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This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

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The test sections were originally designed to accommodate roughly 10,000,000 EWL's which is equivalent to 10 a year Traffic Index of about 9.0. The performance of the test road after reaching the number of design EWL's was satisfactory for all structural types. However, after 15 years of service the treated base sections showed better performance than the untreated base sections.

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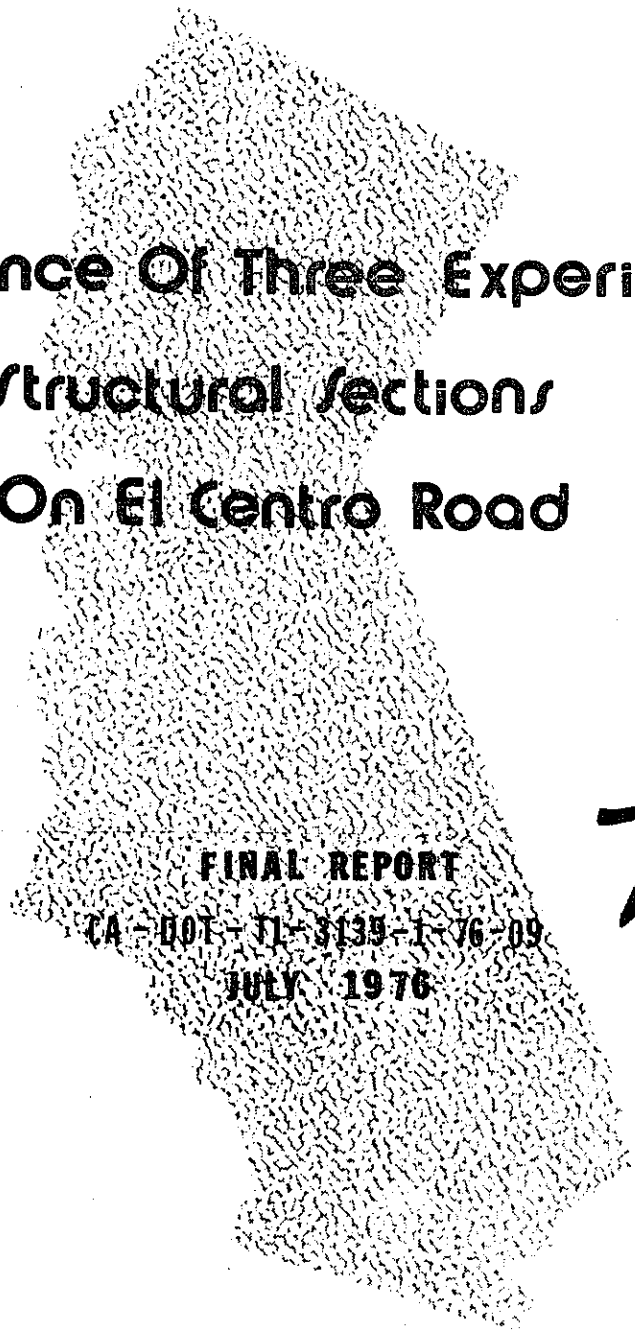
DIVISION OF STRUCTURES AND ENGINEERING SERVICES

TRANSPORTATION LABORATORY

RESEARCH REPORT

Performance Of Three Experimental Structural Sections On El Centro Road



FINAL REPORT

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JULY 1976

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Prepared in Cooperation with the U.S. Department of Transportation,

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CALIFORNIA DEPARTMENT OF TRANSPORTATION

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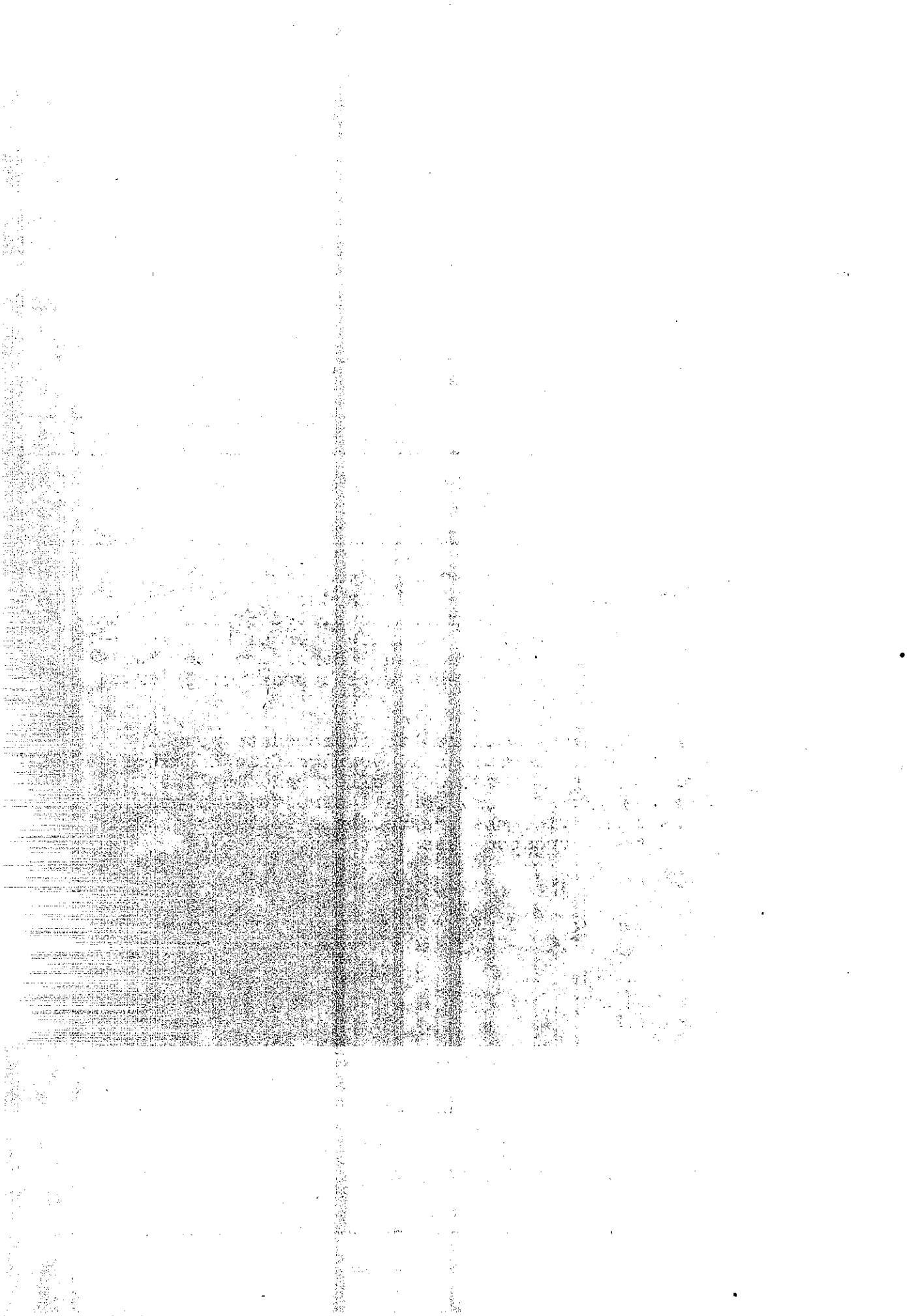

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES & ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

July 1976

FHWA NO. D-4-138
TL No. 633139

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

PERFORMANCE OF THREE EXPERIMENTAL STRUCTURAL SECTIONS ON EL CENTRO ROAD

Study made by	Roadbed & Concrete Branch
Under the Supervision of	John B. Skog and Donald L. Spellman
Principal Investigator	James A. Matthews
Co-Investigators	Roy W. Bushey and Donald V. Roberts
Report Prepared by	Gary W. Mann, Charles A. Curtis and Donald V. Roberts

Very truly yours,

George A. Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

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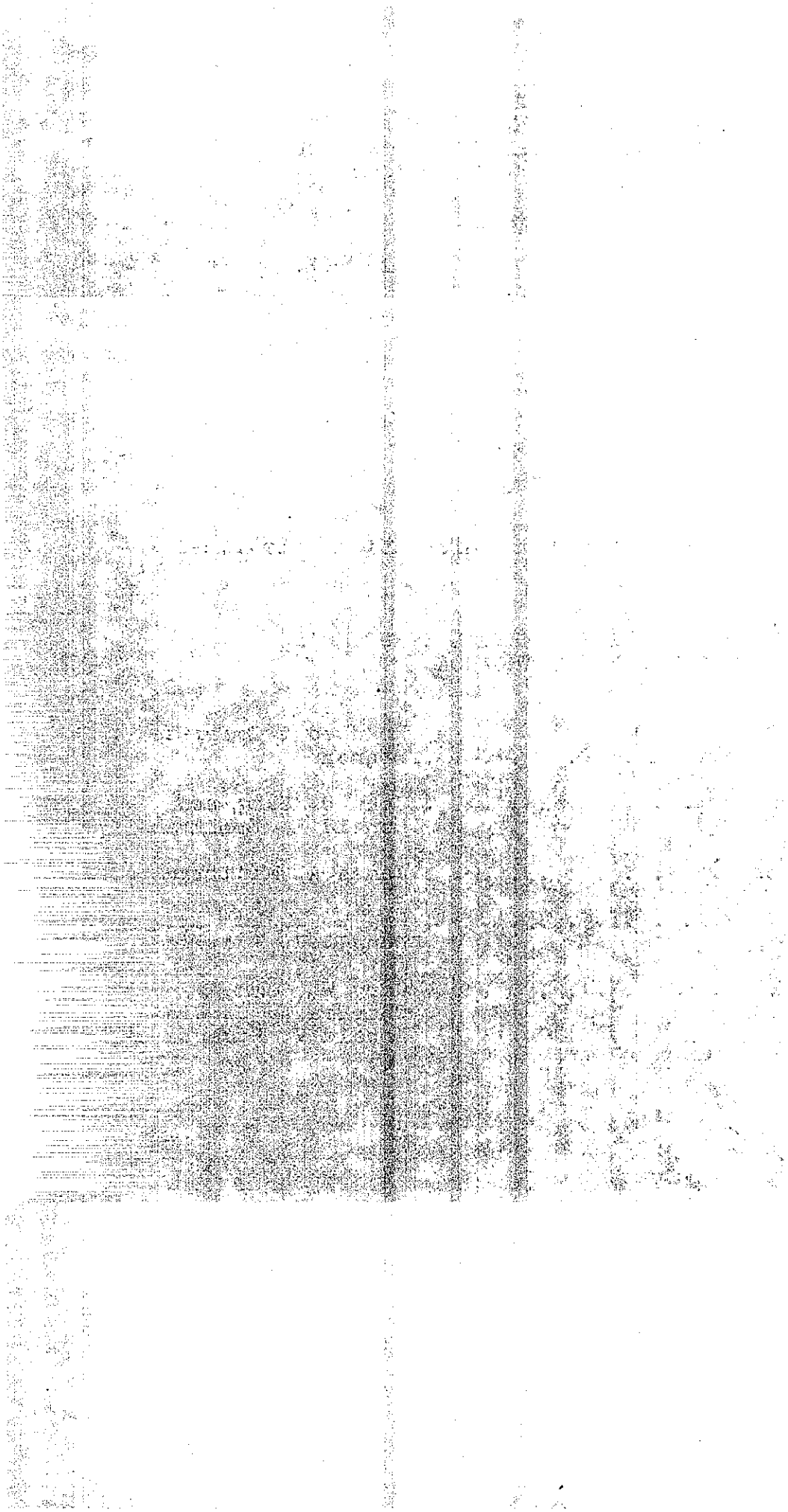

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The contents of this report reflect the views of the Transportation Laboratory which is responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. The report does not constitute a standard, specification, or regulation.

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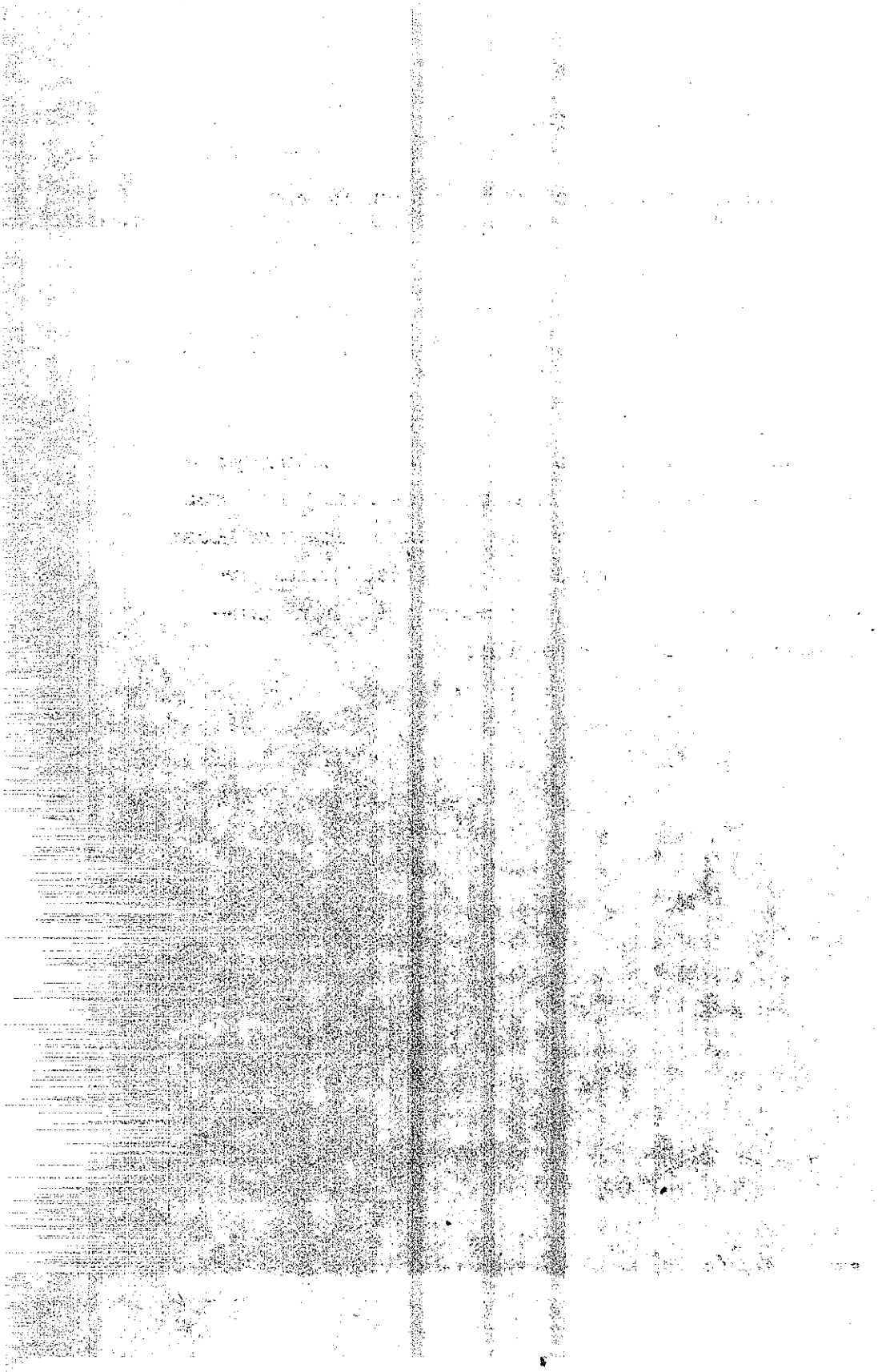

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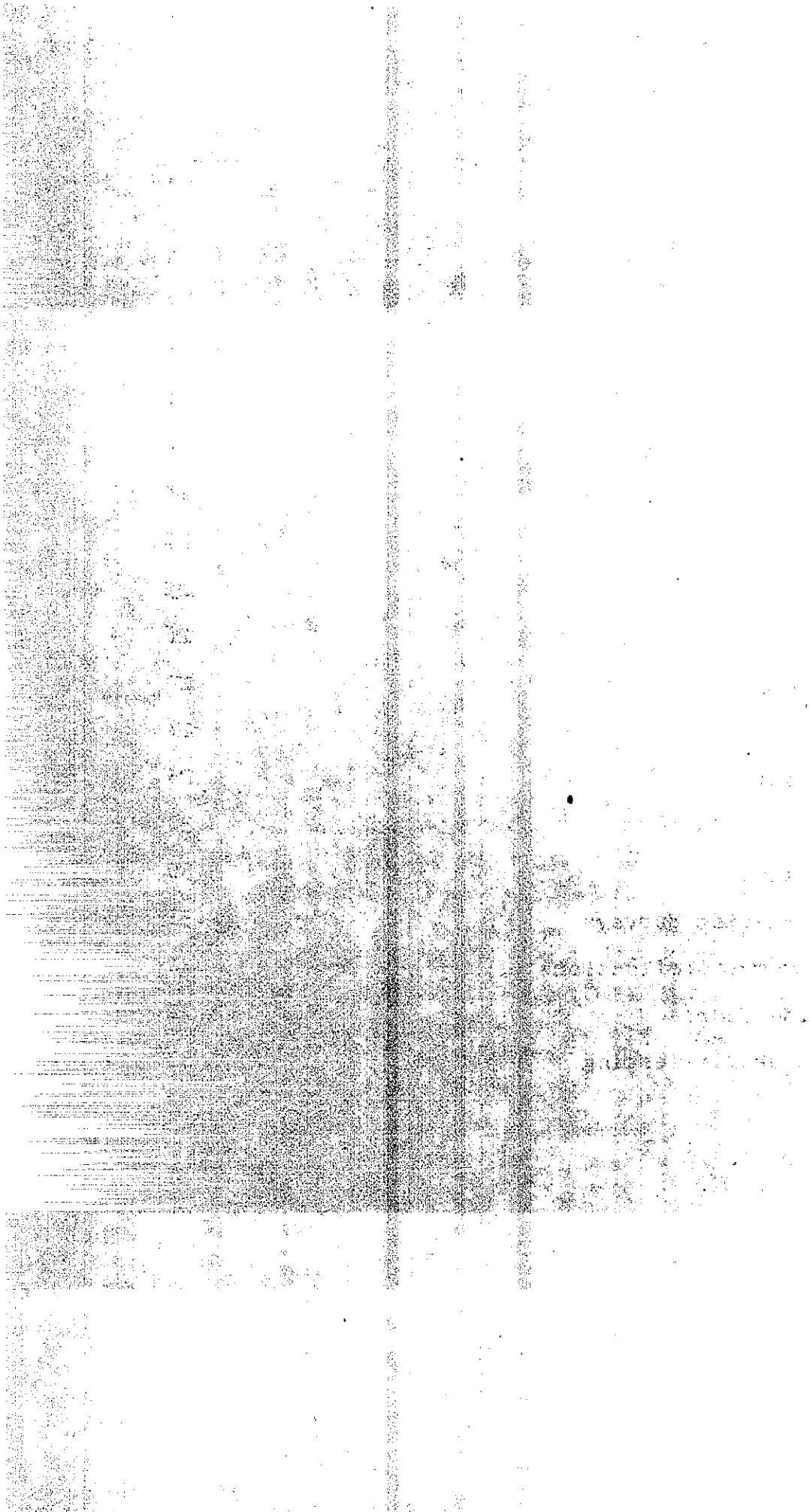

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INTRODUCTION

In June of 1970 an interim report titled "Deflection Studies Performed on El Centro Road (03-Sac-99) Ten Year Report" was published, which evaluated the capacity to reduce pavement deflections of three different types of structural sections constructed over highly resilient soils (1). The study was a result of earlier work by F. N. Hveem and R. M. Carmany (2) recognizing the importance of plastic deformation and the need for a solution to the problem of pavement fatigue failures. A later report by F. N. Hveem (3) offered the following three solutions for preventing fatigue failures: provide a pavement that is sufficiently flexible to accommodate repeated substantial vertical deflections without serious cracking; decrease the magnitude of the vertical deflections to a tolerable amount by providing greater stiffness with greater depths of granular bases and subbases under the pavement; or provide a pavement with a slab strength sufficient to sustain the forces induced by traffic which cause cracking.

During 1959 and 1960, a test road was constructed over the existing roadway on State Route 99, El Centro Road, utilizing cement treated base (CTB), asphalt concrete base (ACB), and aggregate base (AB) sections. The new structural sections were designed so that gravel equivalents were approximately equal for the three types of layered systems. The primary objectives for the test road at that time were:

1. To determine the reduction in deflection achieved by adding layers of various materials to the structural section.

2. To determine the range of deflections that could be expected on the existing roadway at various times during the year.

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3. To determine the time required for a cement treated base section to cure sufficiently to reduce deflection.

4. To investigate the adequacy of our present criteria for maximum permissible deflections of various structural sections.

Other objectives were formed after the project was underway. These objectives were:

1. To determine the effect of temperature on deflection measurements.

2. To compare the performance of high quality and low quality CTB.

The performance of each of the test sections was observed and deflection measurements were made annually from 1959 to 1969. It was estimated that by 1968 the total traffic loading had reached the 10,000,000 EWL's for which the road was designed. Based on this information, the following conclusions were made for the June 1970 interim report:

1. The deflections were reduced as each layer of structural section was added. The actual deflection reductions agreed reasonably well with the expected reductions. The CTB sections reduced deflections a greater amount than the other two base sections.

2. The average deflections of individual test sections on the original road varied from 0.037 to 0.087 inch (0.9 to 2.2 mm). There was also a seasonal variation in the deflections. The largest deflections occurred during the spring and apparently resulted from high moisture contents in the base and underlying soil.

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3. The cement treated base layer gained most of its resistance to deflection within four days after being placed.

4. The performance of the test sections exceeded the performance predicted by current California deflection design criteria. These criteria, however, were established from many projects on a Statewide basis. Many of these projects had poorer performance than El Centro Road. It appears that other factors need to be considered, along with deflection, to accurately predict pavement performance.

5. Temperature directly affected deflection readings. An increase in temperature increased the deflections. The deflections on the ACB sections changed about 0.0005 inch (0.01 mm) for each 1°F of change in 5 day average mean temperature. The temperature had less influence on the deflections of the cement treated base and aggregate base sections than it did on the deflections of the asphalt concrete base sections.

6. After 10 years (over 10,000,000 EWL's) traffic had not induced failures in any of the sections.

7. In order to fully meet the objectives of this study, the performance of this test road needs to be evaluated yearly until failures occur.

In 1964, El Centro Road was adopted as part of California's "Statewide Flexible Pavement Performance and Deflection Study" (4, 5, 6). Pavement deflections, surface condition surveys, and in-place samples of the materials of the structural sections were taken on a regular basis to help evaluate the performance of the experimental test sections.

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In November of 1972, a pavement deflection study was requested by the local highway district for El Centro Road. An evaluation of the test road and overlay recommendations were made. At that time, rather extensive alligator cracking was observed on the aggregate base test sections.

District plans were to widen and resurface the test road area in the fall of 1974. During the spring of 1974 this study was initiated to summarize the performance of the three experimental structural sections such that a final analysis could be made before reconstruction.

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CONCLUSIONS

1. All test sections performed on an essentially maintenance cost free basis for their designed traffic service life of 10,000,000 EWL repetitions (1960-1968). However, after 15 years of service the two treated type base test sections have performed better than the aggregate base test sections.

2. From 1970-1975, all the experimental test sections required minor maintenance work consisting of crack scaling and/or skin patching. It was noted, however, that the untreated base sections required more maintenance than the treated base test sections.

3. The cement treated base sections was the most effective in reducing deflection (see Figure 7).

4. The results of a deflection study during 1972 indicated that structural rehabilitation of the experimental test sections for an additional 10-year service life would require the following overlay on each section:

Aggregate Base	0.30 ft. (9.1 cm)
Asphalt Concrete Base	0.15 ft. (4.6 cm)
Cement Treated Base*	0.10 ft. (3.0 cm)

*Petromat fabric was used on portions of this section to control reflection cracking.

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IMPLEMENTATION

Findings of the study were used to assist in making refinements to California's overlay design method. Adjustments were made to the tolerable deflection chart and the asphalt concrete overlay design guide as shown in Test Method No. Calif. 356-E.

The results of this study will also be provided to the Division of Project Development of the Department of Transportation. This section is responsible for the design methods incorporated into the Highway Design Manual.

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BACKGROUND INFORMATION

The test road location for the original study (1) was selected for several reasons. The roadway exhibited high deflection, had the need for major reconstruction, and was conveniently located.

This portion of Route 99, known locally as El Centro Road, served as the main connection between Sacramento and Marysville until 1968. With the completion of Interstate 5, portions of the test road were no longer subjected to heavy traffic.

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The road traverses low farmland which has an average annual rainfall of about 18 inches (46 cm). Much of the area is flood irrigated rice fields with deep drainage ditches parallel to the road on both sides throughout most of its length. Photographs of the reconstructed road are shown in Figures 1 and 2.

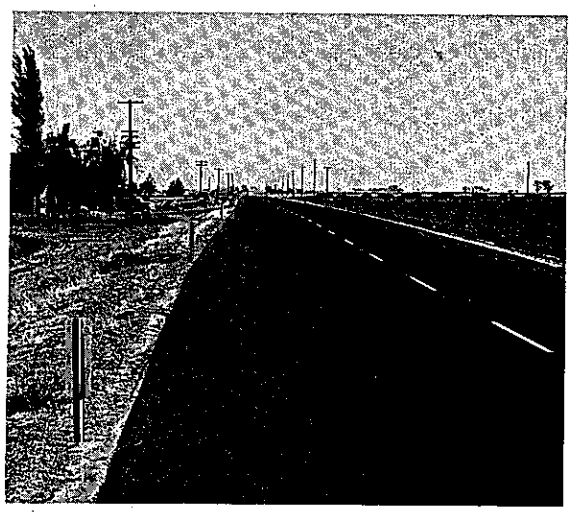

Figure 1 - Typical Area Without Drainage Ditch (Looking North From Station 28+70)

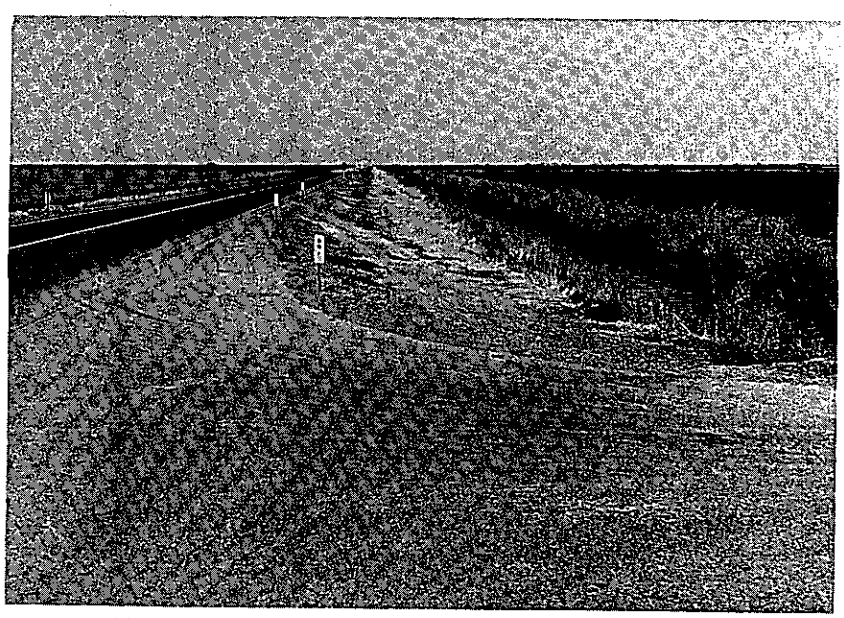

Figure 2 - Drainage Canal Parallel to Road (Looking North From Elverta Road)

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At the time El Centro Road was adopted into the State highway system, the existing structural section consisted of approximately 3/4 inch (1.9 cm) armor coat surfacing, 6 inches (15 cm) of aggregate base material (sand and gravel) and 9 inches (23 cm) of imported subbase material (sand). Native soils in the area are poor quality clay having R-values less than 5. El Centro Road was constructed by Sacramento County between 1949 and 1953 and no major improvements were made prior to the time of the reconstruction in 1959 and 1960. Sampling and testing of the in-place materials indicated that the R-values and resilience characteristics of the native soils, imported subbase, and aggregate base were reasonably uniform throughout the length of the test sections. Test results for existing materials prior to the 1959 reconstruction are summarized in Tables 1 through 3.

Prior to reconstruction, this road was in poor condition due to insufficient cover over the low quality basement soil. The traveled way was cracked, deformed and costly to maintain. Many deflection measurements, taken on the existing road, were quite large.

As plans were being made for the 1959 reconstruction of El Centro Road, it was decided to try three different structural section designs to determine which type would be the most effective in reducing high deflections. The primary difference in the sections was the type of base used. Based on the 1957 California design method, a traffic volume of 10,000,000 EWL's was estimated for the 1960 to 1970 design life. Projections from truck counts made in 1959 and 1963 indicate that the design EWL's was reached around 1968.

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TABLE 1

TEST RESULTS OF
EXISTING BASEMENT SOIL

Station	Grading			SE	PI	R-value	Resilience*
	#4	#30	#200				
323+10	99	99	75	6	19	6	High
342+00	99	92	33	3	25	8	High
350+30	100	99	85	5	38	3	High
351+80	100	99	92	5	34	7	High
373+30	100	99	86	4	21	6	High
397+35	100	97	78	6	19	9	High
411+90	82	76	62	6	18	8	High
437+70	100	95	62	9	12	15	High
438+70	100	96	72	5	19	13	High
467+60	100	96	61	8	17	3	High

*A criteria developed in the Roadbed and Concrete Branch of the Transportation Laboratory to classify the rebound characteristics of different materials.

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TABLE 2

TEST RESULTS OF
EXISTING IMPORTED SUBBASE MATERIAL

Station	Grading 3/4"	#4	#30	#200	SE	R-value	Resilience*
323+10	100	100	96	14	47	72	Low
342+00	100	98	23	3	44	71	Low
350+30	99	98	94	16	33	72	Low
351+80	100	100	97	16	39	75	Low
373+30	100	100	98	18	29	71	Low
392+35	100	100	96	17	32	74	Low
411+90	100	100	68	20	26	74	Low
438+70	99	97	73	27	56	77	Low
467+60	100	100	67	15	40	72	Low

*A criteria developed in the Roadbed and Concrete Branch of the Transportation Laboratory to classify the rebound characteristics of different materials.

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TABLE 3

TEST RESULTS OF
EXISTING AGGREGATE BASE MATERIAL

Station	Grading 1-1/2"	3/4"	#4	#200	SE	R-value	Resilience*
323+10	100	83	46	7	54	79	Low
350+30	100	71	35	6	44	79	Low
373+30	100	71	37	6	54	79	Low
411+90	100	77	47	13	23	77	Low
436+70	100	80	50	13	23	72	Low
467+60	100	86	67	14	30	77	Low
Unknown	100	67	34	4	43	78	Low
"	100	68	32	2	45	77	Low
"	100	70	39	8	27	78	Low
"	100	73	46	4	56	78	Low

*A criteria developed in the Roadbed and Concrete Branch of the Transportation Laboratory to classify the rebound characteristics of different materials.

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STRUCTURAL SECTIONS AND MATERIALS

The test sections discussed in the June 1970 interim report were constructed under two separate contracts. Each of the three structural sections are shown and identified according to the type of base used. They were designed so that total gravel equivalents were nearly equal as determined from the Highway Design Manual, section on Asphalt Concrete Pavement, (7-651)(7). Throughout the remainder of this report the designations CTB, ACB and AB will be used to identify the structural section containing cement treated base, asphalt concrete base and aggregate base, respectively. (AC is asphalt concrete and OG is open graded asphalt concrete.)

Samples taken during construction indicated that the materials placed in the roadway generally conformed to the specifications and the project was constructed substantially as planned. A summary of test results of materials sampled by construction personnel are given in Tables 4 through 8.

Cement Treated Base Section

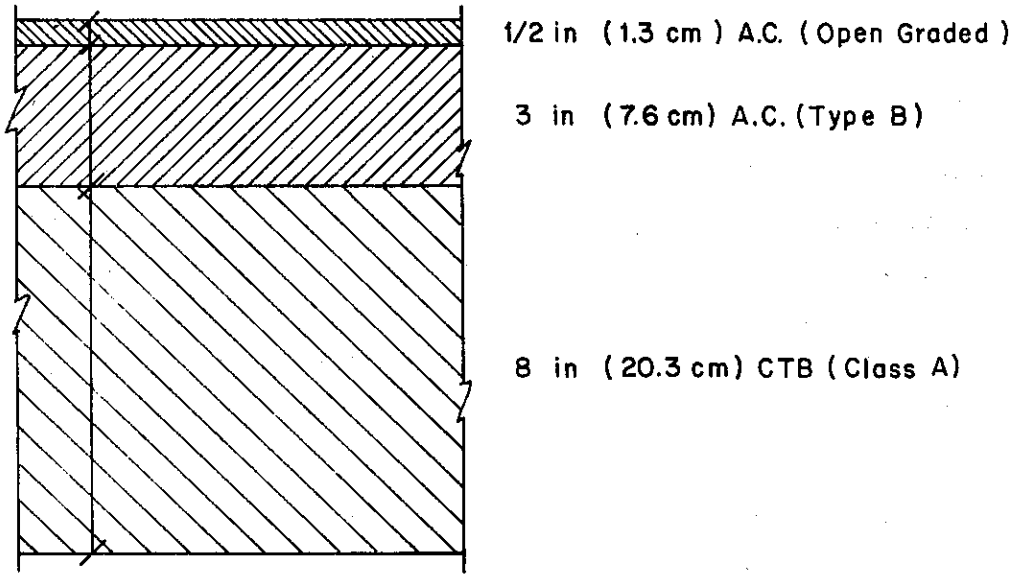

Figure 3 - CTB Test Section

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The structural section consisting of 1/2 inch (1.3 cm) of open graded AC, 3 inches (7.6 cm) of AC, and 8 inches (20.3 cm) of Class "A" CTB was constructed in 1959 under contract 60-3TC20. The limits of this contract are between Stations 7+40 and 315+00.

Mineral aggregate for the CTB was obtained from Cache Creek near Woodland, California and conformed to the 1954 California Standard Specifications for one inch maximum Class A CTB (8).

Four percent cement and seven percent mixing water were used. This mixture was designed to meet the laboratory compressive strength requirement of 650 psi (4.48 MN/m^2) at seven days.*

The mineral aggregate for CTB was deposited on the roadway with dump trucks and a motor grader was used to blade the material into windrows. Cement was then distributed on the windrow by trucks and the material was mixed by two Pettibone-Wood pug mixers. The mixed material was spread by a motor grader over the existing roadway in an eight-inch (20 cm) lift and compacted with a three wheeled steel roller and a pneumatic roller. Public traffic was allowed on the CTB as soon as a curing seal and sand cover could be placed on the compacted material.

Forty CTB test specimens were fabricated during construction to obtain compressive strengths. Two-thirds of these specimens had the required seven day compressive strength of 650 psi (4.48 MN/m^2)(see Table 4). Generally, the strengths of the other samples were only slightly below 650 psi (4.48 MN/m^2)

*Standard Specifications in 1954 requited 650 psi (4.48 MN/m^2) at 7 days for Class A CTB.

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and none of these low strengths were within the planned test sections. The four specimens taken between Stations 209+50 and 212+80 represent an area where it was necessary to mix the cement and aggregate with a motor grader. A wet grade after a heavy rainfall made it impossible to use the road mix machine in this area. The compressive strengths of all four of these specimens were far below the required strength.

The two lifts of Type "B" AC and the 1/2 inch (1.3 cm) of open graded AC were placed with a Barber Greene paving machine and compacted with a two wheeled steel roller. The AC mix generally conformed to the 1954 California Standard Specifications for Type "B", 3/4 inch (1.9 cm) maximum, however, a few samples were slightly high on the number 8 and 30 sieve sizes. All of the samples tested met the 35 minimum stability requirement. The material was mixed with 5.5 percent of 85-100 penetration paving asphalt. See Table 5 for a summary of tests. Of the 57 samples of asphalt tested, three were slightly out of specifications on the flash test and one failed to meet penetration requirements.

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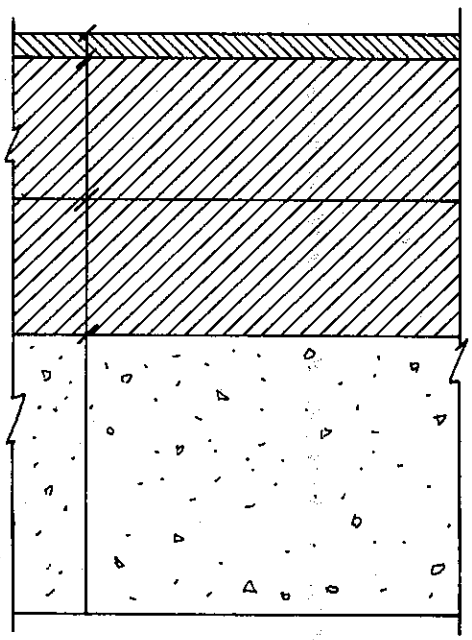
Asphalt Concrete Base Section



Sta. 360+00 to Sta. 444+00
Figure 4 - ACB Test Section

The structural section consisting of 1/2 inch (1.3 cm) open graded AC, 3 inches (7.6 cm) AC, 3 inches (7.6 cm) ACB and 6 inches (15.2 cm) AB was constructed in 1960 under contract 61-3TC9. The limits of this structural section are between Stations 360+00 and 444+00.

The aggregate base material was obtained from Cache Creek near Woodland, California. Only three samples of the base material from the above test section limits were tested during construction. Each sample met the grading requirements, but one failed to meet the R-value requirement and all three sand equivalents were below the specification requirements. These data are summarized in the top portion of Table 6. The AB material was deposited on the existing grade with dump trucks and spread to approximate grade by a tractor with a blade attachment. Compaction was accomplished with a three wheeled steel roller and a motor grader was used to obtain finish grades.

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The three inch (7.6 cm) ACB layer was spread and compacted in one lift. The aggregate conformed to the 1960 California Standard Specification requirements for 1-1/2 inch (3.8 cm) maximum base course. Five and one half percent of 85-100 penetration asphalt was used. Although five of six samples taken during construction showed the grading to be slightly out of specifications, all of the stabilometer values were well above the 35 minimum (see Table 7).

The asphalt concrete surface was placed in two 1-1/2 inch (3.8 cm) lifts with a Cedar Rapids paving machine and compacted with a two wheeled steel roller. Five and one half percent of 85-100 penetration asphalt was used in the mix. The gradings on four of the six samples tested were slightly out of specifications but the stabilometer values were at or above the 35 minimum required. These data are included in the upper part of Table 8. Tests on 42 asphalt samples showed eleven to be slightly out of specifications for penetration and two out of specifications for the flash test.

Asphalt tests on the open graded AC showed one sample to be slightly out of the grading specifications.

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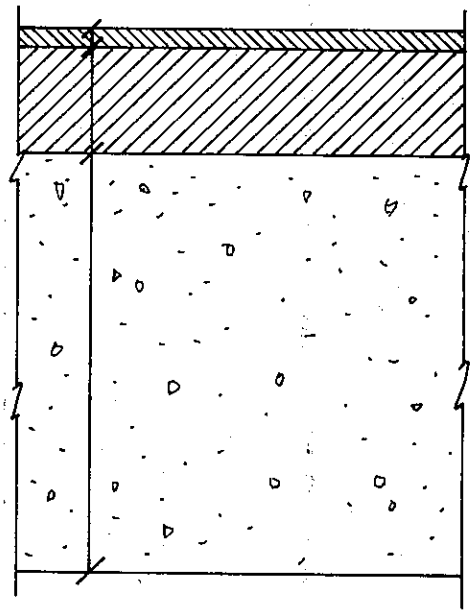
Aggregate Base Section



Sta. 315+00 to Sta. 360+00
Sta. 440+00 to Sta. 484+09

Figure 5 - AB Test Section

This section was also constructed in 1960 under contract 61-3TC9. The structural section consisted of 1/2 inch (1.3 cm) open graded AC, 3 inches (7.6 cm) AC and 12 inches (30.5 cm) AB. The limits of this section are between Stations 315+00 and 360+00 and between 444+00 and 484+09.

The aggregate base material was the same as was used in the ACB section and the manner of spreading and compacting was similar except that it was placed in two lifts. Tests on 11 samples taken for both test sections during construction indicated that three of the samples did not meet grading requirements and the R-value results were low on two. Three of the samples also had low sand equivalent values. These data are included in the summary in the bottom portion of Table 6.

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The asphalt concrete was the same as that used in the surface course of the ACB section. Tests on samples taken within this section also showed all of the stabiliometer values to be well above minimum requirements, but again the gradings were slightly out of specifications on three of the four samples tested. These data are included in Table 8.

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TABLE 4

TEST RESULTS OF
CEMENT TREATED BASE (CLASS A *)

Station	Compressive Strength (psi)	Time	Station	Compressive Strength (psi)	Time
32+00	640	7 day break	195+00	832	7 day break
"	528	"	"	704	"
52+00	1168	"	"	512	"
"	960	"	"	400	"
40+00	1232	8 day break	209+50**	496	"
"	1040	"	210+60**	304	"
60+00	544	"	211+70**	256	"
"	448	"	212+80**	224	"
98+00	640	7 day break	220+00	1216	"
"	656	"	224+00	2000	"
105+00	816	10 day break	258+00	1040	"
"	656	"	259+00	944	"
129+75	784	"			
"	656	"	268+00	1552	"
			"	1409	"
158+00	608	7 day break	288+00	1040	"
"	480	"	"	1008	"
186+00	752	"	262+00	1040	"
188+00	688	"	"	944	"
208+00	800	"			
209+00	1072	"	297+00	848	"
			"	720	"

*Standard Specifications in 1954 required 650 psi at 7 days for "Class A" CTB. The designed cement content for this aggregate was four percent.

**Blade Mixed Section

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TABLE 5

TEST RESULTS OF
ASPHALT CONCRETE SURFACING TYPE B
(3/4 INCH MAXIMUM, MEDIUM GRADING)

	Grading							% Asphalt Extracted	Stability
Specs. / Sta.	1"	3/4"	3/8"	#4	#8	#30	#200	5.5% Planned	35 Min.
	100	95-100	65-80	45-60	30-45	15-25	3-7		
54+25	100	91	70	57	47	28	5	-	35
93+00	100	100	71	61	46	29	6	4.7	44
120+00	100	100	85	70	53	30	6	6.2	41
140+00	100	100	76	68	51	29	6	6.0	38
142+00	100	97	72	57	43	30	6	4.8	38
152+00	100	100	73	56	43	29	5	5.6	43
155+00	100	97	68	55	42	24	4	5.7	41
203+00	100	98	66	52	42	35	5	4.9	42
207+20	100	100	74	58	45	28	6	5.2	43
288+00	100	99	75	60	47	33	6	5.1	36
289+00	100	100	80	63	47	28	7	5.5	44
302+00	100	98	78	61	49	34	7	5.0	45
303+00	100	100	78	58	45	29	5	5.5	44
305+00	100	100	76	56	46	31	6	5.2	42
Truck	100	100	81	65	50	32	6	5.3	43

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TABLE 6

TEST RESULTS OF
AGGREGATE BASE, CLASS 2
(1-1/2 INCH MAXIMUM GRADING)

	Grading						R-value	SE
	2"	1-1/2"	3/4"	#4	#30	#200		
Specs. / Sta.	100	90-100	50-85	25-45	10-25	2-9	78 Min.	30 Min.
ACB TEST SECTION								
372+00	100	97	81	44	22	7	71	28
401+00	100	99	84	45	20	6	79	25
430+00	100	97	83	43	18	6	79	25
AB TEST SECTION								
326+00	100	96	79	42	20	6	78	25
329+00	100	96	85	46	21	6	81	30
330+00	100	98	84	47	22	6	81	31
331+00	100	97	83	39	16	6	78	38
333+00	100	96	80	45	22	5	79	33
334+00	100	93	76	42	22	6	75	27
342+00	100	97	82	39	15	7	78	30
346+00	100	98	81	45	23	5	76	-
349+00	100	97	84	37	16	6	78	27
350+00	100	98	88	50	24	7	78	31
446+20	100	95	83	47	20	6	78	33

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TABLE 7

TEST RESULTS OF
ASPHALT CONCRETE BASE, TYPE B
(1-1/2 INCH MAXIMUM GRADING)

	Grading							% Asphalt Extracted	Stability
Specs. / Sta.	1-1/2"	1"	3/4"	3/8"	#4	#30	#200	5.5% Planned	35 Min.
	90-100	75-90	65-85	45-65	30-45	12-25	2-7		
442+30	100	84	58	44	30	14	3	4.3	40
423+00	100	91	78	63	38	15	5	5.0	39
Truck	100	85	75	60	26	13	5	5.7	48
Truck	100	86	79	61	37	15	4	6.0	43
Truck	100	100	79	63	45	15	3	5.6	43
Truck	100	95	84	75	42	21	11	5.0	45

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TABLE 8

TEST RESULTS OF
ASPHALT CONCRETE SURFACE COURSE, TYPE B
(3/4 INCH MAXIMUM MEDIUM GRADING)

	Grading							% Asphalt Extracted	Stability
Specs. / Sta.	1"	3/4"	3/8"	#4	#8	#30	#200	5.5% Planned	35 Min.
	100	90-100	65-80	45-60	30-45	15-25	3-7		
ACB TEST SECTION									
362+00	100	96	69	42	27	20	5	4.2	43
364+00	100	100	80	51	40	24	6	5.5	40
404+50	100	99	83	64	44	20	5	5.2	36
438+00	100	100	81	54	39	22	5	5.6	44
439+00	100	99	82	59	40	22	5	5.6	44
440+00	100	100	75	53	35	21	5	5.2	46
AB TEST SECTION									
355+00	100	100	84	59	42	28	8	6.0	44
356+00	100	100	83	54	42	24	7	5.5	49
452+00	100	97	73	49	38	23	6	5.3	45
453+00	100	100	81	59	43	28	6	5.7	40

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TESTING PROGRAM

In the initial study on El Centro Road (1), five CTB, four ACB and three AB test sections were established as shown below:

Test Section	Base Type	Station Limits	Lane
1	CTB	101+17 to 106+17	NB
2	"	209+00 to 217+00	SB
3	"	235+00 to 240+00	NB
4	"	278+00 to 283+00	NB
5	"	303+00 to 308+00	SB
6	ACB	369+00 to 374+00	NB
7	"	395+00 to 400+00	NB
8	"	409+25 to 414+25	SB
9	"	435+00 to 440+00	NB
10	AB	321+00 to 326+00	NB
11	"	342+30 to 352+30	SB
12	"	466+00 to 471+00	SB

Pavement deflections were measured on the test sections shortly after completion of the projects in 1959 and 1960. Deflection values were remeasured on an annual basis as described in the June 1970 interim report (1). In 1964, the experimental test sections were incorporated as part of a research project titled "Statewide Pavement Performance and Deflection Study" (4, 5, 6). Deflection measurements, condition surveys, and testing of in-place materials were performed on the 12 test sections on a regular basis from 1964 to 1968. In late 1968, Test Sections 1 through 3 were destroyed due to the construction of a portion of Interstate 5. Unfortunately, this eliminated the comparative performance study between good and low quality CTB as the low quality CTB section was test section number 2. From 1968 to 1974, Test Sections 4 through 12 were monitored regularly.

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In 1972, it was noted that some of the test sections showed considerable amounts of surface distress. Thus, as requested by District personnel, a pavement deflection study was performed on El Centro Road in accordance with Test Method No. Calif. 356 (9). At that time, overlay recommendations were made for the various experimental test sections. It was anticipated that the experimental test sections on El Centro Road would be overlaid either in the fall of 1974 or the spring of 1975.

From 1974 to 1975, under this research project, pavement deflections, conditions surveys, materials testing, and ride scores were performed to obtain final test data to help evaluate the performance of the various test sections. The testing program on El Centro Road ended during the spring of 1975 when the experimental sections were overlaid.

Condition Surveys

The visual condition of each test section was recorded on condition survey sheets from 1964 to 1974. Condition surveys were taken annually except for 1973. As shown in Figure 6, a condition survey is a representation of the cracking and patching of a roadway surface. These data were obtained by walking near the edge of the roadway and plotting individual cracks and patches as they appeared in each test section. A pacing wheel was used to determine distances from the beginning of each test section. Lengths of the surface cracks or patches were estimated visually or measured with the pacing wheel.

Three basic types of cracks were recorded on the Condition Survey Sheets: (1) transverse cracks - surface cracks perpendicular to the direction of traffic, (2) longitudinal cracks - surface cracks parallel to the direction of traffic, and

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(3) alligator or block cracks - a network of intersecting transverse and longitudinal cracks.

In 1974, the section of El Centro Road from Station 260 ± to the Sutter-Sacramento County line was photologged to obtain a final comparison of the pavement distress for the various layered systems. Photos were taken at approximately 30 foot (9.1 m) intervals throughout the length of the project.

A summary of the surface distress of the experimental test sections is presented in Table 9.

Pavement Deflections

From 1959 to 1967, the test sections on El Centro Road were measured for pavement deflections using a Benkleman beam. A dump truck with a 15,000 pound (6,800 kg) single axle load on the rear tires was utilized to obtain pavement deformations. Deflection measurements were taken between a set of dual tires [11.00x22.5 and 70 psi (480 kN/m^2)] in the outer wheel track at approximately 30 foot (9.1 m) intervals and an average deflection value was determined for each test section. Deflection measurements were taken on an annual basis.

From 1968 to 1975, pavement deflections were measured using the California Deflectometer with its 18,000 pound (8,200 kg) single axle load on the rear tires [11.00x22.5 and 70 psi (480 kN/m^2)]. The Deflectometer measures pavement deflections in both wheel tracks simultaneously at about 20 foot (6.1 m) intervals. An average deflection value was obtained in the outer wheel track for each test section. Deflection measurements were taken annually, except for the years 1971, 1972, and 1974. All Deflectometer deflections were converted to equivalent Benkelman beam deflections using the following equation:

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$$Y = (X+0.0034)/0.99$$

where Y = Benkelman beam deflection in thousandths of an inch [Dump Truck with 15,000 lb (6,800 kg) rear axle load].

X = Deflectometer deflection in thousandths of an inch [Deflectometer with 18,000 lb (8,200 kg) rear axle load].

A summary of these deflection data obtained for the test sections on El Centro Road from 1959 to 1975 is presented in Figure 7.

Ride Scores

The riding quality of the test sections was determined during the spring of 1975 using a PCA Roadmeter mounted in a 1973 Plymouth stationwagon. The Roadmeter is an electromechanical device which numerically records relative differences in vertical movement between the rear axle of a vehicle and its frame (10). The ride score is simply the number of 1/8 inch (3.2 mm) vertical displacements per mile of roadway divided by 50. During operation, the test vehicle travels at a constant speed of 50 miles (80 km) per hour.

Table 10 shows average ride score values for the test sections measured.

Materials Testing

In-place samples of asphalt concrete were sampled nearly every other year from 1964 to 1975 by taking 4-inch (10.2 cm) and

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12 inch (30.5 cm) cores of the pavement surface. Abson Recovery tests were performed on the sampled materials to determine asphalt content, penetration, softening point and ductility. Specific gravity and Modulus of Rupture* values were also determined. A summary of the test results is presented in Table 11.

In 1968, in-place samples of asphalt concrete base were obtained at two locations from the ACB test section. Abson Recovery tests were performed on the recovered asphalt and these test data are shown in Table 12.

In 1975, in-place aggregate base was sampled from the ACB and AB test sections. Grading analyses and moisture contents were determined for the materials sampled. These test data are presented in Table 13.

*Modulus of Rupture test conducted in accordance with method described in the 1959, ASTM Special Technical Publication No. 277, page 96.

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DATA ANALYSIS

General Discussion

If a roadway can adequately accommodate traffic loads in a safe, comfortable manner, it is generally considered serviceable. A serviceable roadway must be (1) structurally adequate, that is, have sufficient strength to support vertical loads without major failures, (2) have an acceptable ride quality, and (3) be sufficiently textured to provide a safe level of skid resistance. Whether or not a roadway will be serviceable over its entire design life depends on many factors, some of which are:

1. traffic
2. design of structural section (based on traffic estimates and soil tests)
3. materials utilized in the structural section
4. construction techniques
5. environmental effects
6. maintenance

From a maintenance standpoint, a pavement is considered failed only when extensive digouts, maintenance blankets or overlays are needed to make the roadway serviceable. Thus, surface cracks alone are not totally indicative of pavement failures. Transverse and longitudinal cracks are quite common in most asphalt concrete pavements and it is anticipated that these cracks will occur to some extent during the service life of a roadway. For example,

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when AC is placed over CTB, transverse cracks generaly occur on the AC surface at approximately 15 to 20 foot (4.6 to 6.1 m) intervals due to shrinkage of the CTB acting as a slab.

However, the total extent of cracking does determine the serviceability of the roadway. As long as the cracking does not progress into severe block or alligator cracking, the roadway usually requires only minor maintenance work.

From this, it follows that some of the ways to evaluate pavement performance are the visual condition surveys (crack counts), pavement deflection measurements, PCA Roadmeter ride scores, and material properties. Another useful means to help measure pavement performance is to determine the maintenance and rehabilitation costs during the original design life of the project.

Analysis of Condition Surveys

After ten years of traffic on El Centro Road (1959-1969), all three experimental structural sections had very little surface cracking (Table 9). No maintenance was required during this 10-year period for any of the structural sections.

During 1971, the first significant signs of pavement distress occurred in the AB test section. Alligator cracks were such that skin patches were placed on the AB sections by maintenance personnel. The following year transverse cracks in the CTB section were sealed with a mixture of sand and emulsion. The transverse cracks in the CTB section were again sealed during 1973-74. Alligator cracking in the AB section continued to increase during 1973-74 and additional skin patches were placed. The last recorded condition survey in 1974 showed the ACB section still had very little cracking. However, just prior to the overlays being placed in 1975 a review of the test

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sections showed the rate of alligator cracking in the ACB section was increasing. In the spring of 1975, maintenance personnel sealed all surface cracks 1/4 inch (6.4 mm) wide or wider on the experimental structural sections with a petro-elastic material just prior to the rehabilitatioN of these sections.

Analysis of Pavement Deflections

The average deflections for the three experimental structural sections on El Centro Road are presented in Figure 7. As shown the ACB and AB test sections had about twice the magnitude of deflection as the CTB test section. Annual variations in deflection measurements appeared to be consistent for all experimental test sections. This could well be attributed to the time of measurement, pavement temperature, testing devices, and/or a combination of these and other environmental factors. However, the primary observation is that the deflections overall did not increase with time for any of the experimental structural sections. In fact, a slight reduction was noted. It was concluded, that pavement deflections alone cannot be used to indicate the performance or predict longevity of a roadway. The ability of the pavement to undergo deflections depends on its "flexibility". Due to hardening of the asphalt, the amount of deflection the pavement will sustain before cracking will decrease with time.

Analysis of Ride Scores

On asphalt concrete pavements a ride score value of 20 or less (RS = 20) is considered a smooth pavement; ride score values from 25 to 35 are considered moderately rough but acceptable. Pavements with ride score values of 40 or higher are considered rough and quite objectionable to the average motorist.

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On El Centro Road, ride scores averaged 15 on the CTB test section, 18 on the ACB test section and 25 on the AB test section. These results are from PCA Roadmeter tests conducted on March 25, 1975, just prior to the rehabilitation work (Table 10).

Ride scores can be an indication of the condition of the pavement surface. A pavement having many "pot holes" for example will have a high ride score. As expected, the test section with the highest amount of maintenance work, the AB test section, also had the highest ride score. The ride scores showed that the CTB and ACB test sections were in better riding condition than the AB test section.

Analysis of Materials Testing

In the analysis of the experimental structural sections, material variations would definitely be a factor in the evaluation of roadway performance. In the construction of the three test sections on El Centro Road, it should be noted that all AB materials utilized on the two contracts were taken from the same material site at Cache Creek. The asphalt for the surfacing of all three test sections was the same penetration grade, namely 85-100.

Table 13 shows gradings, sand equivalents and moisture contents performed on aggregate base materials sampled in-place for the ACB and AB test sections 15 years after construction. It was noted that gradings did not change appreciably between 1960 and 1975 (refer Table 3). Gradings of in-place materials sampled in 1975 were well within specifications. Sand equivalent values showed a slight reduction from the original test results in 1960, but still were within specification limits. Moisture contents

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for the aggregate base material sampled showed an average increase of only 0.3 percent in the AB test sections and 1.6 percent in the ACB test section.

It was concluded that no major changes due to degradation in material properties or moisture content were evident between the AB materials placed in the ACB and AB test sections during the 15 years of service.

As shown in Table 11, the percent asphalt content for the AC surface was virtually the same for each of the experimental test sections. However, it should be noted that even though all asphalts utilized on the test projects were the same type (85-100), they came from three different sources. Observing the penetration and ductility values for the recovered asphalt in the AC over the CTB, ACB and AB test sections presented in Table 11, indicates that the asphalt used on the ACB test section did not age harden as quickly as that used on the AB or CTB test sections. Additional evidence of this can be seen by the tests made in 1968 for the asphalt concrete base material (Table 12). These 1968 test data showed the asphalt to be considerably softer than the surface material for the same time period. The low penetration and ductility values of the AB and CTB test sections from 1970 to 1975 suggest that the roadway was at incipient failure in 1970. It was noted by the condition surveys that a marked increase in cracking for both test sections occurred between 1970 and 1975. This suggests that critical conditions might be identified by relating hardness of the asphalt and amount of measured deflection.

As expected it was found that the percent asphalt and specific gravity of the asphalt concrete did not vary appreciably through the years. This rules out reasons for possible deviations in roadway performance due to different densities and asphalt contents for these three experimental test sections.

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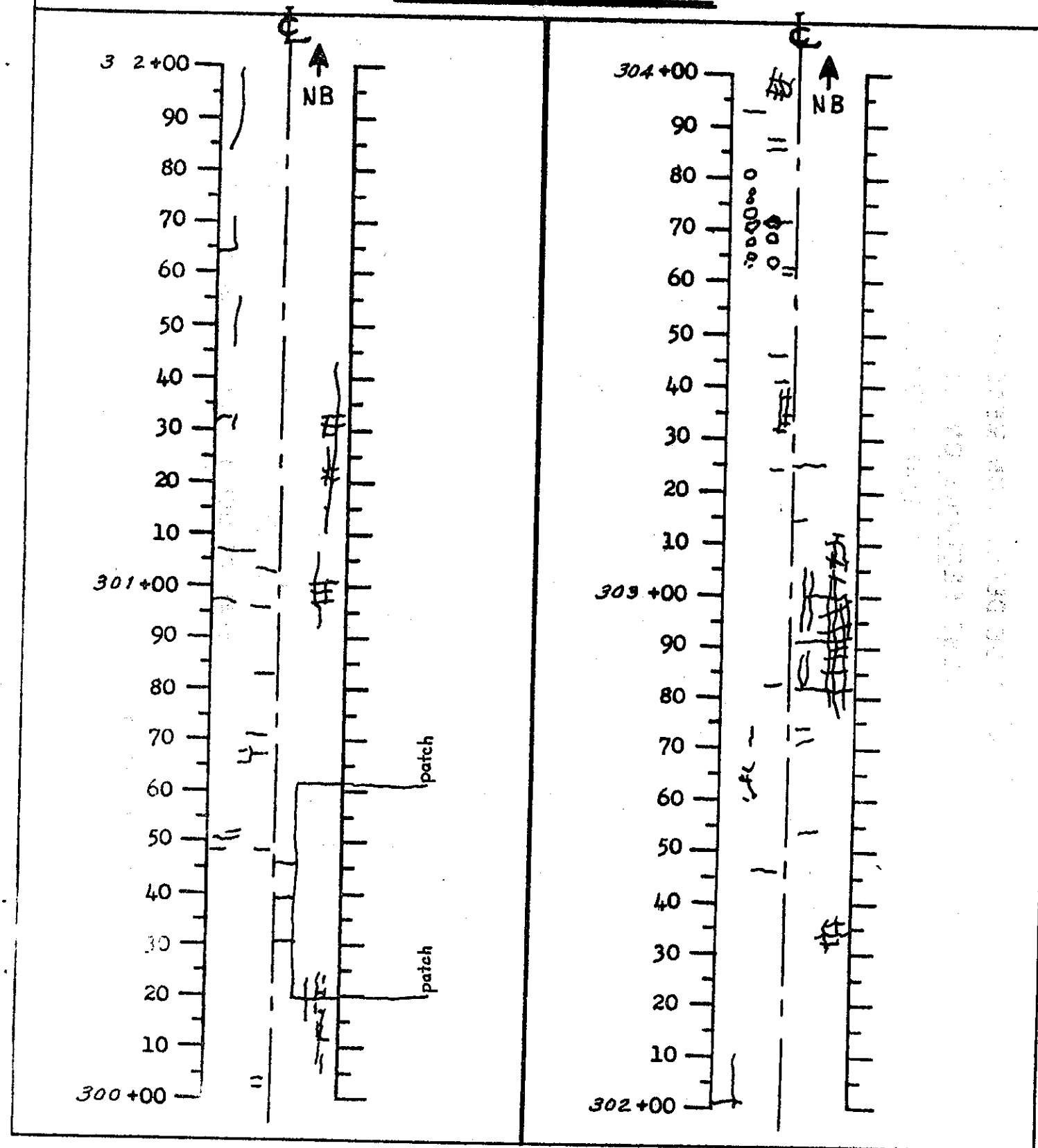
Figure 6

State of California
Materials & Research Dept.
W.O. Number _____
Job Designation _____
Date 10-2-74

Dist.Co.Rte.P.M. 03-Soc-99
Sta. 300 ~ to 304 ~
Lane NB & SB
Sheet No. 14 of 18

ROADWAY CONDITION SURVEY



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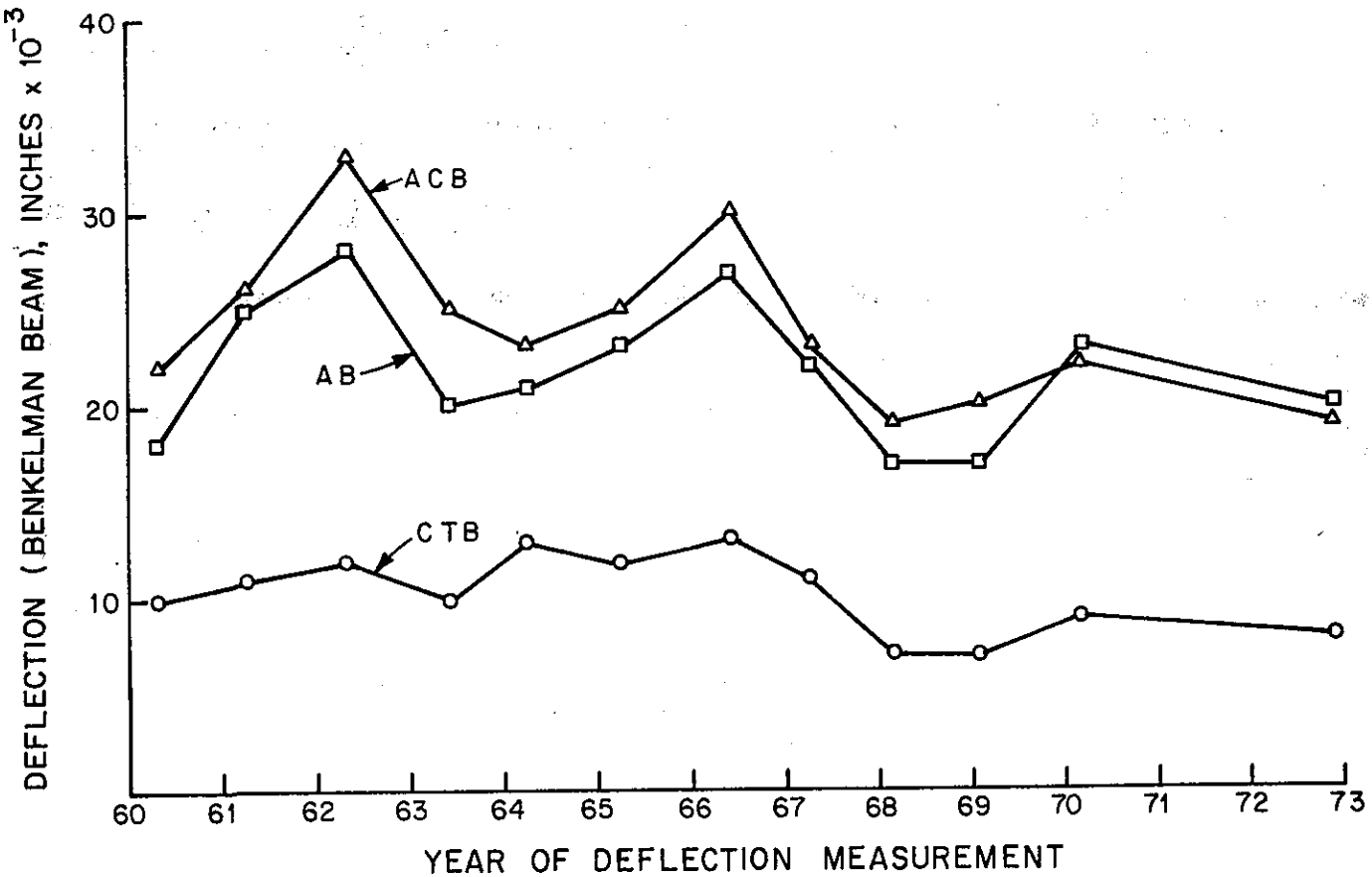
AVERAGE DEFLECTION MEASUREMENTS FOR THE TEST SECTIONS ON EL CENTRO ROAD (1960 – 1972)



Note: 1 in = 25.4 m

Figure 7

TABLE 9

RESULTS OF THE CONDITION SURVEY ON EL CENTRO ROAD

YEAR	CTB TEST SECTION				ACB TEST SECTION				AB TEST SECTION			
	TRANSVERSE CRACKS (Average linear ft. per 100 ft. of test section)	LONGITUDINAL CRACKS (Average linear ft. per 100 ft. of test section)	BLOCK OR ALLIGATOR CRACKS (Average sq. ft. per 100 ft. of test section)	PATCHING (Average sq. ft. per 100 ft. of test section)	TRANSVERSE CRACKS (Average linear ft. per 100 ft. of test section)	LONGITUDINAL CRACKS (Average linear ft. per 100 ft. of test section)	BLOCK OR ALLIGATOR CRACKS (Average sq. ft. per 100 ft. of test section)	PATCHING (Average sq. ft. per 100 ft. of test section)	TRANSVERSE CRACKS (Average linear ft. per 100 ft. of test section)	LONGITUDINAL CRACKS (Average linear ft. per 100 ft. of test section)	BLOCK OR ALLIGATOR CRACKS (Average sq. ft. per 100 ft. of test section)	PATCHING (Average sq. ft. per 100 ft. of test section)
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	6	3	0	0	0	0	0	0	1	1	0	0
1967	6	4	0	0	1	1	0	0	1	1	0	0
1968	8	7	0	0	1	1	0	0	1	2	0	0
1969	16	10	0	0	1	1	0	0	1	2	0	0
1970	16	14	0	0	1	1	0	0	1	2	0	0
1971	17	18	0	0	1	1	0	0	3	6	5	174
1972	21	22	0	0	1	1	0	0	14	6	52	174
1973	-	-	-	-	-	-	-	-	-	-	-	-
1974	61	27	0	0	1	4	0	0	17	14	126	286

Note: 1 ft=0.305m

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TABLE 10

TEST RESULTS OF THE ROAD METER SURVEY
(Spring 1975)

LOCATION	COUNTS PER MILE		AVERAGE COUNTS PER MILE	RIDE SCORE*	AVG. RIDE SCORE PER TEST SECTION
	RUN #1	RUN #2			
(CTB TEST SECTION)					
P.M. 32.75 to P.M. 33.66(NBL)	650	704	677	14	15
P.M. 33.66 to P.M. 32.75(SBL)	739	820	780	16	
(ACB TEST SECTION)					
P.M. 34.51 to P.M. 36.10(NBL)	931	963	947	19	18
P.M. 36.10 to P.M. 34.51(SBL)	766	813	790	16	
(AB TEST SECTION)					
P.M. 36.10 to P.M. 36.86(NBL)	1118	1237	1177	24	25
P.M. 36.86 to P.M. 36.10(SBL)	1240	1287	1264	25	

*Ride Score = Counts per mile/50

Note: 1 mi= 1.6km

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TABLE 11

AVERAGE TEST RESULTS OF THE ASPHALT CONCRETE SURFACE

CTB TEST SECTION

YEAR SAMPLED	PERCENT ASPHALT	PENETRATION (at 77°F)	SOFTENING POINT (°F)	DUCTILITY (at 77°F)	SPECIFIC GRAVITY	MODULUS OF RUPTURE (psi)
1964	5.5	27	139	100+	2.39	262
1966	-	22	143	-	2.40	320
1968	5.0	17	144	100+	2.41	361
1971	4.8	12	148	100+	2.36	560
1975	4.7	7	172	0	-	317

ACB TEST SECTION

YEAR SAMPLED	PERCENT ASPHALT	PENETRATION (at 77°F)	SOFTENING POINT (°F)	DUCTILITY (at 77°F)	SPECIFIC GRAVITY	MODULUS OF RUPTURE (psi)
1964	5.1	45	129	100+	2.41	93
1966	5.3	26	138	100+	2.41	241
1968	4.9	24	140	100+	2.40	222
1970	5.2	26	139	100+	2.35	--
1975	5.5	22	153	40	--	223

AB TEST SECTION

YEAR SAMPLED	PERCENT ASPHALT	PENETRATION (at 77°F)	SOFTENING POINT (°F)	DUCTILITY (at 77°F)	SPECIFIC GRAVITY	MODULUS OF RUPTURE (psi)
1964	5.4	30	139	100+	2.40	223
1966	--	26	138	97	2.41	255
1968	5.0	19	145	100+	2.35	91
1970-71	4.9	12	150	42	2.36	320
1975	5.0	15	158	9	--	204

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TABLE 12

TEST RESULTS OF IN-PLACE ASPHALT CONCRETE BASE
SAMPLED EIGHT YEARS AFTER CONSTRUCTION

STATION	PERCENT ASPHALT	PENETRATION AT 77°F	SOFTENING POINT °F	DUCTILITY AT 77°F
410+00	5.4	76	116	100+
372+60	5.0	33	137	100+

Note: $^{\circ}C = 5/9(^{\circ}F-32)$

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TABLE 13

TEST RESULTS OF IN-PLACE AGGREGATE BASE
SAMPLED 15 YEARS AFTER CONSTRUCTION

STATION	STRUCTURAL SECTION	GRADING (PERCENT PASSING SIEVE SIZES)				SAND EQUIVALENT	MOISTURE CONTENT, PERCENT
		1-1/2"	3/4"	#4	#200		
323+00	0.05' OGAC 0.25' AC 1.00' AB	97	81	46	6	30	4.3
349+10	0.05' OGAC 0.25' AC 1.00' AB	99	84	45	6	30	5.1
468+70	0.05' OGAC 0.25' AC 1.00' AB	98	82	46	6	29	4.4
372+60	0.05' OGAC 0.25' AC 0.25' ACB 0.50' AB	97	85	49	6	32	6.0
410+00	0.05' OGAC 0.25' AC 0.25' ACB 0.50' AB	98	84	48	9	25	5.5
438+00	0.05' OGAC 0.25' AC 0.25' ACB 0.50' AB	99	86	49	7	30	5.6

Note: 1 im=2.54 cm
1 ft=0.305m

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SUMMARY

The results of the condition surveys were generally indicative of the performance of the three experimental structural sections. For the original design life of the roadway all test sections performed well, both from a visual standpoint and from maintenance required. After 15 years of service the AB test sections had significantly more cracking and patching and required more maintenance than the other two sections.

The results of the PCA Roadmeter indicated the CTB and ACB test sections were smoother riding at the time they were rated than the AB test section.

The deflection results showed the CTB test section had better in-place strength or stiffness than either the ACB or AB test sections.

The material tests taken after construction showed that the three experimental test sections contained comparable and fairly uniform materials. Therefore, the materials used on El Centro Road are not considered a primary factor in the roadway performance.

The rehabilitation study made in 1972 for the three test sections on El Centro Road resulted in the following overlay recommendations for an additional 10 year service life:

AB test section	0.30 foot (9.1 cm) AC
ACB test section	0.15 foot (4.6 cm) AC
CTB test section	0.10 foot (3.0 cm) AC

Analysis of the data obtained on this research project leads to the following general conclusion. The treated base test sections on El Centro Road gave better roadway performance than the untreated base test sections.

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