been examined. The reason for this settlement has not yet been determined, but would seem to be a function of impact loading on the acute angle upon leaving the previous slab.

The numerous transverse cracks in some sections and the relatively few in others appear to be at least partially connected with environmental conditions. Where more pumping takes place, more cracking occurs, evidently from loss of slab support. The extra strength concrete did not seem to slow the cracking, but in the section of extra slab thickness, cracking was reduced considerably. While the extra thickness sections have lower PSI values than most of the others, they exhibit less deterioration in the form of pumping and cracking.

The transverse cracking in the longer slabs on this and a few other projects led to a reevaluation of California's specified joint spacing. As a result, joint spacing was changed from repetitive spacing of 13, 19, 18 and 12 ft to 12, 15, 13 and 14 ft. This appears to have greatly reduced the transverse cracking problem.

Photo IA-9. Low-lying area - slow draining.
Southerly end of project.

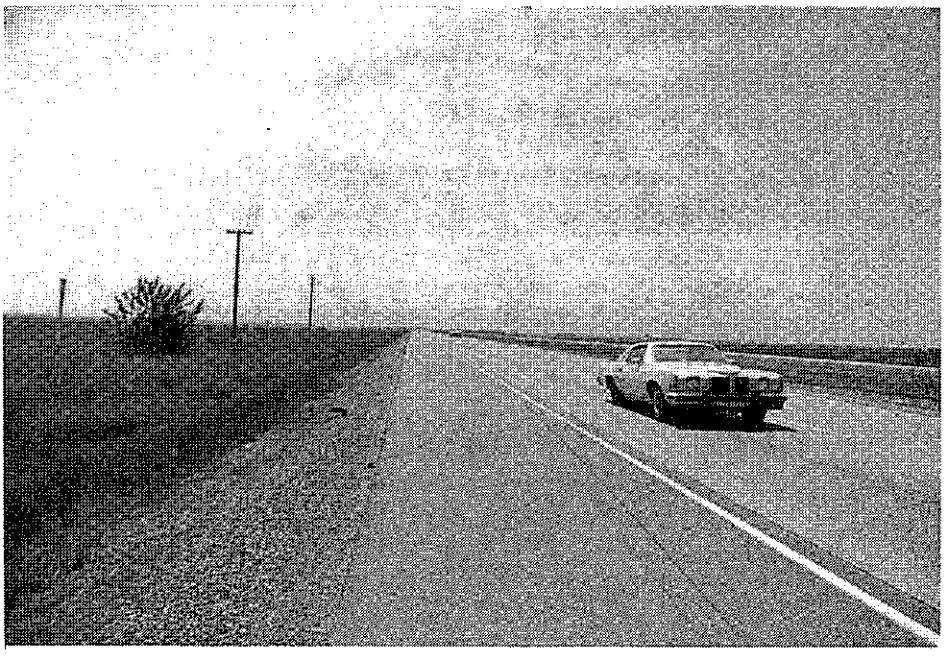


Photo IA-10. Higher fill area. Faster draining.
Northerly end of project.

PART II - JOINT SEALS

California does not routinely seal joints in concrete pavements except in mountain areas where snow removal and sanding are expected. It has long been the contention of state engineers that the practice is not cost-effective. In 1974, Caltrans was persuaded by a group of contractors and suppliers to place a number of sealed joint sections in a nonmountainous area on an experimental basis.

The site selected for the experiment was on I-680 in Milpitas, Santa Clara County, near the San Francisco Bay. The highway consisted of four 12-foot lanes in each direction. The sealants selected were, 1) a hot pour material meeting Federal Specification SS-S-1401; 2) a polyurethane sealant; 3) a hot pour elastomeric polymer type and 4) preformed neoprene compression seal. Test sections were 1,000 feet in length. Following are some of the details of construction, as reported in Reference (II-1).

Transverse Joints Only

1. Immediately following sawing, a fiber welt cord was installed in top of the transverse weakened plane joints. Between 3 and 7 days after sawing, the cord was rolled to the bottom. The joints were then cleaned with compressed air and filled with Sealflex 1401. The Contractor's estimated cost was $0.15 to $0.20/lin. ft. Actual cost was $0.30/lin. ft.

Longitudinal and Transverse Joints

2. Saw cuts were widened and deepened to 3/8 in. and 1-1/4 in., respectively, then sandblasted and cleaned. A 1/2 in. diameter expanded closed cell neoprene rod was installed in the bottom of the saw cut, the sides were primed, the joint was sealed with Sealflex 39, a polyurethane sealant. The Contractor's estimated cost was $0.50 to $0.60/lin. ft. The actual cost was $1.15/lin. ft.

3. Saw cuts were widened, deepened and cleaned as in No. 2 above. A 1/2 in. diameter fiber welt cord was installed in the bottom of the saw cut and the joint was sealed with Sealflex 1401. The Contractor's estimated cost was $0.38 to $0.48/lin. ft. The actual cost was $0.79/lin. ft.

4. Same as No. 3 above, except joint sealant was Superseal 444, an elastomeric polymer type. The Contractor's estimated cost was $0.40 to $0.50/lin. ft. and the actual cost was $1.01/lin. ft.

5. Joint grooves were cut to a width to accept 5/16 in. preformed elastomeric joint seal. Joints were sandblasted, cleaned and primed before sealant installation. The Contractor's estimated price was $0.50 to $0.60/lin. ft. The actual cost was $0.51/lin. ft.

6. Saw cuts were made through plastic insert joint material to form a 3/4 by 1-1/4 in. reservoir. Because of the difficulty and expanse of sawing, the section was reduced to 500 ft. After sawing, treatment was the same as in No. 2 above for Sealflex 39. On one half of this section, the outer shoulder joint was also cut and sealed with the same material. The Contractor's estimated price was $0.50 to $0.60/lin. ft. and the actual cost was $1.06/lin. ft.

7. This was the same as above (including shortening section and treating one half the shoulder joint) except the joints were sealed with Superseal 444. The Contractor's estimated price was $0.40 to $0.50/lin. ft. The actual cost was $0.91/lin. ft.

Evaluating performance was expected to take a number of years, but problems encountered during the sealing process were anticipated to have an adverse effect on performance. Maintaining the proper sealant level (1/4 inch below the pavement surface) proved quite difficult and a number of joints were overfilled. Also, strong winds blew dust and sand almost every day, making it very difficult to keep the joints clean until sealed. This created bonding problems when adhesives were used and at longitudinal and transverse joint intersections where sealant was placed in one direction, then later in the other direction. After three years service, a number of adhesion failures (bond to concrete) were found, along with a few cohesion failures.

It was the contractors' contention that the joint seals would prevent water from getting under the pavement and causing pumping and faulting. It was Caltrans' belief that joint seals were not completely effective in preventing water entry and that a positive means of removing infiltrated water from under the pavement might be more cost-effective. To test this theory, Caltrans personnel installed a 1,000 foot section of drainage pipe along the edge of the pavement at the base-pavement interface, the first such system in California. The pipe was 1-1/2 inch PVC with two rows of slots at 1/3 points. Unslotted outlet pipes were placed every 100 feet to remove water to the outside of the shoulder. After three years, the drains

were still working effectively. Flow measurements at the outlets indicated that water was being removed at rates as high as 60 gallons per hour.

The most recent surveys of these experimental sections was made after almost 11 years of service. The survey consisted of a subjective evaluation and photographs.

Federal Specification SS-S-1401 Sealant

There were two sections placed with this material. In Section 1, joints were formed by sawing initially, but not widened for the sealant. While both the pavement and shoulder are performing satisfactorily, some of the sealant is missing from many of the joints. Some pumping is evident in this section (see Photos 1 and 2).

In Section 3, joint and shoulder performance are much better. While there is some sealant failure, both adhesive and cohesive, the sealant appears to be staying in the joint and keeping out much of the sand, gravel and other debris. Photos 3 and 4 show typical conditions of this section. Some pumping is evident, but it is minor compared to the first section. The shoulder joint was not sealed.

Elastomeric Polymer Sealant

The hot-pour elastomeric polymer sealant was also placed in two different sections. In Section 4, there are some sealant failures and missing sealant. Pumping and shoulder depressions are typically noted near most joints (see Photos 5 and 6). In Section 7, the integrity of the sealant has been damaged, with some material missing. Pumping with shoulder depression is quite evident (see Photos 7 and 8).

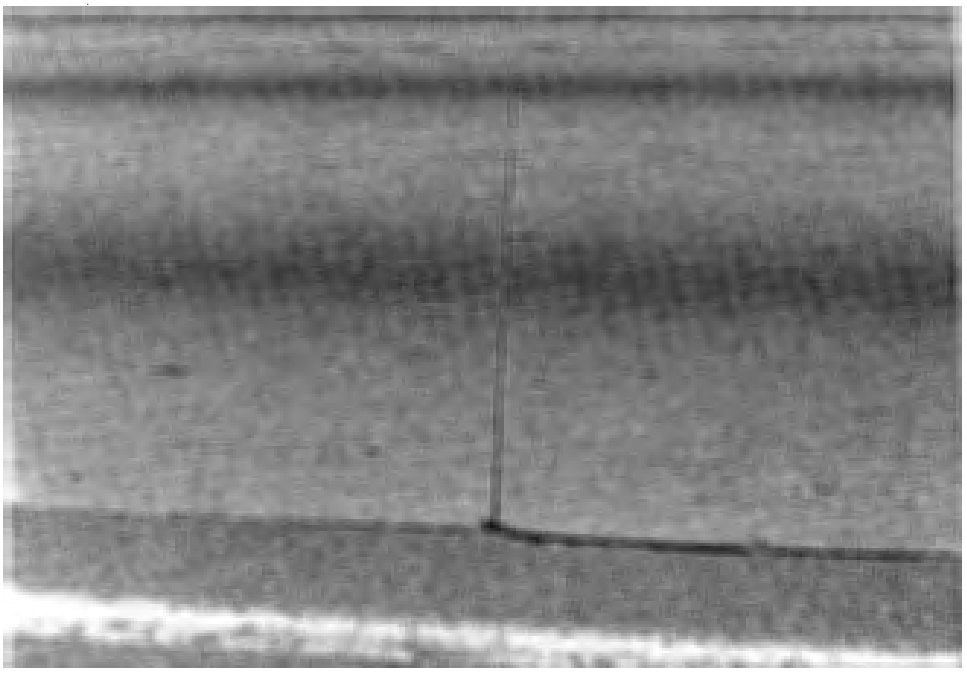


Photo II-1. Joint not widened, but sealed with SS-S-1401 sealant.

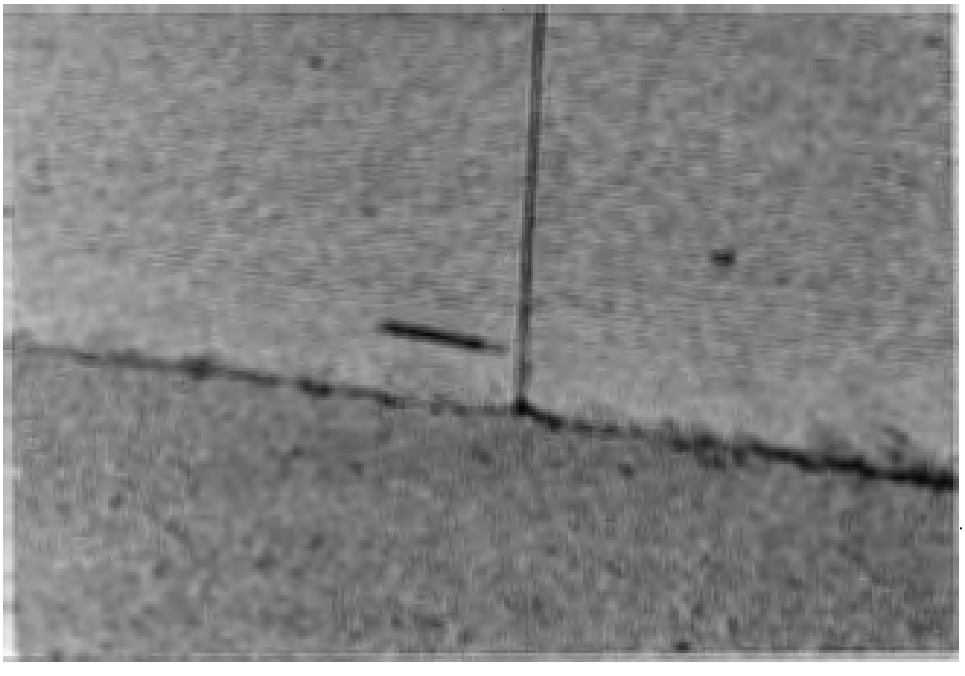


Photo II-2. Close-up, same as II-5.

Photo II-3. Transverse joint sealed with SS-S-1401 sealant.

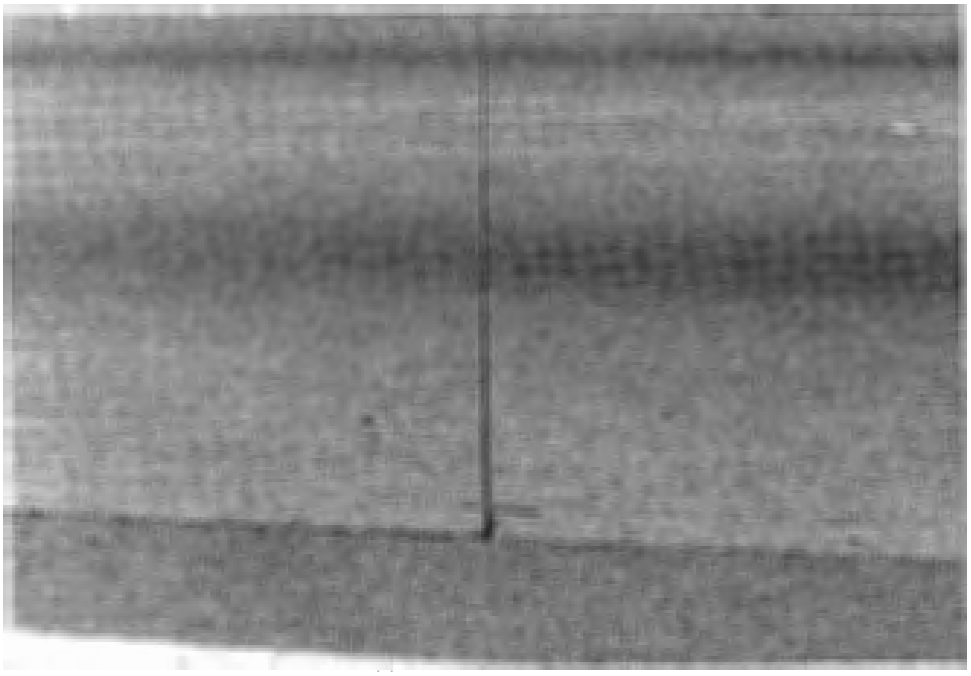


Photo II-4. Close-up of sealed joint.

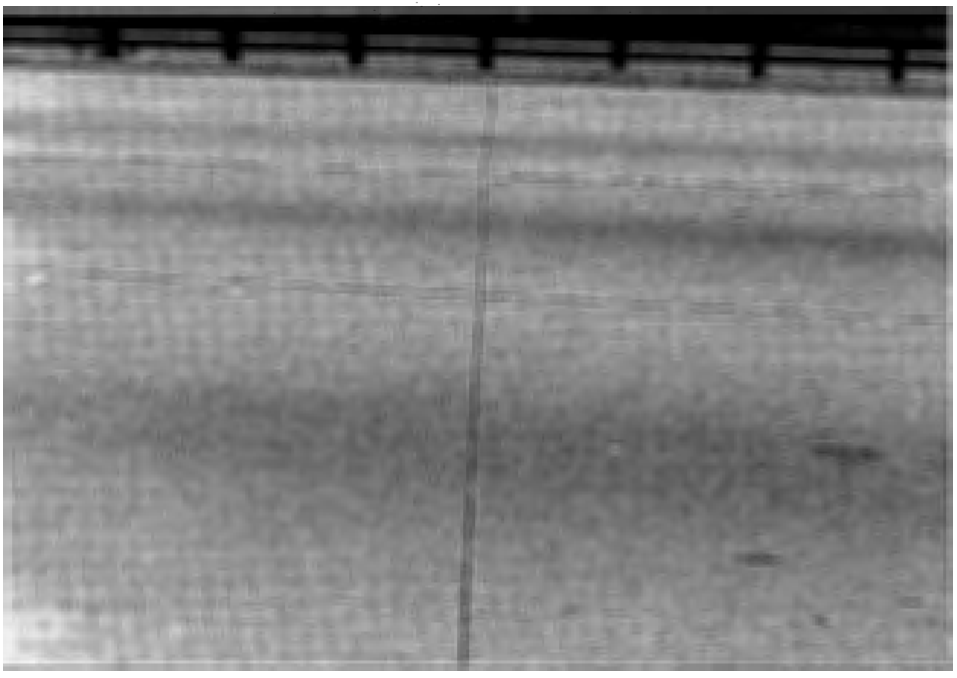


Photo II-5. Widened saw cut sealed with Superseal 444 sealant

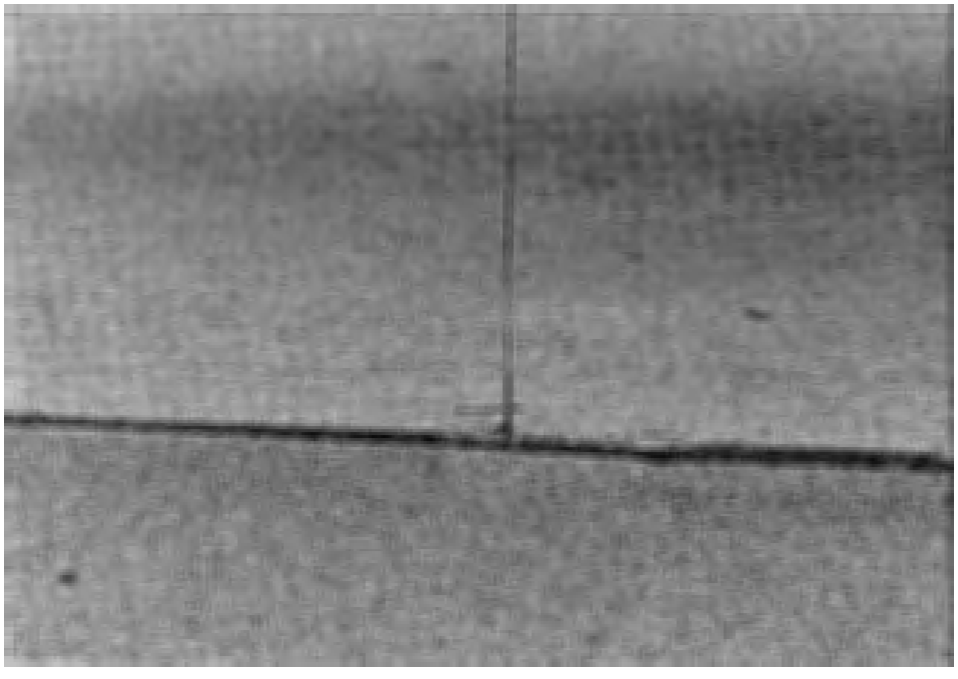


Photo II-6. Same as above, note depressed shoulder.

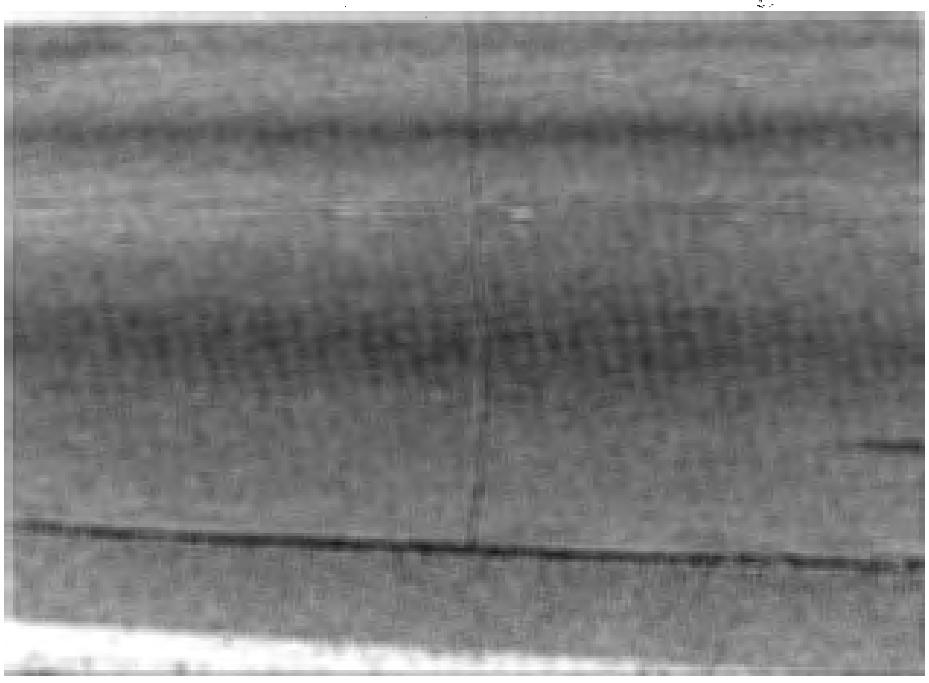


Photo II-7. Insert joint routed and sealed with Superseal 444 sealant.

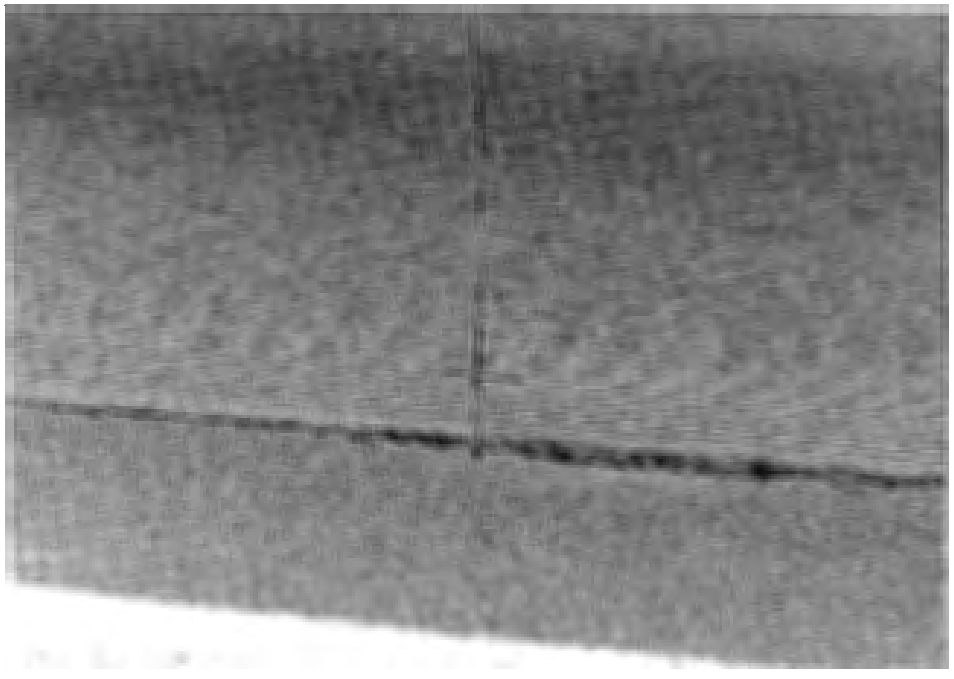


Photo II-8. Same as above, some sealant missing.

Polyurethane Sealant

Some failures are also occurring in the polyurethane sealant in Section 2. Pumping is quite severe in this section which is located in a cut area (see Photos 9 and 10). Section 6 is downhill from a structure fill that appears to have a spring in it as water comes out of the joints at lower locations for much of the year. Although most of the joint material was still in place, water pumping through the joints and shoulder area had damaged the integrity of the sealant and there were both adhesive and cohesive failures. Photo 11 shows the shoulder seal in place. Photo 12 shows a depression of the shoulder near the joint. An asphaltic material had already been used to fill this depression.

Preformed Neoprene

The preformed neoprene seals still appear to be in good shape although there are numerous adhesive failures. However, there is evidence of pumping and the shoulders are depressed at some joints (see Photos 13 and 14).

Edge Drain Section

While the section with edge drains is performing satisfactorily, there is evidence of pumping as seen in Photos 15 and 16. Shoulder damage is fairly slight, however. Unfortunately for evaluation of this experiment, about three years after construction, the outlet pipes for the edge drains were destroyed by landscaping crews. No attempt was ever made to reestablish the drains.

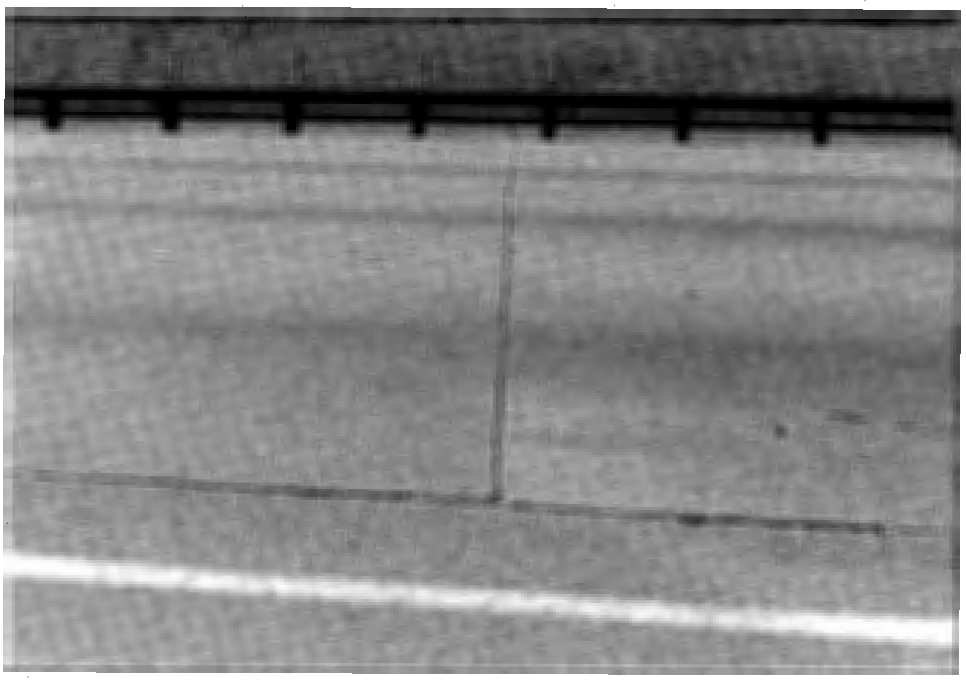


Photo II-9. Widened saw cut sealed with polyurethane sealant.

Photo II-10. Same as above, note pumping stains at joints.

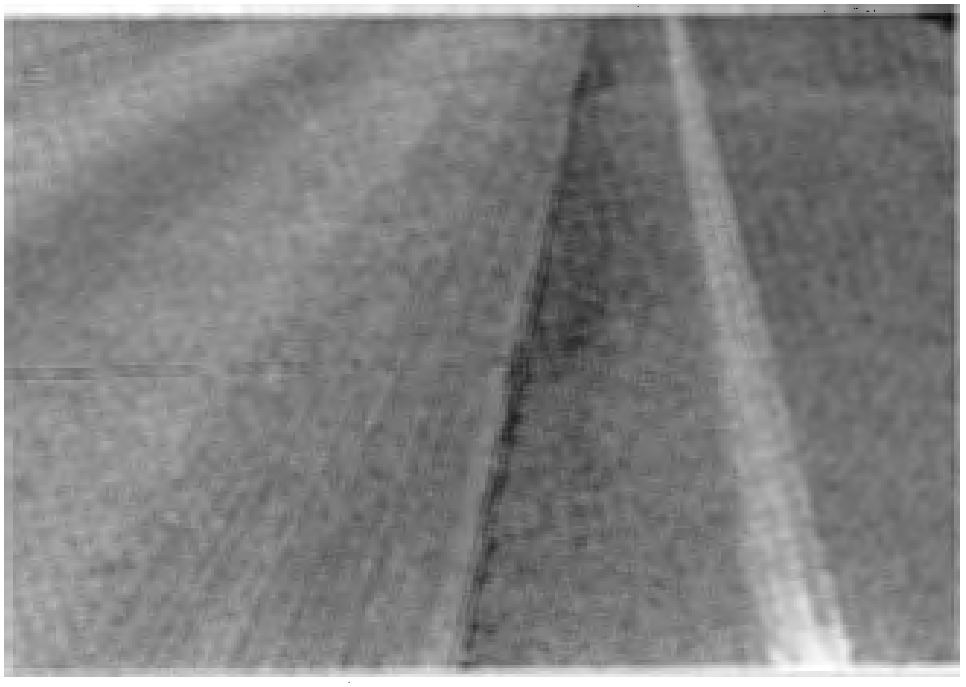


Photo II-11. Shoulder joint sealed with Superseal 444 sealant.

Photo II-12. Shoulder depression partially filled with an asphaltic material.

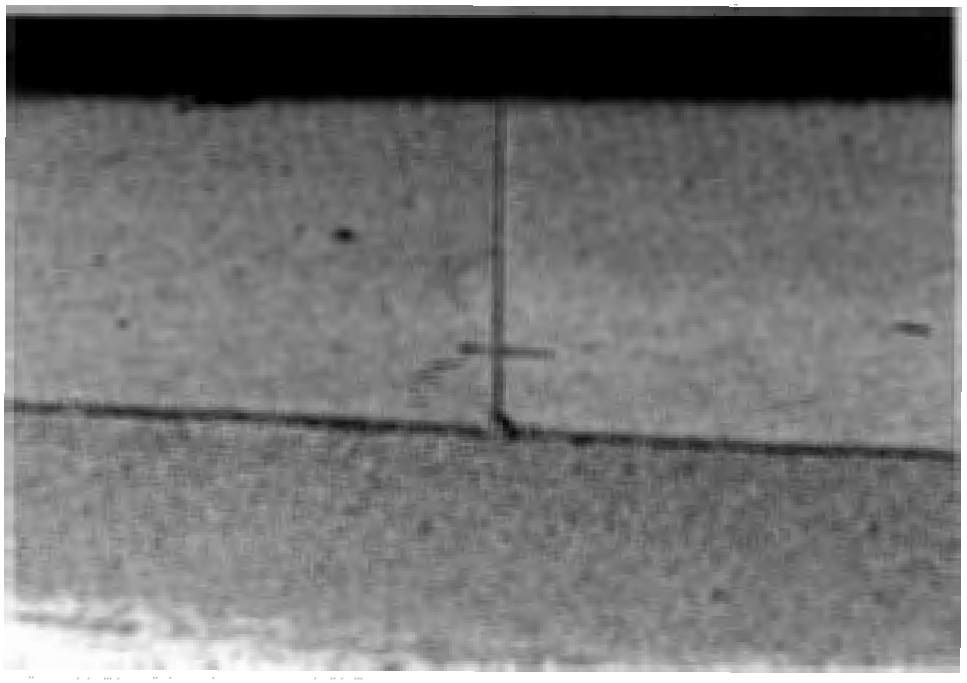


Photo II-13. Joint sealed with preformed neoprene compression seal.

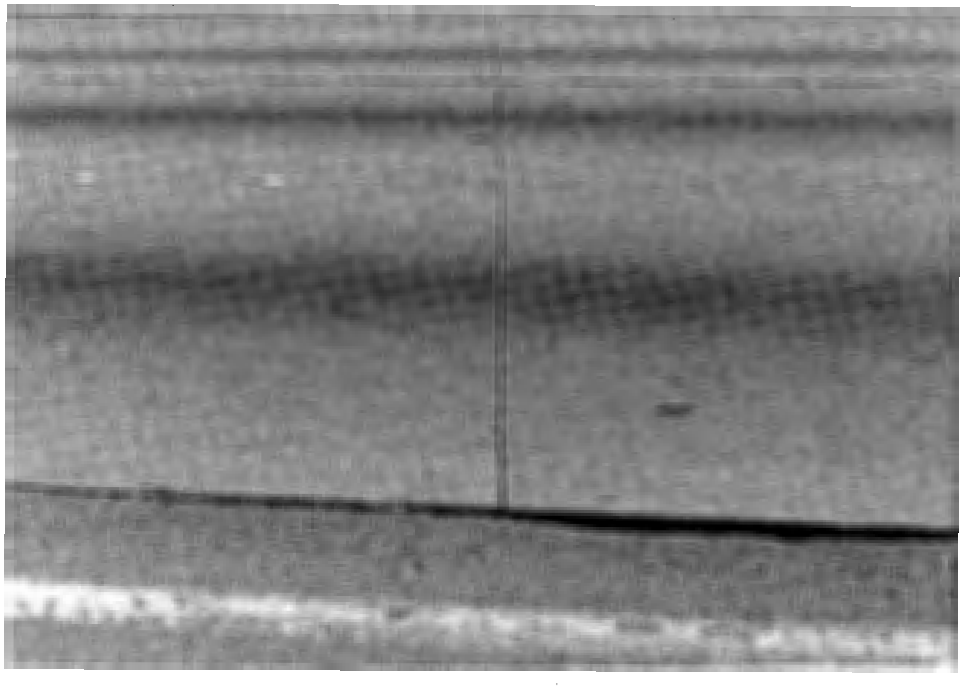


Photo II-14. Same as above, note depressed shoulder.

Photo II-15. Area of edge drains. Note pumping stains at joints.

Photo II-16. Same as above.

Control Section (Joints Not Sealed)

In areas with no joint seals, the pavement appears to be performing as well as with joint seals. Joints look good with no significant spalling. Pumping is occurring, but the shoulders are not appreciably depressed. Photos 17 through 20 show typical conditions.

Summary

Of the four types of joint seals used, the preformed neoprene compression seals seem to have maintained integrity and effectiveness best. However, the overall performance of the "sealed" pavement does not appear to be significantly better than that of the unsealed pavement. Spalling is minor in both areas, and pumping with slight faulting (less than 0.10 inch) is occurring throughout the project. None of the findings from this study would indicate any improvement in joint or pavement performance from the use of joint seals. Water was not prevented from getting under the pavement as evidenced by all the stains from pumping. Also, except for Section 5 with the preformed elastomeric material, costs for the installed sealants were about double the amount estimated by the Contractor.

While the above findings are accurate as far as this study is concerned, it is recognized that the test sections were quite short, and may not reflect true costs and performance. The performance may have also been affected by the small temperature differentials occurring in the area of this project. Undoubtedly, the blowing dust was also a factor in performance, but this condition may arise in any area of this or any other state.

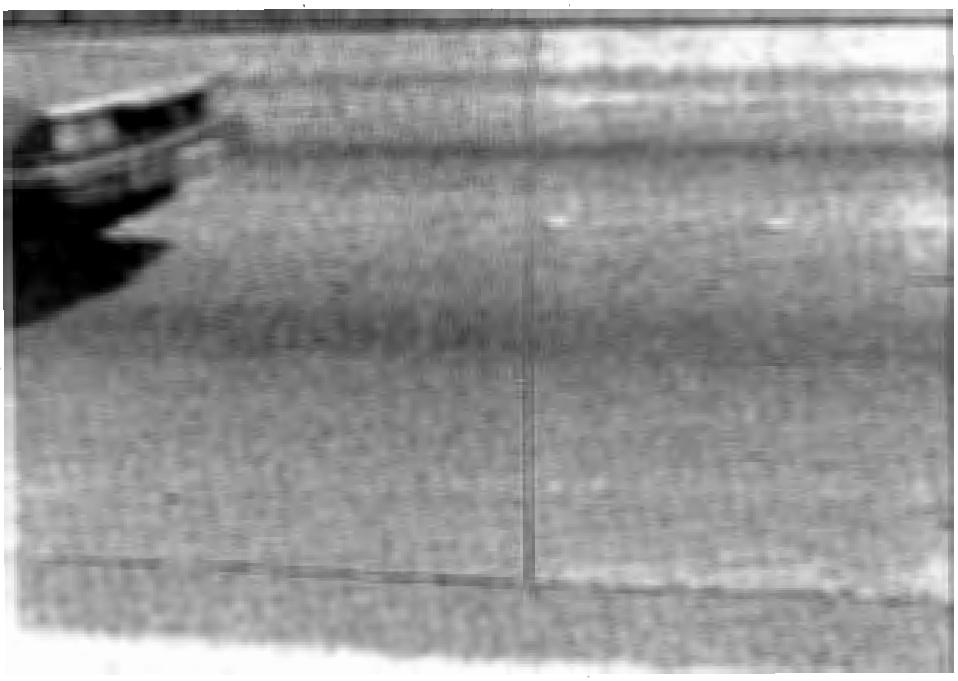


Photo II-17. Unsealed joint in control area.

Photo II-18. Shoulder in control area.

Whether the edge drains would have been effective in improving pavement performance had they not been damaged is not known. However, they were quite effective initially in removing water from under the pavement. Because of this effectiveness, drainage systems were subsequently installed on other Caltrans contracts. When problems arose, such as drains becoming plugged, changes in installation, including provisions for cleaning, were made. As performance improved, drains were adopted as standard practice and are now required on new construction projects. In addition, many older projects have been retrofitted with drains. See Figure II-1 for the standard plan for edge drain installations and Appendix II-1 for the specifications currently being used by Caltrans for edge drains.

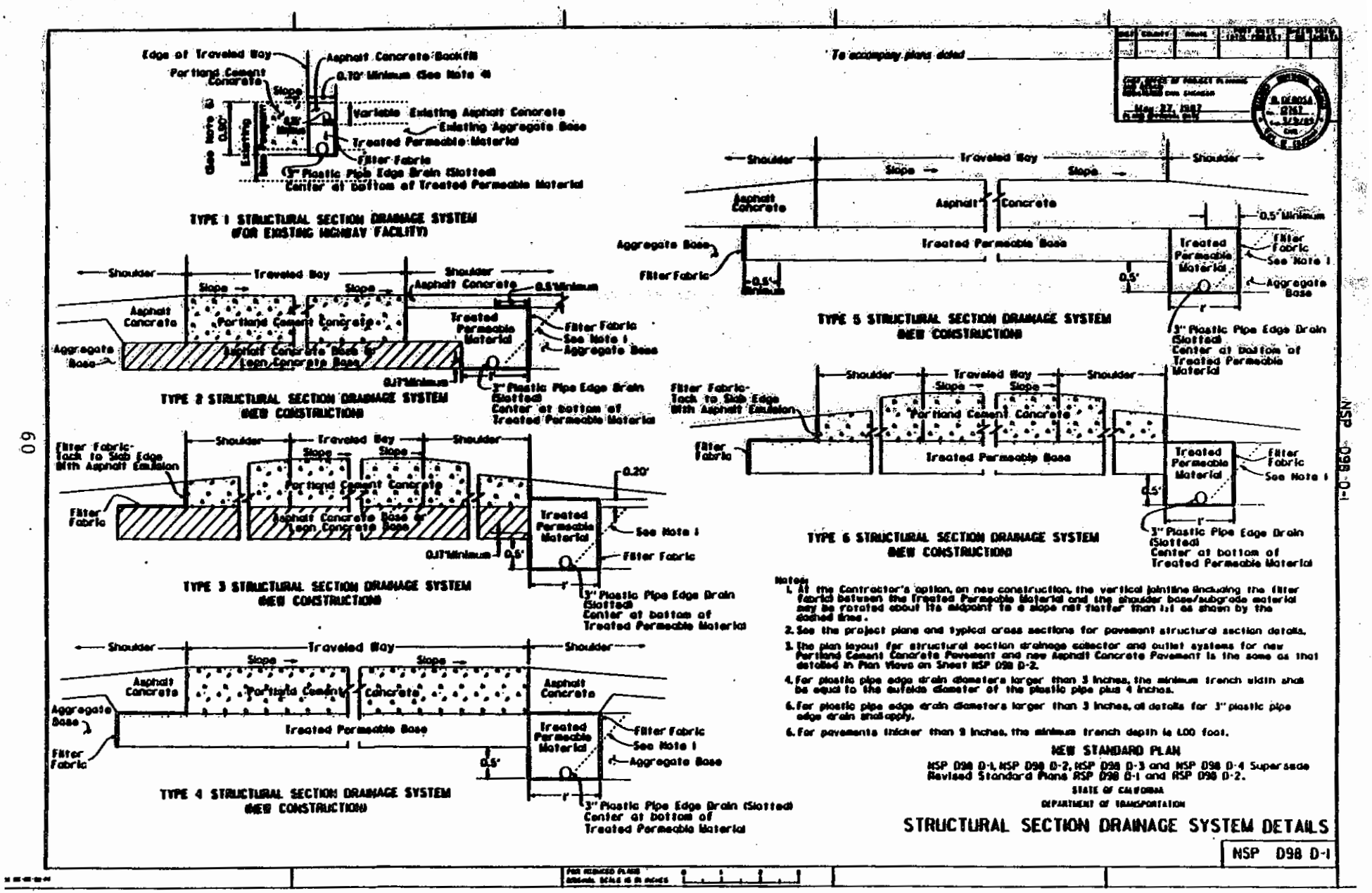

Edge of Traveled Way
Portland Cement Concrete
Asphalt Concrete Backfill
0.70' Minimum (See Note 4)
Slope
Variable Existing Asphalt Concrete
Existing Aggregate Base
Treated Permeable Material
Filter Fabric
3" Plastic Pipe Edge Drain (Slotted)
Center at bottom of Treated Permeable Material
TYPE 1 STRUCTURAL SECTION DRAINAGE SYSTEM
(FOR EXISTING HIGHWAY FACILITY)
Shoulder
Traveled Way
Asphalt Concrete
Portland Cement Concrete
Aggregate Base
Asphalt Concrete Base or Lean Concrete Base
0.5' Minimum
See Note 1
0.17' Minimum
TYPE 2 STRUCTURAL SECTION DRAINAGE SYSTEM
(NEW CONSTRUCTION)
Filter Fabric-Tack to Slab Edge With Asphalt Emulsion
0.20'
0.5'
TYPE 3 STRUCTURAL SECTION DRAINAGE SYSTEM
(NEW CONSTRUCTION)
Treated Permeable Base
TYPE 4 STRUCTURAL SECTION DRAINAGE SYSTEM
(NEW CONSTRUCTION)
To accompany plans dated
TYPE 5 STRUCTURAL SECTION DRAINAGE SYSTEM
(NEW CONSTRUCTION)
TYPE 6 STRUCTURAL SECTION DRAINAGE SYSTEM
(NEW CONSTRUCTION)
Notes:
1. At the Contractor's option, on new construction, the vertical joinline (including the filter fabric) between the Treated Permeable Material and the shoulder base/subgrade material may be rotated about its midpoint to a slope not flatter than 1:1 as shown by the dashed lines.
2. See the project plans and typical cross sections for pavement structural section details.
3. The plan layout for structural section drainage collector and outlet systems for new Portland Cement Concrete Pavement and new Asphalt Concrete Pavement is the same as that detailed in Plan View on Sheet NSP D98 D-2.
4. For plastic pipe edge drain diameters larger than 3 inches, the minimum trench width shall be equal to the outside diameter of the plastic pipe plus 4 inches.
5. For plastic pipe edge drain diameters larger than 3 inches, all details for 3" plastic pipe edge drain shall apply.
6. For pavements thicker than 9 inches, the minimum trench depth is 1.00 foot.
NEW STANDARD PLAN
NSP D98 D-1, NSP D98 D-2, NSP D98 D-3 and NSP D98 D-4 Supersede Revised Standard Plans RSP D98 D-1 and RSP D98 D-2.
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
STRUCTURAL SECTION DRAINAGE SYSTEM DETAILS
NSP D98 D-1
NSP D98 D-1

Figure II-1

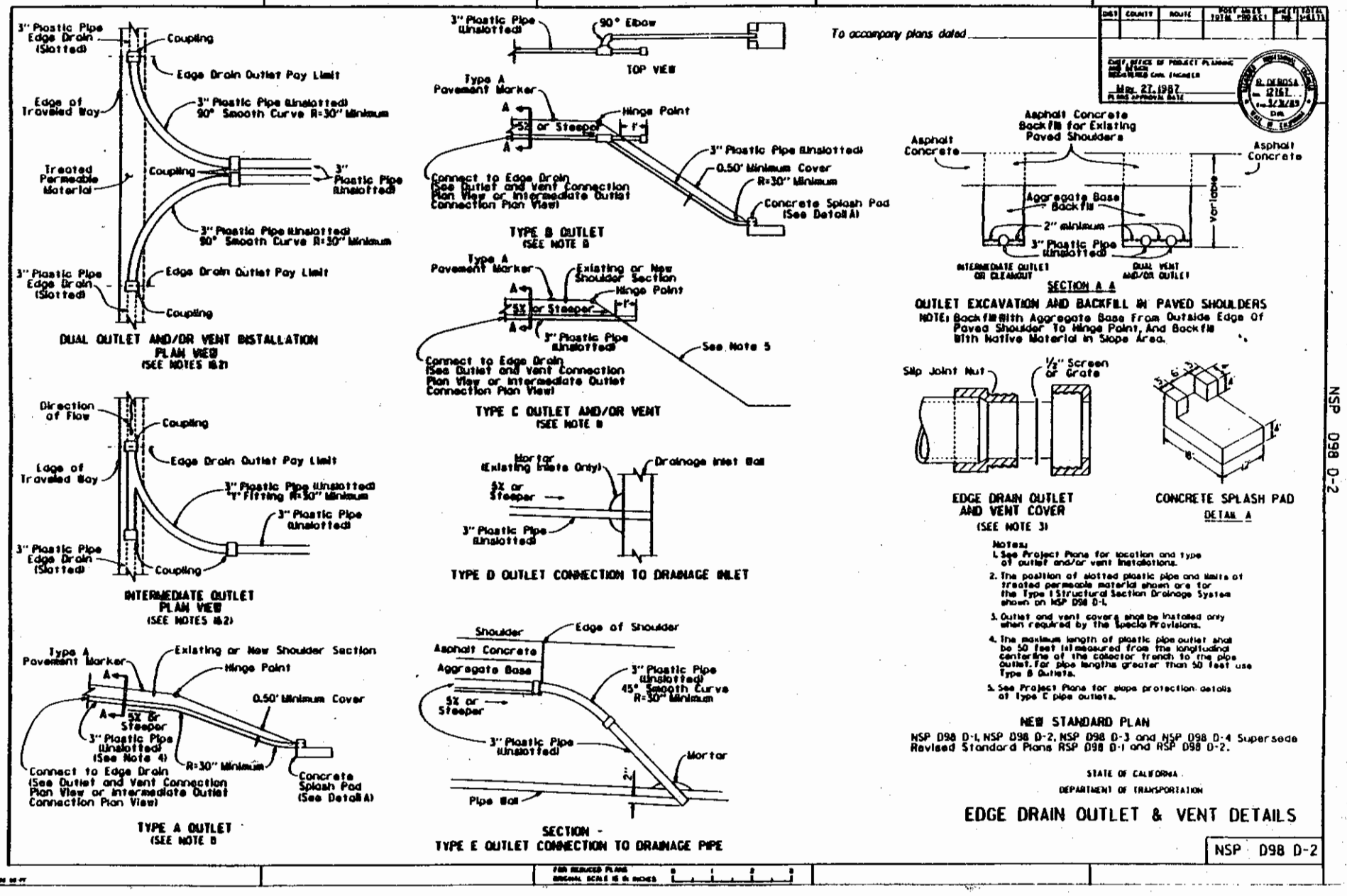

To accompany plans dated
DIST COUNTY ROUTE POST MILES TOTAL PROJECT SHEET NO. TOTAL SHEETS
CHIEF, OFFICE OF PROJECT PLANNING AND DESIGN
REGISTERED CIVIL ENGINEER
May 27, 1987
PLANS APPROVAL DATE
R. DEROSA
No. 12167
3/31/89
DATE
3" Plastic Pipe Edge Drain (Slotted)
Coupling
Edge Drain Outlet Pay Limit
Edge of Traveled Way
3" Plastic Pipe (Unslotted) 90° Smooth Curve R=30" Minimum
Treated Permeable Material
Coupling
3" Plastic Pipe (Unslotted)
3" Plastic Pipe (Unslotted) 90° Smooth Curve R=30" Minimum
3" Plastic Pipe Edge Drain (Slotted)
Edge Drain Outlet Pay Limit
Coupling
DUAL OUTLET AND/OR VENT INSTALLATION
PLAN VIEW
(SEE NOTES 1&2)
Direction of Flow
Coupling
Edge Drain Outlet Pay Limit
Edge of Traveled Way
3" Plastic Pipe (Unslotted) "Y" Fitting R=30" Minimum
3" Plastic Pipe (Unslotted)
3" Plastic Pipe Edge Drain (Slotted)
Coupling
INTERMEDIATE OUTLET
PLAN VIEW
(SEE NOTES 1&2)
Type A Pavement Marker
Existing or New Shoulder Section
Hinge Point
0.50' Minimum Cover
5% or Steeper
3" Plastic Pipe (Unslotted) (See Note 4)
R=30" Minimum
Connect to Edge Drain (See Outlet and Vent Connection Plan View or Intermediate Outlet Connection Plan View)
Concrete Splash Pad (See Detail A)
TYPE A OUTLET
(SEE NOTE 1)
3" Plastic Pipe (Unslotted)
90° Elbow
TOP VIEW
Type A Pavement Marker
Hinge Point
5% or Steeper
3" Plastic Pipe (Unslotted)
0.50' Minimum Cover
R=30" Minimum
Connect to Edge Drain (See Outlet and Vent Connection Plan View or Intermediate Outlet Connection Plan View)
Concrete Splash Pad (See Detail A)
TYPE B OUTLET
(SEE NOTE 1)
Type A Pavement Marker
Existing or New Shoulder Section
Hinge Point
5% or Steeper
3" Plastic Pipe (Unslotted)
See Note 5
Connect to Edge Drain (See Outlet and Vent Connection Plan View or Intermediate Outlet Connection Plan View)
TYPE C OUTLET AND/OR VENT
(SEE NOTE 1)
Mortar (Existing Inlets Only)
Drainage Inlet Ball
5% or Steeper
3" Plastic Pipe (Unslotted)
TYPE D OUTLET CONNECTION TO DRAINAGE INLET
Shoulder
Edge of Shoulder
Asphalt Concrete
Aggregate Base
3" Plastic Pipe (Unslotted) 45° Smooth Curve R=30" Minimum
5% or Steeper
3" Plastic Pipe (Unslotted)
Mortar
Pipe Ball
SECTION -
TYPE E OUTLET CONNECTION TO DRAINAGE PIPE
Asphalt Concrete Backfill for Existing Paved Shoulders
Asphalt Concrete
Asphalt Concrete
Aggregate Base Backfill
2" minimum
3" Plastic Pipe (Unslotted)
Variable
INTERMEDIATE OUTLET OR CLEANOUT
DUAL VENT AND/OR OUTLET
SECTION A A
OUTLET EXCAVATION AND BACKFILL IN PAVED SHOULDERS
NOTE: Backfill With Aggregate Base From Outside Edge Of Paved Shoulder To Hinge Point, And Backfill With Native Material In Slope Area.
Slip Joint Nut
1/2" Screen or Grate
EDGE DRAIN OUTLET AND VENT COVER
(SEE NOTE 3)
CONCRETE SPLASH PAD
DETAIL A
Notes:
1. See Project Plans for location and type of outlet and/or vent installations.
2. The position of slotted plastic pipe and limits of treated permeable material shown are for the Type I Structural Section Drainage System shown on NSP D98 D-1.
3. Outlet and vent covers shall be installed only when required by the Special Provisions.
4. The maximum length of plastic pipe outlet shall be 50 feet (measured from the longitudinal centerline of the collector trench to the pipe outlet). For pipe lengths greater than 50 feet use Type B Outlets.
5. See Project Plans for slope protection details of Type C pipe outlets.
NEW STANDARD PLAN
NSP D98 D-1, NSP D98 D-2, NSP D98 D-3 and NSP D98 D-4 Supersede Revised Standard Plans RSP D98 D-1 and RSP D98 D-2.
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
EDGE DRAIN OUTLET & VENT DETAILS
NSP D98 D-2
NSP D98 D-2
FOR REDUCED PLANS ORIGINAL SCALE IS 0 1 2 3 INCHES

Figure II-1

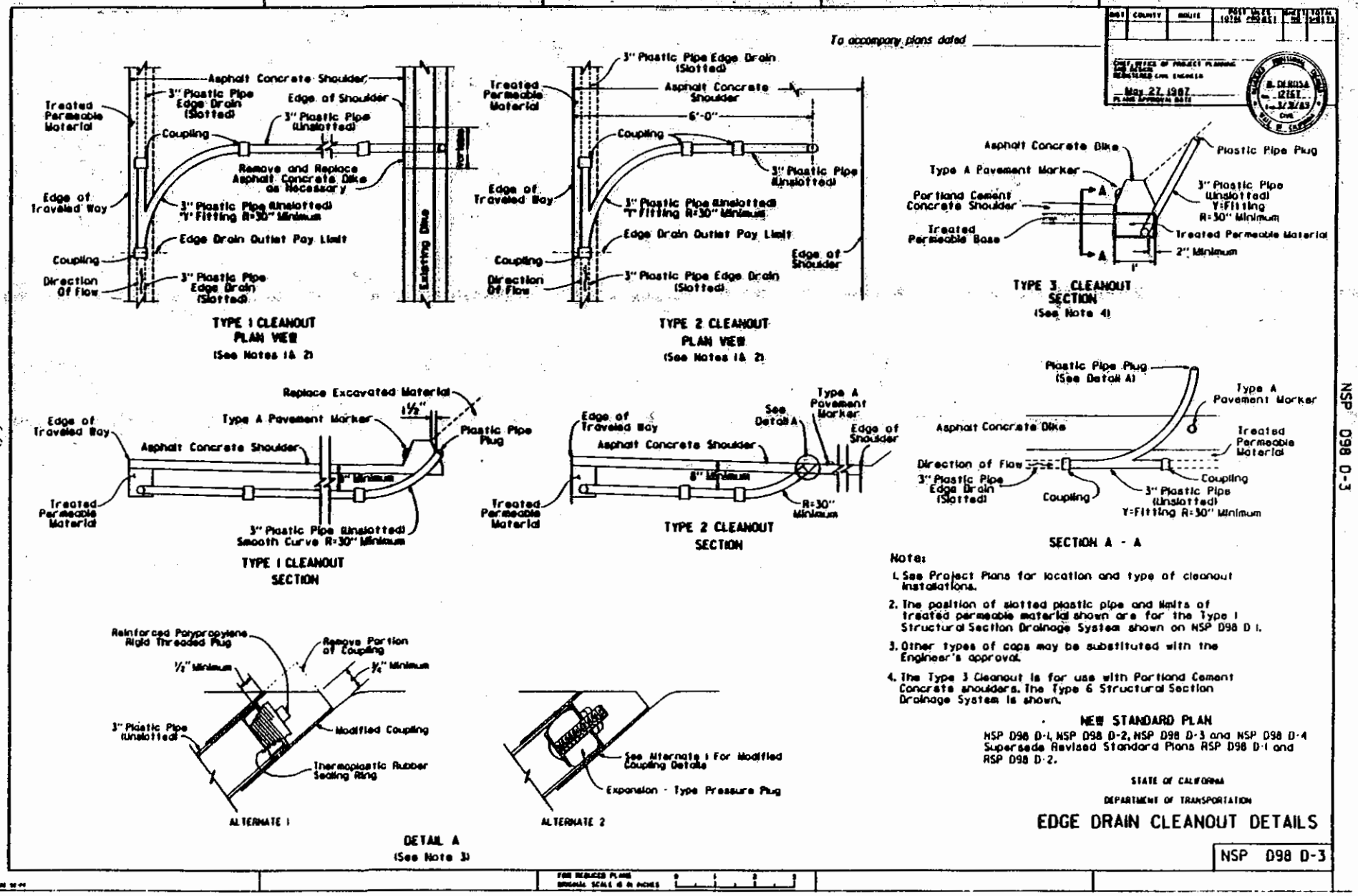

To accompany plans dated
Asphalt Concrete Shoulder
3" Plastic Pipe Edge Drain (Slotted)
Edge of Shoulder
3" Plastic Pipe (Unslotted)
Treated Permeable Material
Coupling
Remove and Replace Asphalt Concrete Dike as Necessary
Edge of Traveled Way
3" Plastic Pipe (Unslotted) "Y" Fitting R=30" Minimum
Edge Drain Outlet Pay Limit
Coupling
Direction Of Flow
3" Plastic Pipe Edge Drain (Slotted)
Existing Dike
TYPE 1 CLEANOUT PLAN VIEW
(See Notes 1 & 2)
3" Plastic Pipe Edge Drain (Slotted)
Asphalt Concrete Shoulder
6'-0"
Treated Permeable Material
Coupling
3" Plastic Pipe (Unslotted)
Edge of Traveled Way
3" Plastic Pipe (Unslotted) "T" Fitting R=30" Minimum
Edge Drain Outlet Pay Limit
Coupling
Direction Of Flow
3" Plastic Pipe Edge Drain (Slotted)
Edge of Shoulder
TYPE 2 CLEANOUT PLAN VIEW
(See Notes 1 & 2)
Asphalt Concrete Dike
Plastic Pipe Plug
Type A Pavement Marker
3" Plastic Pipe (Unslotted) Y-Fitting R=30" Minimum
Portland Cement Concrete Shoulder
Treated Permeable Base
Treated Permeable Material
2" Minimum
TYPE 3 CLEANOUT SECTION
(See Note 4)
Replace Excavated Material
1½"
Edge of Traveled Way
Type A Pavement Marker
Plastic Pipe Plug
Asphalt Concrete Shoulder
3" Minimum
Treated Permeable Material
3" Plastic Pipe (Unslotted) Smooth Curve R=30" Minimum
TYPE 1 CLEANOUT SECTION
Edge of Traveled Way
See Detail A
Type A Pavement Marker
Edge of Shoulder
Asphalt Concrete Shoulder
8" Minimum
Treated Permeable Material
R=30" Minimum
TYPE 2 CLEANOUT SECTION
Plastic Pipe Plug (See Detail A)
Type A Pavement Marker
Asphalt Concrete Dike
Treated Permeable Material
Direction of Flow
3" Plastic Pipe Edge Drain (Slotted)
Coupling
Coupling
3" Plastic Pipe (Unslotted) Y-Fitting R=30" Minimum
SECTION A - A
Reinforced Polypropylene Rigid Threaded Plug
Remove Portion of Coupling
½" Minimum
¼" Minimum
3" Plastic Pipe (Unslotted)
Modified Coupling
Thermoplastic Rubber Sealing Ring
ALTERNATE 1
See Alternate 1 For Modified Coupling Details
Expansion - Type Pressure Plug
ALTERNATE 2
DETAIL A
(See Note 3)
Note:
1. See Project Plans for location and type of cleanout installations.
2. The position of slotted plastic pipe and limits of treated permeable material shown are for the Type 1 Structural Section Drainage System shown on NSP D98 D 1.
3. Other types of caps may be substituted with the Engineer's approval.
4. The Type 3 Cleanout is for use with Portland Cement Concrete shoulders. The Type 6 Structural Section Drainage System is shown.
NEW STANDARD PLAN
NSP D98 D-1, NSP D98 D-2, NSP D98 D-3 and NSP D98 D-4 Supersede Revised Standard Plans RSP D98 D-1 and RSP D98 D-2.
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
EDGE DRAIN CLEANOUT DETAILS
NSP D98 D-3
May 27, 1987
NSP D98 D-3

Figure II-1

REFERENCES

II-1. Performance of PCC Pavements in California. A Transportation Laboratory report, No. FHWA-CA-TL-78-06.

APPENDIX II-1

EDGE DRAINS

(Para. 8 is new.)
(Paras. 2, 5, 10, and 12 are revised.)
(Para. 5- Use when Type 2 cleanouts are required.)
(Para. 6- Use when Type 1 cleanouts are required.)
(Use para. 11 or para. 12, but not both.)

10-1. EDGE DRAINS.--Edge drains shall conform to the requirements in Section 68-3, "Edge Drains," of the Standard Specifications and these special provisions.

Section 68-3.02A, "Pipe and Pipe Fittings," of the Standard Specifications is amended to read: 2

68-3.02A Pipe and Pipe Fittings.--Pipe and pipe fittings for edge drains and edge drain outlets, vents, and cleanouts shall be of the size or sizes shown on the plans or designated in the Engineer's Estimate. 2a

Pipe installed in trenches to be backfilled with asphalt treated permeable material shall be polyvinyl chloride (PVC) 90° C. electric conduit, Type 40 or Type 80, conforming to the requirements of NEMA Specification TC-2. 2b

All other pipe for edge drains and edge drain outlets, vents, and cleanouts shall, at the Contractor's option, be either: 2c

1. PVC 90° C. electric conduit, Type 40 or Type 80, conforming to the requirements of NEMA Specification TC-2, or 2c

2. PVC plastic pipe, Schedule 40 or Schedule 80, conforming to the requirements of ASTM Designation: D 1785. The type, grade, and design stress designation of the pipe shall, at the Contractor's option, be either 1120, 1220, 2120, 2116, 2112, or 2110 as specified in said ASTM Designation. 2c

Pipe shall be straight end or bell end. Bell end sockets shall conform to the requirements of ASTM Designation: D 2672 except for marking. 2d

In addition, pipe designated as slotted on the plans shall have 3 rows of slots in the pipe. The rows shall be in the longitudinal direction of the pipe and the slots shall be cut in the circumferential direction of the pipe. The 3 rows shall be spaced equally around the circumference of the pipe. Each row shall have 22 (+/-1) uniformly spaced slots per linear foot of pipe. The slots shall be 0.045-inch to 0.065-inch wide and of such length as to provide a minimum of 2.00 square inches of slot opening per linear foot of pipe. Other suitable configurations of slots which provide drainage equal to or better than the above slot requirements may be used if approved in writing by the Engineer. 2e

Except as otherwise provided for "Y" fittings, fittings for PVC 90° C. electric conduit shall conform to the requirements of NEMA Specification TC-3, and fittings for PVC plastic pipe shall be socket-type fittings conforming to the requirements of ASTM Designation: D 2467 for Schedule 80 pipe and ASTM Designation: D 2466 for Schedule 40 pipe. "Y" fittings shall be shop fabricated from pipe conforming to the requirements for the kind of edge drain pipe installed. The fitting shall provide an unobstructed passageway through both legs of the "Y". 2f

The third paragraph in Section 68-3.02B(2), "Cement Treated Permeable Material," of the Standard Specifications is amended to read: 3

Not less than 282 pounds of cement shall be used for each cubic yard of cement treated permeable material produced. The water-cement ratio shall be approximately 0.37. The exact water-cement ratio will be determined by the Engineer. 3a

The third paragraph of Section 68-3.02D, "Miscellaneous," of the Standard Specifications is deleted. 4

Expansion type pressure plugs for Type 2 cleanouts shall seat firmly against the lip of the pipe and shall conform to one of the following: 5

Expandable plugs manufactured from neoprene conforming to the requirements for neoprene in Section 51-1.14, "Waterstops," of the Standard Specifications with commercial quality stainless steel bolts and 2 hex nuts. 5a

Commercial quality expandable duct plugs consisting of reinforced polypropylene rigid threaded plug with a commercial quality thermoplastic rubber sealing ring. 5b

Galvanized fence post caps for Type 1 cleanouts shall fit the pipe and shall be commercial quality. 6

The fourth paragraph in Section 68-3.03, "Installation," of the Standard Specifications is amended to read: 7

The fabric shall be aligned and placed in a wrinkle-free manner. 7a

The tenth and eleventh paragraphs in said Section 68-3.03 are amended to read: 8

Treated permeable material may be spread in one layer. The material shall be compacted with a vibrating shoe-type compactor connected to the spreading device. The vibrating shoe-type compactor shall be operated only when the treated permeable material is actually being placed in the trench. 8a

The seventeenth paragraph in said Section 68-3.03 is amended to read: 9

Asphalt concrete backfill shall be spread and compacted in approximately 2 equal layers by methods that will produce an asphalt concrete surfacing of uniform smoothness, texture, and density. Each layer shall be compacted before the temperature of the mixture drops below 250°F. Prior to placing the asphalt concrete backfill, a paint binder of asphaltic emulsion conforming to the provisions in Section 94, "Asphaltic Emulsions," shall be applied to the vertical edges of existing pavement at an approximate rate of 0.05-gallon per square yard. 9a

The last paragraph in said Section 68-3.03 is amended to read: 10

The edge drain outlet, vent and cleanout pipes shall be clean at the time of installation and shall be free of obstructions after installation. The Contractor shall use a high pressure, flexible hose with a nominal one-inch diameter nozzle containing flushing and propelling jets. The hose shall be inserted into each edge drain outlet, vent and cleanout pipe and pushed through the pipe with a minimum 1000 PSIG water pressure so that the entire edge drain system shall be penetrated by the flushing nozzle. Pipes that are found to be plugged shall be replaced by the Contractor at his expense, including replacement of permeable material, surfacing and backfill materials. 10a

Outlet and vent covers will not be required. 11

Outlet and vent covers consisting of commercial quality 1/2 inch mesh galvanized metal screens or grates with polyvinyl chloride slip-joint nut fittings shall be installed at the end of each outlet pipe and vent pipe. 12

Section 68-3.04, "Measurement," and Section 68-3.05, "Payment," of the Standard Specifications are amended to read: 13

68-3.04 Measurement.--The various sizes of edge drains and edge drain outlets, vents, and cleanouts will be measured by the linear foot along the line of the pipe. The length to be paid for will be the slope length of the pipe designated by the Engineer. Pipe placed in excess of the length designated by the Engineer will not be paid for. Outlet pipe, vent pipe and cleanout pipe will be measured and paid for as plastic pipe (edge drain outlet). 13a

No deduction in the length of plastic pipe (edge drain) will be made for gaps in edge drain pipe at locations of dual outlet, dual vent, or dual outlet and vent connections to the edge drain. 13b

The "Y" fitting at cleanout pipes and at intermediate outlet connections will be measured and paid for as plastic pipe (edge drain outlet) between the couplings at each end of the curved section of the "Y" fitting, and as plastic pipe (edge drain) between the couplings at each end of the straight section of the "Y" fitting. 13c

68-3.05 Payment.--The contract price paid per linear foot for plastic pipe (edge drain) for the size or sizes shown in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in constructing edge drains, complete in place, including excavation (and removal of any concrete deposits that may occur along the edge of the concrete pavement in Type 1 installations) and asphalt concrete backfill for Type 1 edge drain installation, asphaltic emulsion for paint binder, filter fabric, and treated permeable material, as shown on the plans, as specified in these specifications and the special provisions, and as directed by the Engineer. 13d

The contract price paid per linear foot for plastic pipe (edge drain outlet) of the size or sizes shown in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in constructing edge drain outlets, vents, and cleanouts, complete in place, including outlet and vent covers when required, cleanout caps and expansion plugs, pavement markers, concrete splash pads, connecting outlets and vents to drainage facilities and excavation and backfill (aggregate base, asphaltic emulsion for paint binder, asphalt concrete, and native material) for outlets, vents, and cleanouts to be installed in embankments and existing shoulders, as shown on the plans, as specified in these specifications and the special provisions, and as directed by the Engineer. 13e

PART III - CONCRETE SHOULDER

This project was initiated in 1971 as a result of NEEP Project 7, "Concrete Shoulders," and a recommendation by the Portland Cement Association (PCA). In meetings with Caltrans design and construction engineers and the PCA, a detailed plan was developed. It was not until the summer of 1975, however, that construction of the project was completed.

The site selected for the project was on U.S. 101 in Sonoma County at Geyserville. The highway consisted of four to six lanes of PCC pavement with 5-foot inside or median shoulders and 10-foot outer shoulders. The concrete shoulder sections were constructed only on the outside 10 feet. Four 1,000-foot sections were constructed (separately from pavement construction) in each traffic direction. Variables were 1) no tie bars to pavement, joints not sealed; 2) no tie bars, joints sealed; 3) tie bars, joints sealed; and 4) tie bars, joints not sealed. The shoulder thickness was 0.75 foot (the same as the pavement) adjacent to the pavement and tapered to 0.50 foot at the outside edge. Cement treated base was not extended beyond the standard 1-foot outside the pavement edge, so most of the concrete shoulder was placed on aggregate base.

In addition to the concrete shoulders, approximately one mile of shoulder in each direction was constructed of full depth asphalt concrete (AC). Thickness varied from 0.75 foot adjacent to the pavement to 0.30 foot at the outer edge. The AC thickness for the outside 10-foot wide

standard shoulders on the project was 0.30 feet and for the inside shoulders it was 0.20 feet thick. Both were placed over aggregate base.

A survey of the project was made recently after about 10 years of service. Photographs were obtained of the individual test sections.

PCC Shoulder - No Joint Seal, No Tie Bars

The unsealed joints in and near the shoulder were generally filled with sand, gravel and other incompressibles. At the beginning of the section, the concrete shoulder had moved longitudinally over an inch with respect to the main line pavement due to incompressibles in the joints. Photos 1 through 4 show typical conditions of these sections.

PCC Shoulders - Joints Sealed, No Tie Bars

Photo 5 shows the preformed neoprene compression seal protruding from the shoulder edge of a transverse joint. The joint opening above the seal is filled with incompressibles. Photo 6 shows no significant separation between the mainline and shoulder, even without tie bars. The longitudinal joint is filled with a hot-pour elastomeric sealant.

PCC Shoulders - Joints Sealed, Tie Bars

Shoulder and mainline transverse joints are filled with neoprene compression seals. The longitudinal joint between the mainline and shoulder is filled with a hot-pour elastomeric sealant. All joints appear to be in good condition with no spalling or lane separation (see Photos 7 and 8).

Photo III-1. Beginning of Concrete Shoulder. No joint sealant, no tie bars.

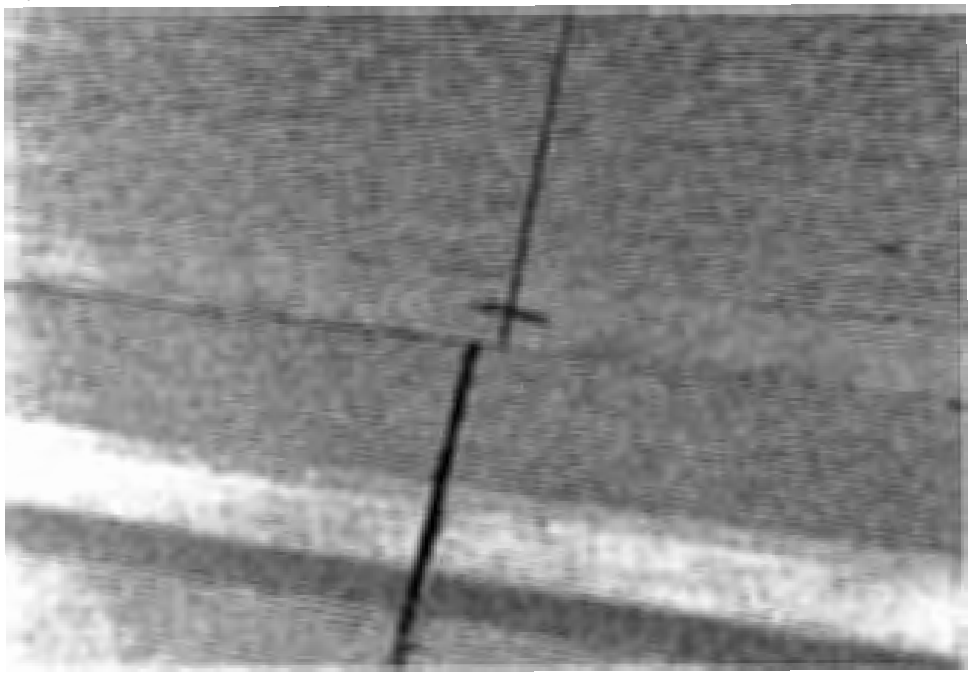


Photo III-2. Longitudinal offset of shoulder. Joint filled with incompressibles.

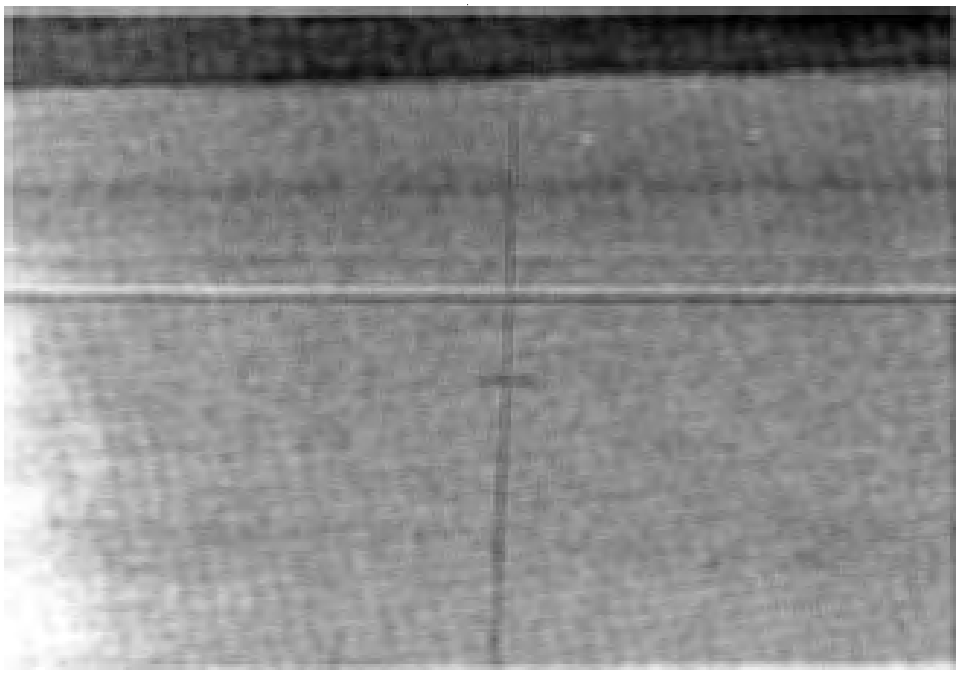


Photo III-3. Another shoulder joint filled with incompressibles.

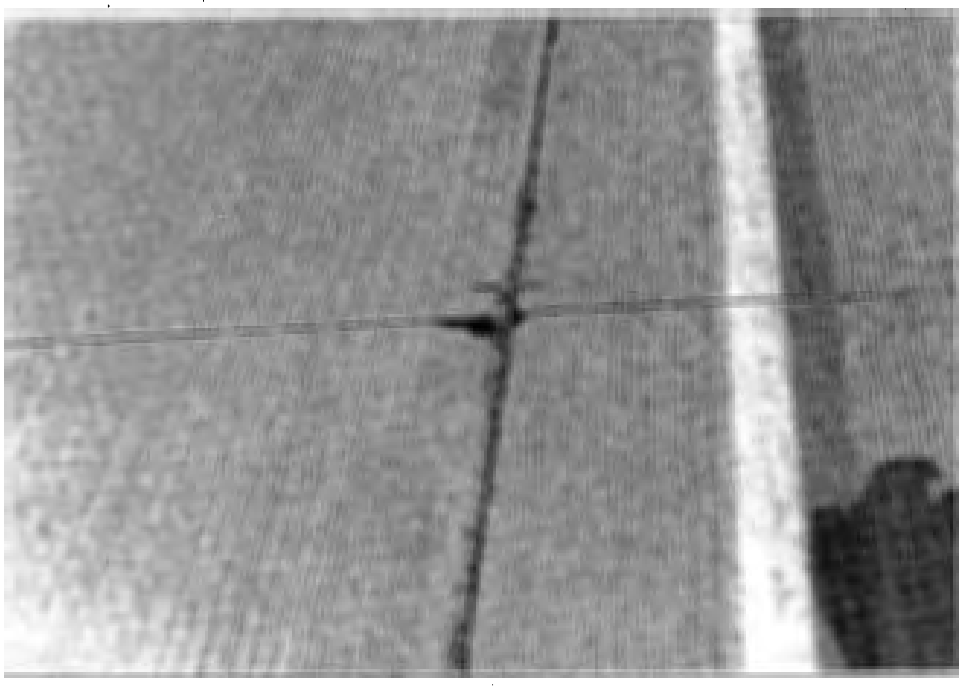


Photo III-4. Spalling of longitudinal joint between shoulder and mainline pavement.

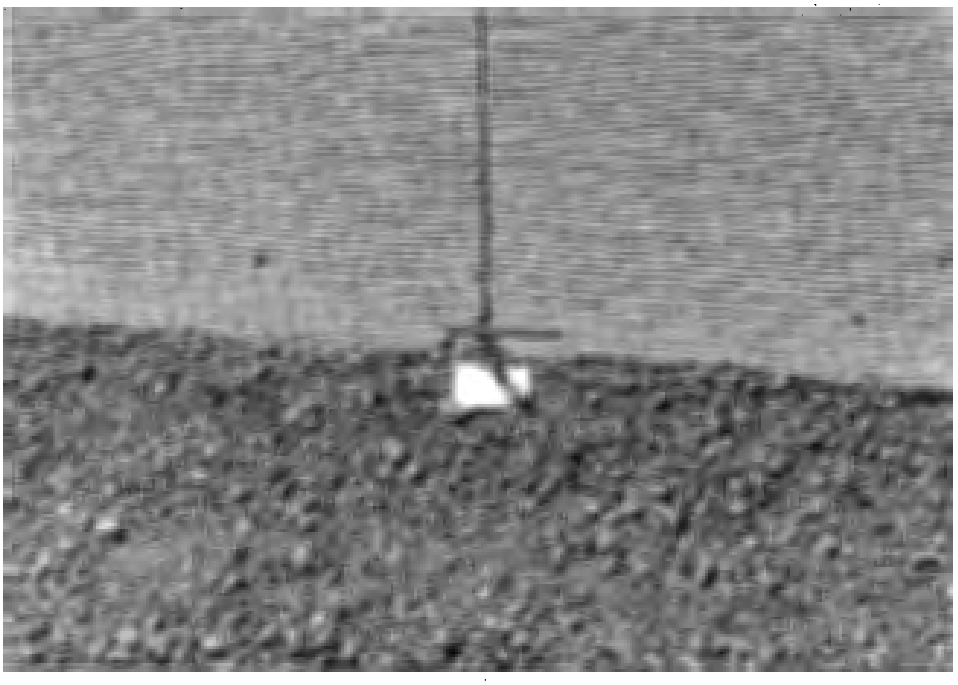


Photo III-5. Neoprene compression seal, no tie bars.

Photo III-6. Sealed longitudinal joint in good condition.

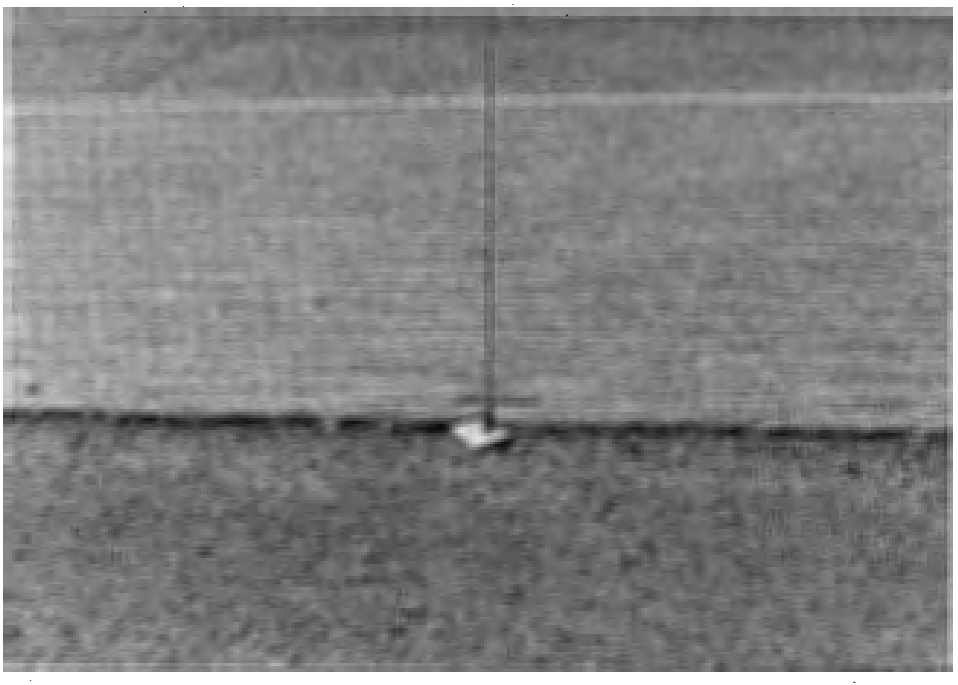


Photo III-7. Joint sealed, shoulder tied to mainline pavement.

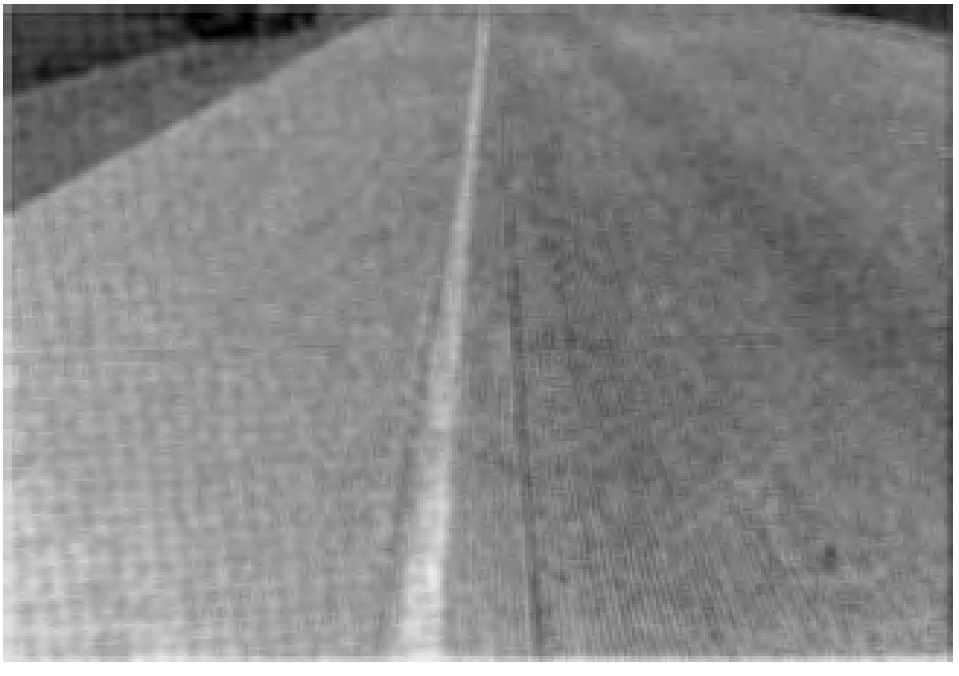


Photo III-8. Longitudinal joint in excellent condition.

PCC Shoulders - No Joint Seals, Tie Bars

The joints, especially in and near the shoulder, are full of incompressibles. There is no significant separation between the shoulder and mainline pavement (see Photos 9 and 10).

Full Depth AC Shoulder

Photos 11 and 12 show the typical condition of these sections. They appear to be performing satisfactorily, although some slight staining due to pumping is evident.

Control Sections

Performance of the standard shoulders is quite variable. Photos 13 and 14 show portions that look very good, but Photos 15 and 16 show damage due to pumping. A number of the shoulder depressions are between 2 and 3 inches in depth. The reason(s) for this difference in performance is not apparent.

Summary

Probably the best performing experimental shoulder section is the one with concrete shoulders with tie bars and all joints sealed. The full depth AC shoulders are also doing well. However, portions of the standard shoulder sections are also performing satisfactorily, and the standard shoulder is considerably cheaper to build. The primary problem with standard construction is pumping due to water under the pavement. The bid price for concrete shoulders on this project was about $27,000/mile. Thus, the use of standard shoulders with edge drains to remove the water would appear to be both cheaper and more effective.

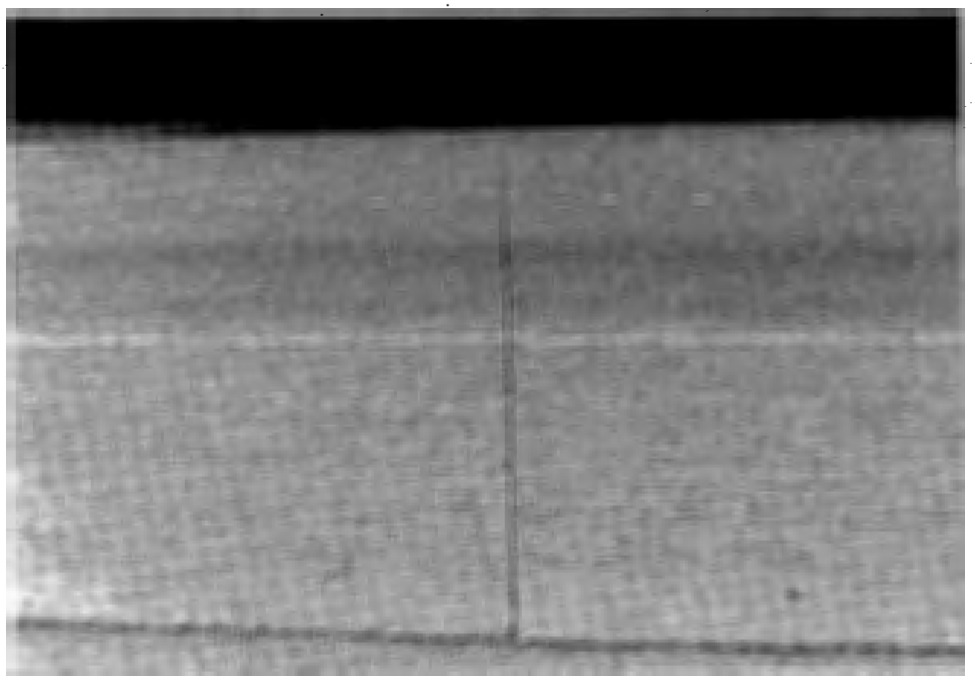


Photo III-9. Shoulder joint filled with incompressibles.

Photo III-10. Unsealed joint with untied shoulder shows slight separation with some spalling.

Photo III-11. Full Depth AC Shoulder.

Photo III-12. Same as III-11.

Photo III-13. Standard shoulder in good condition.

Photo III-14. Standard shoulder with slight staining from pumping.

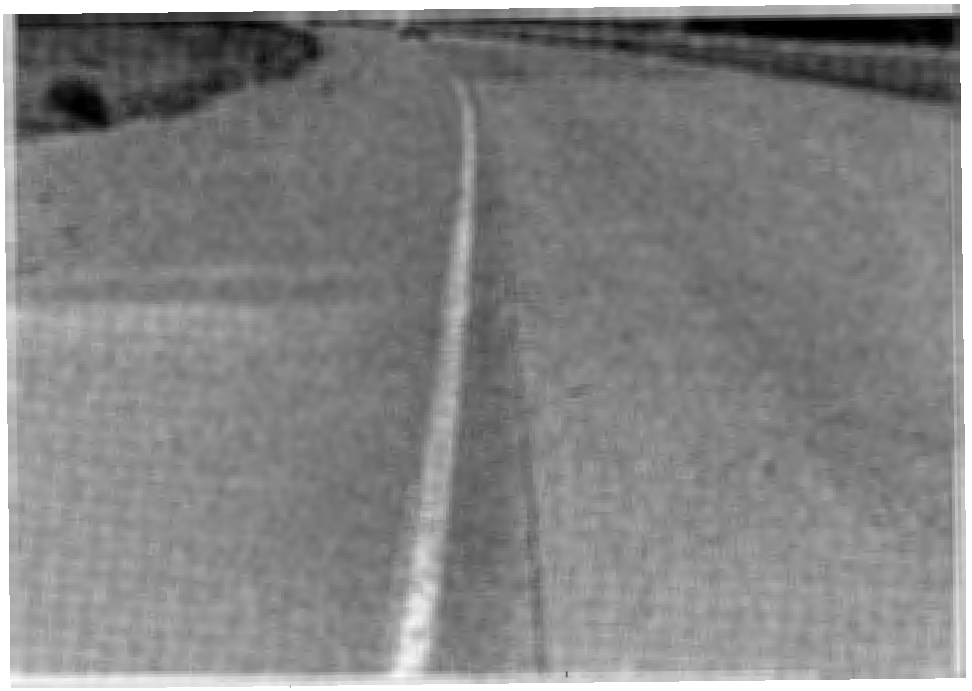


Photo III-15. Standard shoulder with heavier pumping stains and shoulder depressions at joints.

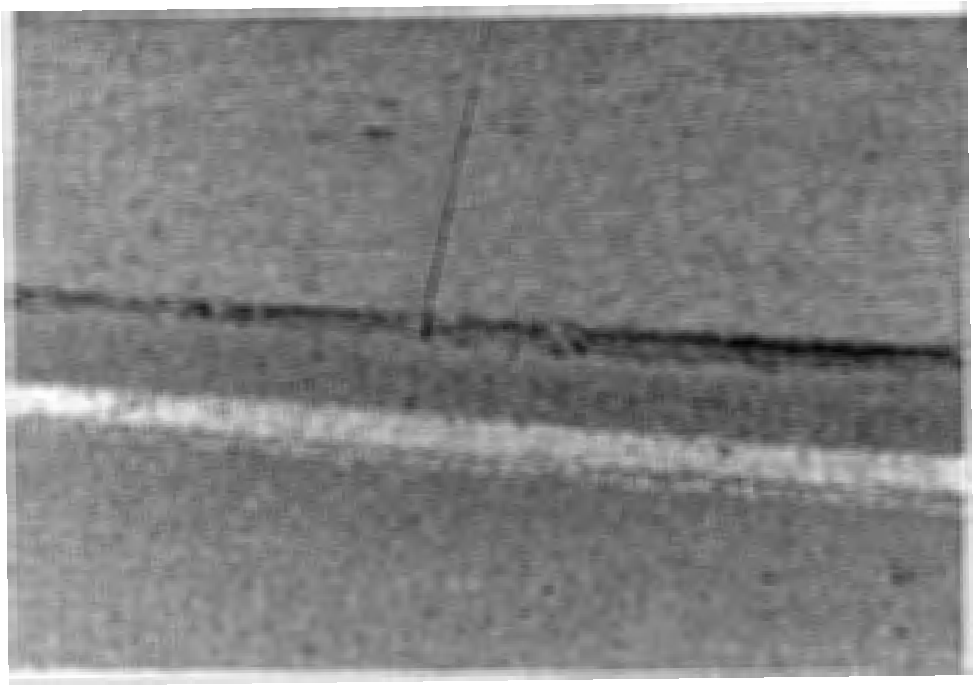


Photo III-16. Shoulder depressed over 2 inches.

PART IV - CONSTRUCTION-EVALUATED PROJECTS

Experimental Bridge Approach Slabs

In 1979, a contract was awarded to replace PCC pavement and bridge approach slabs on U.S. 101, the Ventura Freeway, in Los Angeles County. The section of highway involved was just west of I-405 and very heavily traveled. Because traffic conditions did not reasonably permit closing lanes during daylight hours, the project was scheduled for night construction, roughly during the hours from 9 p.m. to 6 a.m. This meant that accelerated-set concrete had to be used so that traffic could use the pavement after approximately four or perhaps five hours of curing time. For the pavement slabs, this was not considered a problem since a mix with 7 sacks of cement per cubic yard with 2% calcium chloride (by weight of cement) had been used extensively with no significant problems. However, since the bridge approach slabs are reinforced and chlorides cause corrosion of steel, an alternative procedure was needed.

Concrete made with calcium aluminate cement had been used in limited quantities with no particular problems and was, therefore, recommended for this project. Before construction, however, experience with additional mixes prepared under controlled conditions made it clear that the set time of concrete made with calcium aluminate cement can be very difficult to control, especially under field conditions. Also, control of the water-cement ratio and the temperature of the concrete during hydration of the cement and early curing is very critical. The water-cement ratio must not be allowed to exceed 0.40, including any water in the

aggregates. If the temperature of the concrete is allowed to exceed approximately 100°F, a crystaline conversion takes place that results in a loss of compressive strength of some 35 to 50%. To avoid excessive field problems, the number of planned approach slab replacements with this concrete was reduced from 24 to 6. This provided the opportunity to try other slab designs. The variables as actually built were:

Eastbound lanes, 2 bridges

Lane 1: PCC with calcium chloride, no reinforcement.
Lane 2: PCC with calcium chloride, epoxy coated steel.
Lane 3: Concrete with calcium aluminate cement, reinforcing steel.
Lane 4: PCC without calcium chloride, reinforced, min. 72 hour cure.

Westbound lanes, 1 bridge

Lanes 1, 2 and 3: PCC with calcium chloride, epoxy coated steel.
Lane 4: Concrete with calcium aluminate cement, reinforcing steel.

The amount of concrete removed each night was limited to that which could be replaced by 2 a.m. For the bridge approach slabs, this proved to be one slab 12 feet wide and 60 feet long. The pavement and cement treated base were removed, the subbase recompacted, and the new 12-18 inch thick slab placed. Transverse weakened plane joints to match adjacent slabs (approximately 15-foot spacing) were sawed the following night. Adjacent slabs were not tied or keyed to each other.

A few problems were encountered during construction. Due to the travel time and distance for the concrete trucks and the unpredictability of the setting time of calcium aluminate cement, the cement had to be added to the trucks at the job site. The delays resulted in numerous cold joints since the concrete from the first truck would be set before the next truck could be mixed and unloaded. Additional, less serious delays were also created by the need to add the calcium chloride at the job site.

Evaluating the performance of these experimental pavement slabs is complicated by the extremely heavy traffic and the lack of shoulders where a vehicle can be parked. To avoid the hazards involved with on-site surveys, an attempt was made in 1981 to utilize the photolog system which would allow a survey to be made by looking at photographs at one's leisure. The system normally snaps pictures each 0.01 mile traveled at highway speeds. To provide better detail, arrangements were made to have the pictures taken at intervals of 0.005 mile; i.e., about 26 feet. This was accomplished on a weekend to lessen interference from traffic.

While the pictures appeared clear enough, there was difficulty in distinguishing cracks from oil or asphalt streaks or other types of stains. Only a few cracks and one area patched with asphalt could be definitely identified so an on-site survey was made for comparison purposes. The slabs with calcium aluminate cement (Lane 3 EB, Lane 4 WB) were found to be in the worst condition with two or three cracks in each slab, and one slab that required patching due to excessive cracking and spalling. The next worst was the regular concrete without calcium chloride (Lane 4 EB), with

about two cracks per slab. There were no cracks in the slabs with calcium chloride and no reinforcement (lane 1, EB). Lane 2 (EB and WB), and Lane 3 WB with calcium chloride and epoxy coated reinforcement, had an average of one crack per slab.

Since lanes 3 and 4 get most of the truck traffic, the greater number of cracks in these lanes may be due in large part to the heavier traffic. However, due to the problems encountered during construction with the calcium aluminate concrete, and the relatively poor performance, further use is not being recommended at this time.

Asphalt Treated Permeable Base (ATPB) for PCC Pavement

For a number of years, ATPB has been used as a drainage blanket. At times, it has also been used as a base for asphalt concrete (AC) surfacing. In 1980, an opportunity arose to place the material under a PCC pavement on an experimental basis. Four short sections, each about 50 feet in length, were available, having been omitted during paving and used as temporary county road connections.

The ATPB was placed in these sections in lieu of the planned lean concrete base. The thickness of the sections was approximately 6 inches. Aggregate conforming to the following grading requirements was used:

Sieve Size	Percent Passing
1"	100
3/4"	90-100
3/8"	25-60
No. 4	0-15
No. 8	0-5

The asphalt was AR-4000, added at a rate of 2% by dry weight of the aggregate. The ATPB was placed with a paving machine moving transversely across the roadway and compacted with a four-ton roller after the material had cooled considerably. A heavier roller was tried first, but became stuck and had to have help to get out of the ATPB. Photos 1 through 4 show the placement of the material.

Concrete pavement was placed about three days after the ATPB. A nonwoven filter fabric was laid over the ATPB at two locations prior to paving. This was done to prevent intrusion of concrete mortar into the permeable material. There was concern that such an intrusion would adversely affect length measurements of PCC cores which are used to determine pay quantities for the PCC pavement. Lateral subgrade drains were placed under the shoulder in each section to drain water away from the permeable base.

Cores taken through the pavement and base following construction indicated that no mortar penetrated the fabric and entered the permeable material. Where no fabric was placed, penetration varied from zero to one inch. This variation is dependent on the slump of the concrete and the amount of vibration the concrete receives. A subsequent specification covering the use of ATPB and CTPB states that it is anticipated that concrete mortar will penetrate the permeable layer an average of approximately 0.03 foot.

After nearly five years of service, there is no significant difference in the performance of the experimental pavements compared to adjacent (standard construction) sections. However, on control sections for three of the four test sections, the shoulders have longitudinal cracking, while there is none in the shoulders adjacent to the test areas. The reason for this is not clear (see Photos 5 through 12).

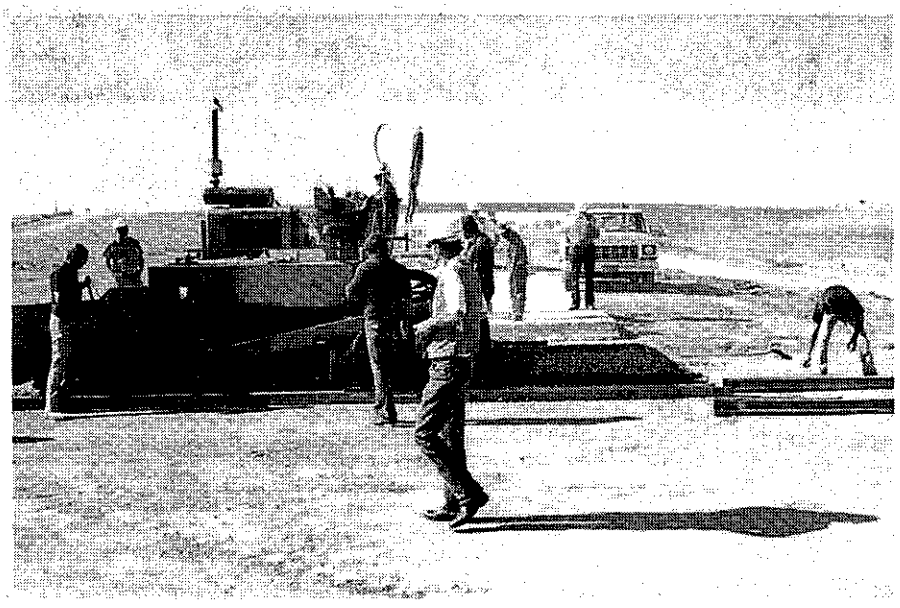


Photo IV-1. Machine placing ATPB.

Photo IV-2. ATPB directly behind machine.

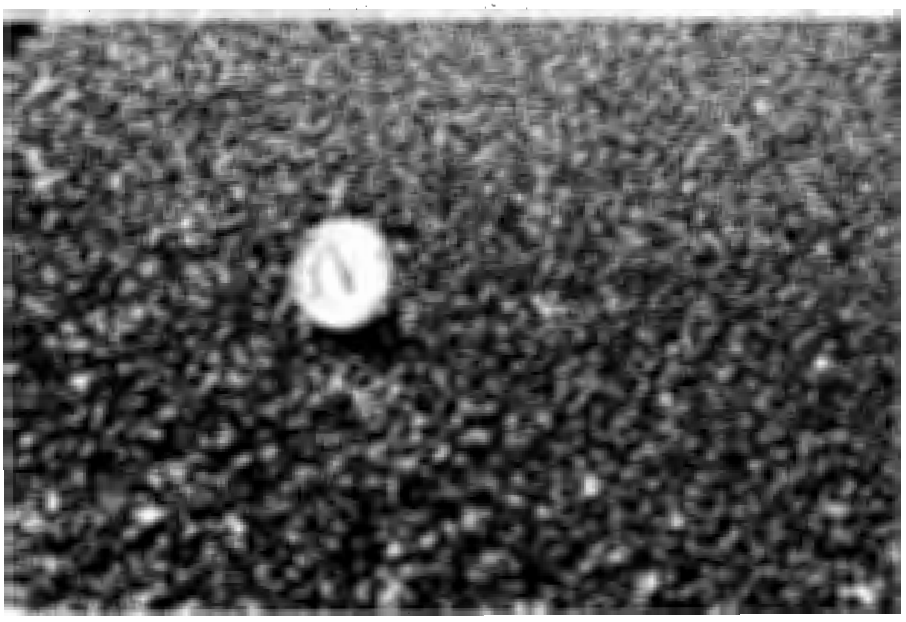


Photo IV-3. Close-up of ATPB and thermometer.

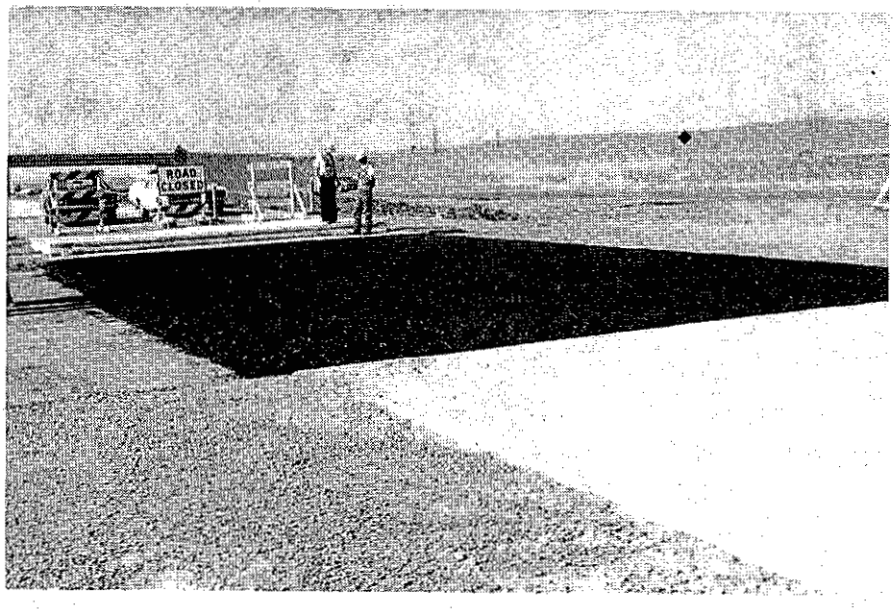


Photo IV-4. Completed ATPB base section.

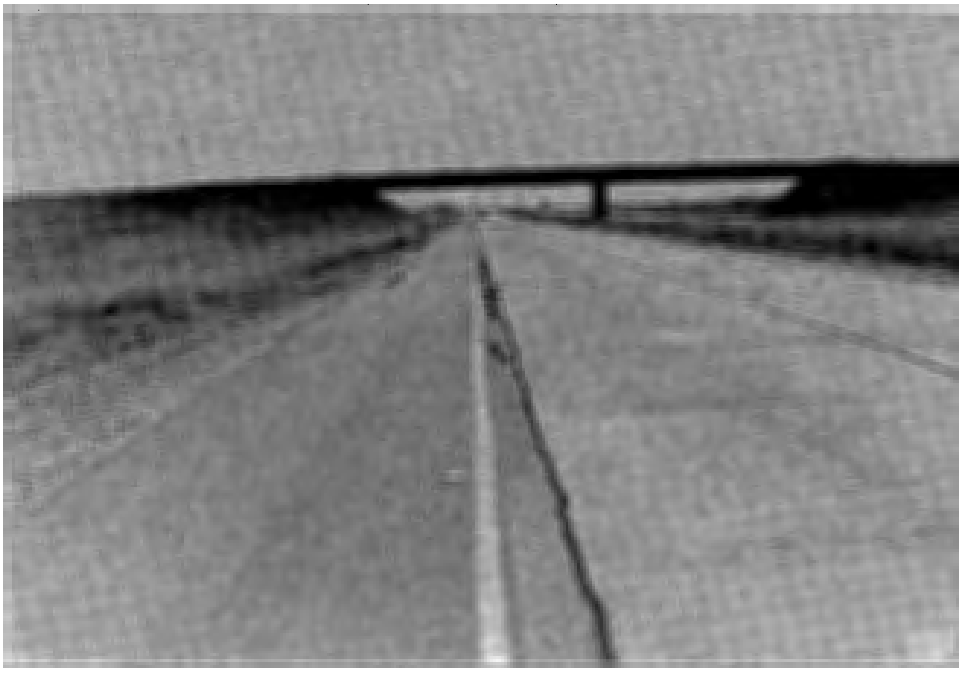


Photo IV-5. Looking south from end of ATPB base section. Note repaired cracks in adjacent control section.

Photo IV-6. Looking north from same spot as above. Pavement crack is in control area.

Photo IV-7. Looking north. No cracks in shoulder.

Photo IV-8. Looking south. Again, no cracks in shoulder.

Photo IV-9. Looking north. Cracks in shoulder of control area.

Photo IV-10. Looking south. Cracks in shoulder of control area.

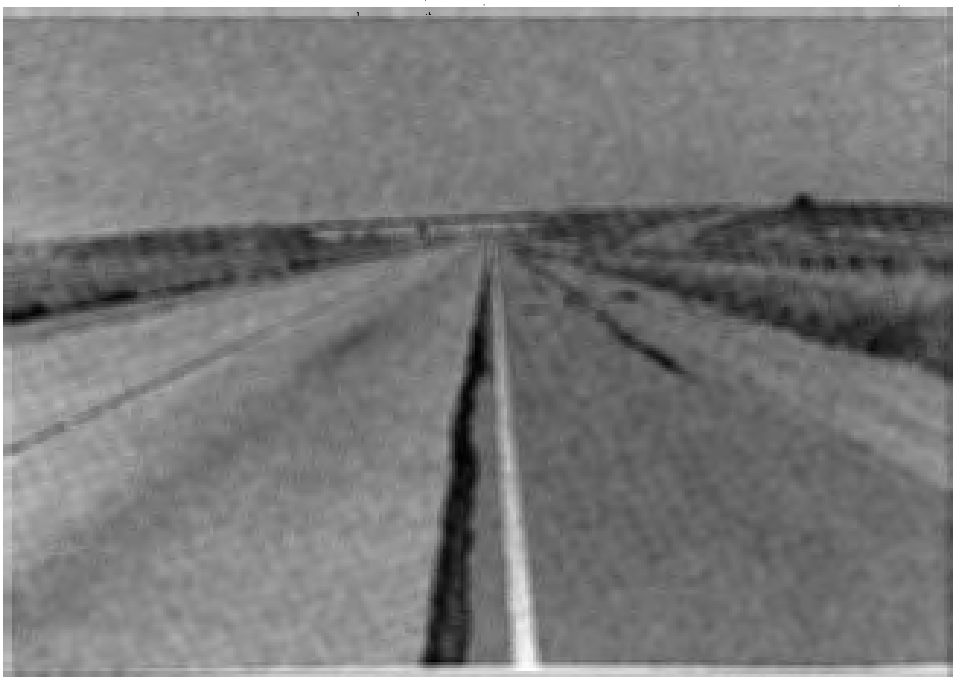


Photo IV-11. Looking north. Cracks in shoulder of control area.

Photo IV-12. Looking south. Car is parked at ATPB Section.

As stated above, Caltrans policy now generally requires the use of treated permeable base under PCC pavements. Penetration of the mortar into the surface voids is not considered a major problem, and the rapid removal of infiltrated water provides a major benefit in preventing pumping and the resultant pavement faulting. The asphalt treated permeable base also provides an erosion-resistant surface, another deterrent to pavement faulting. Caltrans specifications for ATPB are included in this report as Appendix IV-1.

Cement Treated Permeable Base (CTPB) Und r PCC Pavement

This project was constructed in 1980 under Contract Change Order on Interstate 210 near Los Angeles. Preliminary investigations had indicated that considerable ground water could be anticipated when two large cut sections were opened. The design of the subsurface drainage system was deferred to the construction stage so that the sources and magnitude of the ground water could be determined. Also, any detrimental lenses of expansive material could be removed.

During excavation operations, numerous ground water seepage areas were encountered flowing through fissures and fracture zones. After two years of observation, it was noted that considerable water was present year-round, with the flow increasing during winter rains and subsequent periods of high ground water.

Since horizontal drains and french drains had not been entirely successful in stabilizing cut slopes on adjacent projects, it was proposed to place a permeable layer under the pavement. Such a blanket could be expected to dewater the subgrade and eliminate the conditions which cause the pumping action that subsequently leads to pavement failures.

The CTPB blanket was placed 6-in. deep and 50-ft wide in one pass with a paving machine. This layer would not only drain ground water and surface infiltrated water, but also serve as a base for the PCC pavement. Before paving, a two-inch layer of AC was placed over the CTPB. Some 6,000 feet of the highway in each direction was constructed in this manner.

The CTPB was placed by the slipform paving machine without vibration to a thickness of 6-3/4 inches, then compacted with a light roller. Curing was accomplished by spraying with water periodically. No significant problems were encountered with this construction procedure. Current Caltrans specifications for CTPB are included in this report as Appendix IV-2.

To date, this drainage layer is working very well. Seepage groundwater drains out year-round as can be seen at the locations where collector pipes channel the water.

Summary

For bridge approach slab replacement where accelerated-set concrete is required, the calcium aluminate cement is not considered an acceptable material. Concrete with calcium chloride and epoxy coated reinforcement appears to be the more suitable method. While the approach slabs with calcium chloride concrete and no reinforcement are performing satisfactorily in the Number 1 lane, it is believed that reinforcement is needed for heavier traffic areas. The photolog system did not prove to be a satisfactory method of pavement surface evaluation.

The pavement and shoulders where ATPB was used as a base are performing as well as, or better than, those using lean concrete as a base. At three of the four ATPB locations, cracking is occurring in the adjacent shoulder sections, but stops short of the ATPB sections.

The CTPB drainage layer is performing very well also. Thus, current Caltrans practice is to require a treated permeable base (either ATPB or CTPB) beneath PCC pavement.

APPENDIX IV-1

ASPHALT TREATED PERMEABLE BASE

(Para 2 revised to set a fixed amount of asphalt and a method of adjusting the price for ordered changes. Use SSP 39.01.5)
(Delete Para 7 if automatic batch plant is not required.)
(Delete para 20 if not applicable.)
(Delete paras 17a and 21 if asphalt concrete will not be placed on the ATPB.)
(Delete paras 17b, 22 and 23 if portland cement concrete pavement will not be placed on the ATPB.)
(Use Item No. 290201 ASPHALT TREATED PERMEABLE BASE.)

29.05
3-28-85

10-1.___ ASPHALT TREATED PERMEABLE BASE.--Asphalt treated permeable base shall conform to the provisions for asphalt concrete in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

The aggregate shall be combined with 2 1/2 percent paving asphalt by weight of the dry aggregate, the exact amount will be determined by the Engineer. After testing samples of the Contractor's proposed aggregate supply, the Engineer may order an increase or decrease in the asphalt content. If such increase or decrease is ordered, and the increase or decrease exceeds the above specified amount by 0.1 percent by weight of the dry aggregate, the compensation payable to the Contractor for asphalt treated permeable base will be increased or decreased on the basis of the total increase or decrease in asphalt in the same manner as provided for any increase or decrease in asphalt in asphalt concrete in the section of these special provisions entitled "Asphalt Concrete". 2

Asphalt binder shall be Grade AR-8000 paving asphalt unless another grade is ordered by the Engineer. 3

Aggregate for asphalt treated permeable base shall conform to the following grading when determined by California Test 202. 4

Sieve Sizes	Percentage Passing
1"	100
3/4"	90-100
1/2"	35-65
3/8"	20-45
No. 4	0-10
No. 8	0-5
No. 200	0-2

The aggregate shall conform to the following quality requirements prior to the addition of the asphalt: 5

Test	California Test	Requirements
Percentage of Crushed Particles	205	90% Min.
Los Angeles Rattler		
Loss at 500 Rev.	211	45% Max.
Cleanness Value	227	57 Min.
Film Stripping	302	25% Max.

Aggregate need not be separated into sizes. The temperature of the aggregate before adding the binder shall be not more than 275° F. 6

If the Contractor selects the batch mixing method, asphalt treated permeable base shall be produced by the automatic batch mixing method as provided in Section 39-3.03A(1b), "Automatic Proportioning," of the Standard Specifications. 7

The asphalt content of the asphalt mixture will be determined, at the option of the Engineer, by extraction tests in accordance with California Test 310 or California Test 362 or by use of California Test 379. The bitumen ratio (pounds of asphalt per 100 pounds of dry aggregate) shall not vary by more than 0.5-pound of asphalt above or 0.5-pound of asphalt below the amount designated by the Engineer. Compliance with this requirement will be determined either by taking samples from trucks at the plant or from the mat behind the paver before rolling. If the sample is taken from the mat behind the paver, the bitumen ratio shall be not less than the amount designated by the Engineer, less 0.7-pound of asphalt per 100 pounds of dry aggregate. 8

The subgrade to receive asphalt treated permeable base, immediately prior to placing the asphalt treated permeable base thereon, shall conform to the compaction and elevation tolerances specified for the material involved and shall be free of loose or extraneous material. 9

Areas of the subgrade to receive asphalt treated permeable base which are lower than the grade established by the Engineer shall be filled with asphalt treated permeable base. Volumes of asphalt treated permeable base so placed will not be included in the volume calculated for payment. 10

Asphalt treated permeable base shall be placed only when the atmospheric temperature is above 40° F. 11

Asphalt treated permeable base shall be placed at a temperature of not less than 200° F. nor more than 250° F. Material stored in excess of 2 hours shall not be used in the work. 12

Asphalt treated permeable base shall be spread with an asphalt paver. The material shall be deposited directly from the haul vehicle into the hopper of the paving machine. The procedure in which material is deposited in a windrow, then picked up and placed in the asphalt paver with loading equipment will not be permitted. The material may be spread and compacted in one layer. 13

Compaction of the asphalt treated permeable base shall consist of one complete coverage with a steel-tired, 2-axle tandem roller weighing not less than 8 tons nor more than 10 tons. Rolling shall begin as soon as the mixture has cooled sufficiently to support the weight of the rolling equipment without undue displacement. 14

The finished surface of asphalt treated permeable base shall be uniform and shall not vary at any point more than 0.05-foot above or below the grade established by the Engineer. 15

Asphalt treated permeable base with a surface higher than 0.05-foot above the grade established by the Engineer shall be removed and replaced with asphalt treated permeable base which complies with these specifications, or if permitted by the Engineer, the high spots may be removed to within specified tolerance by any method that does not produce contaminating fines nor damage the base to remain in place. Grinding will not be permitted. 16

Hardened asphalt treated permeable base with a surface lower than 0.05-foot below the grade established by the Engineer shall be removed and replaced with asphalt treated permeable base which complies with these specifications, or if permitted by the Engineer, the low areas shall be filled with pavement material as follows: 17

When pavement material is asphalt concrete, the low areas shall be filled with asphalt concrete conforming to the requirements for the lowest layer of asphalt concrete to be placed as pavement. This shall be done as a separate operation prior to placing the lowest layer of pavement. 17a

When pavement material is portland cement concrete, the low areas shall be filled with pavement concrete at the time and in the same operation that the pavement is placed. 17b

Full compensation for filling low areas will be considered as included in the contract price paid per cubic yard for asphalt treated permeable base and no additional compensation will be allowed therefor. 17c

Care shall be exercised to prevent contamination of treated permeable base. Treated permeable base which, in the opinion of the Engineer, has been contaminated shall be removed and replaced by the Contractor at his expense. 18

Attention is directed to Section 7-1.02, "Weight Limitations," of the Standard Specifications. The second paragraph of said section is amended to read: 19

No traffic or Contractor's equipment will be permitted on the asphalt treated permeable base except for that equipment required to place the permeable base and the subsequent layer of pavement. Haul trucks shall enter onto and exit from the asphalt treated permeable base at the nearest practical point. Damage to the base shall be repaired promptly by the Contractor at his expense, as directed by the Engineer. 19a

Where longitudinal subgrade drain pipes or edge drain pipes are to be installed in the asphalt treated permeable base adjacent to the edge of pavement the asphalt treated permeable base outside the edge of traveled way may be placed in a separate operation. Such base shall be placed and compacted by methods that will produce a firm material of uniform density. 20

When asphalt concrete is placed directly upon the asphalt treated permeable base the asphalt concrete shall be placed with a paver equipped with tracks unless the layer being placed is 0.15-foot or less in compacted thickness. 21

It is anticipated that when portland cement concrete pavement is placed over asphalt treated permeable base the concrete will penetrate the treated permeable base an average of approximately 0.03-foot. Volumes of portland cement concrete that penetrate the asphalt treated permeable base will not be included in the volume of concrete pavement to be paid for. 22

When cores are taken to determine the thickness of portland cement concrete pavement it is anticipated a layer of asphalt treated permeable base will adhere to the bottom of the core. Prior to determining the thickness of the portland cement concrete pavement all particles of asphalt treated permeable base will be removed from the bottom of the core. 23

The quantity of asphalt treated permeable base to be paid for will be measured by the cubic yard. The volume to be paid for will be calculated on the basis of the dimensions shown on the plans adjusted by the amount of any change ordered by the Engineer. No allowance will be made for asphalt treated permeable base placed outside said dimensions unless otherwise ordered by the Engineer. 24

The contract price paid per cubic yard for asphalt treated permeable base shall include full compensation for furnishing all labor, materials (including paving asphalt) tools, equipment and incidentals, and for doing all the work involved in constructing asphalt treated permeable base, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer. 25

APPENDIX IV-2

CEMENT TREATED PERMEABLE BASE

(Delete Para. 17 if not applicable.)
(Delete Paras. 7, 19, 20, 23b, 25, and 26 and "and asphaltic emulsion" from Para. 28 if portland cement concrete pavement will not be placed on the CTPB.)
(Delete Para. 23a if asphalt concrete pavement will not be placed on the CTPB.)
(Use 290301 Cement Treated Permeable Base.)

29.10
7-3-84

10-1.____ CEMENT TREATED PERMEABLE BASE.--This work shall consist of constructing a cement treated permeable base to the lines, grades and dimensions shown on the plans and in accordance with the Standard Specifications and these special provisions.

Cement treated permeable base shall consist of a mixture of aggregate, portland cement and water. 2

The portland cement content of cement treated permeable base shall be not less than 282 pounds per cubic yard. 3

MATERIALS.--Portland cement shall be Type II Modified conforming to the provisions in Section 90-2.01, "Portland Cement," of the Standard Specifications. Pozzolan shall not be substituted for portland cement. 4

Water shall conform to the provisions in Section 90-2.03, "Water," of the Standard Specifications. 5

Aggregate shall conform to the provisions in Sections 90-2, "Materials," and 90-3, "Aggregate Gradings," of the Standard Specifications. The grading of the aggregate shall conform to the 1" x No. 4 primary aggregate nominal size coarse aggregate grading. 6

Asphaltic emulsion shall be SS1h conforming to the provisions in Section 94, "Asphaltic Emulsions," of the Standard Specifications. 7

SUBGRADE.--The subgrade to receive cement treated permeable base, immediately prior to placing the cement treated permeable base thereon, shall conform to the compaction and elevation tolerances specified for the material involved, shall be free of loose or extraneous material, and shall be uniformly moist. 8

Areas of the subgrade to receive cement treated permeable base which are lower than the grade established by the Engineer shall be filled with cement treated permeable base. Volumes of cement treated permeable base so placed will not be included in the volume calculated for payment. 9

PROPORTIONING, MIXING AND TRANSPORTING.--Proportioning cement treated permeable base shall conform to the requirements for proportioning concrete pavement in Section 90-5, "Proportioning," of the Standard Specifications except that dividing of aggregate into sizes will not be required. 10

Mixing and transporting cement treated permeable base shall conform to the requirements for mixing and transporting concrete in Section 90-6, "Mixing and Transporting," of the Standard Specifications except that the requirements concerning amount of water and penetration in Section 90-6.06, "Amount of Water and Penetration," shall not apply. 11

The water-cement ratio (the ratio of the amount of water, exclusive only of that absorbed by the aggregates, to the amount of cement, by weight) shall be approximately 0.43. The exact water-cement ratio will be determined by the Engineer. 12

PLACING.--Placing of cement treated permeable base shall conform to the requirements for placing concrete pavement in Section 40-1.06, "Placing," of the Standard Specifications except that the third paragraph in said Section 40-1.06 shall not apply. 13

SPREADING, COMPACTING AND SHAPING.--Cement treated permeable base shall be spread, compacted and shaped in accordance with the requirements for spreading, compacting and shaping concrete pavement in the first and fourth paragraphs of Section 40-1.07, "Spreading, Compacting and Shaping," of the Standard Specifications except that vibrators shall not be used. 14

Compaction shall be performed with a 2-axle steel-tired roller weighing not less than 6 tons nor more than 10 tons. Compaction shall follow within one-half hour after the spreading operation and shall consist of 2 complete coverages of the treated material. 15

The finished surface of cement treated permeable base shall be uniform and shall not vary at any point more than 0.05-foot above or below the grade established by the Engineer. 16

Where longitudinal subgrade drain pipes or edge drain pipes are to be installed in the cement treated permeable base adjacent to the edge of pavement the cement treated permeable base outside the edge of traveled way may be placed in a separate operation. Such base shall be placed and compacted by methods that will produce a firm material of uniform density. 17

CURING.--The completed cement treated permeable base shall be cured by sprinkling the surface with a fine spray of water every 2 hours for a period of 8 hours. Curing shall start the morning after the base has been placed. 18

Prior to placing portland cement concrete pavement on cement treated permeable base the surface of the base shall be covered with SS1h asphaltic emulsion to facilitate measuring pavement thickness. The asphaltic emulsion shall be applied uniformly at a rate of between 0.10- and 0.20-gallon per square yard. The exact rate will be determined by the Engineer. 19

Damage to the asphaltic emulsion shall be repaired prior to placing pavement over the cement treated permeable base. 20

Care shall be exercised to prevent contamination of cement treated permeable base. Cement treated permeable base which, in the opinion of the Engineer, has been contaminated shall be removed and replaced by the Contractor at his expense. 21

SURFACES NOT WITHIN TOLERANCE.--Hardened cement treated permeable base with a surface higher than 0.05-foot above the grade established by the Engineer shall be removed and replaced with cement treated permeable base which complies with these specifications, or if permitted by the Engineer, the high spots may be removed to within specified tolerance by any method that does not produce contaminating fines nor damage the base to remain in place. Grinding will not be permitted. 22

Hardened cement treated permeable base with a surface lower than 0.05-foot below the grade established by the Engineer shall be removed and replaced with cement treated permeable base which complies with these specifications, or if permitted by the Engineer, the low areas shall be filled with pavement material as follows: 23

When pavement material is asphalt concrete, the low areas shall be filled with asphalt concrete conforming to the requirements for the lowest layer of asphalt concrete to be placed as pavement. This shall be done as a separate operation prior to placing the lowest layer of pavement. 23a

When pavement material is portland cement concrete, the low areas shall be filled with pavement concrete at the time and in the same operation in which the pavement is placed. 23b

Full compensation for filling low areas will be considered as included in the contract price paid per cubic yard for cement treated permeable base and no additional compensation will be allowed therefor. 23c

WEIGHT LIMITATIONS.--Attention is directed to Section 7-1.02, "Weight Limitations," of the Standard Specifications. The second paragraph of said section is amended to read: 24

No traffic or Contractor's equipment will be permitted on the cement treated permeable base except for that equipment required to place the permeable base and the subsequent layer of pavement. Haul trucks shall enter onto and exit from the cement treated permeable base at the nearest practical point. Damage to the base shall be repaired promptly by the Contractor at his expense, as directed by the Engineer. 24a

PAVEMENT THICKNESS.--It is anticipated that when portland cement concrete pavement is placed over cement treated permeable base the concrete will penetrate the cement treated permeable base an average of approximately 0.03-foot. Volumes of portland cement concrete that penetrate the cement treated permeable base will not be included in the volume of concrete pavement to be paid for. 25

When cores are taken to determine the thickness of portland cement concrete pavement it is anticipated a layer of cement treated permeable base will adhere to the bottom of the core. Prior to determining the thickness of the portland cement concrete pavement all particles of cement treated permeable base will be removed from the bottom of the core. 26

MEASUREMENT.--The quantity of cement treated permeable base to be paid for will be measured by the cubic yard. The volume to be paid for will be calculated on the basis of the dimensions shown on the plans adjusted by the amount of any change ordered by the Engineer. No allowance will be made for cement treated permeable base placed outside said dimensions unless otherwise ordered by the Engineer. 27

PAYMENT.--The contract price paid per cubic yard for cement treated permeable base shall include full compensation for furnishing all labor, materials (including cement and asphaltic emulsion) tools, equipment and incidentals, and for doing all the work involved in constructing cement treated permeable base, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer. 28