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16. ABSTRACT

Synopsis

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Supplementing the Indiana studies, in the fall of 1947 the Illinois Division of Highways and the New Jersey State Highway Department undertook similar constructions(2) and during 1949 at the instigation of the U.S. Bureau of Public Roads the California Division of Highways constructed a one-mile section of continuously reinforced concrete pavement in Solano County in the vicinity of the town of Fairfield.

Eastern State projects contain a number of test sections with variable size, spacing and position of the steel. For various reasons, which it is not necessary to review in this report, it was decided to confine the California project to the limited number of variables herein recited. There is therefore no opportunity to compare directly with the three earlier projects described in Proceedings of the Highway Research Board except where the conditions are reasonably similar.

The California project was designed primarily to study the stresses in the steel reinforcing and the crack incidence in an 8" uniform thickness continuously reinforced pavement slab, with the steel centrally placed in the depth of the slab, as well as long time performance with relation to riding qualities.

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January, 1951

REPORTS ON EXPERIMENTS WITH CONTINUOUS REINFORCEMENT IN CONCRETE PAVEMENTS - CALIFORNIA

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SYNOPSIS

In the fall of 1938 the Public Roads Administration and the Indiana State Highway Commission initiated the construction of a number of experimental sections of reinforced concrete pavement(1).

Supplementing the Indiana studies, in the fall of 1947 the Illinois Division of Highways and the New Jersey State Highway Department undertook similar constructions(2) and during 1949 at the instigation of the U. S. Bureau of Public Roads the California Division of Highways constructed a one-mile section of continuously reinforced concrete pavement in Solano County in the vicinity of the town of Fairfield.

Eastern State projects contain a number of test sections with variable size, spacing and position of the steel. For various reasons, which it is not necessary to review in this report, it was decided to confine the California project to the limited number of variables herein recited. There is, therefore, no opportunity to compare directly with the three earlier projects described in Proceedings of the Highway Research Board except where the conditions are reasonably similar.

51-05

(1) Reported in the Proceedings of the Highway Research Board December 1939, Page 193. 10 Year Performance Report 1949, Page 45.
(2) Reported in the Proceedings of the Highway Research Board, December, 1949, Page 33.

The California project was designed primarily to study the stresses in the steel reinforcing and the crack incidence in an 8" uniform thickness continuously reinforced pavement slab, with the steel centrally placed in the depth of the slab, as well as long time performance with relation to riding qualities.

<u>General Description</u>

The project is part of U. S. Route 40 connecting the metropolitan areas of the San Francisco Bay Region and Sacramento. The test section was constructed as part of a contract in Solano County between Ledgewood Creek and 3.5 miles east of Fairfield.

Fig. 1 shows a general layout of the project. Fig. 2 shows information regarding grades, location of test section, dates pavement was constructed, etc.

The project in general consists of a four-lane divided highway over new alignment. Each side of the divided highway consists of two 12 ft. wide contiguous lanes of 8 in. thick Portland cement concrete. The contiguous lanes are tied together with 5/8 in. diameter 30 in. long tie bolts on 30 in. centers. There is a tongue and groove joint at the junction of the two lanes.

The territory traversed is generally flat valley land used for grazing. The native soil along the project is of adobe of somewhat variable composition, having a California Bearing Ratio ranging from 2% to 20% and expansions ranging from 1.7% to 10.8% and Atterberg limits of L.L. 36 to 43 and P.I. 16 to 23. A ten inch layer of gray volcanic ash (Tuff) was placed as imported borrow over the adobe. The Tuff has an average compacted weight of 65 lbs. per cubic foot at 25% to 30% optimum moisture and a California Bearing Ratio ranging from 150% to 200%. As the Tuff had little cementing value the upper 4 in. of this subgrade material was treated with 3.5% of cement by weight of dry material to avoid washing, shifting, pumping, and step-offs.

The imported base material was specified for the project as a whole, including the reinforced test section.

The pavement concrete was Class B (5 sack) with 2-1/2 in. maximum size coarse aggregate. Outside of the mile long reinforced section, weakened plane joints were placed at 15 ft. intervals with no expansion joints except at each end of the continuously reinforced test section. The surface of the newly laid pavement was kept moist by applying water with a fog nozzle until the application of a light gray pigmented curing compound.

Traffic

The average daily traffic over this road amounts to approximately 12,000 vehicles of all types. Therefore, the traffic on the test section over which only the west bound traffic passes is approximately one-half this amount or an average of 6,000 per day.

Description of Test Section

The one mile of continuously reinforced test section with 4 in. unrestrained expansion joints at each end was constructed in the two contiguous west-bound lanes. The longitudinal reinforcement consisted of 1/2 in. old type deformed steel bars on 4 in.

and 5 in. centers placed at the center of the slab. Transverse 1/2 in. steel bars were placed on 5 ft. centers. No weakened plane joints were placed in the reinforced section except as noted in the portions in which stress measuring SR-4 gages had been installed.

One grade of steel was specified but two grades were used owing to the fact that the contractors purchased the steel from two vendors and one vendor had, through a misunderstanding, rolled a harder grade than the other (Fig. 3).

Advantage was taken of this happenstance to use one grade for one half of the mile long test section and the other grade in the other half, the reinforcement being continuous throughout.

The lower strength bars were spaced 4 in. c/c and the higher strength 5 in. centers.

The amount of 1/2 in. reinforcing for one 12 ft. lane per mile and average characteristics of the steel were as follows:

Section	Spacing	% Steel	Tons Steel Per Mile	AVERAGE Elastic Limit	AVERAGE Ultimate Strength
1	4"	0.62	71.4	54,090 p.s.i.	84,120 p.s.i.
2	5"	0.5	58.3	71,935	121,250

The reinforcing steel was furnished to the job in 30 ft. lengths. All splices were staggered and lapped 40 diameters or 20 in. for the 1/2 in. steel. The longitudinal reinforcing steel was carried continuously through all construction joints and through the transition between Sections #1 and #2, (Fig. 4).

Test Units

A. Longitudinal Movement

Reference points for measuring the overall longitudinal movement of the pavement on the subgrade were installed in both lanes at the beginning and end of the test section. Additional units were installed in the traffic lane in both the standard concrete and the reinforced concrete at 100,200,300,400,600 and 800 ft. from each end of the test section. Three additional points were installed, one at the midpoint of the test section and the other two at 100 ft. each side of the midpoint.

The reference points consisted of an open bottom steel box fitted with a weatherproof lid and a reference rod driven 2 feet into the subgrade. Measurements of the longitudinal movement were made with calipers and micrometers with an accuracy of 0.01 in.

Movement up to one year is shown in Fig. 5.

B. Joint and Crack Width Measurements

Brass inserts were placed, in the fresh concrete, across each expansion joint in both the traffic and passing lanes for measuring the opening and closing of the joints. Brass inserts were also placed across the first 14 weakened plane joints, in the traffic lane only, in the standard unreinforced concrete, extending from each end of the test section. Additional brass inserts were placed across a few formed weakened plane joints in the reinforced sections at points where the stress in the reinforcing steel was to be measured. Readings were made with a micrometer to an accuracy of 0.002 in.

At an early age before the formation of the bulk of the intermediate shrinkage cracks, the maximum measured crack opening was 0.04 in. at an interior construction joint. At the weakened planes the maximum at the same age was 0.017 in. The crack widths of all of the early formed cracks decreased with further intermediate cracking, even with a 40° drop in temperature.

Additional brass inserts on 48 in. centers were placed in the traffic lane for the first 100 ft. from the expansion joints in the reinforced steel section to catch and measure changes in width of any naturally occurring transverse cracks. Readings were made with a special micrometer to an accuracy of 0.005 in.

Curing

Curing of the concrete was with a light gray pigmented solution under specifications similar to the Bureau of Reclamation specifications for white pigmented curing solutions, but lightly tinted to reduce potential glare.

Order of Construction

Paving of the left (traffic) lane of the test section was started on May 23, 1949 and finished on May 25, an average run of 1427 feet or 521 cubic yards per day for the 12 ft. wide by 8 in. thick concrete slab.

The specifications required the contractor to start paving each lane of the test section at the beginning of the day and to carry the reinforcing continuously across the transverse construction joint between daily runs. It was required that pouring the second lane should match the operations on the first lane; namely, to start the second lane in the morning at the same station as the first lane and to quit at the end of the first day in the second lane at the same station as the first day in the first lane. This procedure was followed on both lanes for the first day and the start of the second day.

However, on the second day of the second lane, the speed of the contractor's operations had increased to such an extent that he was able and was permitted to complete the entire mile the second day; the second day's run being 3060 lineal feet of pavement.

The atmospheric and concrete temperatures during the paving operations were moderate to high.

C. Stresses in Reinforcing Steel Measured with SR-4 Gages

SR-4 gages were installed on selected reinforcing bars at two locations in each section in each lane; a total of eight groups (Figs. 8,9,10 and 11). The arrangement of reinforcing bars and gages was such that part of the gages measured stress in the reinforcing steel at a formed weakened joint and part the stress in the reinforcing steel in uncracked concrete. Natural cracks have formed at some gage locations.

The SR-4 type A-1 gages were attached at the laboratory to 20 ft. lengths of the reinforcing bars; all loose scale and deformations being first removed from the bars to obtain a smooth surface at the location of gage attachment. The surfaces were thoroughly cleaned and gages attached with Cellulose cement.

General Electric Company 16 A.W.G. 3/64 in. Flamenol insulated wire was soldered to each gage lead. The gages were then waterproofed with 3M EC711 air drying rubber cement, after a minimum of 7 days drying period. The rubber cement waterproofing was applied in 7 to 10 thin coats, allowing a 24 hour drying period between each coat. A final protective coat of 2 layers of 1/2 lapped 3-M Scotch 33 electrical tape was placed over the gages (Fig. 6).

Each gage was calibrated at the Laboratory after attachment to the bar by stressing the bar by increments to just below the yield point and taking strain readings on the gages at each increment of load.

The temperature compensation units consisted of gages cemented to 4 in. lengths of reinforcing steel with lead wires soldered to the gages and then waterproofed, the assembly then being placed in a 6 in. length of 1 in. steel tube conduit with 2 disks of 1/2 in. Celotex placed in each end and sealed with Petrolastic. The whole temperature compensating assembly was then wired to the reinforcing steel with the center line of the assembly at the elevation of the reinforcing steel, mid-depth of the pavement (Fig. 6).

Lead wires from all SR-4 gages were brought out to the shoulder and attached to terminal boxes. Readings were taken with a standard Baldwin SR-4 indicator connected to the lead wires.

A total of 186 active SR-4 gages and 72 temperature compensation gages were installed in the test sections.

The insulation resistance of the active gages decreased materially within the first six months and excessively after the first year, but the temperature compensation gages have, in general, shown a high resistance to ground up to 18 months.

The high percentage of temperature compensating gages still showing a high resistance to ground indicates that the method used to protect the lead wires and waterproof the gages was adequate for at least eighteen months when suitable protection is provided. This would indicate that some better method of protection should be provided for protecting the active gages from the action of the concrete.

The insulation resistance to ground at various intervals after installation in the concrete was as follows:

Age After Installation in Concrete Pavement	PERCENTAGE OF SR-4 GAGES WITH INDICATED OR GREATER MEGOHM RESISTANCE TO GROUND							
	ACTIVE GAGES				TEMP. COMP. GAGES			
	MEGOHM RESISTANCE TO GROUND							
	10	25	50	100	10	25	50	100
	PERCENT GAGES WITH MEGOHM RES. INDICATED ABOVE							
3 Days	100	100	100	100	100	100	100	100
6 Months	87	73	40	15	99	99	99	99
12 Months	74	25	4	0	99	99	99	99
18 Months	5	0			99	99	99	99

It will be noted that at the end of 12 months after construction at least 74% of the active gages still measured 10 megohms or greater resistance to ground. The resistance to ground deteriorated until at 18 months only 5% of the active gages measured 10 megohms or greater to ground. The insulation resistance of the temperature compensating gages has remained high, with 99% having a measured resistance of 100 megohms or better to ground at 18 months.

The average measured stress in the reinforcing steel, between cracks, increased steadily (Fig. 7) irrespective of temperature and moisture conditions in the pavement at the time readings were taken. Readings taken at 18 months (not shown on Fig. 7) were exceptionally high.

The average measured stress in the reinforcing steel, across formed cracks, increased with diminishing temperatures to a high at age of 6 months (Fig. 7) and dropped only slightly with a raise in temperature at age of 13 months. Measurements taken at 18 months, not shown on Fig. 7, were beyond any reasonable figure.

74% of the readings made at 18 months exceeded the range of the SR-4 indicator. The calculated stress, based on calibrations made below the elastic limit, was frequently much above the ultimate strength of the reinforcing bars.

At early ages (less than 3 months) the readings on pairs of SR-4 gages opposite each other on the same reinforcing bar (Figs. 8,9,10 and 11) were in agreement within 10%. There was, however, a noticeable increase in the variations in readings at

3 months and at 6 months, many of the pairs of gages varied 100%. This, plus the drop in insulation resistance of the active gages, indicates that stress readings beyond the 3 month period are not reliable and indicate stresses far in excess of those actually developed in the steel.

Now that the active gages are inoperative, it is in order to cut some cores through the steel bars to inspect the condition of the bars at the points of highest indicated stress.

D. Concrete Temperature Measurements

Iron constantan thermocouples were installed; (1) one inch up from the bottom; (2) on the reinforcing steel in the center of the concrete slab, and; (3) one inch down from the top of the pavement slab. This installation was repeated at sufficient gage locations to secure a temperature record of the concrete at the time the concrete was placed. Temperature records have been made each period at which readings have been taken on the SR-4 gages as well as at any other times measurements have been made of the opening and closing of the joints.

Concrete Tests

Numerous test specimens (in the form of cylinders and beams) were cast during the progress of the work for the usual compression and modulus of rupture tests and compressive and dynamic modulus of elasticity.

In addition to the compression and modulus of rupture tests special 6 in. x 10 in. concrete cylinders were tested for tension.

The tension test procedure and test results are hereinafter described. Remarkably consistent tension strength results were secured. The results are deemed of sufficient significance to justify including as a part of this report. Cores were cut and tested at 28 days and one year.

There are some fairly wide differences in the strength of the concrete poured on different days, but more particularly between the two lanes which were constructed fifteen days apart. These differences can be attributed, in part at least, to differences in temperature at time of placing and in part to differences in water cement ratio. At times the construction engineers were concerned about the proper distribution of the concrete through and around the steel reinforcing (maximum size coarse aggregate 2-1/2 in.). The tendency, therefore, was to increase the W/C ratio and consequently the slump to insure what was felt to be a desirable consistency to avoid honeycomb and hang-up on the steel. After observing some honeycomb along the edges of the first constructed lane the water cement ratio was increased slightly during the construction of the second or passing lane.

However, observation of the cores cut from the relatively dry concrete in the first (traffic) lane and from the wetter concrete in the second (passing) lane, as well as of the concrete adjacent to the side headers did not disclose any material deficiency in placement of any of the concrete, regardless of consistency.

Concrete Strength

As will be noted from a study of the compressive, modulus of rupture and tension tests the concrete was of good quality throughout although there is a marked difference in strength between the earlier built traffic lane and the later built passing lane, (Tables 1 and 2).

As previously stated this difference was probably due to the fact that the temperature of air and concrete during the construction of the earlier built traffic lane was greater and the water cement ratio lower than during the construction of the second (passing) lane.

The effects of the lower strengths are not appreciably apparent to date in the pavement performance, the crack incidence being substantially the same in either lane. It would, therefore, appear that differences in strength of the order noted are insufficient to effect any measurable differences in concrete performance, at least up to the period covered by this report (1-1/2 years).

Tension Test Equipment and Procedure

In an effort to determine the tensile strength of the concrete at early ages - 12, 24 and 48 hours - a special type of test specimen and field testing equipment was designed.

The test specimens consisted of 6" x 10" concrete cylinders cast in standard 6" x 12" split steel molds with facilities for accurately placing and aligning two 5/8" carriage type bolts with specially machined heads abutting at the mid-point in the specimen. Soft rubber tubes were placed over the greater portion of the rods to minimise bond with the surrounding concrete as well as to assist in eliminating any eccentricity in alignment during the application of the load (Fig. 13).

Holes were drilled in the bolt heads for the insertion of a pin to maintain alignment and prevent movement during fabrication.

A special breaking machine was built for the early age field tests (Fig. 14).

Crack Record

Initial shrinkage crack records were made early in the morning following each day's pour. As was anticipated numerous transverse cracks have developed (Figs. 16, 17 and 18). This report includes the crack record up to one year at which time the average number of cracks per 100 ft. of pavement equaled 22 with an average slab length of 4.5 ft. except for the first 140 ft. from each end, where the slab lengths were substantially greater.

As will be noted in the crack record diagrams (Fig. 16) the slab lengths were likewise greater just before the construction joint at the end of each day's pour but quite short at the start of the next day's pour, notwithstanding the continuity of the reinforcing across the construction joint (Figs. 16 and 19).

Roughness Measurements

Initial and subsequent pavement roughness measurements were made with the Hveem Profilometer and by Professor Moyer with equipment developed under his direction at the Institute of Transportation and Traffic Engineering of the University of California, Berkeley. See Fig. 20 for typical profilograph (morning and afternoon) recorded by the Hveem Profilometer.

Comparative Cost Studies

Following is a comparison of the cost per mile of a 12 ft. lane of an unreinforced and a reinforced concrete pavement slab of the thickness and percentages of reinforcement in the Fairfield Test Highway at the project bid prices per cubic yard of concrete ($14.00) and per pound of steel in place ($0.08):

1. Unreinforced — $21,896.00
2. Reinforced with 1/2" bars 4" c (0.62%) — $33,317.00
3. Reinforced with 1/2" bars 5" c (0.50%) — $31,227.00

It would, therefore, appear that reinforcement to control cracking is probably not economical and cannot be justified unless an equivalent benefit is attained with relation to long-time riding qualities and greater durability or the slab thickness and the supporting base can be modified sufficiently to offset the added cost of the reinforcing.

In this connection the following comparative cost data is of interest (all figures being based on the unit bid prices for the Fairfield Test Project):

	D E S I G N	COST PER MILE OF 12' LANE AT CONTRACT PRICES		
		Concrete Slab	Treated Base	Total
(a)	8" Unreinforced (as constructed)	$ 21,896	$ 5,086[1]	$ 26,982
(b)	8" Reinforced (0.5% - 5" c/c) (as constructed)	31,227	5,086[1]	36,313
(c)	8" Reinforced (0.5% - 5" c/c) (No Selec. Mtl. Base)	31,227	0,000	31,227
(d)	6" Reinforced (0.5% - 6.5" c/c) (10" Selec.Mtl.Base(4" Cemt.Tr.)	23,420	5,086[1]	28,506
(e)	6" Reinforced (0.5% - 6.5" c/c) 4" Sel.Mtl.Cemt.Tr. Base	23,420	2,656[2]	26,077
(f)	6" Reinforced (0.5% - 6.5" c/c) No Selec. Mtl. Base	23,420	0,000	23,420

(1) 10" Imported Selected Material Base - Top 4" Cement Treated.

(2) 4" Imported Selected Material Base - All Cement Treated.

From the above tabulation it will be noted that a 6" reinforced concrete base (0.5% Steel - 6.5" c/c) with a 4" Cement Treated Selected Material Base compares in cost with an 8" unreinforced slab with the 10" select material base of which the top 4" was cement treated.

Additional projects designed to compare the performance of the above alternate designs as well as other competitive designs appear in order.

Summary

Owing to the comparatively short period which has elapsed since the construction of the project described in this report there are few conclusions which can be reached with assurance at the present time.

The crack incidence is high in a continuously reinforced slab of the design and length of this project (one mile without substantial expansion or shrinkage relief).

These cracks, although not wide at present may subsequently develop decidedly adverse and objectionable characteristics. In a few cases they have already done so.

To avoid numerous shrinkage cracks it appears necessary to break the continuity of the reinforcing at relatively short intervals - say 100 to 200 ft. This checks with the experience elsewhere.*

Whether or not expansion joints should be provided or weakened planes at the breaks in continuity of reinforcing is not apparent from test data to date, at least under California climatic conditions.

Obviously atmospheric temperature conditions during and immediately following construction is an important factor.

The California project was constructed in the summer and under relatively high atmospheric temperature conditions. Much

*10 Year Progress Report by Cashell and Benham on the Indiana Test Highway, Proceedings, 29th Annual Meeting, Highway Research Board, Vol. 29, 1949.

higher subsequent shrinkage and consequent higher crack incidence could be anticipated than had the construction been carried on during the lower temperature conditions which prevail during the late fall, winter and early spring months.

The effect of time of day and/or order of construction is likewise apparent from the crack development at the construction joints where even though the reinforcing steel is carried continuously across the construction joint the crack incidence is much less at the end of the day's run, just before reaching the construction joint, than during the first hour of the succeeding day when the incidence is somewhat greater than the average.

Up to one and one half years the crack incidence was not materially affected by the percentage of steel, the incidence being substantially the same for the 0.50% - 5" spaced high yield bars as for the 0.62% - 4" spaced standard medium yield bars.

Furthermore, the crack development at 18 months was apparently not appreciably influenced by differences in early concrete strengths of the order observed on the Fairfield project.

Acknowledgements

The author wishes to express appreciation to the staff of the Materials and Research Department for their assistance; particularly to Associate Electrical Engineer J. E. Barton who had charge of the installation of the strain gages and other pavement movement and strain measurement units and the subsequent measurements, recordings and analysis of the strain test data, etc.; also to Associate Materials and Research Engineer L. P. Kovanda who had charge of all work relating to concrete mixture design and concrete tests, including analysis of the concrete test data.

TABLE 1

AVERAGE CONCRETE COMPRESSIVE STRENGTH TESTS

FAIRFIELD TEST HIGHWAY

5-SACK CONCRETE

(1) 6" x 12" Field Cylinders - Compressive Strength in p.s.i.
(Figures are the average of all cylinders cast each day)

	AVERAGE TEMPERATURE		A G E			
Date Cons.	Conc.	Air	3 Days	10 Days	28 Days	1 Year
TRAFFIC LANE						
5-23-49 AM	85°	96°	----	3240	4330	----
5-24-49 AM	83°	88°	2180	3715	4730	6105
5-25-49 PM	100°	99°	----	3145	4130	----
Ave. Tr. Lane	89°	91°	2180	3367	4397	6105
PASSING LANE						
6-7-49 PM	89°	85°	----	2675	4005	----
6-8-49 AM	80°	71°	1525	2995	4270	5315
Ave. Pass.Lane	85°	78°	1525	2835	4138	5315

(2) 5" x 6" Beam Ends (Modified Cube)

TRAFFIC LANE						
5-24-49 AM	83°	88°	2850	4330	5515	6310
PASSING LANE						
6-8-49 AM	80°	71°	1980	3325	4720	5820

(3) Cores from Pavement - Compressive Strength in p.s.i.
(Figures are the average of all cores each day)

TRAFFIC LANE						
5-23-49 AM	85°	96°			5060	6510
5-24-49 AM	83°	88°			4725	6005
5-25-49 PM	100°	99°			4665	6245
Ave.Tr.Lane	89°	91°			4817	6253
PASSING LANE						
6-7-49 PM	89°	85°			3855	4750
6-8-49 AM	80°	71°			3850	5085
Ave.Pass.Lane	85°	78°			3853	4968

TABLE 2

AVERAGE MODULUS OF RUPTURE AND TENSION TESTS

FAIRFIELD TEST HIGHWAY

5-Sack Concrete

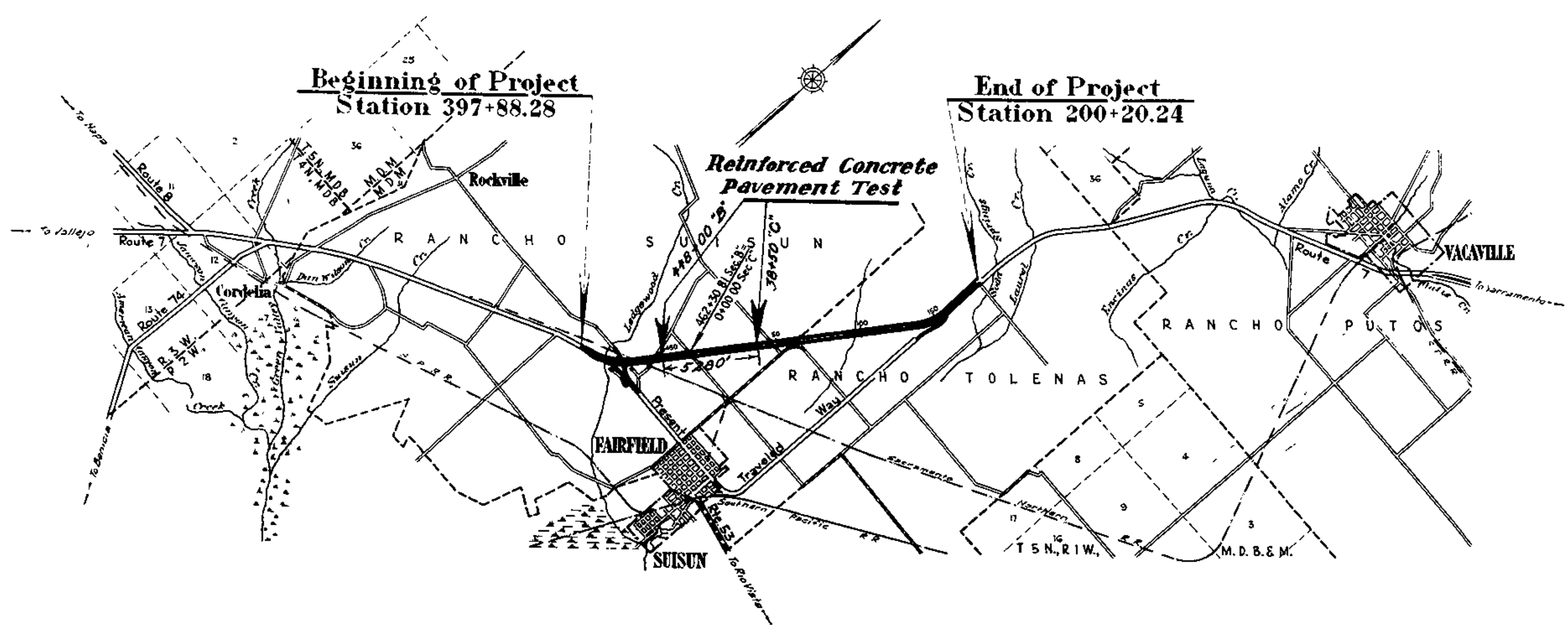
(1) Modulus of Rupture - (5" x 6" x 34" Beams)

	AVERAGE TEMPERATURE		AGE AT TEST			
Date Cons.	Conc.	Air	3 Days	10 Days	28 Days	1 Year
TRAFFIC LANE						
5-24-49	83°	88°	470	625	675	810
PASSING LANE						
6-8-49	80°	71°	355	505	625	685

(2) Tension (6" x 10" Cylinders)

	AVERAGE TEMPERATURE		AGE AT TEST					
Date Cons	Conc.	Air	12 Hrs.	24 Hrs.	48 Hrs.	3 Da.	10 Da.	28 Da.
TRAFFIC LANE								
5-24-49	83°	88°	105	136	184	215	295	327
PASSING LANE								
6-8-49	80°	71°	41	72	123	155	255	284

Fig I



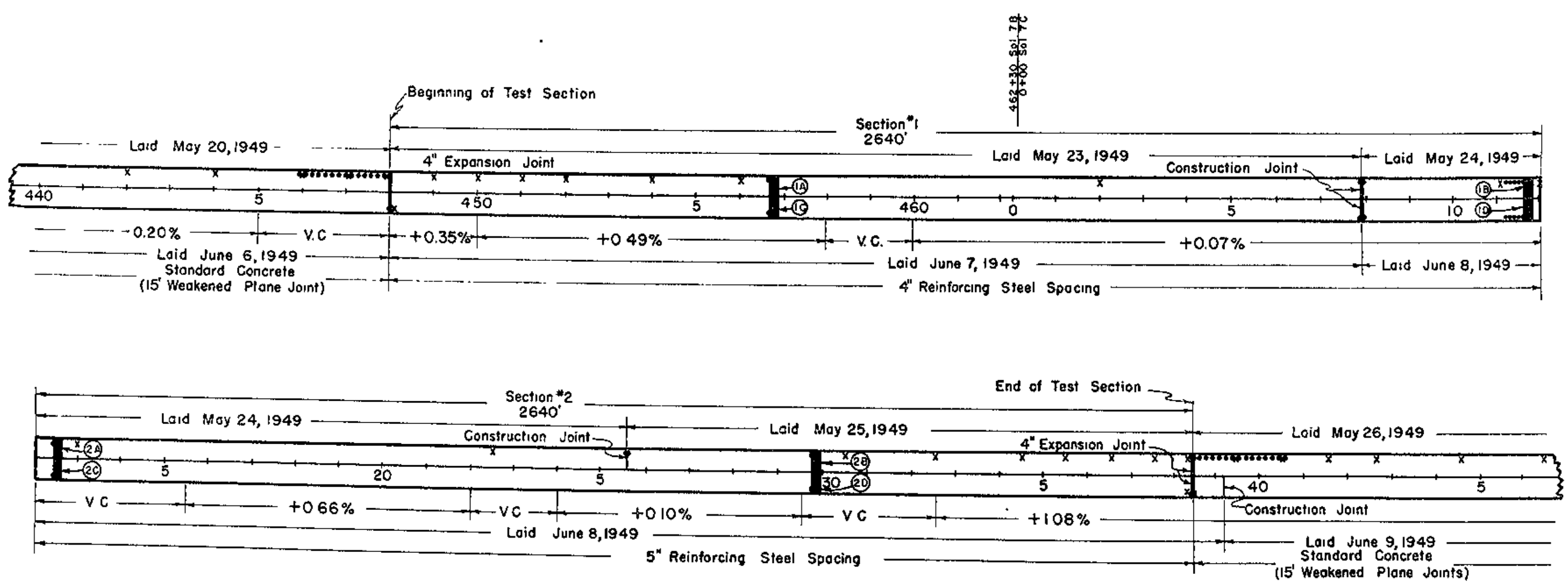
Beginning of Project
Station 397+88.28
End of Project
Station 200+20.24
Reinforced Concrete
Pavement Test
448+00 "B"
462+30.81 Sec."B"=
0+00.00 Sec."C"
38+50 "C"
5280'
Rockville
Cordelia
FAIRFIELD
SUISUN
VACAVILLE
RANCHO SUISUN
RANCHO TOLENAS
RANCHO PUTOS
To Vallejo
To Napa
To Benicia
To Rio Vista
To Sacramento
Route 7
Route 8
Route 74
Present
Traveled
Way
Ledgewood
Laurel
Encinas
Alamo Cr.
Suisun
Southern Pacific R.R.
T5N., R1W.,
M.D.B.&M.

Fig. 2

Res-00238

PLAN OF FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

X - Sol-7-B,C



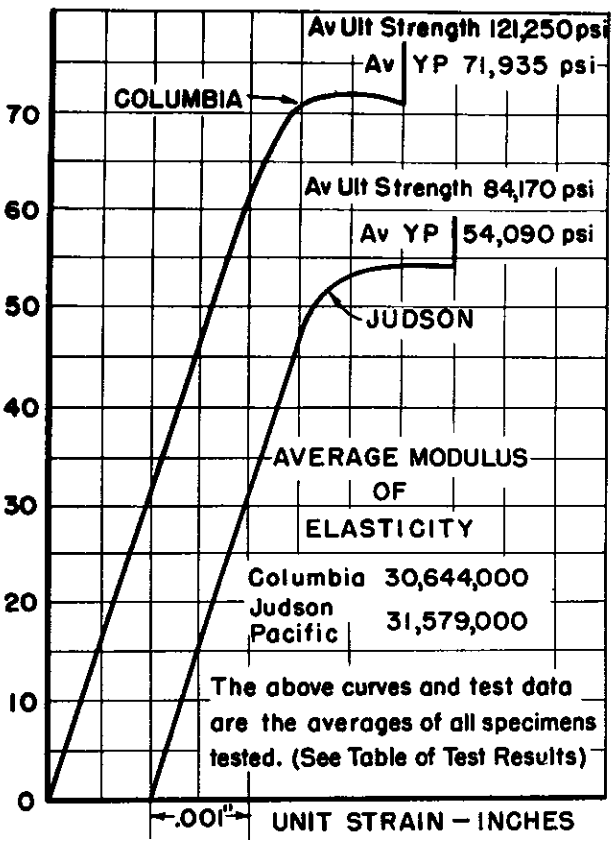
LEGEND

SR-4 Gage Section — See Fig's 8, 9, 10, & 11 for detail

X Longitudinal Movement Boxes

• Gage Points for Joint Openings

STRESS-STRAIN DIAGRAM



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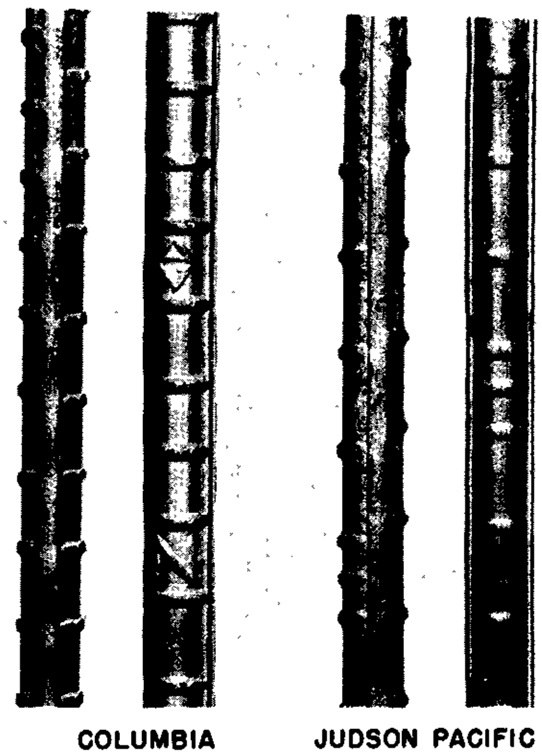


TEST RESULTS

JUDSON PACIFIC

Heat No	No of Tests	Elongation 8" %	Elastic Limit P.S.I.	Ult. Strength P.S.I.	Chemical Analysis % C	Mn	Phos	Sul
1519	6	16.75	55710	87015	.41	.59	.005	.038
2134	6	17.05	54675	86450	.42	.52	.007	.046
1451	5	16.25	54440	83250	.40	.53	.005	.032
1489	6	19.25	52665	81975	.39	.53	.006	.037
2132	6	17.20	52950	81925	.40	.53	.006	.043
Average		17.30	54090	84120	.40	.54	.006	.039

COLUMBIA

Heat No	No of Tests	Elongation 8" %	Elastic Limit P.S.I.	Ult. Strength P.S.I.	C	Mn	Phos	Sul
54078	5	11.97	71725	121260	.56	.85	.016	.035
71568	6	11.23	69625	116195	.60	.93	.011	.027
71948	6	12.11	69160	118390	.58	.88	.012	.030
54508	5	10.57	73460	122670	.61	.87	.013	.035
54078	5	10.23	73010	124750	.55	.98	.020	.036
71988	5	11.92	74630	124440	.56	.74	.014	.028
Average		11.67	71935	121250	.58	.88	.014	.033

Fig 3 Characteristics of ½" Deformed Steel Bars in the Fairfield California Reinforced Concrete Pavement Tests.

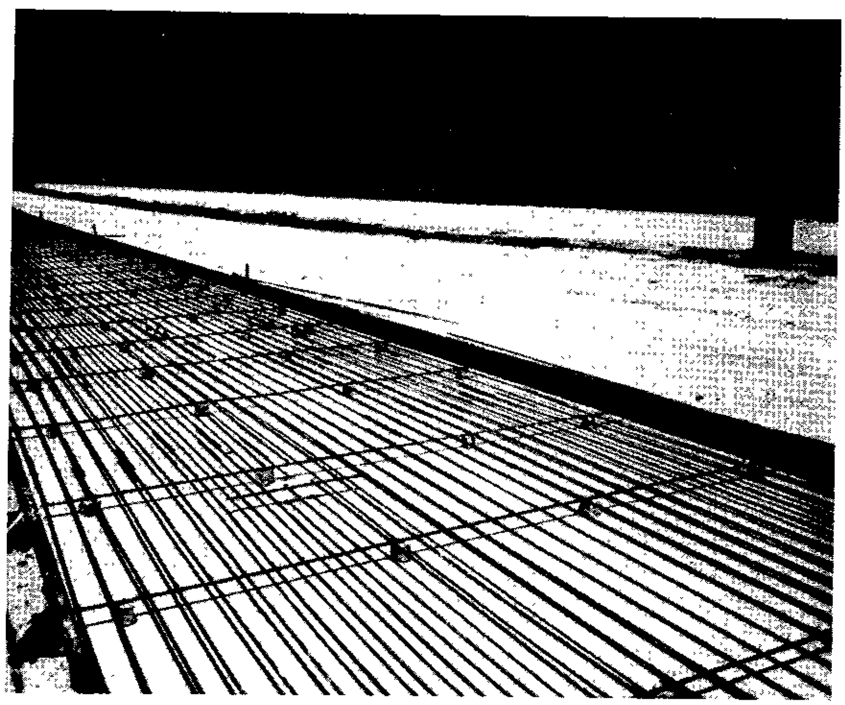


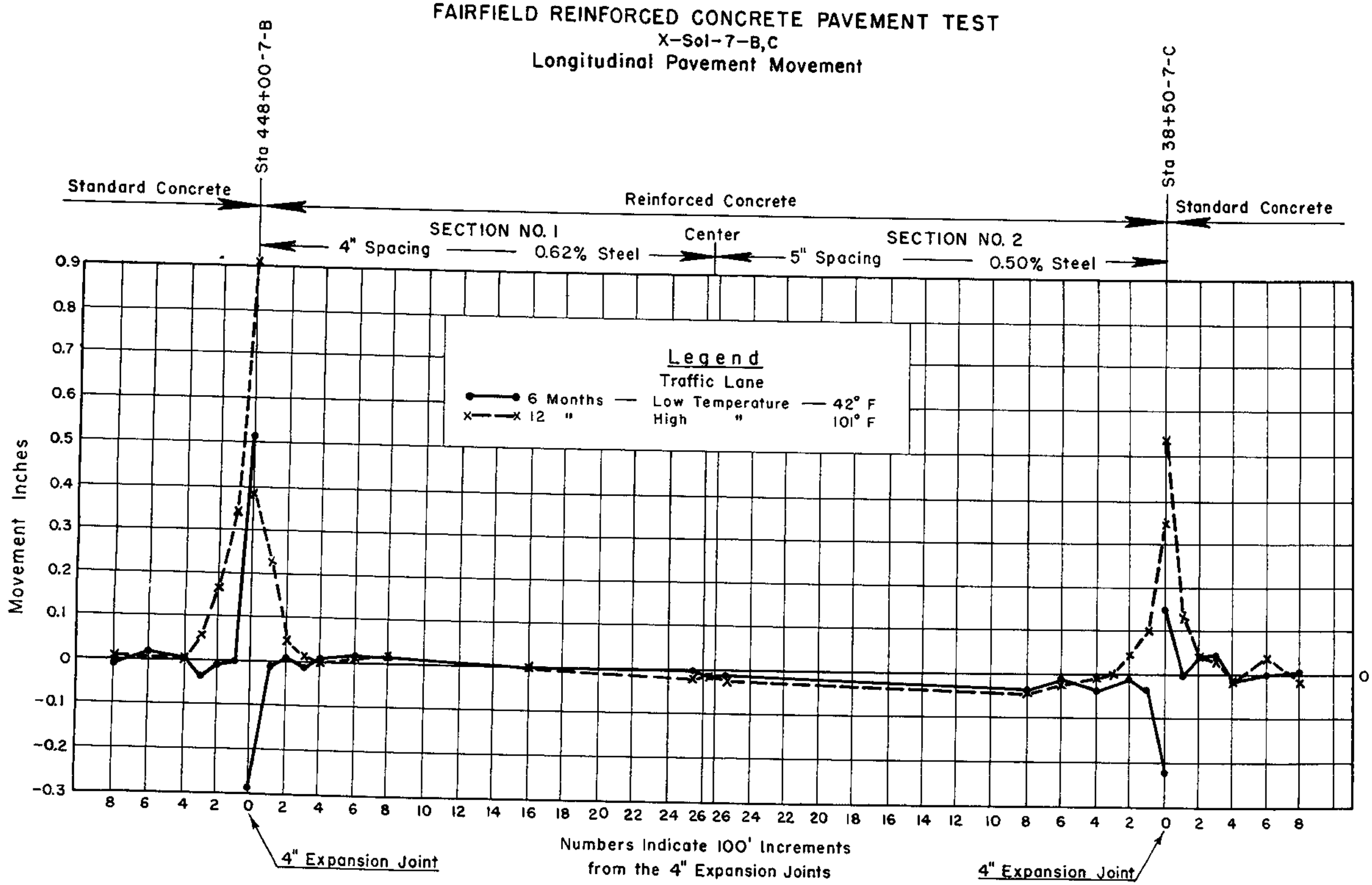
Fig. 4 Reinforcing Steel in place on base

Fig 5

FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

X-Sol-7-B,C

Longitudinal Pavement Movement



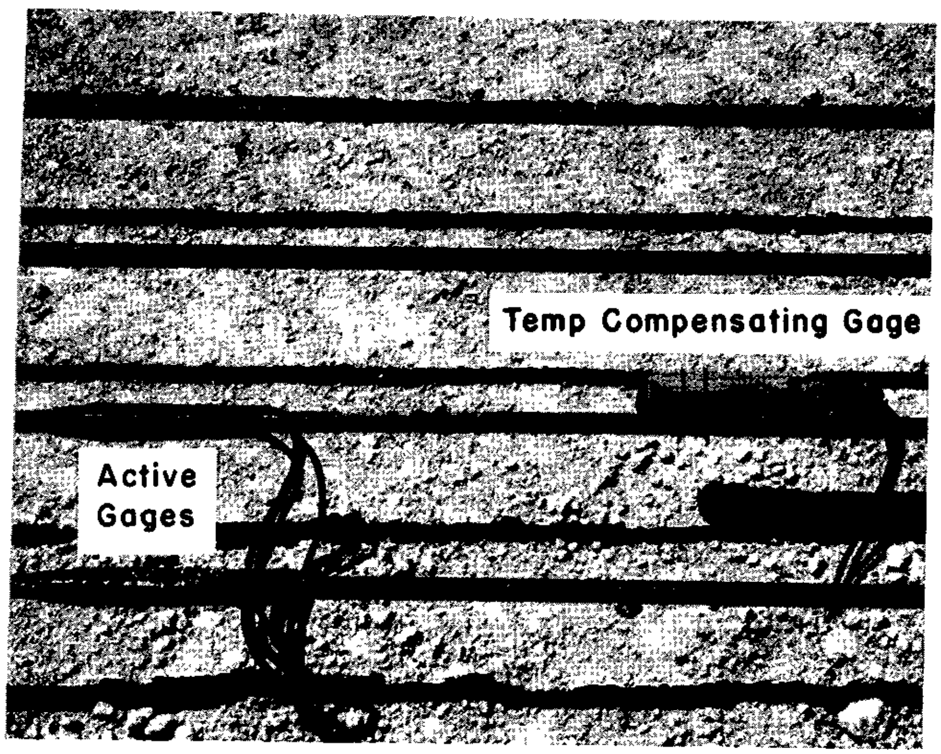


Fig. 6 SR4 gages on reinforcing steel

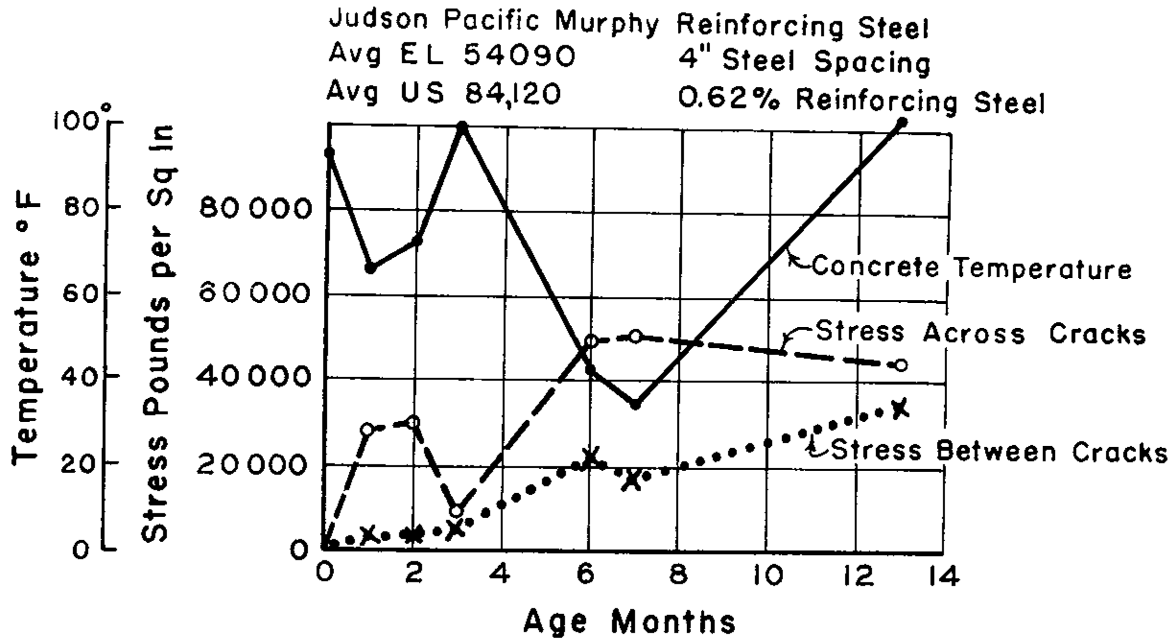
Fig 7

FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

X-Sol-7-B,C

Average Stress in Reinforcing Steel

Section No. 1



Section No. 2

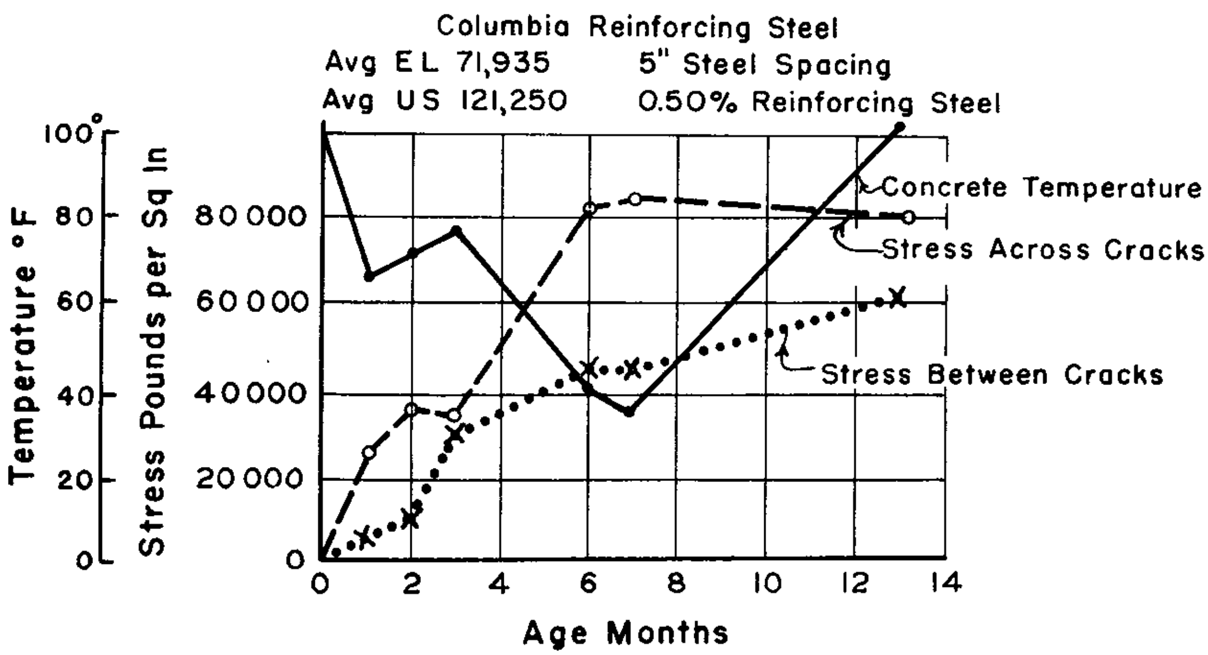


Fig 8

Res. 00238

FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

Plan of Placement of SR-4 Gages on Reinforcing Steel and Crack Formation

X-Sol-7-B,C

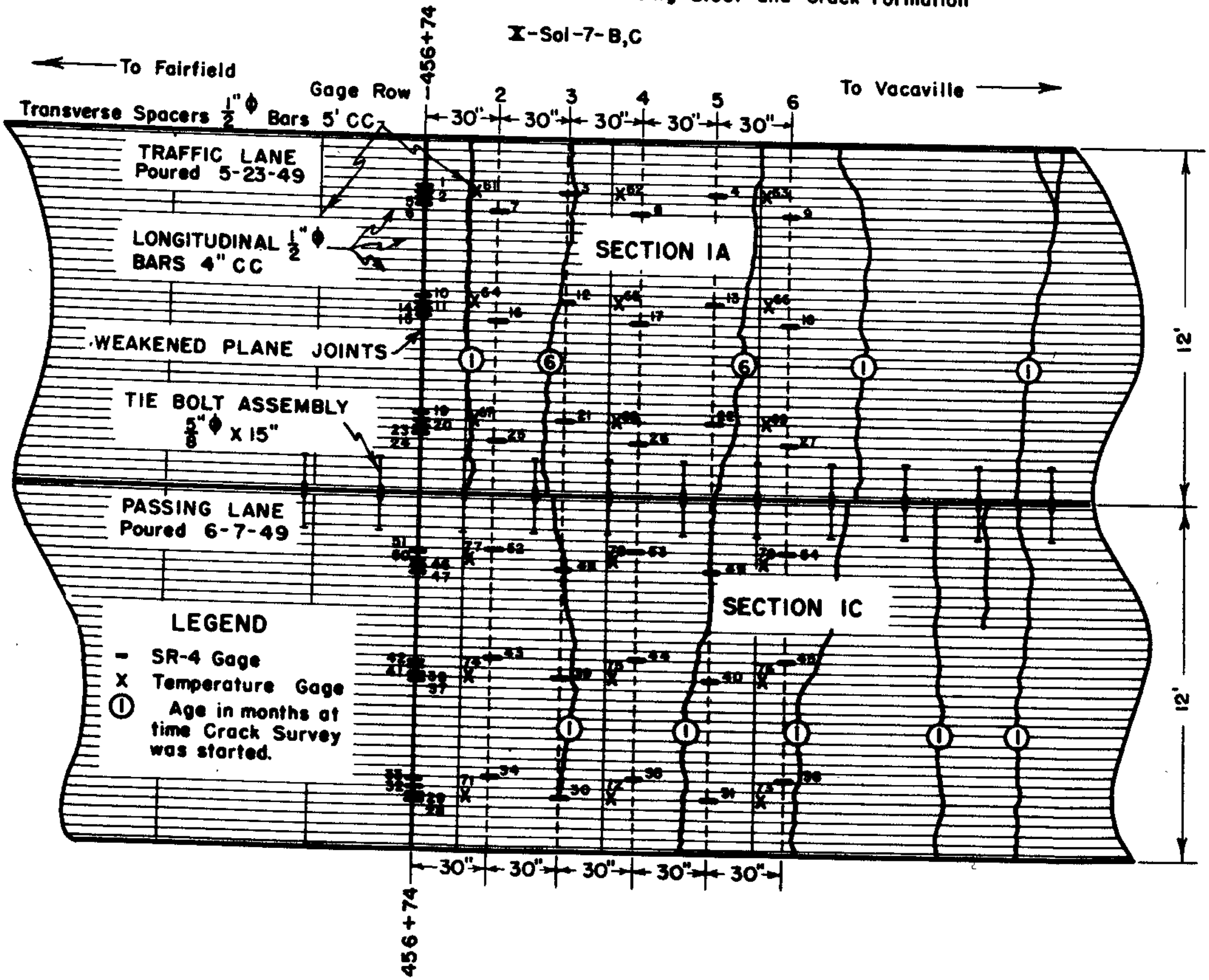


Fig 9

Res. 00238

FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

Plan of Placement of SR-4 Gages on Reinforcing Steel and Crack Formation

X-Sol-7-B,C

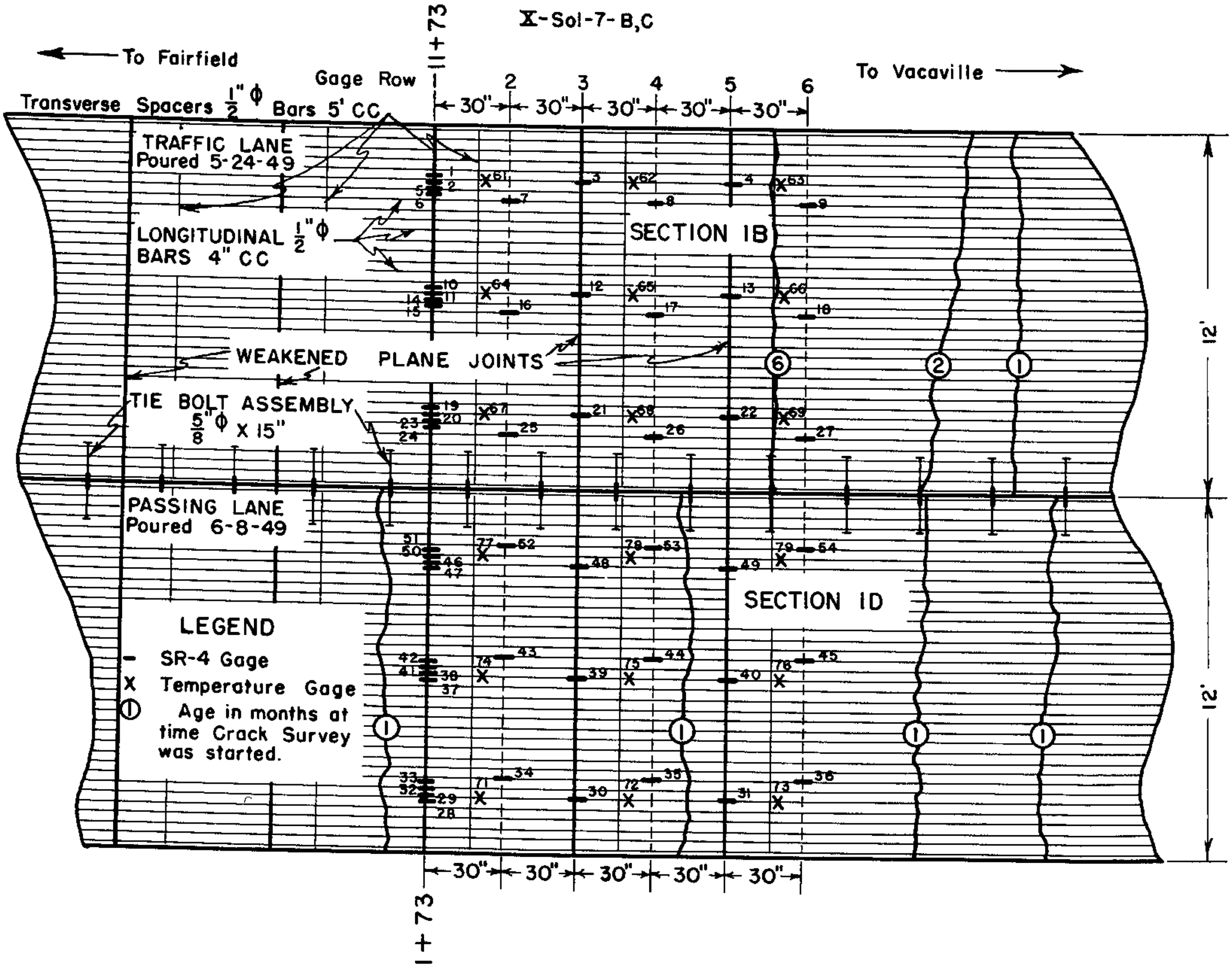


Fig 10

Res 00238

FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

Plan of Placement of SR-4 Gages on Reinforcing Steel and Crack Formation

X-Sol-7-B,C

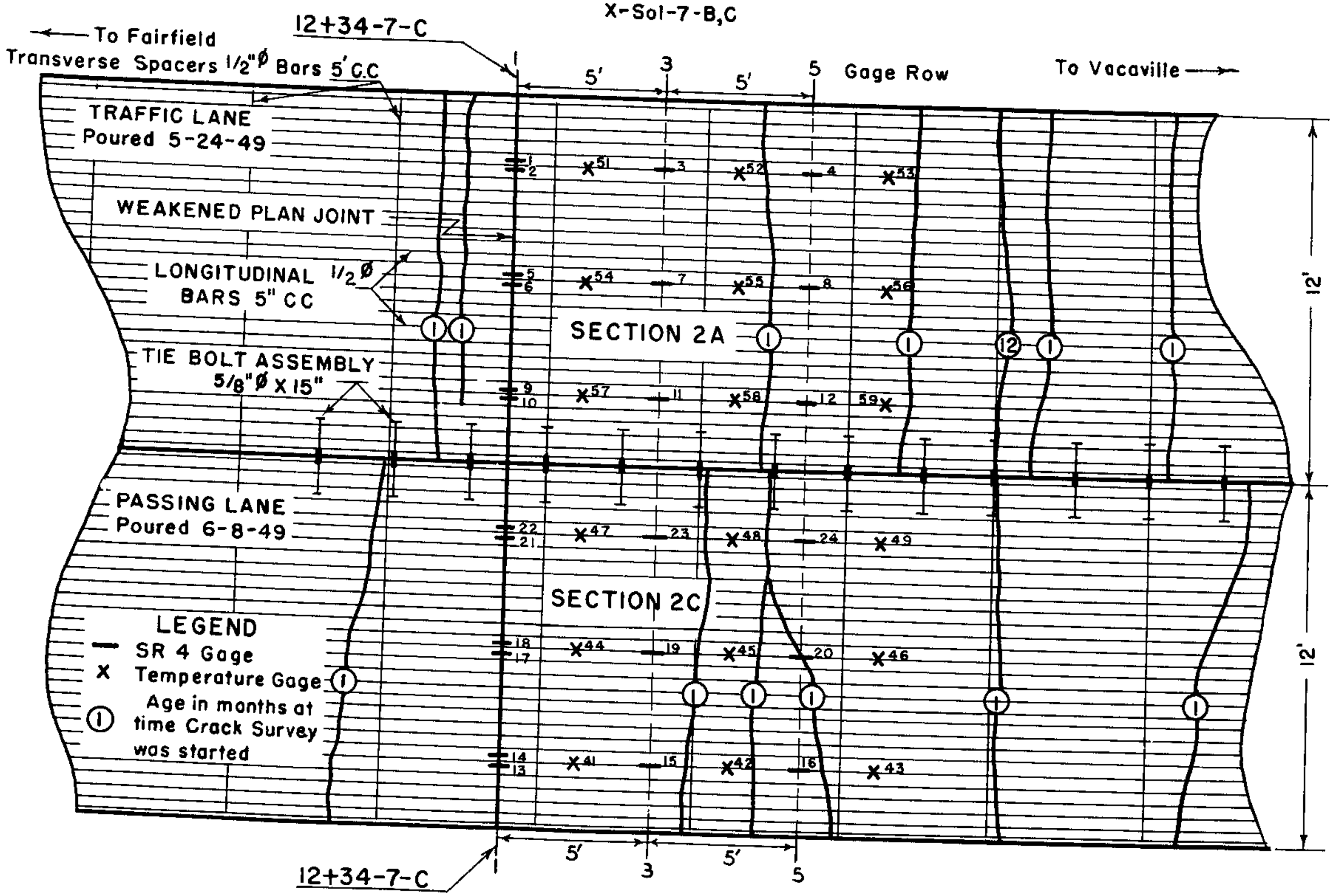


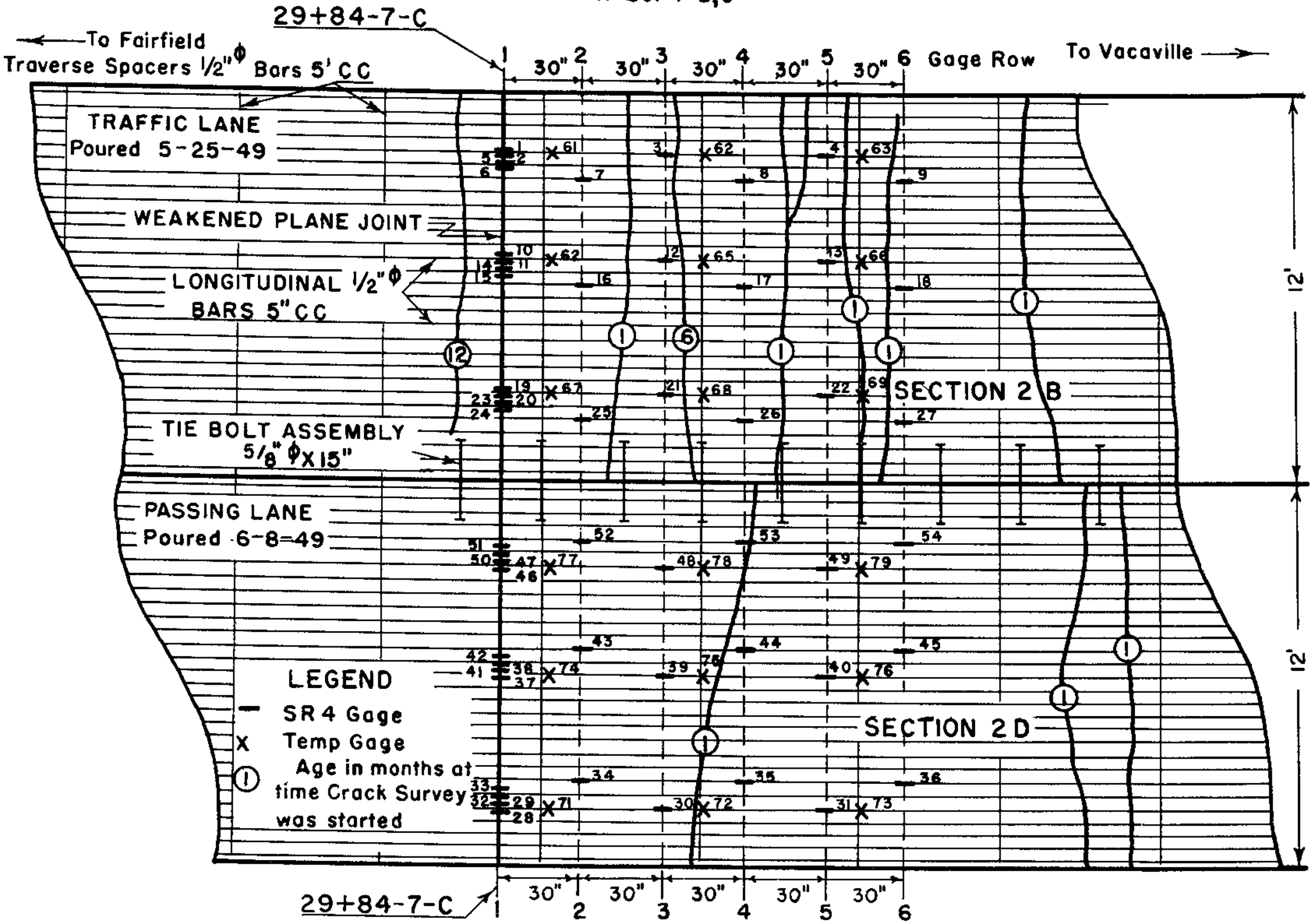
Fig 11

Res 00238

FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

Plan of Placement of SR-4 Gages on Reinforcing Steel and Crack Formation

X-Sol-7-B,C



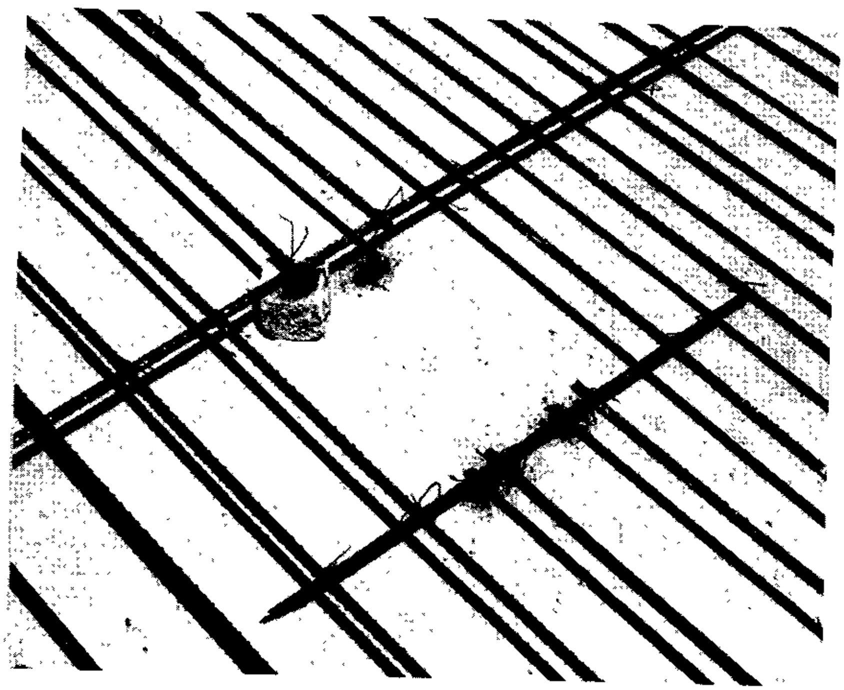


Fig. 12 Open space left in reinforcing steel for cutting core

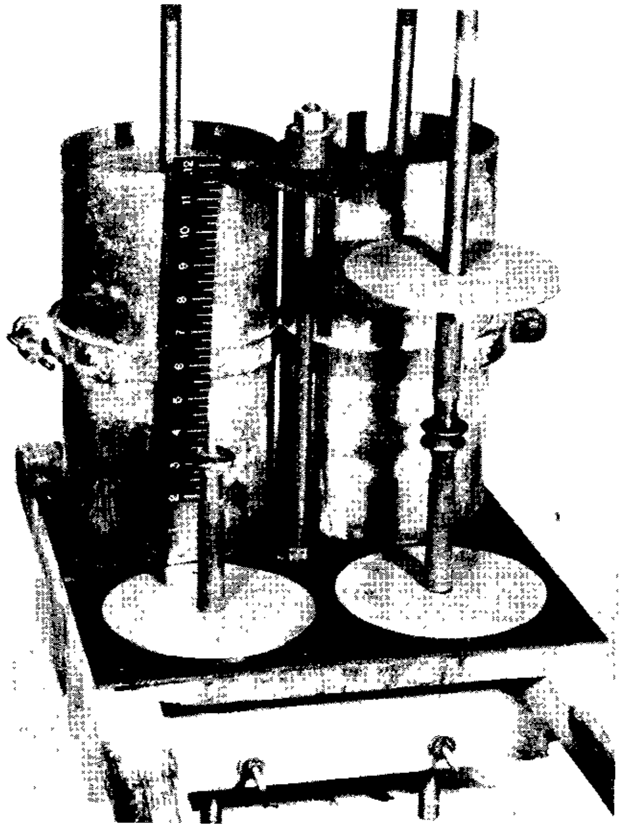
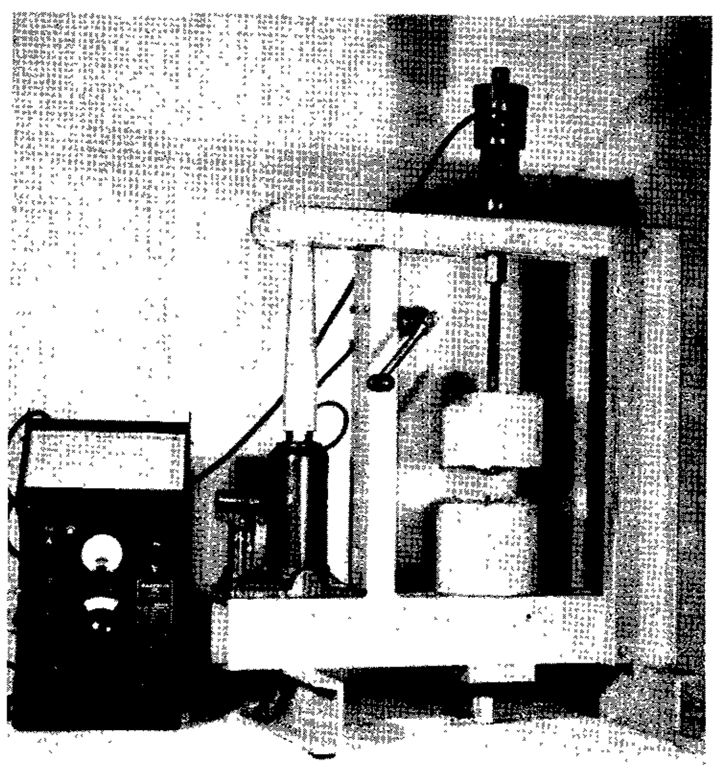


Fig. 13 Molds for making tensile strength test specimens

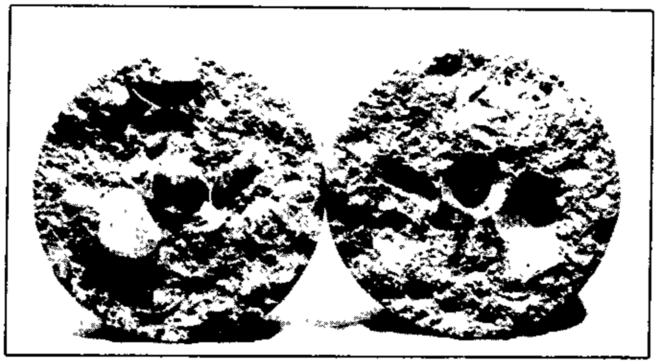


ig. 14 Field equipment for breaking tensile strength test specime

FRACTURES OF TENSILE TEST SPECIMENS

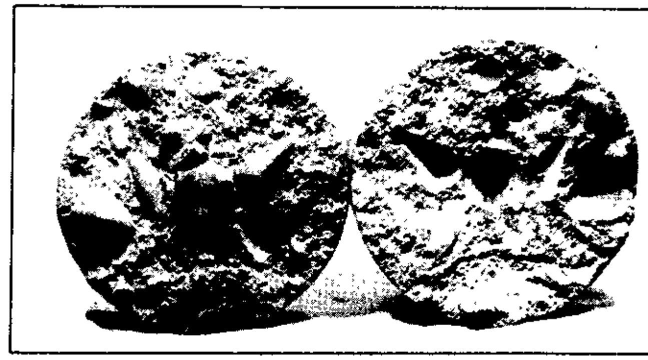
STANDARD CONCRETE

AGE 12 HOURS



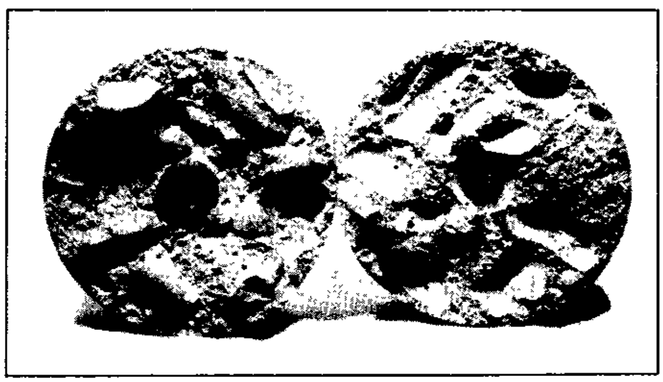
TOP BOTTOM

AGE 24 HOURS



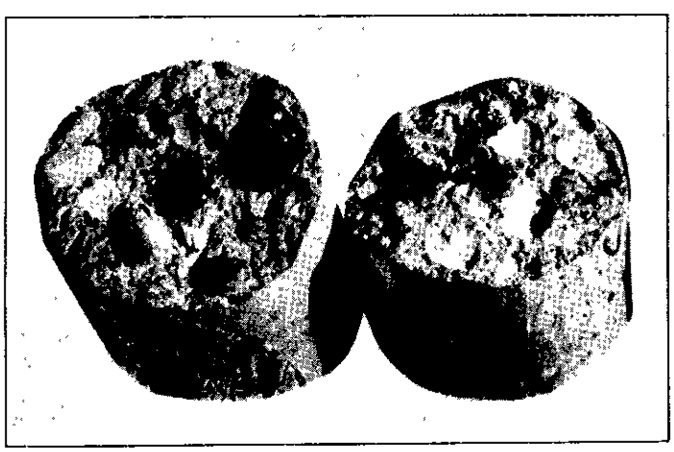
TOP BOTTOM

AGE 48 HOURS



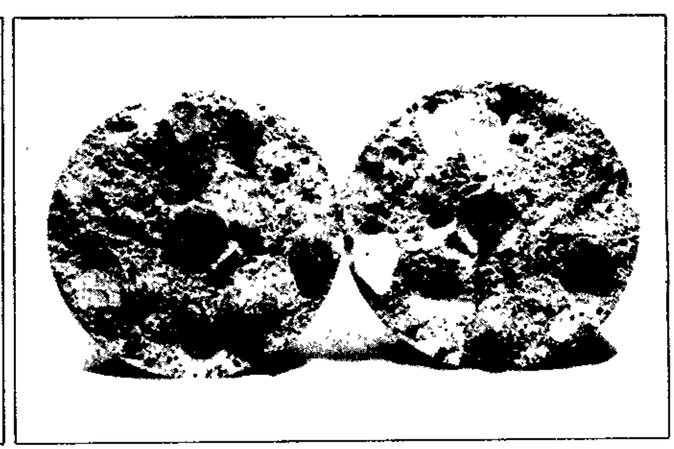
TOP BOTTOM

AGE 10 DAYS



TOP BOTTOM

AGE 28 DAYS



TOP BOTTOM

Fig 15

Fig 16

FAIRFIELD REINFORCED CONCRETE PAVEMENT TESTS

X-SOL-7-B.C

CRACK FORMATION DURING FIRST YEAR

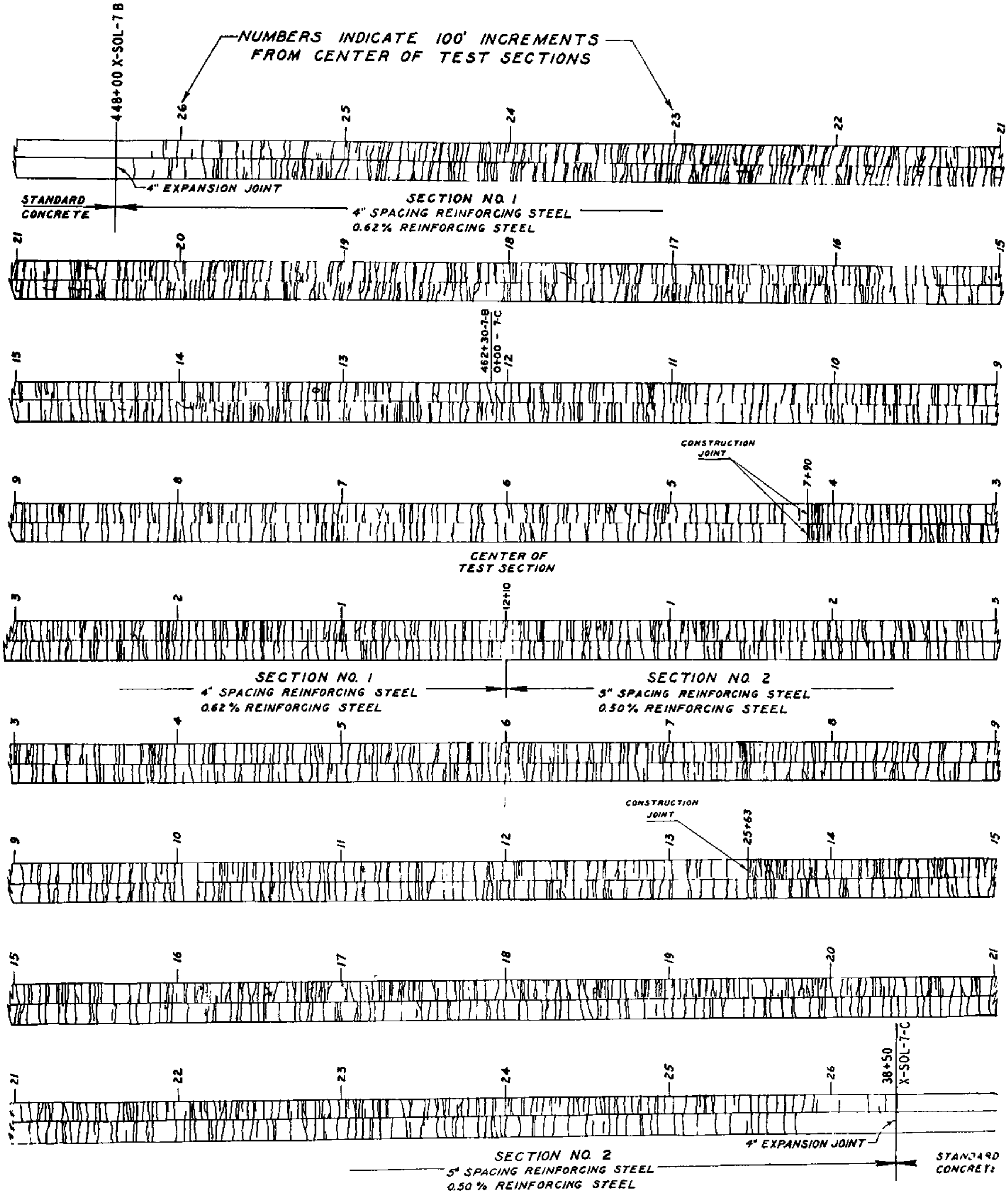


Fig 17

Res 00238

FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

X-Sol-7-B,C

Average Slab Lengths

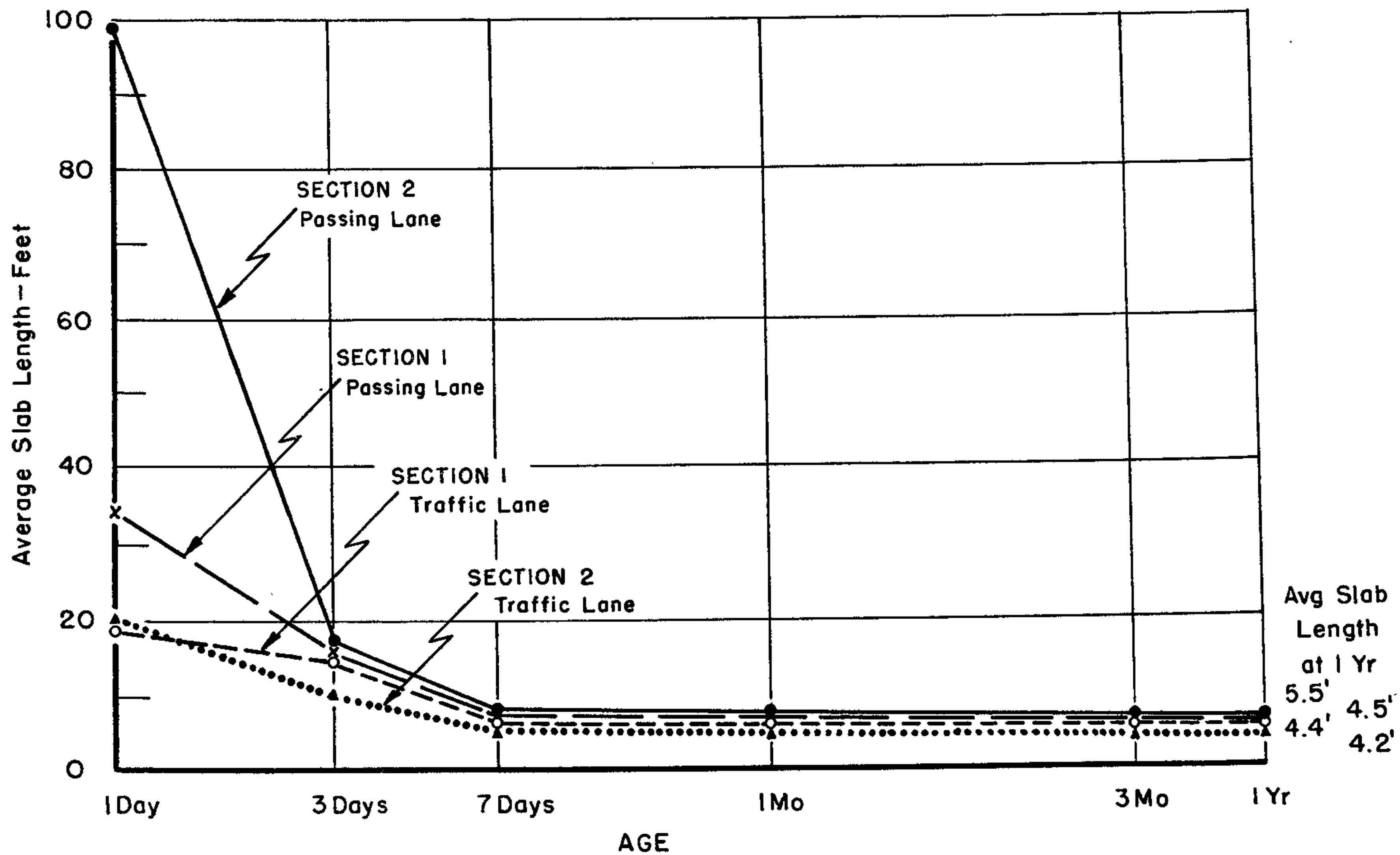


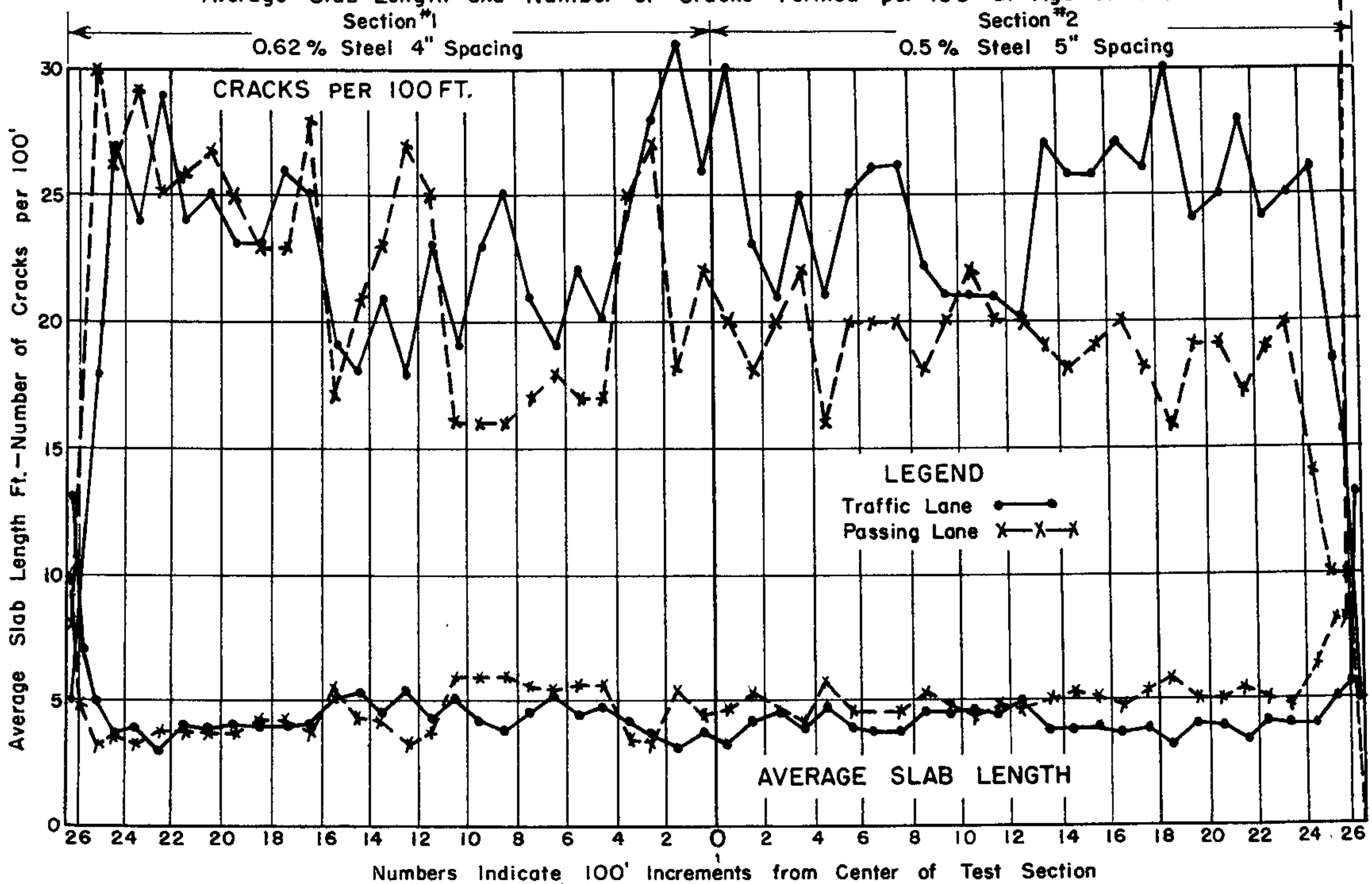
Fig 18

Res. 00238

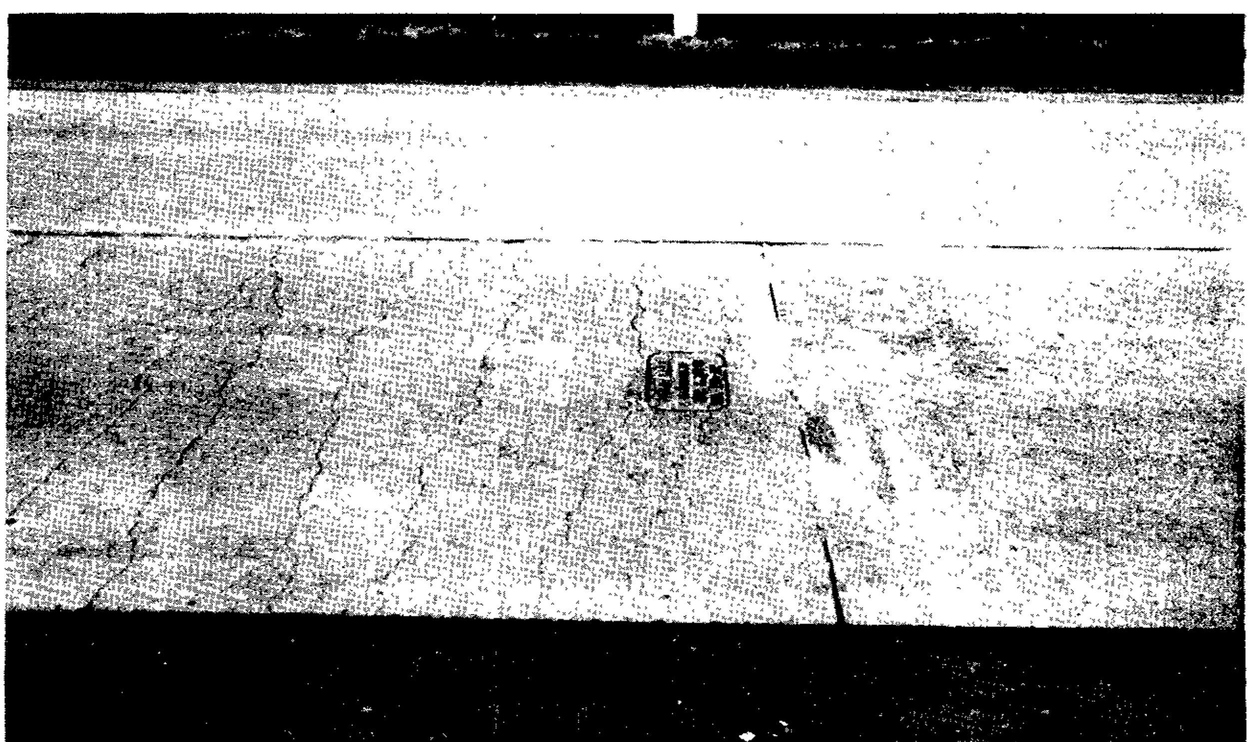
FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

X-Sol-7-B,C

Average Slab Length and Number of Cracks Formed per 100' at Age of 1 Year



(a) At Station 7+90



(b) At Station 25-63

Fig. 19 Photographs of pavement at construction joints, showing difference in crack pattern at end of one days run and start of next days run.

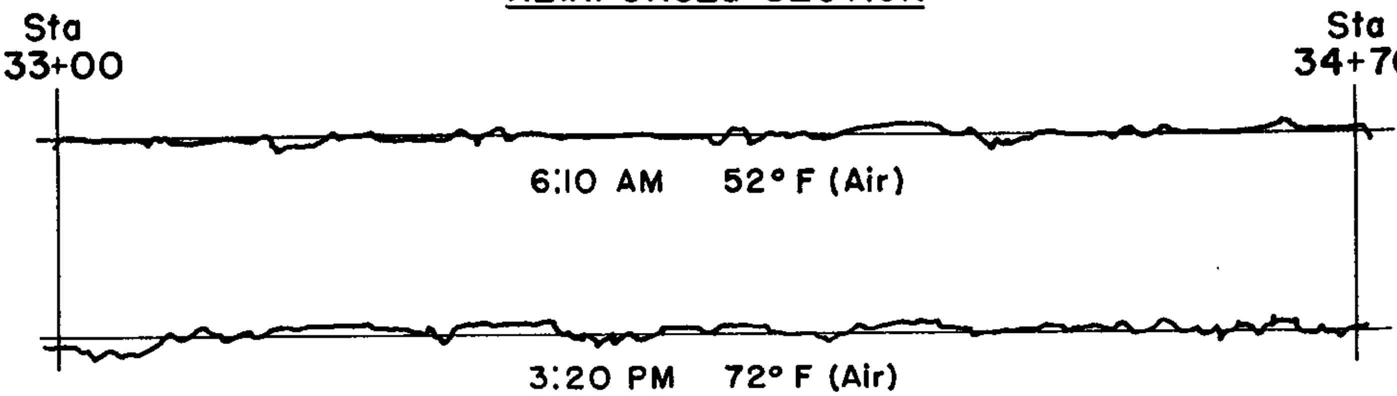
Fig 20

PROFILOGRAPH RECORDS

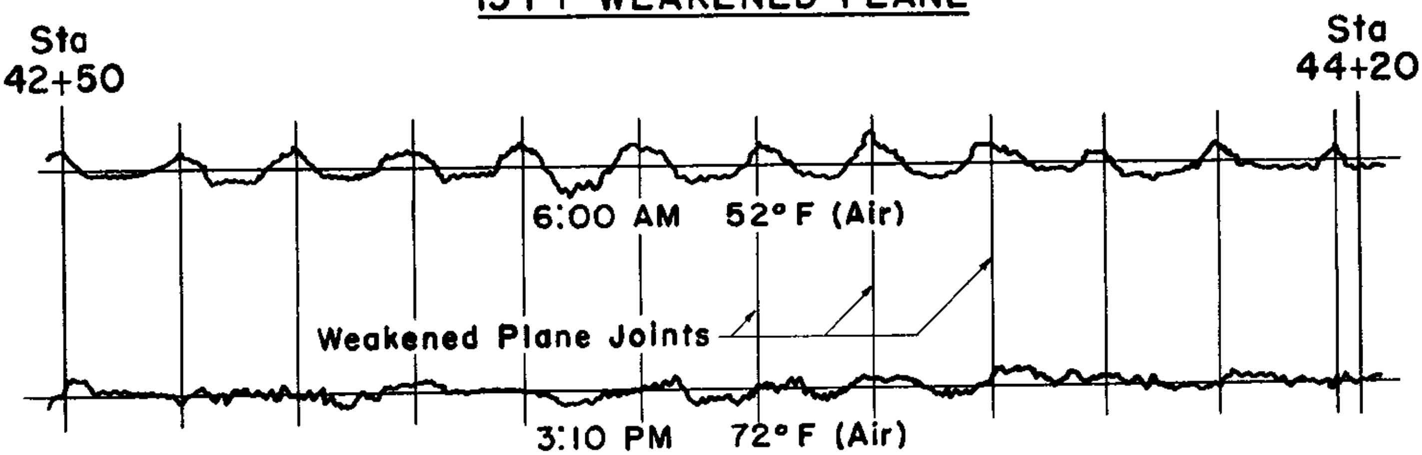
FAIRFIELD REINFORCED CONCRETE PAVEMENT TEST

X-Sol-7-B, C

REINFORCED SECTION



15 FT WEAKENED PLANE



SCALE

HORIZONTAL 1" = 25'

VERTICAL 1" = 1/2"

Profiles recorded on Profilograph approximately 350 feet north and south of 4 inch expansion joint at south end of reinforced section, station 38+50. These profiles were taken June 15, 1950.

RESEARCH No 00238
50-161-2