Technical Report Documentation Page

1. REPORT No.
R-00173

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
A 13 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

5. REPORT DATE
May 1951

6. PERFORMING ORGANIZATION

7. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT No.
R-00173

9. PERFORMING ORGANIZATION NAME AND ADDRESS
State of California
Department of Public Works
Division of Highways
Materials and Research Department

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT & PERIOD COVERED

14. SPONSORING AGENCY CODE

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

16. ABSTRACT

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 originally 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. per square inch at seven (7) days by full size trial batches mixed on the project.

If the average flexural strength, at 7 days, of the best four out of five beams was less than 450 lbs. per square inch, the cement content was to be increased enough to produce the specified strength.

The sources from which the 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 cubic yard and three of them 3 sacks per cubic yard.

The amount of water per sack of cement, the proportion of different sizes of aggregate, and the workability of test batches, together with the results of tests on specimens are shown in Table 2, the data for which was obtained from the "SUPPLEMENTAL REPORT ON THE REDUCTION ON CEMENT CONTENT ON CONTRACT 07XC3-87XC31", by District Engineer S.V. Cortelyou under date of September 1, 1938.

17. KEYWORDS
R-00173
VII-Ora-181-A
Contract 87XC31-07XC8

18. No. OF PAGES:
26

19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1930-1955/51-02.pdf

20. FILE NAME
51-02.pdf

R-00173

STATE OF CALIFORNIA

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

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A 13 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 COUNTY

VII-Ora-181-A

Contract 87XC31-07XC8

REPORT BY

THOMAS E. STANTON
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Report by

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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 originally 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. per square inch at seven (7) days by full size trial batches mixed on the project.

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The pavement was constructed between June 11th and June 24th, 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 cubic yard. Each of the 3-sack sections was approximately 500 feet 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 eight 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 of from seventeen (17) to twenty-two (22) days, but before the pavement was opened to traffic a section of the 3-sack pavement 200 feet in length in each lane was treated with an application of sodium silicate solution equivalent to .0216 gallon of "O" grade per square yard. On the following day, the same sections were given a second application at the same rate per square yard. 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 - Station 460+03 to Station 462+03
Left Lane - Station 441+70 to Station 443+74

Expansion joints were placed at 60 foot intervals throughout the project with intermediate dummy joints every 20 feet. Nine longitudinal 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 select subgrade material one (1) foot in thickness was placed under the entire pavement. It was also noted that the underlying material from Station 423+17 to Station 449+00 was poor while that from Station 449+00 to Station 473+16 was good. It will be noted that the greatest incidence of intermediate cracking subsequent to construction occurred in the portion reported to have a poor subgrade, although much of this portion of the pavement has few volunteer cracks.

Cores were cut and tested for compressive strength at an approximate age of 60 days. A similar set of cores was cut at approximately the same locations in June, 1940, for two-year tests, in July, 1943, for five-year tests, and in July, 1949, for eleven-year tests. Results of tests on these four sets of cores are shown in Table 4. The average core strengths were as follows:

	60 Days	2 Years	5 Years	11 Years
3-Sack	2923	3610	4303	4347
4-Sack	5193	5828	6275	5925

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.

In 1951, at the end of thirteen years of service, very little if any, additional change in surface appearance could be noted. The surface exposure of the fine 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 July, 1940, the total number of cracks amounted to 15, with 9 in the 3-sack and six in the 4-sack sections. In July, 1943, the crack survey showed a total of 14 cracks in each type of concrete and in 1950, there were 24 cracks in the 3-sack and 39 cracks in the 4-sack sections. The number and distribution of cracks at each period were as follows:

Date	Total Number	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
10-23-50	63	7	18	17	21

The locations of the various cracks are shown in Figure 2. It will be noted that the greater portion of the cracks are in the left lane between Station 436+00 and Station 445+00. This is in the area described as underlain with poor subbase material but the reason why there should be 25 cracks in the left lane between those stations and only 6 in the right lane is not apparent.

In general the project is still smooth riding after 13 years. There is no appreciable difference between the riding qualities of the 3-sack and the 4-sack sections except for the slight surface exposure of aggregate previously noted.

The most recent inspection was made by the writer on December 15, 1950. The entire section was in first class condition at that time and provides an excellent illustration of the potentialities of a 3 and 4-sack concrete pavement on subgrades such as are being constructed today, when subjected to what may be classed as moderate traffic as shown by the following traffic count, reported by the Traffic Department for the year 1950.

South on Ora-181-A, at Junction of Routes 181 and 178, 16 hour count, 6 A.M. to 10 P.M.

January to December, 1950

January	1495	July	1955
February	1478	August	1726
March	1691	September	1822
April	1636	October	1777
May	1455	November	1613
June	1957	December	1718

Average 1700

Following is the July traffic count each year since construction in 1938, readings on Sunday and Monday.

Year	Sunday	Monday
1938	2785	1913
1939	2375	1772
1940	2263	1665
1941	2353	1630
1942	1789	1120
1943	1522	1198
1944	992	875
1945	1825	1397
1946	2272	1794
1947	2143	1866
1948	2149	1735
1949	2588	1930
1950	2190	1955

It will be noted that the Sunday traffic after falling in the war years to a minimum of 992, in 1944, has never returned to the 1938 traffic of 2785 being only 2190 in July, 1950. On the other hand, the Monday traffic which in July, 1938, was 1913 and fell to a minimum of 875 in 1944, has returned to approximately the 1938 level in 1950 when the 16 hour count was 1955.

As will be noted from the monthly count for 1950, the average 16 hour traffic on Mondays for the entire year was approximately 1700.

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 Com. Str.		7338	*6006
Sand Mortar % of Ottawa		122.2	106.0

Aver. Combined Grading: 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

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

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

Cement

Date Sampled	2-9-38
Mfr. Southwestern Portland Cement Co., Victorville	
Bin No.	3
C.H.C. No.	44
% Passing #325 Sieve	94.0
Specific Surface	1943
Autoclave Expansion	+.160

Sand Mortar Tests	7 Days	28 Days
Aver. Compressive Strength (1-2)	6330	8050
Aver. Tensile Strength (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

TABLE 2

PRELIMINARY TRIAL BATCHES - COMPOSITION AND TEST RESULTS

THREE AND FOUR SACK CONCRETE

VII-Ona-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
Aggregates % of Each Size # 3	25	25	38	40	35	30	35	32	31	31	31	31	28	26	30
Aggregates % of Each Size 3/4"	20	20	40	10	18	20	18	22	10	10	17	17	18	20	16
Aggregates % of Each Size 1-3/4"	47	47	12	20	24	24	47	22	15	55	24	24	24	25	27
Aggregates % of Each Size 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
Flexural Tests On Beams 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
Compr. Tests on Cyl. 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.

Table 2

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. Date Cast (1938)		2 6-11	3 6-13	4 6-16	4A 6-16	5 6-17	6 6-21	7 6-22	8 6-23	9 6-24
Cement Content Sks. Cu. Yd.	Design Actual Yield	4 4.05	4 3.9	3 2.95	4	4 3.96	4 4.01	3 2.96	4 4.01	4 4.0
Water, Lbs. per Sack		71	74.5	103	76	73.5	74	97	71	72
Slump in Inches		1-1/2	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. # 3 Max. 3/4 Max. 1-3/4 Max. 2-3/4 Max.	5 27 16 26 26	5 27 16 26 26	6 28 18 24 24	5 27 16 26 26	0 32 14 27 27	0 32 14 27 27	4 30 18 24 24	3 29 14 27 27	3 29 14 27 27
Flexural Strength of Beams	7 Day Specimens	610 576 577	458 518 482	330 334 361	488 495 422	541 606 552	518 503 539	323 378 360	394 472 470	450 407 431
	Average	588	486	341	468	566	520	354	445	429
	14 Day Specimens	613 648 631	571 579	376 375 385	602 510 668	538 600 621	528 560 625	336 440 378	605 559 608	559 489 459
	Average	631	575	379	593	586	571	385	591	502
Compressive Strength 6" x 12" Cylinders	10 Day 28 Day 90 Day 1 Year	2525 3720	2225 2935	950 1295		2260 3045	2050 2970 3360 3440	760 1145 1700 2000	2335 2850 3270 3615	2210 2970 3665 3980

TABLE 4
AN ELEVEN YEAR SUMMARY
OF THE
STRENGTH TEST RESULTS

THREE AND FOUR SACK CONCRETE PAVEMENT

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

THREE SACK CONCRETE

Lane	Flexural Strength		COMPRESSIVE STRENGTH							
			Cylinders				Field Cores			
	7 Days	14 Days	10 Days	28 Days	90 Days	1 Year	60 Days	2 Years	5 Years	11 Years
Right	341	379	950	1295			2737	3062	3620	3969
							2777	3554	4090	4015
							3311	3494	4895	4216
							2437	4242	4995	4262
							3463	3959	4235	----
							2625	3452	3960	4992
Left	354	385	760	1145	1700	2000	2803	3510	4505	----
							3248	3553	4860	4620
							2897	3589	4705	4415
							3300	4194	4965	4639
							2840	3157	3580	----
							2636	3548	7025*	3995
Average	Untreated Surface Cores						2934	3502	4230	4167
	Surface Treated Cores						2912	3717	4377	4572
	All 3-sack cores						2923	3610	4303	4347

FOUR SACK CONCRETE

Right	588	631	2525	3720			5309	5485	6815	6558
	486	575	2225	2935			5735	5461	6455	5732
							5347	5383	5930	6145
	468	593					4646	5644	5890	5520
							5133	5256	5705	5909
	566	586	2260	3045			5618	5262	6515	5239
Left	520	571	2050	2970	3360	3440	5277	6052	5785	6088
	445	591	2335	2850	3270	3615	5516	6987	6855	6881
	429	502	2210	2970	3665	3980	4416	6139	6615	6866
							4255	6077	6145	5032
							5867	6358	6320	5501
Average	500	578	2268	3082	3432	3678	5193	5828	6275	5952

*Not included in average

Fig. 1

AVERAGE COMPRESSIVE STRENGTH

28 Days to 1 year for 6"x12" Cylinders
60 Days to 11 years for Cores

THREE & FOUR SACK CONCRETE PAVEMENT

South of Olive Orange Co.
VII-Ore-181-A
CONSTRUCTED JUNE 1938.

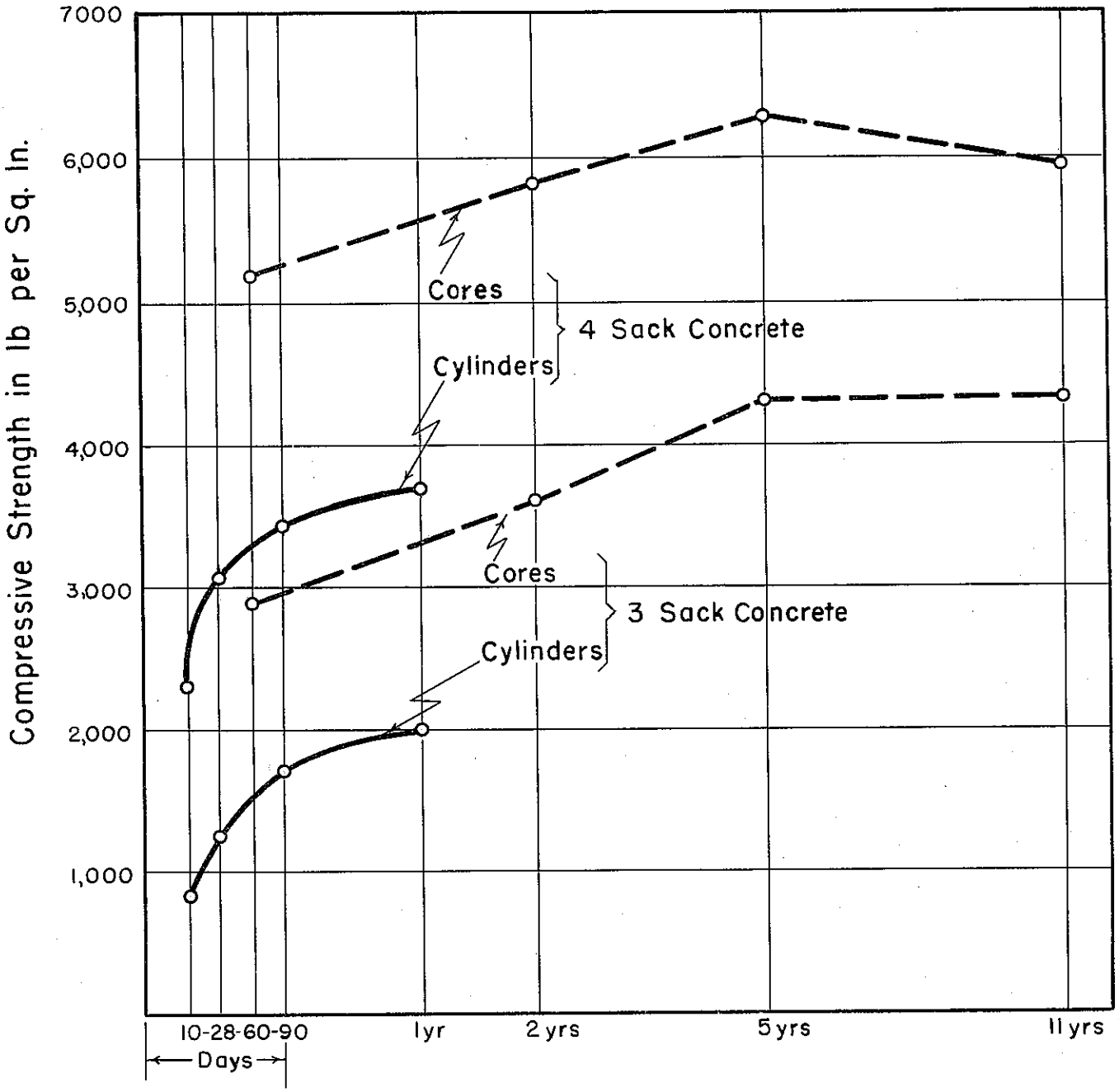

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FIGURE 2

CRACKS IN 3 AND 4 SACK CONCRETE PAVEMENT CONSTRUCTED IN JUNE, 1938, ON VII-ORA-181-A

South of Olive - Orange County

Cracks formed during the thirteen year period between June, 1938 and Oct., 1950