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Sept. 24, 1943

STATE OF CALIFORNIA

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

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A 5-YEAR REPORT COVERING THE CONSTRUCTION, CONDITION, AND ACCUMULATED TEST DATA ON THE THREE AND FOUR SACK CONCRETE PAVEMENT CONSTRUCTED IN 1938 BETWEEN ORANGE AND OLIVE IN ORANGE CO.

VII-Ora-181-A

Contract 87XC31-07XC8

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The project discussed in the following report is a section of State Highway, approximately 0.95 of a mile in length, situated between the towns of Orange and Olive in Orange County. It is a portion of highway VII-Ora-181-A and extends from Sta. 423+17 to Sta. 473+17.

The work was experimental to the extent that the specifications for the concrete pavement were on a strength rather than a fixed cement basis; except that it was not contemplated to use less than four sacks of cement per cubic yard of concrete. Therefore, the Special Provisions permitted a reduction of the cement content below the standard of five sacks to any extent (but not less than four sacks) that the contractor could demonstrate a flexural strength of not less than 450 lbs.

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per square inch at seven days by full size trial batches mixed on the project.

If the average flexural strength, at 7 days, of the best 4 out of 5 beams was less than 450 lbs. per sq. in. the cement content was to be increased enough to produce the specified strength.

The sources from which aggregates and cement were obtained for use in the concrete pavement, together with the results of acceptance tests are shown on Table 1.

In April and May, 1938, approximately 15 trial batches were made at times when concrete was being placed in structures. Twelve of these batches contained 4 sacks of cement per cu. yd. and 3 of them 3 sacks per cu. yd.

The amount of water per sack of cement, the proportion of different sizes of aggregate, and the workability of the test batches, together with the results of tests on specimens fabricated from them, are shown in Table 2, the data for which was obtained from the "SUPPLEMENTAL REPORT ON THE REDUCTION ON CEMENT CONTENT ON CONTRACT 07XC8-87XC31" by District Engineer S. V. Cortelyou under date of Sept. 1, 1938.

The pavement was constructed between June 11th and June 24, 1938, in eight daily sections. Four sack concrete was used throughout except for two experimental sections in which the cement content was reduced to 3 sacks per cu. yd. Each of the 3-sack sections was approximately 500 ft. long, with one section in each lane as follows:

Right Lane - 3-sack concrete Sta. 458+92 to Sta. 463+85
Left Lane - 3-sack concrete Sta. 440+60 to Sta. 445+55

Test specimens, beams and cylinders, were made each day concrete was placed in the pavement. Results of tests on those specimens are shown in Table 3. The average grading of the combined aggregate used in the pavement is shown in Table 1.

The pavement slab was cured under a 3 inch earth blanket saturated with water for 8 days.

A portion of the surface of the 3-sack concrete was treated with a solution of sodium silicate to determine the hardening effect, if any, of the sodium silicate upon the surface of this low cement factor concrete.

At the end of the curing period, but before the pavement was opened to traffic, a section of the 3-sack pavement, 200 ft. in length in each lane, was treated with an application of sodium silicate solution equivalent to .0216 gal. of "O" grade

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per sq. yd. On the following day, the same sections were given a second application at the same rate per sq. yd. The "O" grade sodium silicate was diluted with 3 to 4 parts of water, and the solution applied with push brooms. The silicate treated sections were located as follows:

Right Lane - Sta. 460+03 to Sta. 462+03
Left Lane - Sta. 441+70 to Sta. 443+74

Expansion joints were placed at 60 foot intervals throughout the project with intermediate dummy joints every 20 feet. Nine logitudinal dowels, fitted with expansion caps were placed at each expansion joint.

In the District Engineer's Supplemental Report, mentioned above, it was noted that a blanket of selected subgrade material, 1 ft. in thickness, was placed under the entire pavement. It was also noted that the underlying material from Sta. 423+17 to Sta. 449+00 was poor, while that from Sta. 449+00 to Sta. 473+16 was good.

Cores were cut and tested for compressive strength at an approximate age of 60 days. A similar set of cores was cut in June, 1940, for 2-year tests and, in July 1943, a third set was cut from the same locations for 5-year tests. Results of tests on these three sets of cores, together with the locations from which they were obtained are shown on the attached Table 4. The average core strengths were as follows:

	60 Day	2 Years	5 Years
3-Sack	2923	3610	4303
4-Sack	5193	5855	6275

The treatment with sodium silicate was to harden the surface only; therefore, no difference in compressive strength of the 3-sack concrete was anticipated as a result of this treatment. The core test results shown in Table 4 indicate approximately equal strength for the treated and the untreated pavement.

In Figure 1 the average strengths of the cores and of the daily test cylinders have been plotted to scale. These curves show not only the greater strength of the cores, but also a very striking similarity in shape.

When the 2-year survey of the project was made in 1940, it was noted that the 3-sack pavement showed slightly more evidence of wear than the 4-sack sections as indicated by greater surface exposure of the aggregate. It was likewise noted that the silicate treated areas showed less exposure of the aggregate than the untreated areas.

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In 1943, at the end of five years of service, very little, if any, additional change in surface appearance could be noted. The exposure of the fine surface aggregate was most noticeable on the 3-sack untreated; less pronounced, but still apparent, on the 3-sack treated; and almost unnoticeable on the 4-sack. However, the actual wear, even where most pronounced, was slight.

Transverse cracks, usually extending the full width from center joint to edge, have formed at a number of locations. On July 25, 1938, eleven days after the pavement had been opened to traffic, a total of 13 such transverse cracks were noted; eight in the 3-sack pavement and five in the 4-sack. Two years later, in June, 1940, the total number of cracks amounted to 15, with 9 in the 3-sack and 6 in the 4-sack sections. In July, 1943, the crack survey showed a total of 14 cracks in each type of concrete. The number and distribution of cracks at each period were as follows:

Date	Total No.	Right Lane 3-Sack	Right Lane 4-Sack	Left Lane 3-Sack	Left Lane 4-Sack
7/25/38	13	(8 in 3-sack, 5 in 4-sack)			
6/20/40	15	2	2	7	4
7/28/43	28	2	4	12	10

The locations of the various cracks are shown in Figure 2. The cracks which occurred prior to June, 1940, are shown in black and those which have formed since that date are shown in red. It will be noted that the greater portion of the cracks are in the left lane between Sta. 436+00 and Sta. 435+00. This is in the area described as underlain with poor subbase material but the reason why there should be 18 cracks in the left lane between those stations and only 3 in the right lane is not apparent.

In general the project is a smooth riding section of pavement and there is no appreciable difference between the 3-sack and the 4-sack sections except for the slight surface exposure of aggregate previously noted.

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TABLE 1

TEST RESULTS ON SAMPLES OF

CONCRETE AGGREGATES AND CEMENT

USED IN THE

THREE AND FOUR SACK CONCRETE PAVEMENT

VII-Ora-181-A Contract 87XC31-07XC8

Aggregates

Test	Coarse	Fine: Concrete Sand	Fine: Filler Sand
Date Sampled (1938)	4/1	4/9	4/9
Sample Number	VII7207	7620	7622
% Wear, L.A. Rattler 100 Rev.	3.1		
% Wear, L.A. Rattler 500 Rev.	15.7		
Specific Gravity	2.31	2.64	2.63
Colorimetric Test		O.K.	O.K.
28 Day Results			
Sand Mortar Comp. Str.		7338	6006*
Sand Mortar % of Ottawa		122.2	106.0

* Tests made on a mixture containing 80% concrete Sand and 20% filler sand

Aver. Combined Grading

Percent Passing	Sieve	%
	2-1/2	94
	2	85
	1-1/2	72
	3/4	49
	# 3	37
	# 10	26
	# 20	19
	# 30	13
	# 40	9.5
	# 80	2.1
	#200	0.5

Coarse Aggregate from Graham Bros. Plant at Santiago Creek
Concrete Sand " " " " " "
Filler Sand " " " " " Olive (Santa Ana River)
Water from City of Olive (Domestic Supply)

Cement

Date Sampled	2/9/38
Mfr. Southwestern Port.Cem.Co., Victorville	
Bin No.	3
C.H.C. No.	44
% Passing #325 Sieve	94.0
Surface Area, (Sq. Ft.)	1943
Autoclave Expansion	+.160

Sand Mortar Tests	7 Days	28 Days
Aver. Compressive Str. (1-2)	6330	8050
Aver. Tensile Str. (1-3)	335	475

Chemical Analysis	
Fe_2O_3	1.93
Al_2O_3	3.80
SO_3	1.72
MgO	2.00
Ignition loss	0.91
Insoluble	0.09
C_3A	6.76

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TABLE 2

PRELIMINARY TRIAL BATCHES - COMPOSITION AND TEST RESULTS
THREE AND FOUR SACK CONCRETE

VII-Ora-181-A

Contract 07XC8

Spec. No. Date (1938)		T-2 4/8	T-3 4/8	T-5 4/11	T-6 4/11	T-8 4/20	T-9 4/20	T-10 4/20	T-12 4/29	T-13 4/29	T-14 4/29	T-18 5/9	T-19 5/9	T-20 5/9	T-23 5/18	T-24 5/18
Cement Sks./Cu.Yd.		4	4	4	4	4	4	4	4	4	4	3	3	3	4	4
Water Lbs./Sack		76.5	76.5	74	74	74	74	70	72**	72**	72**	93	93	93	64	65
Aggregates % of Each Size	#30	8	8	0	0	0	3	0	4	4	4	4	4	6	4	0
	# 3	25	25	38	40	35	30	35	32	31	31	31	31	28-	26	30
	3/4"	20	20	40	10	18	20	18	22	10	10	17	17	18	20	16
	1-3/4"	47	47	12	20	24	24	47	22	15	55	24	24	24	25	27
	2-3/4"	0	0	10	20	23	23	0	20	40	0	24	24	24	25	27
Flexural Tests On Beams		426*	450	457	397*	434*	475	473*	390*	371	404	517	398*	474	581	498*
		474	428	437*	399	578	459*	518	423	400	397	442	414	436*	526*	560
		488	400	481	451	470	506	492	400	367*	391	431*	493	466	632	525
		437	419	446	472	466	565	561	408	401	442	452	402	477	578	552
		472	380*	483	403	480	528	569	448	404	385*	452	450	459	527	547
	Aver.	468	424	467	431	498	518	535	420	394	408	466	439	469	578	546
Compr. Tests On Cyl.	10 Day	2505	2520	2110	2095	2355	2175	2335	1785	2125	1760	1965	2070	2039	3070	2900
	28 Day	3645	3370	3560	3400	3385	3280	3460	2540	2925	2610	2500	2515	2700	3935	3905
Workability		Good	Good	Fair	Good	Good	Good	Poor	Good	Good	Fair	Good	Good	Good	Good	Good
Comments		El Monte Muck Sand Used		Mix Appears Too wet				Mix Appears Too dry	Too Wet	Too Wet	Too Wet		Victor "High Early" Cement Used			

* Not used for averages
** Mixes T-12, T-13, T-14 appeared too wet. Additional moisture in aggregate probable. Water per sack probably 76 pounds

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TABLE 3

CONCRETE MIX DATA AND RESULTS OF TESTS ON DAILY CONTROL SPECIMENS, ETC.
THREE AND FOUR SACK CONCRETE PAVEMENT

VII-Ora-181-A

Contract 07XC8

Specimen No.		2	3	4	4A	5	6	7	8	9
Date Cast	(1938)	6/11	6/13	6/16	6/16	6/17	6/21	6/22	6/23	6/24
Cement Content Sks./Cu. Yd.	Design	4	4	3	4	4	4	3	4	4
	Actual Yield	4.05	3.9	2.95		3.96	4.01	2.96	4.01	4.0
Water, Lbs. per Sack		71	74.5	103	76	73.5	74	97	71	72
Slump in Inches		1½	1-3/4	1-3/4		1-3/4	1-3/4	2	1-3/4	1-3/4
Aggregates Average % of Each Size Used	#30 Max.	5	5	6	5	0	0	4	3	3
	# 3 Max.	27	27	28	27	32	32	30	29	29
	3/4 "	16	16	18	16	14	14	18	14	14
	1-3/4 "	26	26	24	26	27	27	24	27	27
	2-3/4 "	26	26	24	26	27	27	24	27	27
Flexural Strength of Beams	7 Day Specimens	610	458	330	488	541	518	323	394	450
		576	518	334	495	606	503	378	472	407
		577	482	361	422	552	539	360	470	431
	Average	588	486	341	468	566	520	354	445	429
	14 Day Specimens	613	571	376	602	538	528	336	605	559
		648	579	375	510	600	560	440	559	489
		631		385	668	621	625	378	608	459
	Average	631	757	379	593	586	571	385	591	502
Compressive Strength 6" x 12" Cylinders	10-Day	2525	2225	950		2260	2050	760	2335	2210
	28-Day	3720	2935	1295		3045	2970	1145	2850	2970
	90-Day						3360	1700	3270	3665
	1-Year						3440	2000	3615	3980

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TABLE 4
A FIVE YEAR SUMMARY
OF THE
COMPRESSIVE STRENGTH OF CORES
FROM THE
THREE AND FOUR SACK CONCRETE PAVEMENT

VII-Ora-181-A — Between Orange and Olive

THREE SACK CONCRETE

Const. Date 1938	Surface Treatm't	Lane	Compressive Strength in lbs./Sq. In. 60 days Station	60 days Comp. Str.	2 Years Station	2 Years Comp. Str.	5 Years Station	5 Years Comp. Str.	Unit Weight Lbs. per Cu. Ft. 60 Day Cores	2 Year Cores	5 Year Cores
6/16	None	Right	459+10	2737	459+18	3062	459+08	3620	150.8	150.7	149.7
"			459+90	2777	459+97	3554	459+93	4090	148.8	149.8	150.8
"			462+50	3311	462+49	3494	462+46	4895	149.5	150.8	152.3
"	Sod.Sil**		460+15	2437	460+18	4242	460+08	3995	147.9	151.5	149.5
"			460+50	3463	460+57	3959	460+60	4235	150.0	149.4	151.0
"			461+50	2625	461+53	3452	461+47	3960	148.5	151.5	150.3
6/22		Left	441+87	2803	441+81	3510	441+90	4505	151.4	149.3	151.4
"			442+48	3248	442+50	3553	442+43	4860	149.6	149.9	150.7
"			443+05	2897	443+09	3589	443+00	4705	148.8	150.6	150.5
"	None		441+20	3300	441+22	4194	441+30	4965	148.1	148.9	151.8
"			444+85	2840	444+94	3157	444+81	3580	148.8	148.7	152.1
"			445+25	2636	445+19	3548	445+30	7025*	150.4	150.9	153.1
	Untreated			2934		3502		4230	149.4	150.0	151.6
	Surf.Treated			2912		3717		4377	149.4	150.4	150.6
	All 3-Sk. Crs			2923		3610		4303	149.4	150.2	151.1

Average Compressive Strength of 3-Sack Cylinders
10-Day 855, 28-Day 1220, 90-Day 1700, 1 Year 2000

FOUR SACK CONCRETE

6/11	None	Right	432+40	5309	432+38	5485	432+30	6815	150.8	149.9	152.8
6/13			437+40	5735	437+36	5461	437+28	6455	151.9	151.3	153.3
"			447+05	5347	446+97	5383	447+03	5930	151.3	151.6	151.9
6/16			458+40	4646	458+34	5644	458+36	5890	151.3	151.4	153.0
"			464+40	5133	464+40	5256	464+36	5705	148.5	149.4	151.3
6/17			467+47	5618	467+40	5262	467+43	6515	153.5	151.9	152.9
6/22		Left	437+70	5277	437+78	6052	437+74	5785	151.3	151.6	154.1
"			440+40	5516	440+42	6987	440+50	6855	150.0	150.4	153.2
6/24			464+20	4416	464+25	6139	464+17	6615	150.9	150.4	152.4
"			467+03	4255	466+98	6077	467+00	6145	148.1	149.2	150.5
"			467+62	5867	467+66	6358	467+58	6320	152.5	152.9	154.3
Average strength of 4-sack Cores				5193		5855		6275	150.9	150.9	152.7

Average Compressive Strength of 4-Sack Cylinders
10-Day 2267, 28-Day 3082, 90-Day 3432, 1 Year 3678

*Not included in average.
**Sod. Silicate treatment consisted of two applications of "O" grade sodium silicate solution to the pavement surface after the concrete had cured 17 to 22 days. Each application was at an approximate rate of .02 gal. per sq. yd. or a total of 0.04 gal. per sq. yd.

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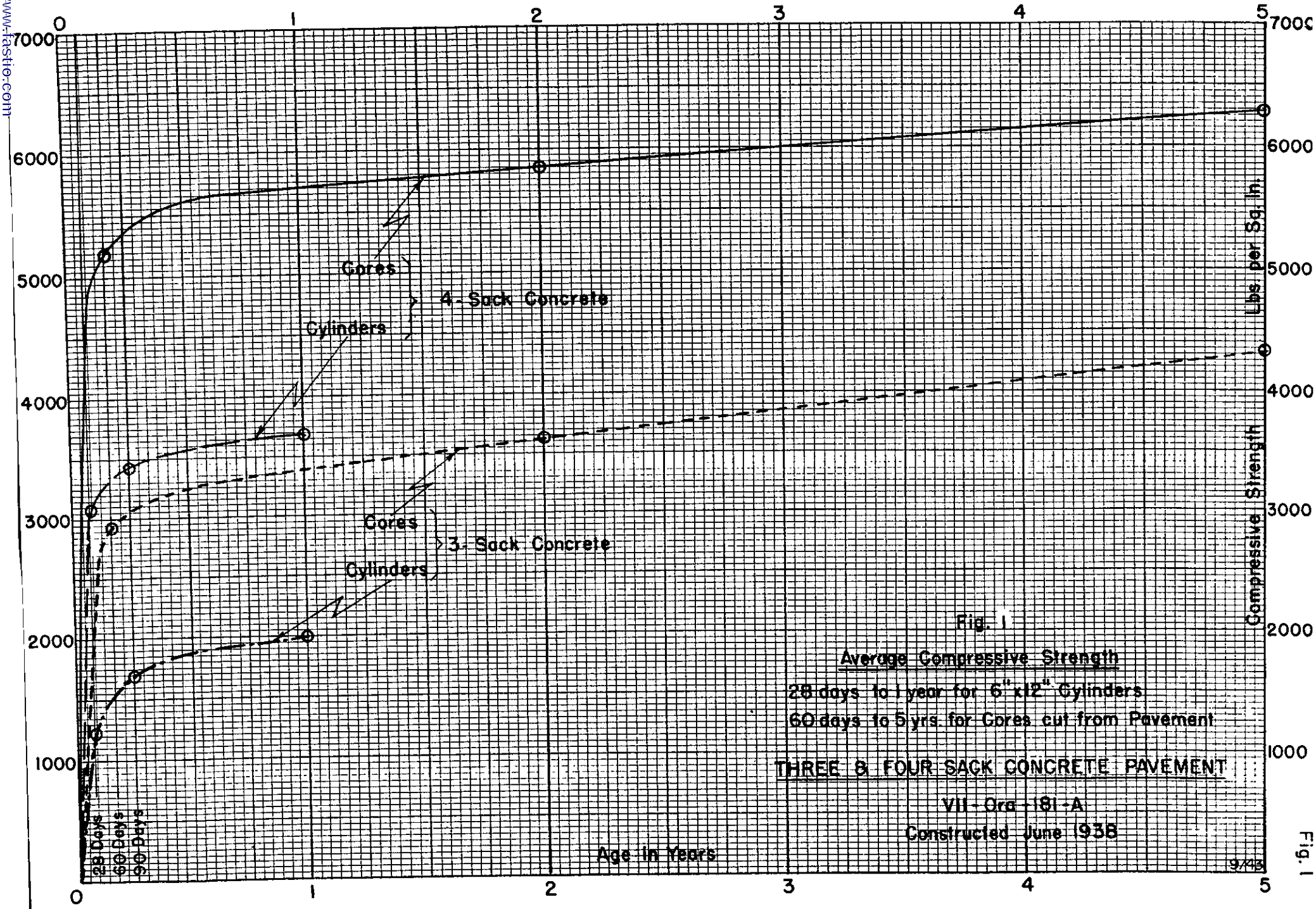

Fig. 1

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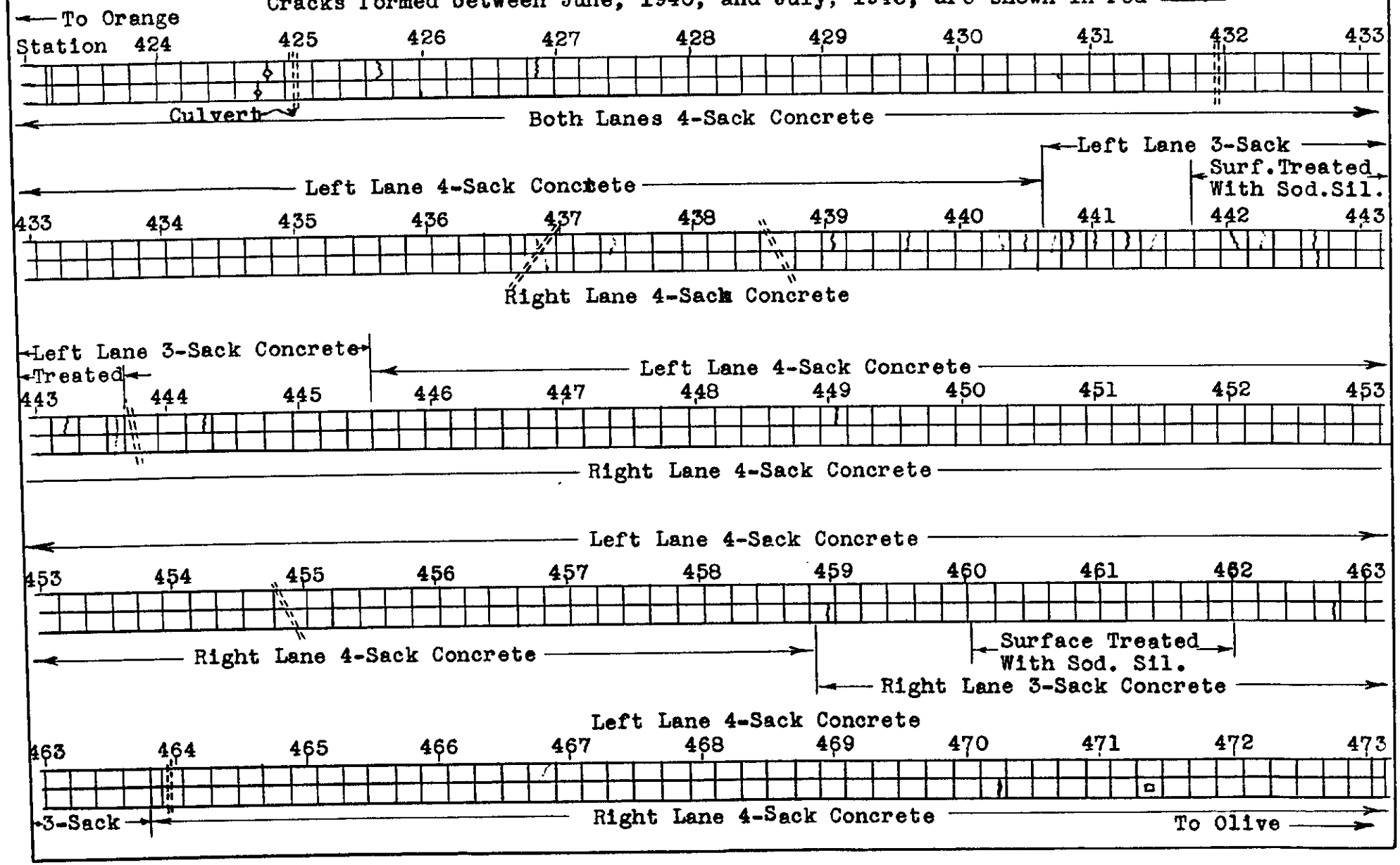
FIGURE 2

LOCATION OF CRACKS IN CONCRETE PAVEMENT CONSTRUCTED IN JUNE, 1938, ON VII-Ora-181-A

Cracks formed prior to June, 1940, are shown in black

Cracks formed between June, 1940, and July, 1943, are shown in red



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