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Investigation of the Use of Lime For Treating Clay Basement Soil For Use As A Base Under Asphalt Concrete Surfacing

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16. ABSTRACT
Clay soils have been lime treated on a limited number of projects on California Highways. In most cases, the lime treated materials have been used on roads with low traffic as a subbase layer under aggregate base and an asphalt concrete surfacing.

A road in Yolo County, California, was constructed utilizing the native clay soils treated with lime as a base and subbase under an asphalt concrete surfacing. Two other types of structural sections were constructed and used for comparison. The three types of structural sections are as follows:

Structural Section A. 15 inches of lime treated material surfaced with 2 inches of asphalt concrete.

Structural Section B. 12 inches of lime treated material with 6 inches of untreated aggregate base surfaced with 2 inches of asphalt concrete.

Structural Section C. 15 inches of untreated aggregate subbase and 6 inches of untreated aggregate base surfaced with 2 inches of asphalt concrete.

Deflection measurements supplemented by visual observations and laboratory tests were used to evaluate the performance of the three types of structural sections.

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Soil stabilization, lime, clays, bases, subbase material, subbase, pavement deflections, pavement evaluation, laboratory tests, expansion contraction

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HIGHWAY RESEARCH REPORT

INVESTIGATE USE OF LIME FOR TREATING CLAY SOIL FOR USE AS A BASE UNDER ASPHALT CONCRETE SURFACING

STATE OF CALIFORNIA

TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 633190

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads June, 1967

U.S. Department of Transportation, Bureau of Public Roads

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
SACRAMENTO, CALIFORNIA

June 1967

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is

A

REPORT ON

INVESTIGATION OF THE USE OF LIME FOR TREATING

CLAY BASEMENT SOIL FOR USE AS A BASE

UNDER ASPHALT CONCRETE SURFACING

ERNEST ZUBE
Principal Investigator

CLYDE GATES
MAS HATANO
Co-Investigators

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

REFERENCE: E. Zube, C. Gates and M. Hatano, "Investigation of the Use of Lime For Treating Clay Basement Soil For Use As A Base Under Asphalt Concrete Surfacing", State of California Department of Public Works, Division of Highways, Materials and Research Department, Research Report 633190-1, June 1967.

ABSTRACT: Clay soils have been lime treated on a limited number of projects on California Highways. In most cases, the lime treated materials have been used on roads with low traffic as a subbase layer under aggregate base and an asphalt concrete surfacing.

A road in Yolo County, California, was constructed utilizing the native clay soils treated with lime as a base and subbase under an asphalt concrete surfacing. Two other types of structural sections were constructed and used for comparison. The three types of structural sections are as follows:

<u>Structural Section A.</u> 15 inches of lime treated material surfaced with 2 inches of asphalt concrete.

<u>Structural Section B.</u> 12 inches of lime treated material with 6 inches of untreated aggregate base surfaced with 2 inches of asphalt concrete.

<u>Structural Section C.</u> 15 inches of untreated aggregate subbase and 6 inches of untreated aggregate base surfaced with 2 inches of asphalt concrete.

Deflection measurements supplemented by visual observations and laboratory tests were used to evaluate the performance of the three types of structural sections.

At the end of 1½ years, structural sections B and C appear to be in excellent condition. Structural section A has over 50 patched areas representing about 2% of the roadway. Due to the extensive repair work required on the lime treated sections, the road (Section A) was seal coated during September, 1966. As an added safeguard, Sections B and C were also seal coated. In April, 1967, after an unusually wet winter, an inspection was made. There were no cracks and the pavement was in good condition.

Deflection measurements at this time (April 1967) showed lower deflections than those taken over one year ago in all three sections.

Laboratory tests indicated that the soil on this project responded well to lime. However, construction operations were not performed in as carefully controlled environment and manner as in a laboratory. Such things as inadequate mixing and curing could have been the cause of the failures in the lime treated section (Structural section A).

Some cracking occurred in the lime treated layers after mixing and compacting. In order to evaluate this problem, some laboratory tests were performed. Test bars were fabricated with varying amounts of water and varying curing time. The laboratory data indicated that expansion and shrinkage of the clay soils were not completely eliminated by lime treatment.

KEY WORDS: Soil stabilization, lime, clays, bases, subbase material, subbase, pavement deflections, pavement evaluation, laboratory tests, expansion contraction.

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INTRODUCTION

Lime treatment of clay soils has been performed on several jobs on California Highways. In most cases, the lime treated material has been used as a subbase layer on roads which carried relatively low traffic. This report describes the use of a lime treated clay as a base and its performance compared with more conventional structural design.

In the summer of 1965, a project in Yolo County near Sacramento, California, was constructed with (A) lime treated clay soils as a subbase and base; (B) a section using a combination of lime treated clay soils as a subbase and untreated aggregate as a base; (C) and a third section with untreated aggregates used as a subbase and base. All sections were surfaced with two inches of asphalt concrete surfacing on the basis of stage construction. An additional two inches of asphalt surfacing will be placed later.

The purpose of this study is to evaluate the performance of the lime treated subbase-base section and to obtain comparisons in performance between the other two types of sections in order to provide information for future design and construction.

The primary method of evaluating the three types of structural sections was by deflection measurements supplemented by laboratory tests and visual observations.

During construction, some cracking occurred in the lime treated layers. In order to determine the causes, laboratory tests were performed.

CONCLUSIONS

1. The section constructed with the lime treated clay soil used as a subbase and base under asphalt concrete surfacing started to show distress shortly after construction. Within one year after construction, there were about 50 patched areas representing about two percent of the road. A screening seal coat was placed in the fall of 1966. No cracks or failures were evident in April 1967 after an exceptionally wet winter.

2. No distress was evident on the sections constructed with a lime treated clay soil as a subbase and untreated aggregate as a base.

3. No distress was evident on the section constructed with untreated aggregate subbase and untreated aggregate base.

4. Average deflection measurements on the inner and outer tracks for the three types of structural sections one and one-half years after construction were as follows:

   A. Lime treated subbase-base section (Ranged from 0.009 to 0.015 inch).

B. Lime treated subbase-untreated aggregate base (Ranged from 0.017 to 0.019 inch).

C. Untreated aggregate subbase-base section (Around 0.017 inch).

5. Laboratory tests on lime treated soils from this project indicated a moisture content over optimum and loose curing periods under 24 hours tended to minimize cracking caused by contraction and expansion.

6. This study indicates that clay can be successfully treated with lime and used as base material under asphalt concrete surfacing when construction details are carefully controlled. There must not be time delays between mixing the various layers since drying of the lime treatment can be detrimental. Any trimming must be done within 48 hours after mixing.

DISCUSSION OF PROJECT

General Project Description

This highway project consisted of improving FAS Route 1196 at four locations between U.S. Interstate 80 near Davis and 8.5 miles north (Figure 1). Construction consisted of a conventional facility with two 12 foot travel lanes and 8 foot shoulders.

Portions of the improvement were on new alignment while other portions were constructed after obliterating the existing roadway. The existing roadway was in poor condition and consisted of varying thicknesses of poor quality base surfaced with a medium seal coat.

The terrain in this area is primarily flat agricultural land. However, subdivisions and commercial developments are starting and are expected to increase. The average annual rainfall in this area is about 15 inches. Farm to market hauling comprises the majority of truck traffic on this road but some through traffic from Sacramento to Woodland uses this road. The traffic index was estimated to be 7.5 for the 20 year period between 1964 and 1984.

Structural Design

The sections of roadway discussed in this report were constructed under two contracts and comprised four sections of roadway totaling about 4.7 miles. Three types of structural sections were used and they are identified as follows:

A. Lime Treated Base (LTB) Section
2 inches of asphalt concrete surfacing
5 inches of lime treated base (Minimum 72 R-value).
10 inches of lime treated subbase (Minimum 60 R-value).

B. Lime Treated Subbase - Aggregate Base (LTS-AB) Section
   2 inches of asphalt concrete surfacing
   6 inches of aggregate base (Minimum 78 R-value).
   12 inches of lime treated subbase (Minimum 60 R-value)

C. Aggregate Subbase-Aggregate Base (AS-AB) Section
   2 inches of asphalt concrete surfacing
   6 inches of aggregate base (Minimum 78 R-value).
   15 inches of aggregate subbase (Minimum 60 R-value).

The above structural sections were designed by the California method.[1]

Materials

Basement soil and borrow material consisted of silty clay with R-values ranging from 7 to 23. The design of the structural section was based on a 5 R-value native soil.

Aggregate subbase and base material are river-run sand and gravel with R-value specifications of 60 and 78, respectively.

Asphalt concrete surfacing is a 3/4 inch maximum size aggregate mixed with 5% asphalt (85-100 penetration).

Commercial hydrated lime containing a minimum of 75% calcium hydroxide was used in amounts of 4% of dry weight of aggregate for lime treatment.

Description of Construction

The construction of the road was performed during the summer and fall of 1965. Traffic was permitted through the project at all times. This inconvenienced and hampered the contractor's operations. The planned lime content was 4% and the material was mixed with a pugmill type road mixer (Woods).

Lime Treated Base (LTB) Section

The lime treated material was placed in three 5-inch lifts. It was necessary to move material to one side of the road while mixing the first and second layers. About 0.15 gallon of SC-250 was used as a curing seal and prime coat on the top lift. Figures 2 and 3 illustrate some of the operations.

In order to obtain proper curing, a water truck was used to keep the lime treated material moist before the curing seal was placed. However, some drying of the lime treated material occurred on hot windy days.

The contractor experienced difficulty in making and maintaining grade due to public traffic. The lime treated material took several days before the material cemented sufficiently to prevent rutting. It was necessary to reshape the surface of the compacted lime treated soil to the proper grade before placing the next layer. This was an undesirable operation. In some cases, the treated material had been compacted for five or more days prior to reshaping.

The two inches of asphalt concrete was placed in a conventional manner with a Barber Greene paving machine.

Lime Treated Subbase-Aggregate Base (LTS-AB) Section.

The construction of the 12 inches of lime treated subbase material was performed in a similar manner as for the 15 inches of LTB material except that the treated material was placed in two 6-inch lifts. The base and surfacing were placed in single lifts in a conventional manner.

Aggregate Subbase-Aggregate Base (AS-AB) Section.

The construction of this section was performed in a conventional manner. The aggregate subbase was placed in two lifts and the aggregate base and asphalt concrete surfacing in single lifts.

DISCUSSION OF TEST PROGRAM

Sampling and Testing

Soil samples were obtained from the project right-of-way before construction and tested to determine whether lime would provide suitable treatment for use as a subbase and base. Table I displays the test data which indicated that the material responds well to lime treatment. Laboratory tests of R-values on the untreated soils ranged from 7 to 23 and after addition of 3% lime, the R-values ranged from 70 to 83 after 24 hours of compacted curing time.

Deflection Program

Test locations for deflection surveys were generally selected at random throughout the project (Figure 1). Each test section was 500 feet long and deflection measurements were generally taken at 20 foot intervals with 2 out of every 3 measurements being in the outer wheel track (OWT) and every third reading being made on the inner wheel track (IWT).

The test locations are identified as follows:

	Figure
Test Location 1 Sta. 60+20 to 65+20 LTB	5 & 5A
Test Location 2 Sta. 93+80 to 98+80 LTB	5 & 5A
Test Location 3 Sta. 1109+20 to 1114+20 LTB	6 & 6A
Test Location 4 Sta. 1133+00 to 1138+00 LTB	6 & 6A
Test Location 5 Sta. 1237+00 to 1242+00 LTS-AB	7 & 7A
Test Location 6 Sta. 1246+00 to 1251+00 LTS-AB	7 & 7A
Test Location 7 Sta. 19+50 to 24+50 AS-AB	8

It was planned to take deflection measurements on each layer of the structural section as it was constructed as well as on the finished roadway at various intervals after construction. However, all deflection measurements at the various test locations could not be made according to the predetermined schedule due to weather conditions, availability of equipment and personnel, contractor's operations and delays over holidays and weekends.

A 15,000 pound single axle dump truck and a Benkelman beam, with an accompanying recorder unit, were used to take deflection measurements (Figure 4).

Analysis of Deflection Data

Deflections over the Lime Treated Base Sections (LTB).

Average deflection measurements on the inner and outer wheel tracks are shown for the LTB test sections 1, 2, 3, and 4 (Figures 5, 5A, 6, and 6A). Deflection measurements were made on the existing roadway to give an indication of the level of deflection before construction. The average deflections of the test sections before lime treatment ranged from 0.018" to 0.117". The existing roadway was obliterated before construction of the new structural section.

After placing and compacting the first 5-inch layer of lime treated material, average deflections of the test sections ranged from 0.015" to 0.125". After the second layer was placed, the average deflections ranged from 0.015" to 0.047". Upon completion of the third layer, the average deflections ranged from 0.016" to 0.041".

Deflections on the finished roadway shortly after construction averaged 0.015" to 0.031". The tolerable deflection for this type of road is estimated to be around 0.032"[2].

The deflections taken about 4 months after completion of construction were slightly lower (average ranged from 0.013" to 0.026"). About 10 inches of rain had fallen during this period.

About 1½ years after completion of construction, the average deflections ranged from 0.009" to 0.015".

Deflections over the Lime Treated Subbase - Aggregate Base Section (LTS-AB).

This section of road was constructed on new alignment. Average deflection measurements on the inner and outer wheel tracks are shown for the LTS-AB sections 5 and 6, on Figures 7 and 7A. Average deflections ranged from 0.029" to 0.049" on the first 6 inches of lime treated soil after 7 days of compacted curing time. Average deflections ranged from 0.026" to 0.031" after the second 6-inch layer of lime treatment and 0.022" to 0.025" after the 6-inch layer of untreated aggregate base and 2 inches of asphalt concrete surfacing were placed.

Average deflections about 4 months after construction ranged from 0.021" to 0.027". About 10 inches or rain had fallen during this period. The tolerable deflection for this type of road is estimated to be around 0.032"[2]. Average deflections 1½ years after completion of construction ranged from 0.017" to 0.019".

Deflections over the Untreated Aggregate Subbase - Aggregate Base Section (AS-AB).

Average deflections on the basement soil ranged from 0.037" to 0.039". After 15 inches of aggregate subbase was placed, the average deflections ranged from 0.028" to 0.033" and 0.021" to 0.023" after 6 inches of aggregate base and 2 inches of asphalt concrete were placed. (Figure 8).

Average deflections ranged from 0.019" to 0.022" about 4 months after construction. There was about 10 inches of rainfall during this period. The tolerable deflection for this type of road is estimated to be around 0.032"[2]. Average deflections 1½ years after completion of construction was 0.017".

Cracking Problem in the Lime Treated Material

Some cracking occurred after mixing and compacting the lime treated material. The cracks generally formed large blocks about 5 to 10 feet square. It was believed that cracking was due to the type of material, curing time, traffic during construction and amount of moisture being used in the lime treatment.

In order to evaluate the cracking problem, field samples were obtained for moisture determinations. The data are displayed on Table II. Test bars (3"x3"x11.25") were fabricated using the soil and lime from the project. Moisture contents were varied to span the moistures used during construction (16 to 22%). Varying periods of loose curing (4 to 64 hours) and compacted curing (1 to 28 days), similar to that encountered in the field, were tried. Figures 9 through 14 display the data. Expansion and contraction tests on the bars were performed in a manner similar to that outlined in a report by E. Zube and J. Cechetini[3]. This test is presently used for testing asphalt concrete specimens and is believed to be somewhat severe for lime treated soils. However, it does appear to give some indication of the expansion-contraction properties.

Briefly, the above test consists of measuring linear expansion or contraction after 7 days in a 100% relative humidity moist-room and 7 days in a 100°F. oven. This test is repeated for 6 cycles.

The test data indicates that the range of expansion and contraction generally appears to be similar in all cases. Moisture content appears to be the dominating factor. In all cases, the test bars with the lowest moisture (16%) were not able to sustain more than 3 or 4 cycles of wetting and drying before cracking. The specimens with higher moisture contents (22%) were generally able to go through more cycles before cracking.

Length of cure time after compaction generally had little effect on number of cycles before cracking. A short loose curing period of 4 to 24 hours seems to resist cracking better than a 64 hour loose cure. Taylor and Arams[4], in their study of lime treatment of Louisiana soils, indicated that fewer failures developed on a project where compaction was completed within 48 hours as compared to those compacted more than 48 hours after mixing.

Norman County, Minnesota, performed some studies on sections of roadway constructed of untreated aggregates or lime treated soils and sections using a combination of the two materials[5]. Photographs in the article indicated extensive cracking in the AC surfacing where lime treated soils were used as a base. Deflection measurements averaged around 0.040"in these sections. The untreated sections and the combination sections appeared to be in better condition, although the average deflections were a little higher than 0.040". Their study seems to corroborate ours and suggests that lime treatment of clay soils is a desirable method of stabilization. However, their data indicates that lime treatment should be used only in the subbase layer.

Maintenance Work Performed on the Lime Treated Section

At the end of one year after construction, the lime treated base-subbase section had over 50 patched areas totaling about 2% of the roadway. The other sections were in excellent condition.

Due to the extensive maintenance work required on the fully lime treated sections, a seal coat was placed on the road in September, 1966, about one year after construction. Although no distress was evident on the lime treated subbase-untreated aggregate base section and on the untreated subbase-base section, a seal coat was also placed on these two sections as an added safeguard. It was felt that the seal coat would help to keep the rain water out.

A field inspection of the pavements was made in April, 1967, after an unusually wet winter. No cracks or evidence of distress could be found.

REFERENCES

1. Test Method No. Calif. 301 - California Division of Highways Materials Manual - Volume I.

and

Structural Design of the Roadbed (Section 7-600), California Division of Highways Planning Manual.

2. Flexible Pavement Maintenance Requirements as Determined by Deflection Measurements by E. Zube, R. Forsyth, presented at the HRB January, 1966.

3. Expansion and Contraction of Asphalt Concrete Mixes by E. Zube and J. Cechetini presented at the HRB January, 1965.

4. Lime Stabilization using Preconditioned Soils by W. H. Taylor and Ara Arams presented in the HRB Bulletin 262, dated January, 1960.

5. Lime Stabilization May Affect Aggregate Scarcity, Public Works Magazine, September, 1966.

TABLE I

SUMMARY OF UNTREATED AND LIME TREATED TESTS

			Grading					Untreated At 300 Exud. Pr.			Lime Treated At 300 Exud. Pr.				
Test No.	Sampled From	Depth Feet	#4	#50	#200	5u	PI	R Val.	% Moist.	Den. pcf	R Val.	% Moist.	Den. pcf	% Lime	Curing Time
65-1682	62+20 20'rt.	0-2.0	100	98	90	26	11	23	15.5	110	75	16.5	109	3.0	1 day
65-1683	95+00 20' lt.	0-2.0	98	95	87	31	12	15	17.5	107	83	15.8	110	3.0	1 day
65-1684	1111+00 20'lt.	0-2.0	92	74	55	27	11	11	16.5	110	70	13.0	117	3.0	1 day
65-1685	1135+00 20'rt.	0-2.0	96	77	50	21	8	16	12.8	119	82	12.7	118	3.0	1 day
65-1686	1240+00 ℄	0-2.0	100	99	90	40	--	11	19.2	104	75	16.2	111	3.0	1 day
63-3073	44+79 ℄	0.5-1.5	100	99	97	42	--	12	25.0	97	77	22.7	100	4.0	7 day
64-0388	1108+00 ℄	0.5-1.5	100	91	72	--	--	7	23.0	101	81	20.0	105	4.0	7 day

TABLE II

LIST OF FIELD MOISTURES

Location	% Field Moisture
Sta. 106+00 12'Lt. ¢	19.3
122+00 3'Lt. ¢	22.9
106+00 12'Rt. ¢	19.3
18+50 3'Rt. ¢	17.9
98+00 16'Rt. ¢	24.4
1132+50 6'Rt. ¢	15.7
28+50 15'Lt. ¢	20.1
98+00 3'Lt. ¢	22.5
1104+00 15'Rt. ¢	15.0
1245+00 15'Rt. ¢	20.8

Figure 1

III - Yol - S-1196(3)

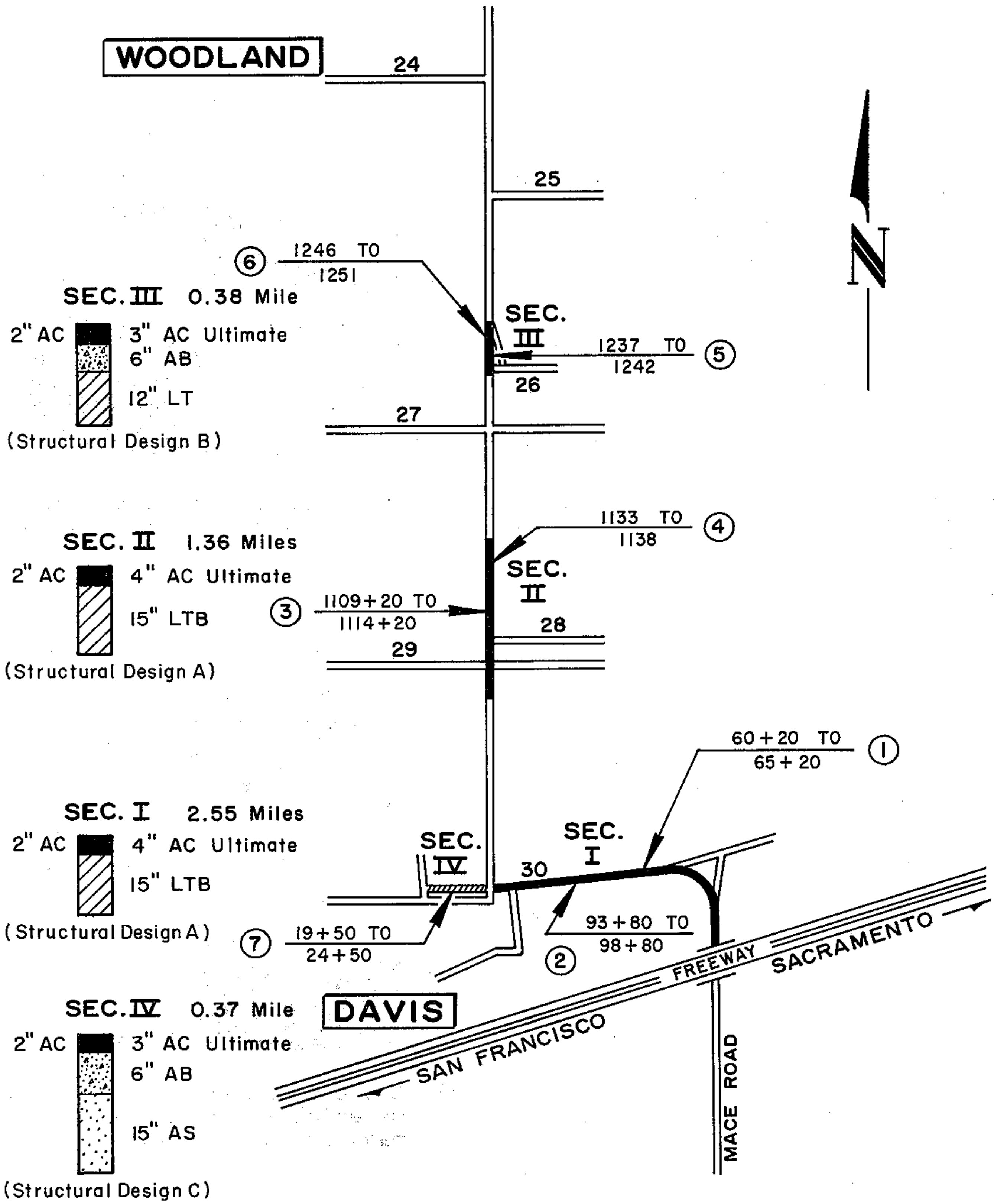
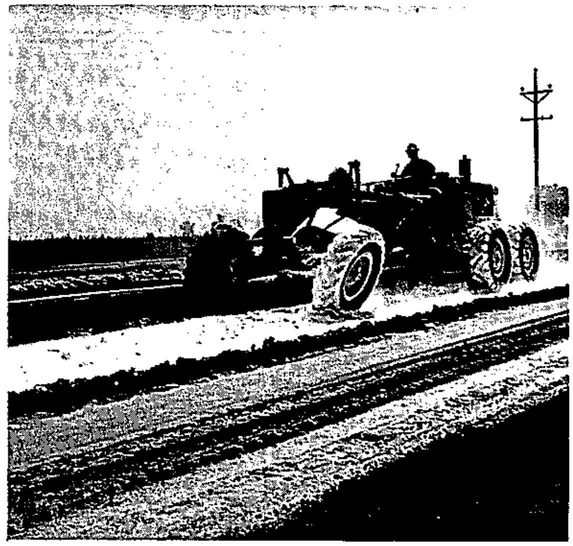


Figure 2

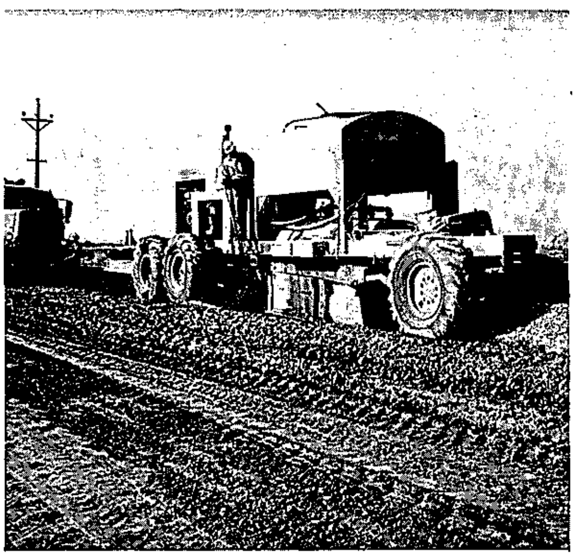
3-Yol-1196

Photos Showing Lime Treatment of Clay Soil

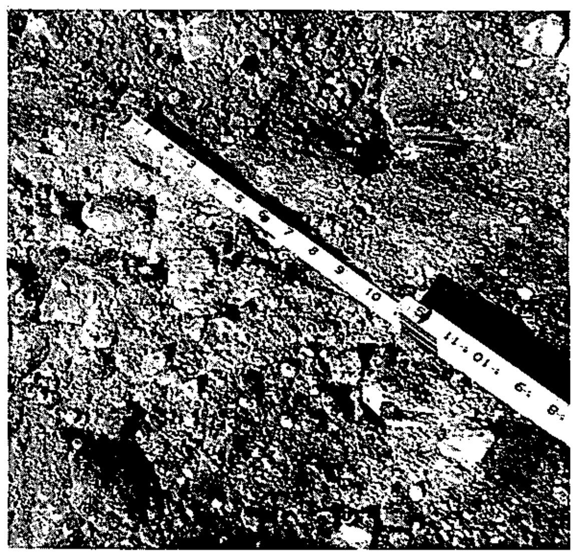
1) Rippers on motor grader initially scarified clay soil and then above photo shows lime being spread.



2) Motor grader covering lime and forming windrow for Woods Mixer.



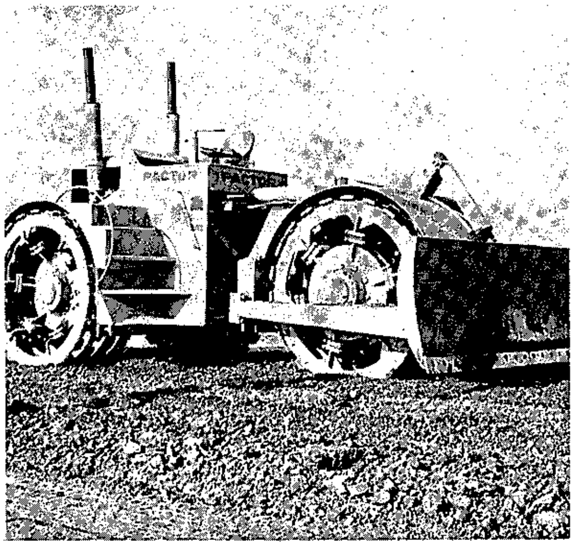
3) Woods Mixer mixing lime treated material.



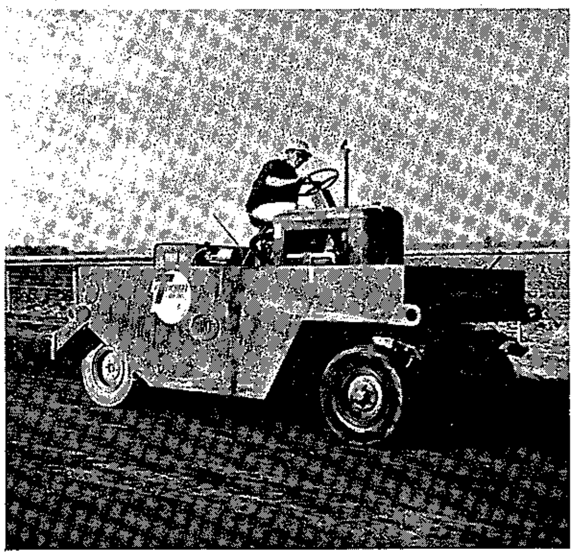
4) Close-up showing lime treated material in windrow after one pass of Woods Mixer.

03-Yol-1196

Photos Showing Lime Treatment of Clay Soils



(5) Segmented 20,000 pound roller compacting lime treated material



(6) Finish rolling with rubber tired compactor

Figure 4

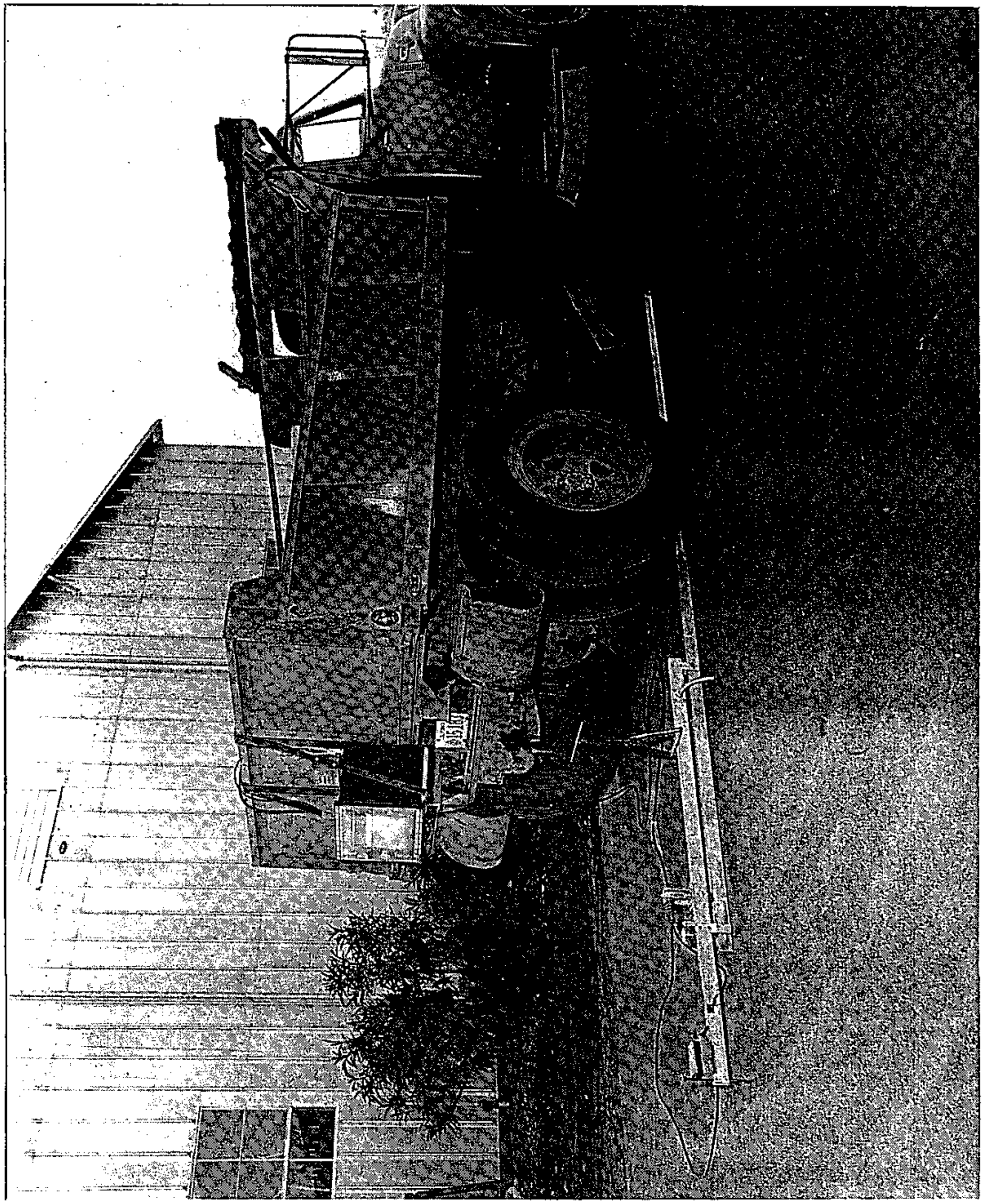


Figure 5

AVERAGE DEFLECTIONS ON ROAD 3-YOL-1196

OWT ± 10' FROM ℄

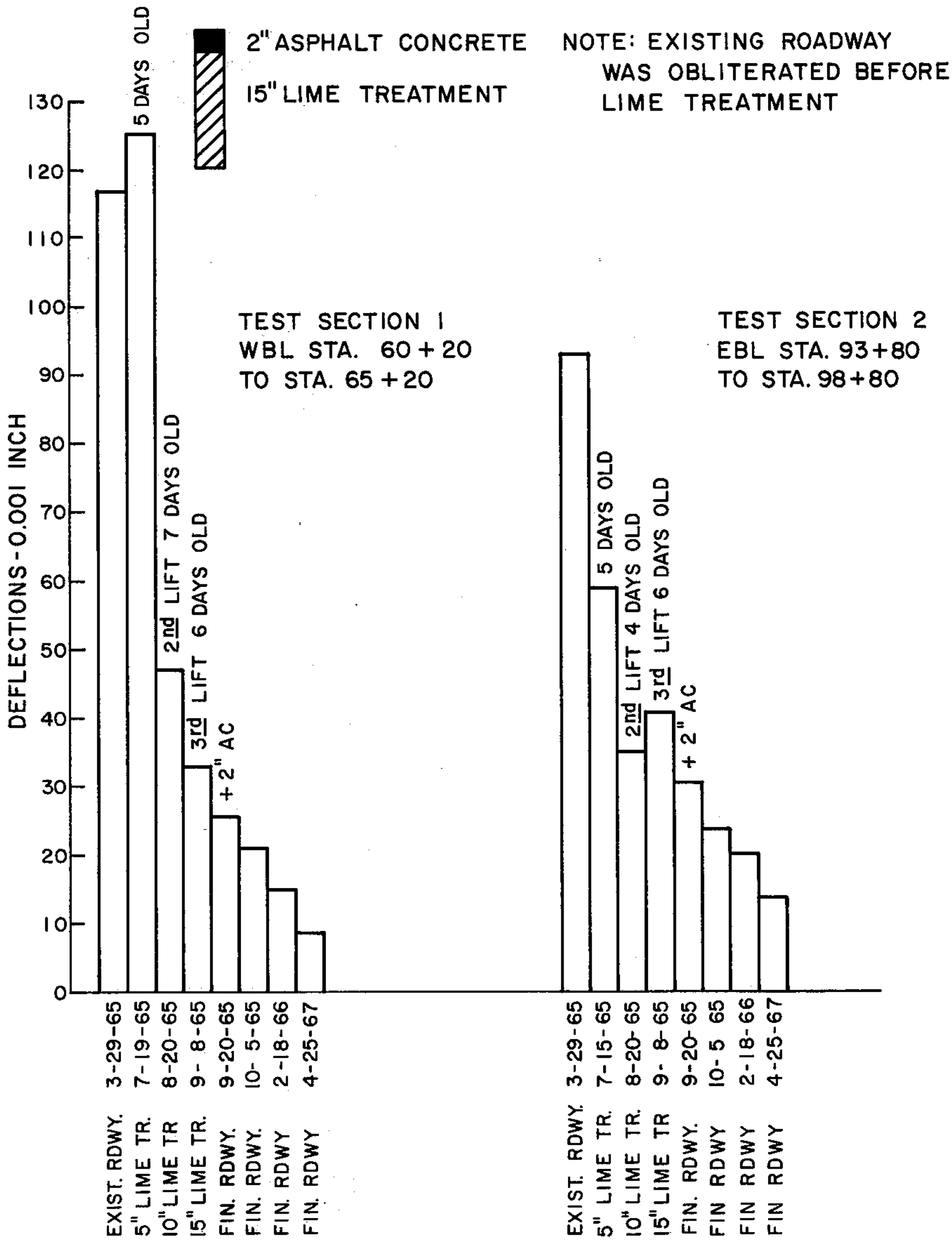


Figure 5A

AVERAGE DEFLECTIONS ON ROAD 3-YOL-1196

IWT ± 4' FROM ℄

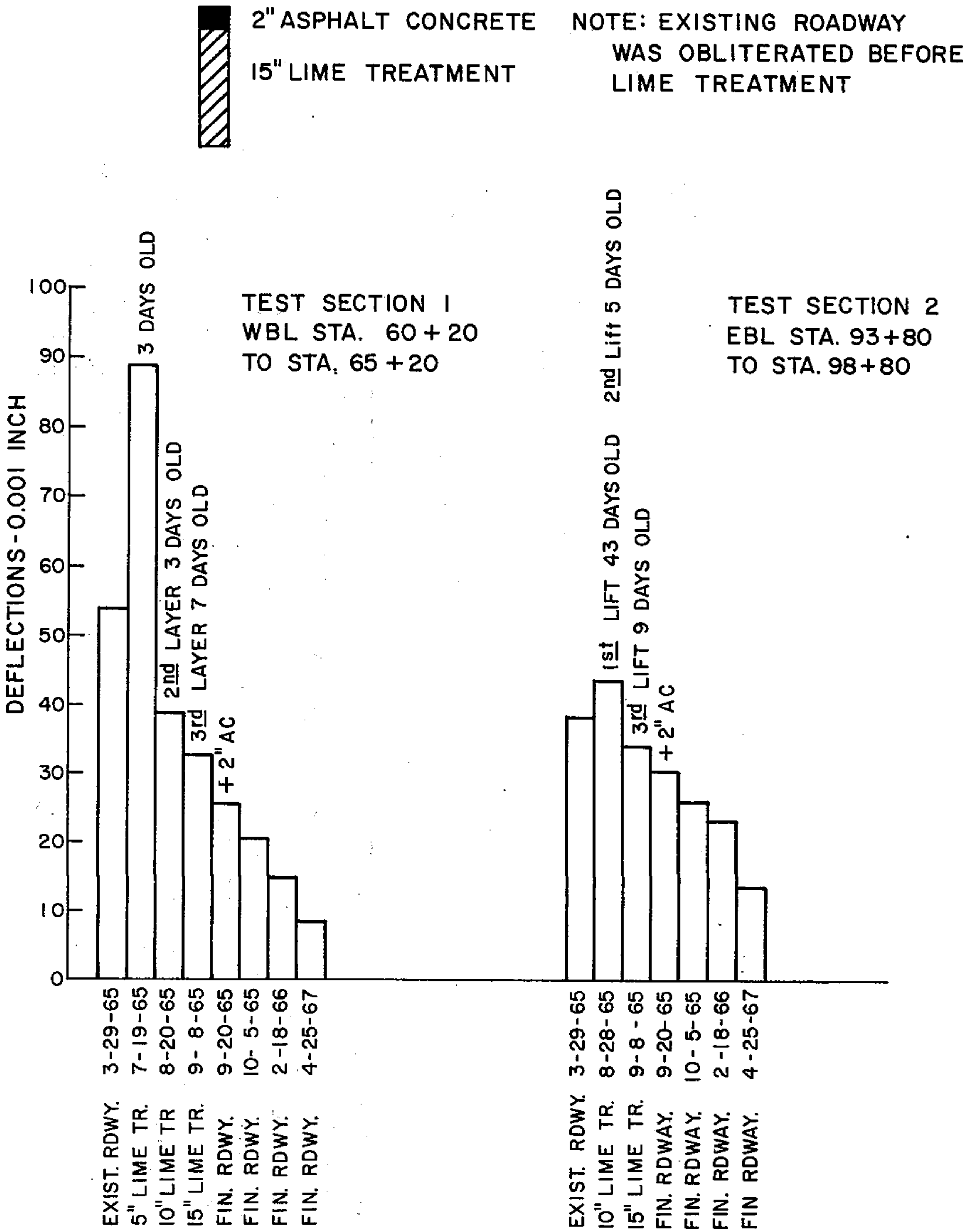


Figure 6

AVERAGE DEFLECTIONS ON ROAD 3-YOL-1196

OWT ± 4' FROM ℄

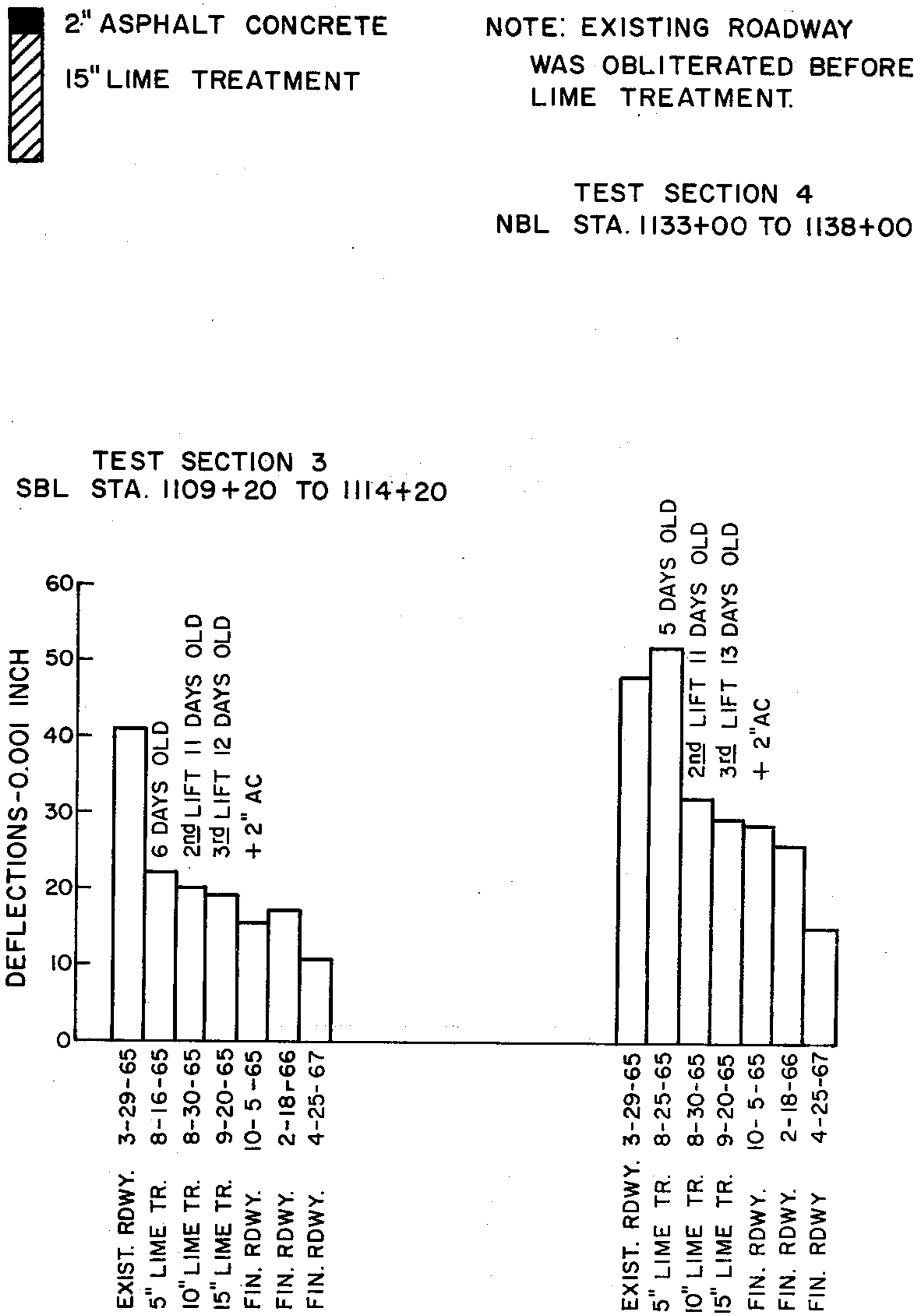


Figure 6A

AVERAGE DEFLECTIONS ON ROAD 3-YOL-1196
IWT ±10' FROM ℄

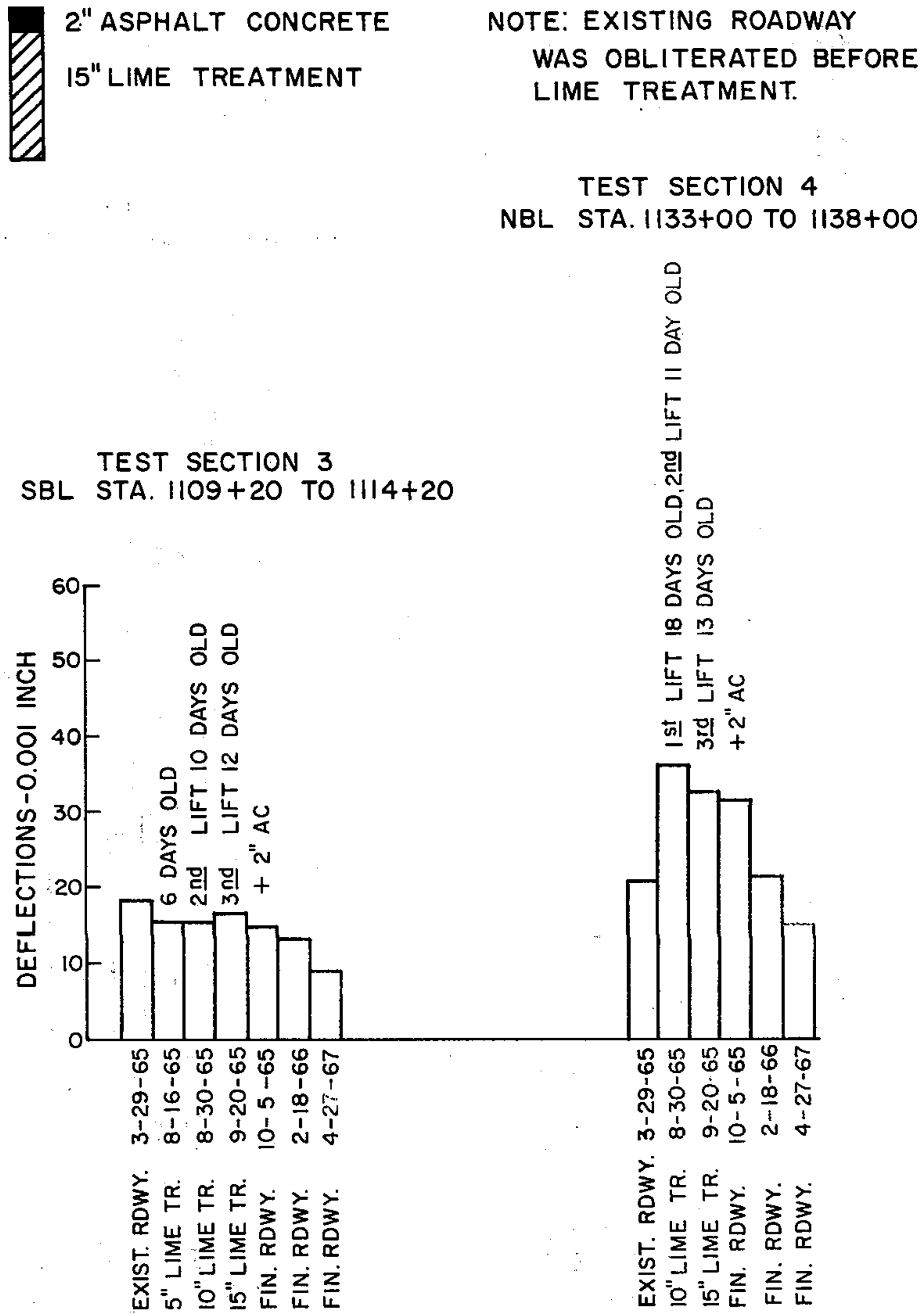


Figure 7

AVERAGE DEFLECTIONS ON ROAD 3-YOL-1196

OWT ± 10' FROM ℄

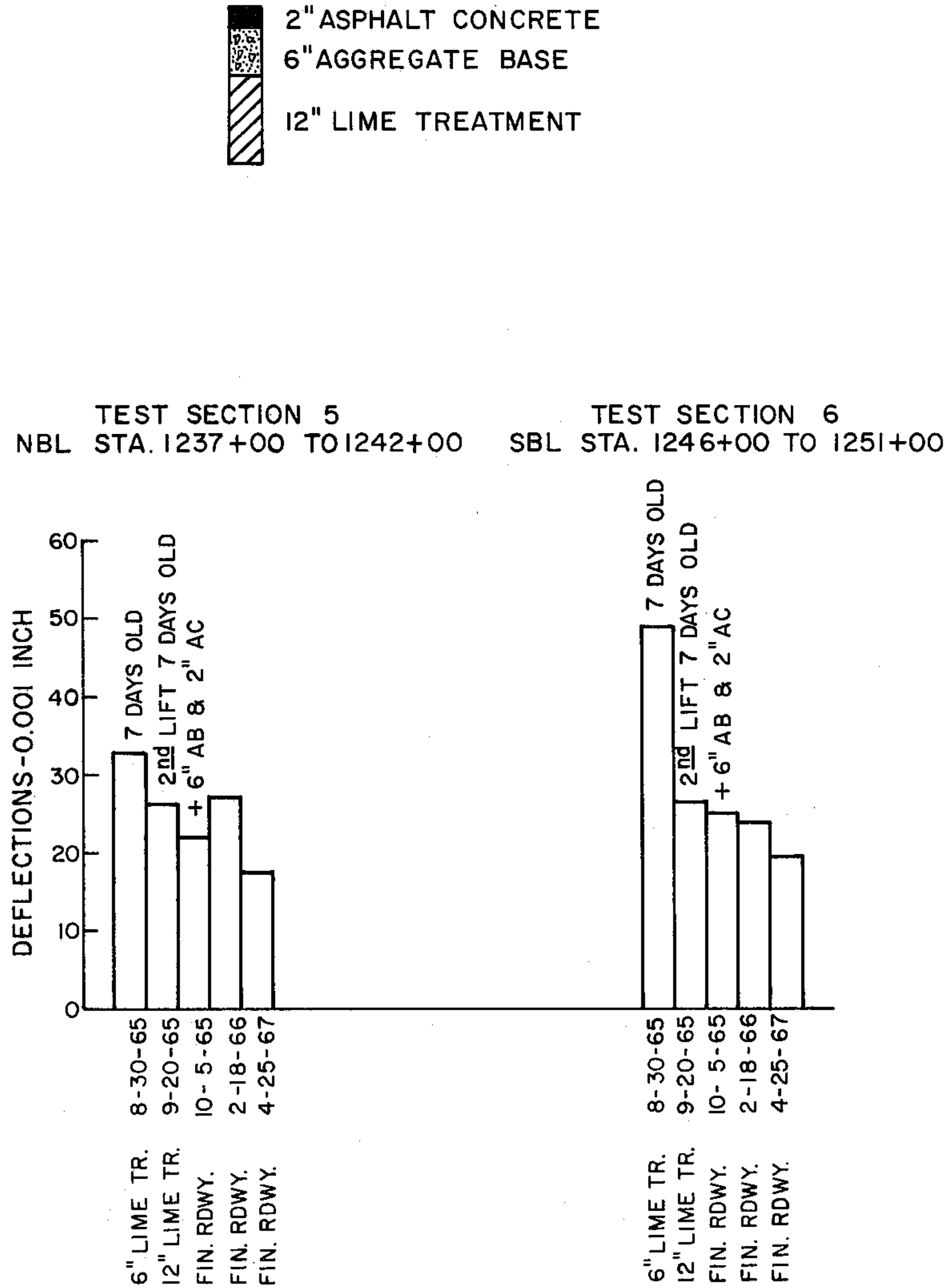


Figure 7A

AVERAGE DEFLECTIONS ON ROAD 3-YOL-1196

IWT ± 4' FROM ℄

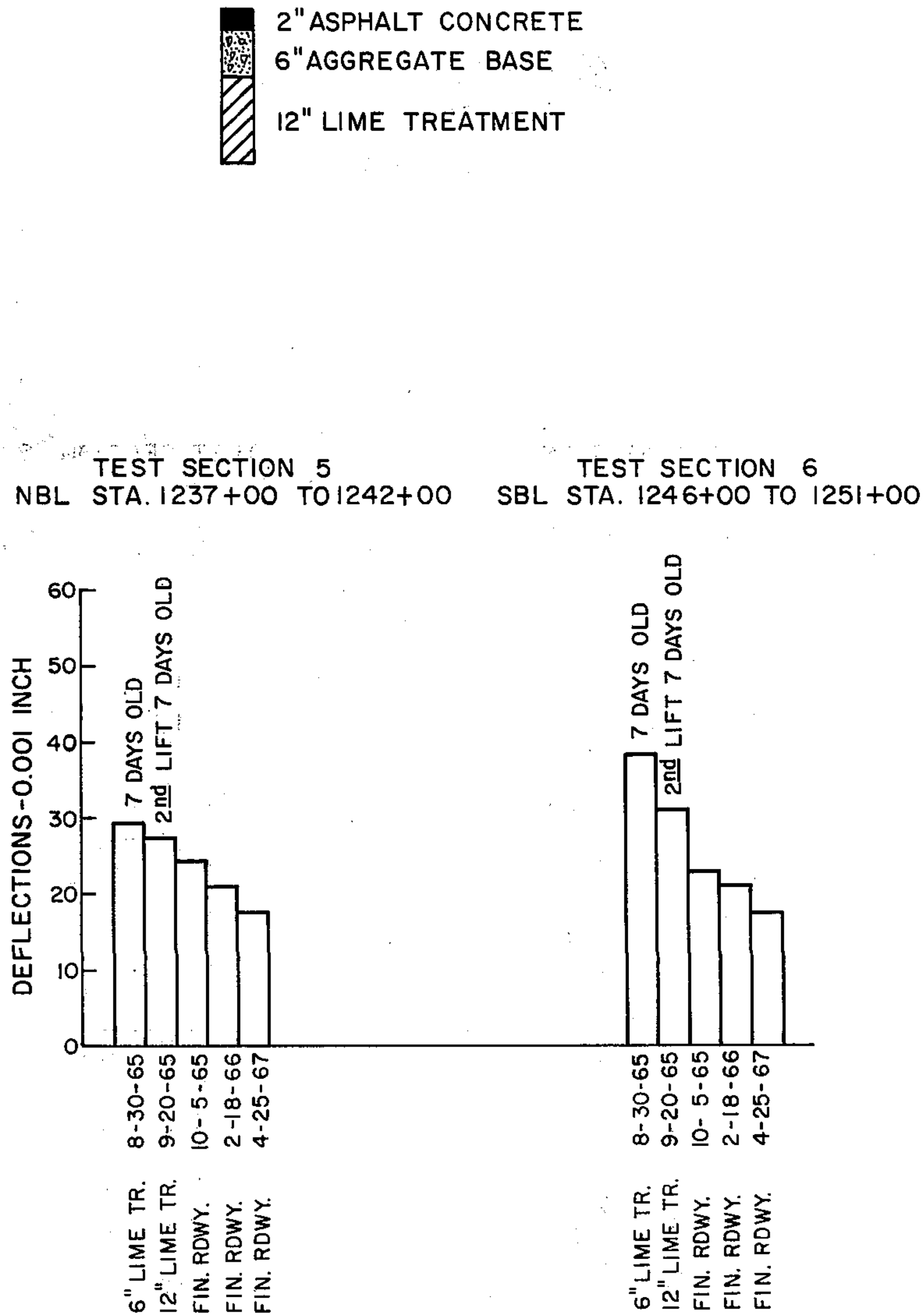
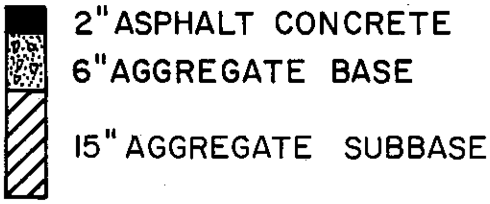


Figure 8

AVERAGE DEFLECTIONS ON ROAD 3-YOL-1196



TEST SECTION 7
EBL STA. 19 + 50 TO 24 + 50

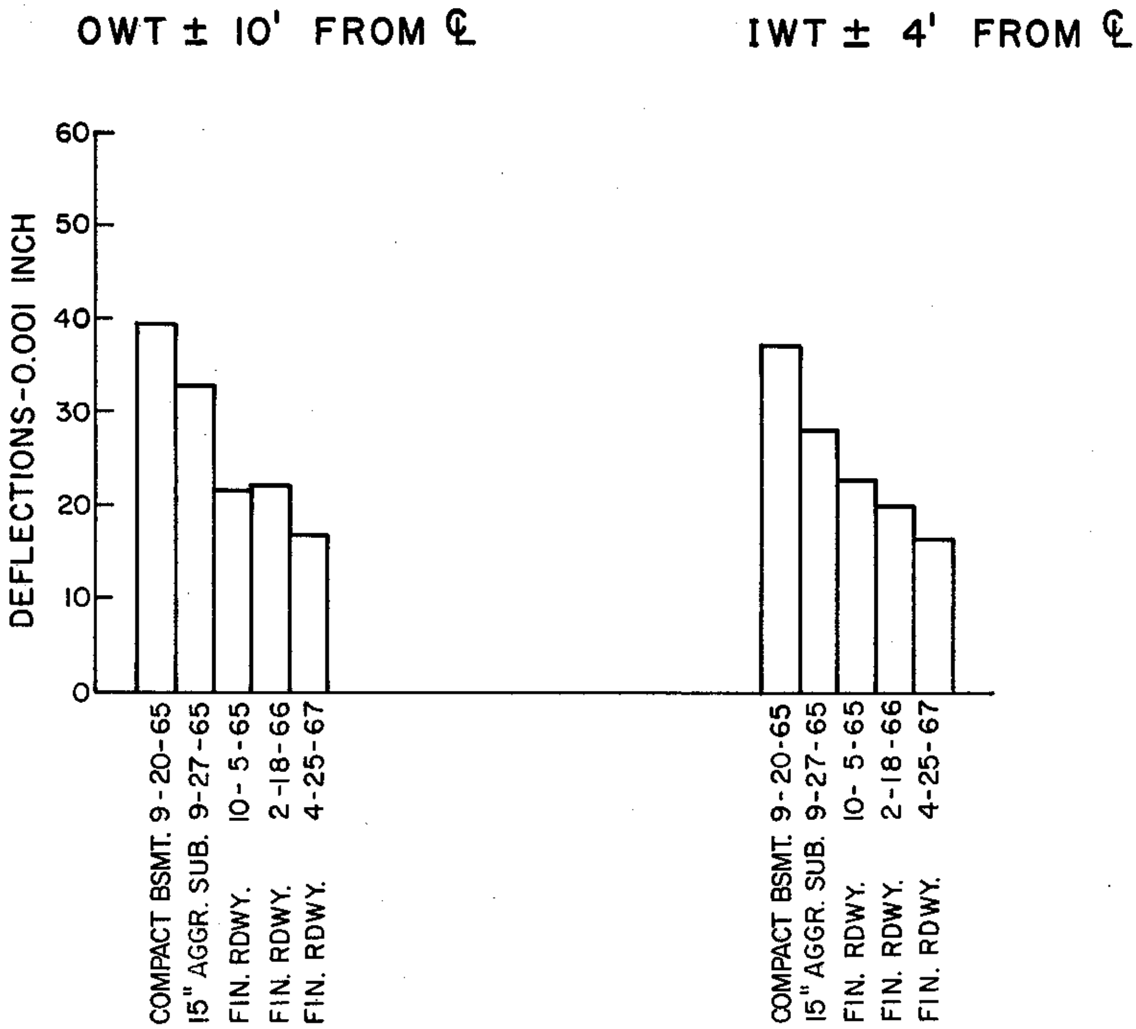


Figure 9

EXPANSION AND CONTRACTION OF LIME TREATED BARS

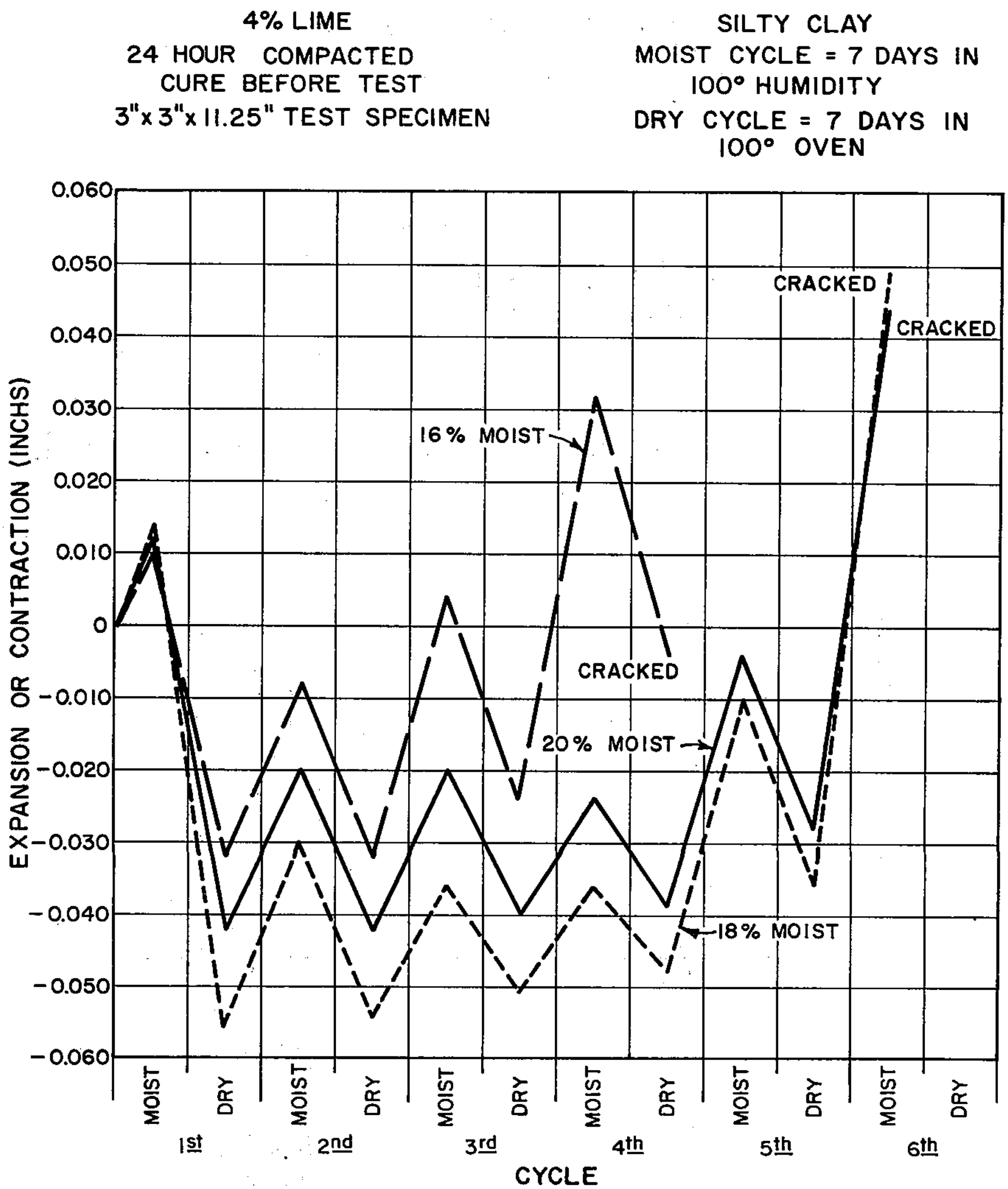


Figure 10

EXPANSION AND CONTRACTION OF LIME TREATED BARS

4% LIME
7 DAY COMPACTED
CURE BEFORE TEST
3"x3"x11.25" TEST SPECIMEN

SILTY CLAY
MOIST CYCLE = 7 DAYS IN 100° HUMIDITY
DRY CYCLE = 7 DAYS IN 100° OVEN

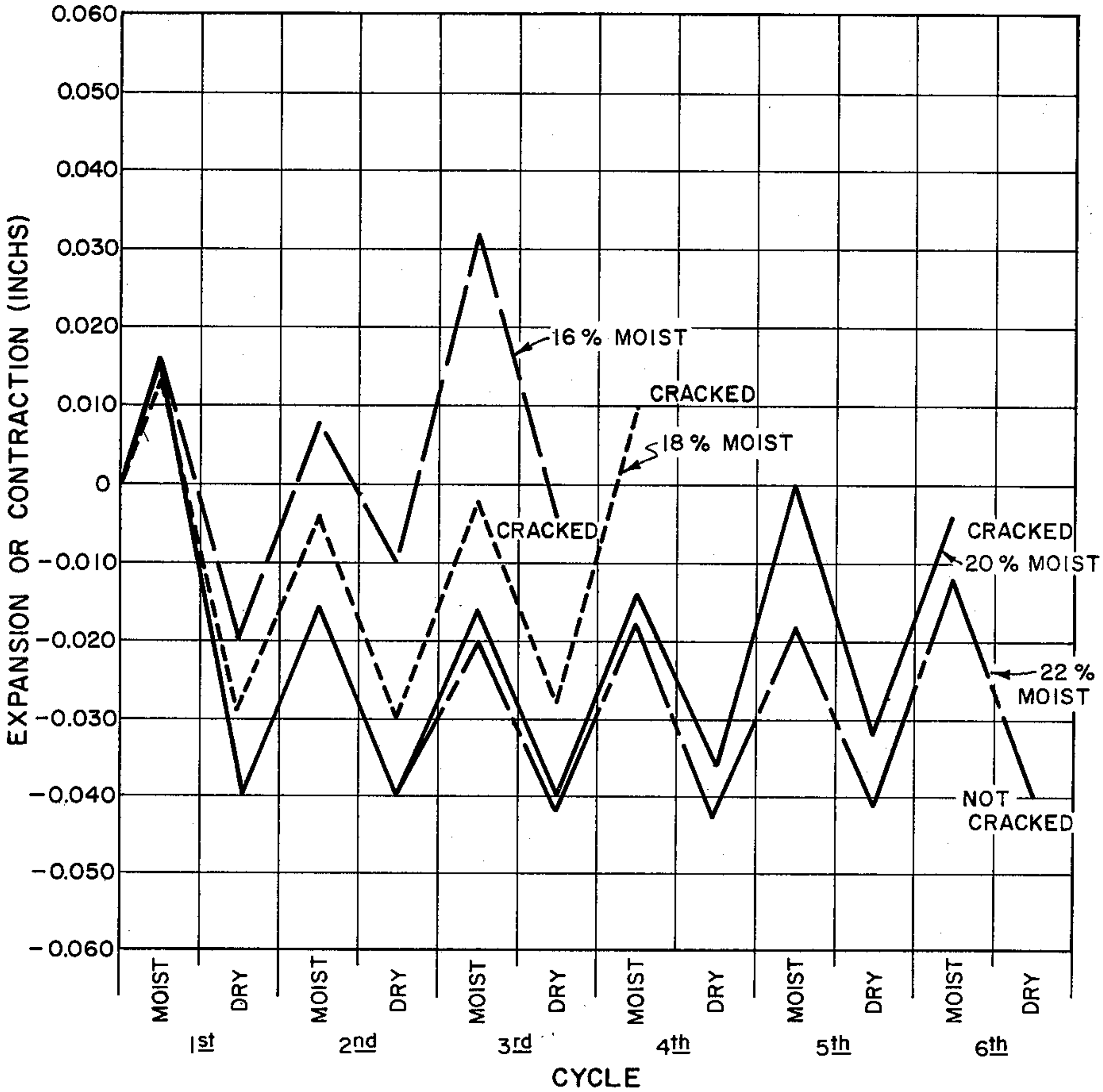
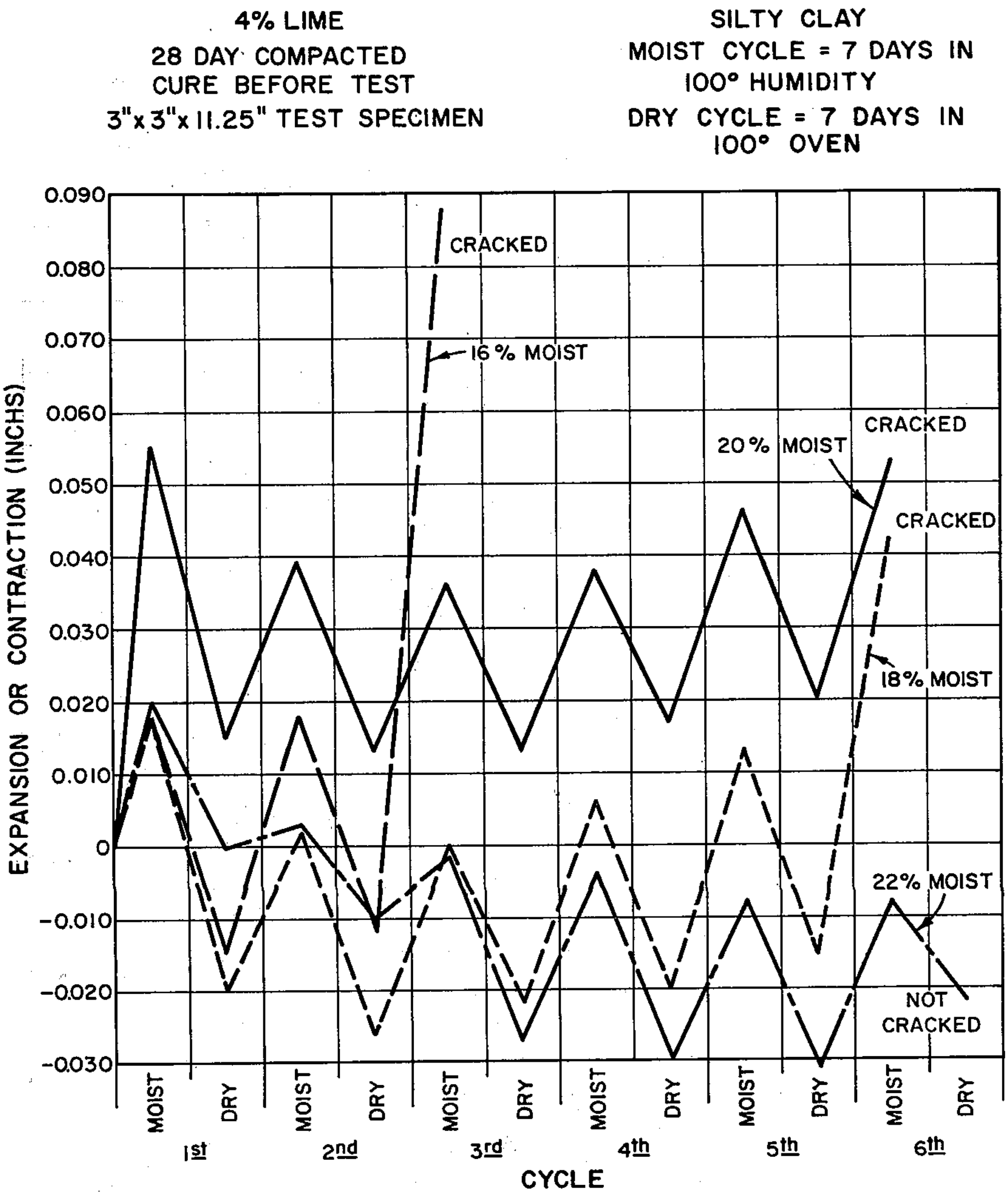


Figure 11

EXPANSION AND CONTRACTION OF LIME TREATED BARS



EXPANSION AND CONTRACTION OF LIME TREATED BARS

4% LIME
4 HOUR LOOSE CURE &
7 DAY COMPACTED CURE
BEFORE TEST
3"x3"x11.25" TEST SPECIMEN

SILTY CLAY
MOIST CYCLE = 7 DAYS IN
100° HUMIDITY
DRY CYCLE = 7 DAYS IN
100° OVEN

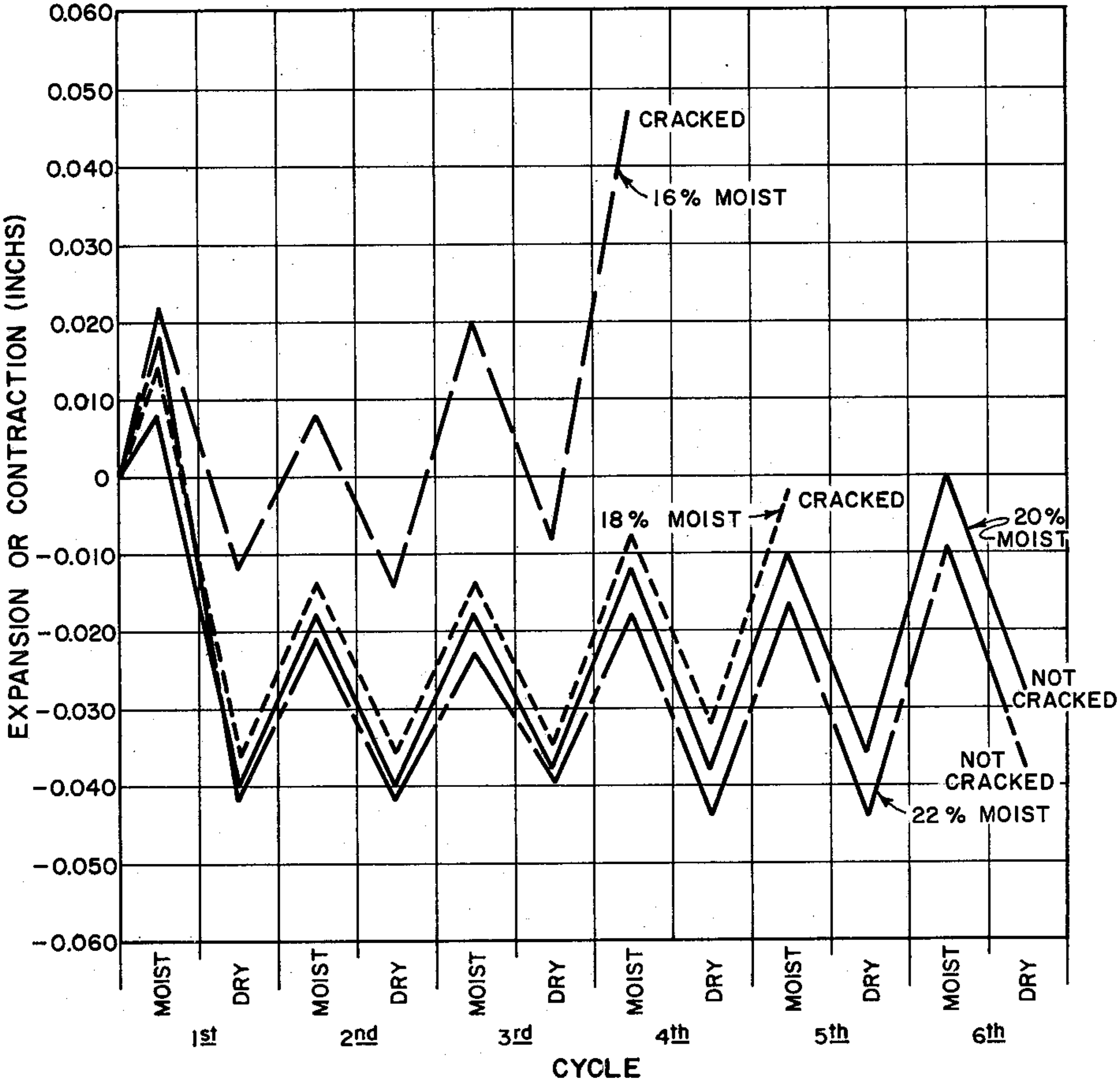


Figure 13

EXPANSION AND CONTRACTION OF LIME TREATED BARS

4% LIME
24 HOUR LOOSE CURE &
7 DAY COMPACTED CURE
BEFORE TEST
3"x 3"x 11.25" TEST SPECIMEN

SILTY CLAY
MOIST CYCLE = 7 DAYS IN
100° HUMIDITY
DRY CYCLE = 7 DAYS IN
100° OVEN

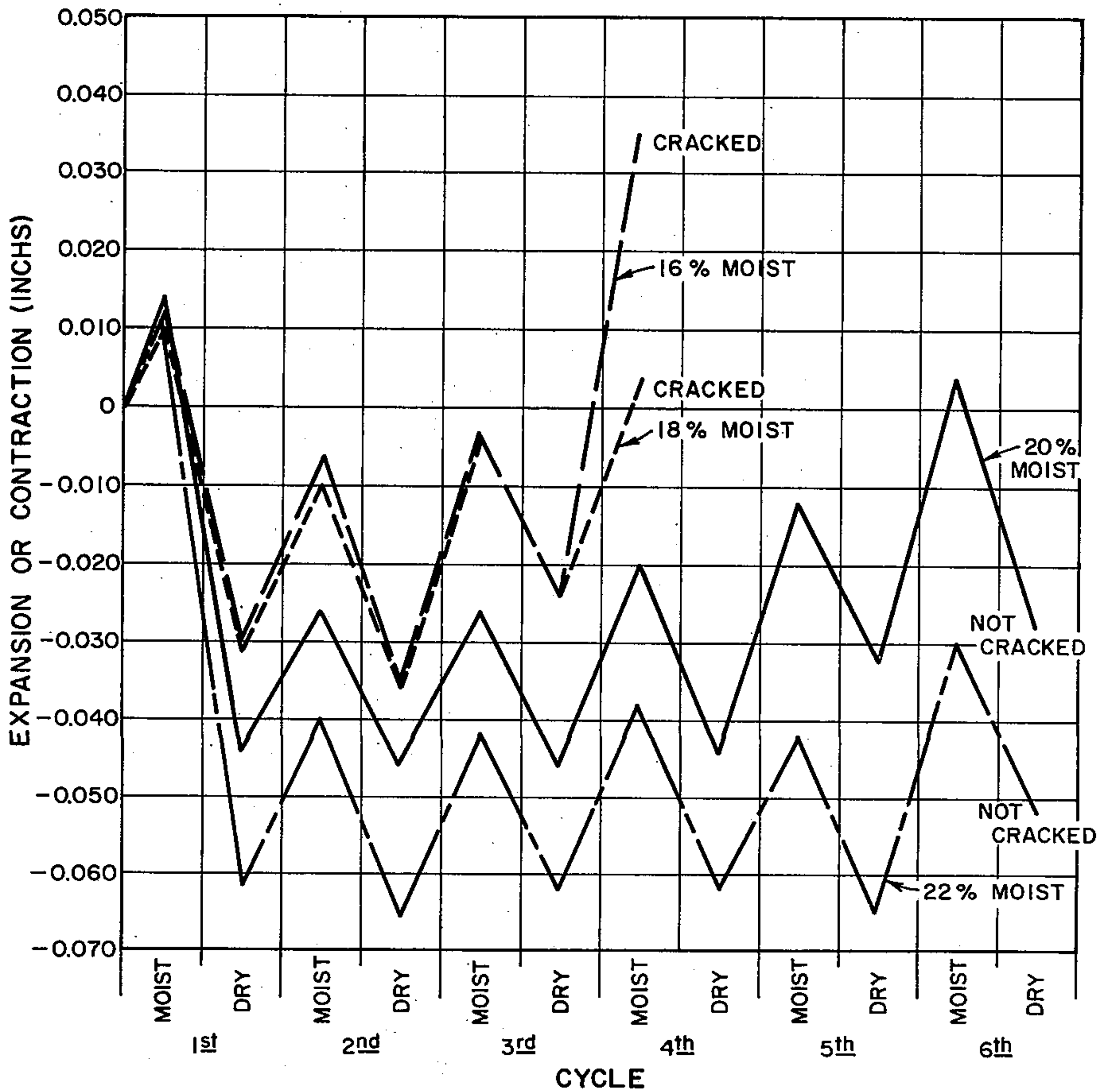


Figure 14

EXPANSION AND CONTRACTION OF LIME TREATED BARS

4% LIME
64 HOUR LOOSE CURE &
7 DAY COMPACTED CURE
BEFORE TEST
3"x3"x11.25" TEST SPECIMEN

SILTY CLAY
MOIST CYCLE = 7 DAYS IN 100° HUMIDITY
DRY CYCLE = 7 DAYS IN 100° OVEN