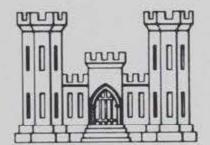
#### WAR DEPARTMENT

#### CORPS OF ENGINEERS, U. S. ARMY

# INVESTIGATION OF THE UNCONFINED COMPRESSIVE STRENGTH OF SOIL-CEMENT MIXTURES



TECHNICAL MEMORANDUM NO. 187-1

## U. S. WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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#### CONTENTS

		Page
SYLLA	BUS General Principal findings	
I.	INTRODUCTION Purpose of investigation	4
II.	SELECTION OF SOILS Specifications	5
III.	TESTING PROGRAM AND TEST RESULTS  Procedures	66 8 9 9 11 12 12
IV.	SUPPLEMENTAL TESTS  Admixtures  Need for a more durable soil-cement  Tests with Vinsol resin  Wet-dry and freeze-thaw tests on soil-cement specimens  treated with TDA solution  TDA test results  Further investigation of the wet-dry test  Discussion of the wet-dry test	15 16 16 17 17
V.	CONCLUSIONS General	20

#### TABLES

Table	Page
l Results of Classification Tests	7
2 Results of Compaction Tests of Raw Soil and Soil-Cement Specimens	7
Tables 3 to 26 follow after text	
Title	Table
Effect of Water-Cement Ratio on Compressive Strength of Sandy Loam Soil-Cement Mixtures	3
Effect of Water-Cement Ratio on Compressive Strength of Sandy Clay Loam Soil-Cement Mixtures	14
Effect of Water-Cement Ratio on Compressive Strength of Clay Loam Soil-Cement Mixtures	5
Effect of Durability Tests on Unconfined Compressive Strength of Sandy Loam Soil-Cement Specimens	6–9
Maximum Compressive Strength and Maximum Strain of Sandy Loam Soil-Cement Specimens	10
Effect of Durability Tests on Unconfined Compressive Strength of Sandy Clay Loam Soil-Cement Specimens	11-14
Maximum Compressive Strength and Maximum Strain of Sandy Clay Loam Soil-Cement Specimens	15
Effect of Durability Tests on Unconfined Compressive Strength of Clay Loam Soil-Cement Specimens	16-19
Maximum Compressive Strength and Maximum Strain of Clay Loam Soil-Cement Specimens	20
Average Maximum Compressive Strength and Average Maximum Strain of Sandy Loam Soil-Cement Specimens	21
Average Maximum Compressive Strength and Average Maximum Strain of Sandy Clay Loam Soil-Cement Specimens	22
Average Maximum Compressive Strength and Average Maximum Strain of Clay Leam Soil-Cement Specimens	23
Relative Effects of Curing Periods and Wet-Dry Cycles on Unconfined Compressive Strength of Sandy Loam Soil-Cement Specimens	24
Relative Effects of Curing Periods and Wet-Dry Cycles on Unconfined Compressive Strength of Sandy Clay Loam Soil-Cement Specimens	25
Relative Effects of Curing Periods and Wet-Dry Cycles on Unconfined Compressive Strength of Clay Loam Soil-Cement Specimens	26

## FIGURES

Title	Figur
Grain Size Curves	1
Compaction Apparatus	2
Loading Machine	3
Moisture Density Control for Sandy Loam	4
Moisture Density Control for Sandy Clay Loam	5
Moisture Density Control for Clay Loam	6
Strength versus Water Content - Sandy Loam	7
Strength versus Water Content - Sandy Clay Loam	8
Strength versus Water Content - Clay Loam	9
Sandy Loam Soil-Cement Specimens after Failure	10
Sandy Clay Loam Soil-Cement Specimens after Failure	11
Clay Loam Soil-Cement Specimens after Failure	12
Stress-Strain Curves for Comparison of Maximum Strengths	13
Strength versus Density for Sandy Loam	14
Strength versus Density for Sandy Clay Loam	15
Strength versus Density for Clay Loam	16
Water-Cement Ratio versus Maximum Strength	17
Percent Increase in Strength versus Percent Increase in Cement	18
Stress-Strain Curves for Sandy Loam 5 Percent Cement	19
Stress-Strain Curves for Sandy Loam 7 Percent Cement	20
Stress-Strain Curves for Sandy Loam 9 Percent Cement	21
Stress-Strain Curves for Sandy Loam 11 Percent Cement	22
Stress-Strain Curves for Sandy Clay Loam 5 Percent Cement	23
Stress-Strain Curves for Sandy Clay Loam 7 Percent Cement	24
Stress-Strain Curves for Sandy Clay Loam 9 Percent Cement	25
Stress-Strain Curves for Sandy Clay Loam 11 Percent Cement	26
Stress-Strain Curves for Clay Loam 5 Percent Cement	27
Stress-Strain Curves for Clay Loam 7 Percent Cement	28
Stress-Strain Curves for Clay Loam 9 Percent Cement	29
Stress-Strain Curves for Clay Toam 11 Percent Cement	30

# FIGURES (CONT'D)

Title	Figure
Stress-Strain Curves for Sandy Loam 9 Percent Cement Wet-Dry Test Investigation	31
Stress-Strain Curves for Sandy Clay Loam 9 Percent Cement Wet-Dry Test Investigation	32
Stress-Strain Curves for Clay Loam 9 Percent Cement Wet-Dry Test Investigation	33

# INVESTIGATION OF THE UNCONFINED COMPRESSIVE STRENGTH OF SOIL-CEMENT MIXTURES

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#### SYLLABUS

#### General

1. This memorandum is a report on the investigation of the unconfined compressive strength of mixtures of various soils and Portland cement, and the effect of the water-cement ratio and of wetting and drying and freezing and thawing upon these strengths. The results of tests conducted to study the effect of a dispersing agent (TDA) on the durability and strength of the soil-cement mixtures are also included. The study was made for the Office, Chief of Engineers, primarily for use in pavement design of airports being constructed under the National Defense Program.

## Principal findings

2. The results of this investigation indicate that the water-cement ratio is not a suitable control for soil-cement mixtures. In the group of soils used: namely, sandy loam, sandy clay loam and clay loam, it was found that the physical characteristics of the individual soils have more effect upon the compressive strength of the soil-cement mixtures than any other factor. Increasing the percentage of cement in a given soil produces a greater increase in strength than any other factor for the mixture. All soil-cement specimens gained in compressive strength at a greater rate than the rate of cement increase.

3. It was found that cycles of wetting and drying produced an increase in the strength in all mixtures of the sandy loam and some increase in the higher percentages of cement in the sandy clay loam and clay loam.

Cycles of freezing and thawing generally produced some decrease in the compressive strength of all specimens. The investigation also showed that no appreciable improvement was found in the durability and strength of the soil-cement specimens containing TDA.

#### I. INTRODUCTION

#### Purpose of investigation

- 4. It was the general purpose of this investigation to determine the effect of certain factors on the unconfined compressive strength of soil-cement mixtures. Specifically it was desired to determine:
  - a. The effect of the water-cement ratio on the compressive strength of soil-cement mixtures.
  - b. The effects of wetting and drying, and freezing and thawing on the compressive strength of soil-cement mixtures.

To accomplish these objectives, unconfined compression tests were performed using three different types of soils; sandy loam, sandy clay loam, and clay loam. By preparing specimens of soil-cement with varying contents of moisture and cement and curing them similarly, it was possible by compression tests, to determine the effect of the water-cement ratio on the unconfined compressive strength of the soils. After determining the moisture content which would produce a specimen of maximum strength for any given soil and cement admixture, specimens were prepared at this predetermined moisture content, cured for 28 days in an atmosphere of approximately 95 percent relative humidity, and then subjected to various cycles of wetting and drying, and freezing and thawing. Some specimens were tested in unconfined compression to failure at the end of 4 cycles of wetting and drying, and freezing and thawing, while other specimens were continued through 8 and 12 cycles. In this manner the effect of wetting and drying, and freezing and thawing upon the compressive strength of the specimens was determined.

#### Authorization

5. This study was authorized in the second indorsement to a letter from the U. S. Waterways Experiment Station to the Chief of Engineers, dated February 6, 1941, subject: "Proposed design tests for airport construction."

#### Personnel

6. This study was conducted by the Soil Mechanics Laboratory of the U. S. Waterways Experiment Station under the supervision of Cleveland R. Horne, Jr., Assistant Engineer, Chief of the Laboratory. This report was prepared by James E. Watkins, Sr. Engr. Aide, under the direction of John D. Watson, Associate Engineer. The entire study was accomplished under the direction of Captain K. E. Fields, C.E., Director of the Experiment Station. Assistance in locating materials for this study was rendered by the personnel of the Vicksburg Engineer District Soils Laboratory.

#### II. SELECTION OF SOILS

#### Specifications

7. It was specifically requested that a sandy loam, sandy clay loam and clay loam be used in this investigation. In addition it was specified that these general types of soils should have a liquid limit below 50, a plasticity index below 25, a clay content below 35, and have at least 60 percent solids at maximum density. (See requirements in manual prepared by the Office, Chief of Engineers, entitled "Design of Airport Runways" dated January 1941.) Because of the above-mentioned specifications, it was difficult to locate the soils in natural deposits in or near Vicksburg because the soil in the Vicksburg area is almost entirely loess deposits. However, with the cooperation of the Vicksburg District Soils Laboratory personnel, it was found from a log of borings for a section of Mississippi River levees that the clay loam could be located in a natural state in the vicinity of Bolivar Lake near Greenville, Mississippi. The sandy clay loam was found in parts of the borrow area of the Meridian Airport, Meridian, Mississippi, then under construction by the Vicksburg District. The sandy loam was produced by mixing a sand and a silt found in deposits along the Mississippi River near Vicksburg, Mississippi.

#### Procedures

8. Reference is made to the Harvard University manual, "Notes on Soil Testing for Engineering Purposes," by A. Casagrande and R. E. Fadum for descriptions of, and procedures for tests that are not described or otherwise referred to in this report.

#### Classification tests

9. Grain size and specific gravity analyses together with Atterberg limits tests were performed on typical samples of the three soils and the results are presented in table 1 and figure 1.

#### Compaction tests

10. The compaction tests for this study were performed in a cylindrical mold 2 in. in diameter by 4 in. in height. The hammer used had a striking surface 1-1/2 in. in diameter, and a sliding weight of 2.2 lb which fell 12 in. to the top of the hammer base (see figure 2). Tests made in this investigation showed that using 3 layers of 20 blows each with this type hammer and mold produced a density with negligible variation from that obtained with 25 blows per layer using the standard hammer and mold specified by Proctor. Compaction characteristics (optimum moisture and maximum density) using this equipment were determined for each of the three raw soils and for each soil when mixed with 5 and 11 percent cement (based on the dry weight of soil). (See table 2 and figures 4, 5 and 6.) The optimum moisture and maximum density for 7 and 9 percent cement mixes were determined by interpolation.

TABLE 1
Results of Classification Tests

Soil Type	A.	tterber: Perce	g Limit: ent	3	Mechai	Specific		
	L.L.	P.L.	P.I.	S.L.	Sand	Silt	Clay	Gravity
Sandy loam	14.3	None	None	14.9	71.0	21.0	8.0	2.67
Sandy clay loam	32.8	15.2	17.6	19.1	73.0	7.6	19.4	2.67
Clay loam	38.3	17.6	20.6	16.5	31.5	38.0	30.5	2.70

TABLE 2

Results of Compaction Tests of Raw Soil and Soil-Cement Specimens

Soil Type	Cement Content by Dry Wt. of Soil	Optimum Water Content	Maximum Dry Density lbs per cu ft	Specific Gravity	Solids at Maximum Density
Sandy loam	0 5 7 9	10.2 10.8 11.0 11.2 11.3	122.0 119.8 119.7 119.7 119.6	2.67 2.69 2.70 2.71 2.72	73.2 71.3 71.0 70.8 70.4
Sandy clay	0	15.4	111.4	2.67	66.8
	5	15.6	110.9	2.69	66.1
	7	15.9	110.0	2.70	65.3
	9	16.2	109.1	2.71	64.5
	11	16.5	108.2	2.72	63.7
Clay loam	0	18.0	107.0	2.70	63.5
	5	18.0	103.8	2.72	61.1
	7	18.2	103.6	2.73	60.8
	9	18.4	103.4	2.74	60.5
	11	18.5	103.3	2.75	60.2

11. There were two reasons for not using the size of mold and the type of hammer which were originally specified by Proctor and which are now standard for the American Society for Testing Materials. First, in making compressive strength tests on a brittle material, it is essential that the height of the specimen be at least twice its diameter in order that shear planes will more nearly develop within the body of the specimen. Since these shear planes ordinarily develop on an angle with the horizontal of more than 60 degrees, a height diameter ratio of at least 2 is required. Proctor's equipment does not provide a specimen satisfying this requirement. Secondly, the Experiment Station did not have a loading machine of sufficient capacity to produce failure in specimens with a diameter of 4 in. the dimension of the Proctor specimen.

#### Preparation of compression test specimens

- 12. All specimens were compacted into the 2 by 4-in. mold, in 3 layers, using 20 hammer blows per layer. Before placing the second or third layer into the mold the top of the previous layer was thoroughly scarified to prevent the formation of a plane of weakness occurring between the layers. The specimens were removed from the mold by means of the screw jack shown in figure 2.
- 13. Every specimen was compacted by the same amount of energy. Different densities were developed by varying the moisture contents. Because of these different densities, it was preferable to base the cement content on the dry weight of soil rather than the volume. Hence, the cement contents of 6, 8, 10, and 12 percent by volume, as specified in the instructions of the basic letter, were changed to 5, 7, 9, and 11 percent by dry

weight, respectively. These values by dry weight are approximately equal to the specified values by volume.

#### Unconfined compression tests

14. Each specimen was loaded to failure in a constant strain type of loading machine (see figure 3). The load was applied by means of a screw which was propelled by a small electric motor. The magnitude of the load was determined by means of a calibrated proving ring, and observations for load and deformation were taken at 30-second intervals until rupture occurred.

#### Water-cement ratio tests

- 15. In order to determine the effect of water-cement ratio on the compressive strength of soil-cement mixes, the following testing schedule was followed for each of the three soil types:
  - a. Duplicate specimens of each of the three raw soils were molded at moisture contents of 2 and 4 percent below optimum, optimum, and 2 percent above the optimum, according to the procedures described in paragraphs 10 and 12. These specimens were then tested to failure in unconfined compression. These results are not reported herein because the maximum strengths were rarely more than 10 1b per sq in.
  - Duplicate specimens for each of the three soils that contained cement contents of 5, 7, 9, and 11 percent by dry weight were molded at moisture contents of 2 and 4 percent below optimum, optimum, and 2 percent above optimum according to procedures described in paragraphs 10 and 12. After 28 days curing in a humid room (temperature 70 degrees F, relative humidity plus 95 percent) these specimens were tested to failure in unconfined compression. The average results of these tests are shown on figures 7, 8, and 9. The conditions of the specimens after failure are shown on figures 10, 11, and 12. The complete results of each individual specimen are shown in tables 3, 4, and 5.

- each of the three soils which contained ll percent cement. These curves represent the maximum strength which was developed by each soil, and serve to show that the strength which a given mixture of soil and cement will develop depends more upon the characteristics of the soil than upon the percentage of cement in the mixture.
- 17. The results shown on figures 14, 15, and 16 make it possible to study the effect of the density on the strength which a specimen will develop. In every case but two (sandy clay loam with 5 and 7 percent cement) the specimen with the greatest density developed the highest maximum strength (see tables 3 to 23, inclusive, for details). In general, a small increase in density produces a large increase in maximum strength. However, there is no uniformity in this relationship, so that this advantage would be of little use for design purposes. Take, for example, the case of sandy loam (figure 14 and table 3). With 5 percent cement the density of the specimen is increased from 116.7 lb per cu ft to 120.3 lb per cu ft by increasing the moisture content from 4 percent below optimum up to optimum. At the same time the strength of the specimen increased from 275 lb per sq in. to 290 lb per sq in. This 3 percent increase in density caused a 6 percent increase in maximum strength. But, with a sandy loam, 7 percent cement, a 3 percent increase in density caused a 50 percent increase in maximum strength. Thus, in general, it can be said that for any given mixture of soil and cement the densest specimen will be the strongest, and a small increase in density will produce a large increase in strength.
- 18. The results plotted on figures 14, 15, and 16 have been made a part of a composite diagram shown on figure 17. This diagram serves to

show that the water-cement ratio is not a suitable method of control for soil-cement mixtures. This results from the fact that every soil and every mixture of soil and cement have different compaction characteristics requiring different quantities of water in order to secure maximum density from the same compaction, and maximum density is generally requisite for maximum strength. (For details of the water-cement ratio tests see tables 3 to 5, inclusive.)

#### Further increase in cement content

19. As a supplement to the above tests, it was decided to mold at approximate optimum moisture two specimens of each soil containing 15 percent cement. The purpose of these tests was to determine if the unconfined compressive strength of a soil-cement mixture will increase in direct proportion to increases in cement content. The answer to this question is that some soils will show a greater proportionate increase in strength than the rate of cement increase, while other soils will not gain in strength as rapidly as the rate of cement increase (see figure 18). Using the lowest cement content (5 percent) as a base, the sandy loam gained in strength at a far more rapid rate than the rate of cement increase up to a total of 15 percent. The sandy clay loam and clay loam increased in strength in direct proportion to the increase in cement content from 5 to 10 percent. But when the cement content in sandy clay loam and clay loam was increased from 10 to 15 percent, the strength increase in these mixtures did not keep pace with the increase in cement content. These results serve to emphasize the point previously made that some soils are more suitable for stabilization with cement than other soils are.

#### Wetting and drying, freezing and thawing tests

20. Each cycle of wetting and drying, or freezing and thawing, required 48 hours. The distribution of time for a wetting and drying cycle was as follows: the specimen was completely submerged in water for 5 hours, oven-dried for 42 hours, and air cocled for 1 hour. For a freezing and thawing cycle the distribution of time was 22 hours in the freezing cabinet (temperature minus 15 degrees F) and 26 hours in the humid room (temperature 70 degrees F, relative humidity plus 95 percent) resting on a saturated sand covered by a flannel material. The ends of the specimens placed on the saturated sand were alternated at the end of each period in the freezing cabinet. Further details of the testing procedure can be obtained from A.S.T.M. Standards No. 559 and 560D-40T. The principal departure from these standards was that none of the specimens were brushed at any time with a wire brush. This step in the procedure was omitted because it was not desirable to brush away any of the specimens before testing in unconfined compression.

## Durability tests

21. Sixteen specimens of sandy loam were molded at optimum moisture content with no cement. Four of these specimens were tested immediately in unconfined compression. Of the other 12, six were to undergo cycles of wetting and drying (2 specimens through 4 cycles, 2 through 8 cycles, and 2 through 12 cycles), and the other 6 were to be given similar cycles of freezing and thawing. However, all specimens disintegrated during the first wetting or first thawing, so this part of the testing program was abandoned.

Sixteen specimens of sandy loam with 5 percent cement were molded 22. at the water content which had given the maximum strength in the previous phase of this study. All of these specimens were cured in a humid room for 28 days. After this curing period, 4 of the specimens were tested to failure in the unconfined compression machine. The results of these tests agreed reasonably well with the results secured on the 5 percent mixes molded at optimum moisture content in step b of paragraph 15. Of the remaining 12 specimens, 6 were put through wetting and drying cycles (2 through 4 cycles, 2 through 8 cycles, and 2 through 12 cycles) and the other 6 specimens were put through a like series of freezing and thawing cycles. All specimens were tested in compression after completing their respective cycles. Seven of the stress-strain curves from these 16 tests are shown on figure 19. Of the 4 specimens which were tested after curing, the results of the specimen having the highest maximum strength is plotted. Similarly, of those specimens tested in pairs, the results of the specimen obtaining the higher maximum strength is the stress-strain curve plotted. The above testing procedure was repeated for sandy loam with 7, 9, and 11 percent cement content, and also for sandy clay loam and clay loam with the same 4 percentages of cement. The stress-strain curves shown on figures 20 to 30, inclusive, show the results of some of these tests. The results of the specimens having the highest maximum strength are plotted. The detailed results of the individual specimens for all of these tests are shown in tables 6 to 23, inclusive.

#### Discussion of test results

to 30, inclusive, were generally quite similar to the curves for the same soil with the same cement content. However, it can be noted from tables 6 to 23 that slight discrepancies in results existed in some cases. Since none of the specimens were capped, it is believed the principal source of error was caused by nonparallel end faces, or damaged ends. With greatest care being exerted in removing the specimens from the mold, slight warping in the soft ones would still occur. Surface disintegration on a specimen would invariably occur on the edges at the ends of the specimen. Such conditions are believed to be responsible for many of the discrepancies in the results from the tests on duplicate specimens.

#### IV. SUPPLEMENTAL TESTS

#### Admixtures

Various admixtures have been used in concrete mixes in an effort to increase the durability and the compressive strength of the concrete under weathering conditions. Reference is particularly made to an article appearing in the June 19, 1941 issue of Engineering News-Record, "Increase in Durability of Concrete by Use of Admixtures," by Mr. R. A. Swayze of the Lone Star Cement Corporation, in which Vinsol resin cement was used as a stabilizing agent, and to an investigation on the "Durability of Concrete containing Portland Cement and Certain Admixtures, Series 'C'," made by the Eastport, Maine Engineer District (see reference file F.C. NAD 3/94 for details). The Dewey and Almy Chemical Company, of Cambridge, Massachusetts, has also made an extensive study on the durability and compressive strength of concrete, using their own admixture (trade name TDA). This material is a mixture of certain salts and lignin sulphonic acid, and serves as a catalyst and aids materially in the dispersion of the cement in the concrete mixing process. It is claimed that slight admixtures of this material in the cement reduced considerably the permeability of concrete, with marked increase in both its durability and compressive strength.

# Need for a more durable soil-cement

25. In the course of this investigation it was noted that the specimens containing the lower percentages of cement (5 and 7 percent) were drastically affected by the freeze-thaw tests, and in some cases by the wet-dry test, some specimens deteriorating after 2 or 3 cycles. Since no investigation, to the knowledge of the Experiment Station, had been conducted on

soil-cement with the use of an admixture in an effort to improve the durability, it was decided that the freeze-thaw and wet-dry tests should be supplemented by following the same procedure previously outlined but with the use of admixtures for at least the lower percentages of cement for the three soils. TDA solution and Vinsol resin were the two materials selected for use as admixtures in the soil-cement specimens.

#### Tests with Vinsol resin

26. At the time of writing this report the Station has been unable to secure a cement pretreated with Vinsol resin. It is claimed that the best results are obtained when the cement is treated with the Vinsol during the grinding process at the mill. For this reason, and the fact that great difficulty is always experienced when attempting to disperse such minute quantities of dry material into a soil in the laboratory (0.02 to 0.03 percent by volume) these tests have not been performed. However, if the Vinsol resin cement can be procured at a later date it is planned to conduct these tests and to present the results as a supplement to this report.

# Wet-dry and freeze-thaw tests on soil-cement specimens treated with TDA solution

- 27. Fourteen specimens of each of the soils were prepared for these tests in the same manner as that described in paragraph 12 except that to the water used for mixing the soil and cement, was added the TDA solution.

  The amount of the solution added was equivalent to 190 cc of 15 percent TDA solution per 100 lb of cement.
- 28. The sandy loam-cement specimens molded with the TDA solution were cured in the humid room for 28 days, and at the end of the curing period two

were tested to failure in unconfined compression. Of the 12 remaining specimens, 6 were to undergo cycles of wetting and drying, and the other 6, cycles of freezing and thawing. These specimens underwent the same procedure as listed in paragraphs 20 and 22. The same testing schedule was repeated for sandy clay loam-cement and clay loam-cement.

#### TDA test results

29. No stress-strain curves are presented to show the results of the specimens treated with TDA, because of their similarity to previous results. However, the results that were obtained are presented in tabular form for each specimen in tables 6 to 23, inclusive. As can be noted from these tables, no appreciable improvement is found by using the TDA admixture. There is a trend, however, for the specimens containing the lower percentages of cement (5 and 7 percent) to endure more cycles of the durability tests than the straight Portland cement mix, but with considerable reduction in compressive strength in most cases. However, it is believed that the slight reduction in density and slight increase in water content is responsible for the strength losses rather than the addition of the TDA to the mixture.

# Further investigation of the wet-dry test

30. During the course of testing, it was noted that many of the specimens subjected to the wet-dry cycles showed a marked increase in compressive strength with increased number of cycles (see figures 19 to 30 and tables 6 to 23, inclusive). Additional tests were therefore performed to determine if this phenomenon was a result of the wet-dry test or the increase in strength due to additional aging.

31. Fourteen specimens of each of the three soils were molded at 9 percent cement content and cured in the humid room for 28 days. At the end of the curing period, 2 specimens of each soil were tested to failure in the unconfined compression machine. Of the remaining 12 specimens of each soil, 6 were subjected to the wet-dry test (2 through 4 cycles, 2 through 8 cycles, and 2 through 12 cycles). The other 6 specimens of each soil were left in the humid room to cure in pairs for periods of time equal to that required for 4, 8, and 12 cycles of the wet-dry test, and at the end of each of these curing periods were tested to failure concurrently with the specimens subjected to the wet-dry test. The results of these tests are shown in tables 24 to 26, inclusive. Stress-strain curves of the specimens developing the highest maximum strengths for the curing periods, and for the cycles of wetting and drying, are presented on figures 31 to 33, inclusive.

# Discussion of the wet-dry test

- 32. It is apparent from the results of this study that the wet-dry test does in some cases materially increase the compressive strength, this being true even with the lower percentages of cement (5 and 7 percent) for some soils. Take, for example, sandy loam (table 6). Using the strength of the 28-day curing period as a base, the compressive strength is 50 percent stronger after 4 cycles of wetting and drying and at the end of 12 cycles has increased to 100 percent. This trend is not apparent in the sandy clay loam and clay loam until the higher percentages of cement are reached (see tables 14 and 18).
- 33. In the special tests to investigate the strength gain from the wet-dry test more thoroughly (tables 24 to 26) the sandy loam soil showed

marked increase in strength with increased cycles of wetting and drying compared with similar specimens cured only in the humid room for equal periods of time. From table 24 it can be seen that the compressive strength at the end of 52 days curing (equivalent to 28 day curing and 12 cycles of wetting and drying) is only approximately one-third the strength of the specimens after 12 cycles of wetting and drying. The sandy clay loam is approximately the same strength, and the clay loam is materially reduced. However, as previously stated, the sandy clay loam and clay loam did not show the increase in strength trend from the wet-dry test until higher percentages of cement were encountered.

#### V. CONCLUSIONS

#### General

- 34. Generally speaking, it is believed that a line of demarcation probably exists in respect to the grain size distribution of soils which can be sufficiently stabilized economically with cement. That is to say, some soils are more easily stabilized than others. Take, for instance, the friable soils (those soils that contain a relatively high sand content). The case of relatively thorough dispersion of the cement in these soils is easily visualized. From the generally accepted gel theory of concrete, it appears that the cementation of the sandy soils when mixed with a given amount of cement would always be greater than when the same amount of cement is mixed with the very fine soils, because in the fine plastic soils the surface area is probably many times that of the coarser-grained soils. Therefore, the logical assumption to be made is that in order to obtain the same strength for all three soils, the more plastic type should require a higher cement content. The above assumption appears to be borne out by figure 17.
- percentage increase in strength for all three soils, a variable increase of cement to the sandy clay loam and clay loam is required over that added to the sandy loam. It can be seen that 13 to 15 percent cement (160 to 200 percent increase in cement content above 5 percent) has to be added to the plastic soils in order for them to have the same percentage increase in strength as the sandy loam with only 8 to 9 percent cement content (70 to 80 percent increase in cement content above 5 percent). On the basis of the above, it is quite evident that it is not economically practical to

stabilize the more plastic soils with cement when such high contents of cement are required.

The failure of the rich clay soils to gain strength with an increase in cement content could be due to the possibility of small balls of clay being dispersed in the soil specimen with only their outer surfaces coated with cement. These small clay balls may be visualized as being in the form of an egg; the outer surface covered with cement being the shell. The interior of the egg would be the raw soil entrapped in the shell of the cement. The ultimate strength then that could be obtained is no more than the strength of the cemented shells and accompanying friction of the mass. This theory seems justified when some study is given to the shape of the stress-strain curves of the clay loam material. Particular note should be made of figure 13. The clay loam curve on this diagram reaches its yield point with very little strain, its maximum strength with slightly more strain, and then a very slow failure very similar to raw soil occurs, which may be assumed to be caused by the deformation of the clay portions dispersed in the specimen.

# Specific

- 37. The following specific conclusions can be stated as a result of this investigation:
  - a. The water-cement ratio, because of the wide difference in the amount of water which is necessary to bring about maximum density of different soil-cement mixtures, is not a suitable control for soil-cement mixtures. It does affect the strength of the mixture, but not as markedly as other factors.
  - b. In a group of soils the physical characteristics of the individual soils have more effect upon the compressive strength of a soil-cement mixture than any other factor.

- c. Increasing the percentage of cement in a given soil from 5 percent to 11 percent produces a greater increase in compressive strength than does any other factor for the mixture.
- d. The densest mixtures of soil and cement will develop the highest compressive strength for a given soil and percentage of cement. A small percentage increase in density produces a larger percentage increase in strength.
- e. As the cement content is increased from 5 to 15 percent by dry weight, the sandy loam soil gains in compressive strength at a greater rate than the rate of cement increase. Within this same range the other two soils do not gain in strength as rapidly as the cement is increased.
- f. No appreciable improvement was found in the durability and compressive strength of the soil-cement specimens containing TDA.
- g. Cycles of wetting and drying produced an increase in the compressive strength in all mixtures of sandy loam, and some increase in the higher percentages of cement in the sandy clay loam and clay loam specimens.
- h. Cycles of freezing and thawing generally produced some decrease in the compressive strength of all specimens, a marked decrease in strength being noted in those specimens which contained the lower percentages (5 and 7) of cement.

TABLES

TABLE 3

EFFECT OF WATER-CEMENT RATIO ON COMPRESSIVE STRENGTH OF SANDY LOAM SOIL-CEMENT MIXTURES

	Proctor T	est Specimens	Compacted Test	Specimens	Actual Water				
Sample	Optimum Water Content Per Cent	Maximum Dry Density 1bs./cu. ft.	Actual Dry Density 1bs./cu. ft.	Actual Water Content Per Cent	Content Minus Optimum Water Content Per Cent	Cement Content Per Cent Dry Wt.	Water Cement Ratio W/C	Strength 1bs./sq. in.	Strain Per Cent
1	10.8	119.8	116.5	6.4	-4.4	5	2.0	273	0.54
2	10.8	119.8	116.9	6.5	-4.3	5	2.0	273	0.47
3	10.8	119.8	118.5	8.0	-2. B	5	2.5	286	0.82
4	10.8	119.8	118.1	8.6	-2.2	5	2.7	259	0.71
5	10.8	119.8	120.1	10.3	-0.5	5	3.2	257	0.65
6	10.8	119.8	120.5	10.2	-0.6	5	3.2	329	0.64
7	10.8	119.8	117.3	12.5	+1.7	5	4.0	149	1. 12
8	10.8	119.8	117.5	12.3	+1.5	5	4.0	137	1.10
1	11.0	119.7	115.5	6.4	-4.6	7	1.5	288	0.54
2	11.0	119.7	115.7	6.3	<b>-4.</b> 7	7	1.5	353	0.55
3	11.0	119.7	117.8	8.5	-2.5	7	2.0	382	0.65
4	11.0	119.7	118.6	8.4	-2.6	7	1.9	525	0.28
5	11.0	119.7	118.0	11.9	+0.9	7	2.7	241	0.86
6	11.0	119.7	119.4	10.4	-0.6	7	2. 4	482	0.70
7	11.0	119.7	117.9	12.1	+1. 1	7	2.8	290	1.35
8	11.0	119.7	118.5	12.1	+1. 1	7	2.8	245	1. 21
1	11. 2	119.7	117.9	6.7	_4.5	9	1.2	5 70	0.90
2	11. 2	119.7	116. 2	7.1	-4.1	9	1.3	540	0.52
3	11.2	119.7	119.1	9.3	-1.9	9	1.7	630	0.62
4	11.2	119.7	-		-	9	=	697	0.53
5	11.2	119.7	119.9	11,6	+0.4	9	2. 1	730	0.86
6	11. 2	119.7	119.4	11.6	+0.4	9	2, 1	723	0.73
7	11.2	119.7	114. 2	13.7	+2, 5	9	2.5	446	0.80
8	11. 2	119.7	114.5	13. 4	+2.2	9	2.4	478	0.70
1	11.3	119.6	116, 2	7.5	-3.8	11	1. 1	684	0.70
2	11.3	119.6	115.4	7.5	-3.8	11	1. 1	669	0.63
3	11. 3	119.6	115.1	9.3	-2.0	11	1.3	7 29	0.80
4	11.3	119.6	115. 2	9.3	-2.0	11	1.3	736	0.58
5	11.3	119.6	119.3	11.6	+0.3	11	1.7	863	0.89
6	11.3	119.6	119.2	11.5	+0.2	11	1.7	902	0.92
7	11.3	119.6	114.4	13.5	+2.2	11	2.0	548	0.77
В	11.3	119.6	114.0	13.5	+2. 2	11	2.0	503	0.64

TABLE 4

EFFECT OF WATER-CEMENT RATIO ON COMPRESSIVE STRENGTH OF SANDY CLAY LOAM SOIL-CEMENT MIXTURES

	Proctor T	est Specimens	Compacted Test	Specimens	Actual Water				
Sample	Optimum Water Content Per Cent	Maximum Dry Density 1bs./cu. ft.	Actual Dry Density lbs./cu. ft.	Actual Water Content Per Cent	Content Minus Optimum Water Content Per Cent	Cement Content Per Cent Dry Wt.	Water Cement Ratio W/C	Strength 1bs./sq. in.	Strain Per Cent
1	15.6	110.9	104.1	11.7	-3.9	5	3.7	238	0.43
2	15.6	110.9	102.5	11.6	-4.0	5	3.7	235	0.57
3	15.6	110.9	109.4	13.3	-2.3	5	4. 2	360	0.39
4	15.6	110.9	109.1	13.5	-2,1	5	4.2	331	0.79
5	15.6	110.9	110.5	15.5	-0.1	5	4.9	308	0.41
6	15.6	110.9	109.6	15.5	-0.1	5	4.9	273	0.55
7	15. 6	110.9	108.2	17.4	+1.8	5	5.5	188	0.82
8	15.6	110.9	108.0	17.5	+1.9	5	5.5	207	0.68
1	15.9	110.0	105.1	12.1	-3.8	7	2.8	430	0.50
2	15.9	110.0	106.0	11.9	-4.0	7	2.7	331	0.48
3	15.9	110.0	110.2	13.8	-2.1	7	3.2	490	0.58
4	15.9	110.0	109.5	13.9	-2.0	7	3.2	455	0.39
5	15.9	110.0	110.4	15.7	-0.2	7	3,6	312	0.73
6	15.9	110.0	110.0	16. 1	+0.2	7	3.7	299	0.89
7	15.9	110.0	107.3	18.4	+2.5	7	4. 2	25 1	0.75
8	15.9	110.0	108.5	17.5	+1.6	7	4.0	229	0.80
1	16.2	109.1	107.0	12.0	-4.2	9	2.2	429	0.50
2	16.2	109.1	107.0	12.0	-4.2	9	2.2	407	0.51
3	16. 2	109.1	110.5	14. 2	2.0	9	2.6	550	0.69
4	16.2	109.1	111.9	14. 1	-2.1	9	2.6	579	0.65
5	16.2	109.1	110.7	15.5	-0.7	9	2.8	506	0.71
6.	16.2	109.1	111.3	15.5	-0.7	9	2.8	472	0.84
7	16.2	109.1	108.0	17.6	+1.4	9	3.2	302	0.85
8	16. 2	109. 1	108.7	17.5	+1.3	9	3.2	318	0.78
1	16.5	108.2	105.9	12.4	-4. 1	11	1.9	513	0.46
2	16.5	108.2	105.6	12. 2	-4.3	11	1.9	586	0.47
3	16.5	108.2	110.0	14.0	-2.5	11	2.1	678	0.62
4	16.5	108.2	110.9	14. 1	-2.4	11	2.1	723	0.62
5	16.5	108.2	110.1	16. 1	-0.4	11	2. 4	605	0.85
6	16.5	108. 2	110.0	17.7	+1.2	11	2. 7	567	0.84
7	16.5	108.2	108.9	17. 7	+1.2	11	2. 7	407	0.93
8	16.5	108. 2	108.2	18.1	+1.6	11	2.7	395	1.06

	Proctor T	est Specimens	Companted Test	Specimens	Actual Water				
Sample	Optimum Water Content Per Cent	Maximum Dry Density 1bs./cu. ft.	Actual Dry Density lbs./cu. ft.	Actual Water Content Per Cent	Content Minus Optimum Water Content Per Cent	Cement Content Per Cent Dry Wt.	Water Cement Ratio W/C	Strength 1bs./sq. in.	Strain Per Cent
1	18.0	103.8	101.5	14. 2	-3.8	5	4.5	154	0.62
2	18.0	103.8	101.5	14, 2	-3.8	5	4. 5	137	0.61
3	18.0	103.8	103.7	15.9	-2.1	5	5.0	143	0.64
4	18.0	103.8	10 2. 8	16.0	-2.0	5	5.0	145	0.61
5	18.0	103.8	104.0	17.6	-0.4	5	5.5	159	0.74
6	18.0	10 3. 8	103.9	17.8	-0.2	5	5.5	165	0.72
7	18.0	103.8	10 1. 9	20.5	+2.5	5	6.5	122	0.95
8	18.0	103.8	10 2. 2	20.3	+2.3	5	6.4	122	0.92
1	18, 2	103.6	101.1	14.6	-3.6	7	3.4	52	0.99
2	18.2	103.6	101.1	14.6	-3.6	7	3.3	134	0.69
3	18. 2	103.6	104.0	16. 1	-2.1	7	3. 7	203	0.57
14	18, 2	103.6	103.0	16. 1	-2. 1	7	3. 7	202	0.58
5	18. 2	103.6	103.4	18. 1	-0.1	7	4. 2	218	0.54
6	18.2	103.6	105.3	17, 5	-0.7	7	4.0	226	0.73
7	18. 2	103.6	10 2. 2	20.2	+2.0	7	4.6	-	-
8	18. 2	103.6	10 2. 3	20.3	+2, 1	7	4. 7	181	0.77
1	18.4	103.4	100.4	14.3	-4.1	9	2.6	165	0.81
2	18.4	103.4	101.3	14.3	-4.1	9	2.6	252	0.67
3	18.4	103.4	103.2	16.1	-2.3	9	2.9	296	0.71
4	18.4	103.4	104.0	15.9	-2.5	9	2.9	296	0.61
5	18.4	103.4	105.4	17.8	-0.6	9	3. 2	305	0.86
6	18.4	103.4	104.8	17.5	-0.9	9	3.2	292	0.65
7	18.4	103.4	104.2	19.5	+1.1	9	3.5	248	1.10
8	18.4	103.4	104.2	18.9	+0.5	9	3.5	279	0.93
1	18.5	103.3	102.9	14, 4	-4.1	11	2. 2	325	0.71
2	18.5	103.3	100.9	14.7	-3.8	11	2.2	260	0.77
3	18.5	103.3	104.3	15.7	-2.8	11	2.4	318	0.55
4	18.5	103.3	104.1	15.6	-2.9	11	2.4	350	0.64
5	18.5	103.3	105.0	17.3	-1.2	11	2.6	356	0.59
6	18.5	103.3	105.0	17. 2	-1.3	11	2.6	353	0.73
7	18.5	103.3	104.8	18.8	+0.3	11	2. 9	337	0.90
8	18.5	103.3	104.3	18.8	+0.3	11	2.9	321	0.83

TABLE 6

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF SANDY LOAM SOIL-CEMENT SPECIMENS

Cement Content -- 5% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

		TREA	TED WITH TDA	SOLUTION				UNTRE	ATED	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						1	10.1	121.7	410	0.64
8-Day Curing						2	10.6	121.5	424	0.61
Period Only	1	11.7	119.7	197	0.70	3	9.8	121.5	400	0.59
1000 000 000	2	12.0	118.4	216	0.62	4	9.6	121.8	382	0.71
Wet-Dry	3	11. 1	119.7	442	0.52	7	10.8	120.9	643	0.79
4 Cycles	4	11.7	118.7	357	0.56	8	10.1	120.9	574	0.64
Freeze-Thaw	5	11.5	119.3	197	0.62	5	10.6	121. 3	331	0.62
4 Cycles	6	11.5	118.6	175	0.37	6	11. 1	121. 4	309	0.93
Wet-Dry	7	11.6	119.0	267	0.82	13	10.1	120.6	446	0.83
8 Cycles	8	11.7	119.0	501	0.95	14	9.7	121. 1	462	0.69
Freeze-Thaw	9	11.7	118.9	175	0.51	9	10.3	120.6	274	0.64
8 Cycles	10	_	_	146	0.56	10	10.6	120.6	289	0.68
Wet-Dry	11	12.0	118.5	442	0.76	15	10.2	120.9	809	0.98
	12	11.3	119.7	616	0.73	16	10.6	120.0	696	0.90
12 Cycles					7.5.E.	***	10.0	120.0	0,0	
Freeze-Thaw	13	11.8	119.1	156	0.51	11	10.8	120.6	223	0.85
12 Cycles	14	11.9	118.8	127	0.47	12	10.1	121.1	121	0.92

TABLE 7

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF SANDY LOAM SOIL-CEMENT SPECIMENS

Cement Content -- 7% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

		TF	REATED WITH TO	A SOLUTION				UNT	REATED	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 10s/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						1	11.0	118.0	541	0.64
8-Day Curing						2	10.9	121.1	5 2 2	0.79
Period Only	1	12.0	119.1	267	0.43	3	10.5	118.7	509	0.81
	2	11.7	119.3	216	0.84	4	10.3	121.1	5 28	0.80
Wet-Dry	3	11.8	119. 1	490	0.58	7	10.4	121. 1	1100	0.72
4 Cycles	4	11.6	119.6	471	0.75	8	10.5	120.8	935	0.96
Freeze-Thaw	5	11.4	120.3	277	0.54	5	10.3	121.1	554	0.79
4 Cycles	6	11.5	119. 2	256	0.42	6	10.6	120.6	518	0.68
Wet-Dry	7	11.4	119.7	694	0.90	13	10.5	120.2	1050	1.04
8 Cycles	8	11.4	119.9	705	1.00	14	9. 2	122, 8	80 2	0.75
Freeze-Thaw	9	11.8	118.7	267	0.56	9	11.5	120.2	431	0.66
8 Cycles	10	11.6	119.8	277	0.55	10	10.7	120.2	477	0.87
Wet-Dry	11	11.6	119.6	563	1.01	15	10.2	120.2	896	0.90
12 Cycles	12	11.6	119.6	554	0.91	16	10.4	120.6	1069	0.78
Freeze-Thaw	13	12.0	118.9	288	0.67	11	10.5	120.6	490	0.81
12 Cycles	14	11. 2	120.2	277	0.54	12	11.0	120.2	452	0.65

TABLE 8

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF SANDY LOAM SOIL-CEMENT SPECIMENS

Cement Content -- 9% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

		TRE	ATED WITH TDA	SOLUTION				UNT	REATED	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						1	10.9	118.9	804	0.75
28-Day Curing						2	10.9	121.1	674	0.86
Period Only	1	11.6	119.5	357	0.59	3	11.0	120.0	693	0.72
	2	11.5	120.0	433	0.52	4	11.1	122. 2	716	0.84
Wet-Dry	3	11.3	120.3	645	0.79	7	10.6	120.2	1446	0.84
4 Cycles	4	12.5	117.7	635	0.57	8	10.6	121.1	1170	0.78
Freeze-Thaw	5	11.7	119.5	481	0.46	5	11. 1	120.9	713	0.72
4 Cycles	6	11.4	119.6	471	0.47	6	10.6	120.9	751	0.76
Wet-Dry	7	12.3	117.5	869	0.75	13	10.6	120.2	1372	0.83
8 Cycles	8	12. 1	118.0	931	0.82	14	11.0	120.2	1438	0.94
Freeze-Thaw	9	12.6	117.8	40 1	0.67	9	11.0	120.2	674	0.64
8 Cycles	10	12.7	117.7	481	0.49	10	10.4	121.4	696	0.71
Wet-Dry	11	12. 1	118.5	922	0.92	15	10.7	120.6	1975	1. 12
12 Cycles	12	12.0	118.9	10 1 1	0.59	16	11.3	119.4	1680	1.06
Franza Thaw	13	11.8	119.3	554	0.43	11	10 11	120.0	501	0.72
Freeze-Thaw 12 Cycles	14	12.6	117.9	512	0.32	12	10.4 9.4	120.9 121.1	581 440	0.73

TABLE 9

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF SANDY LOAM SOIL-CEMENT SPECIMENS

Cement Content -- 11% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

Type of Dur- ability Test after 28 days curing.		TRE	ATED WITH TDA	SOLUTION		UNTREATED						
	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent		
						1	10.7	121.8	970	0.83		
8-Day Curing						2	11.1	121.8	922	0.95		
Period Only	1	12.4	118.6	616	0.59	3	10.9	122.1	949	0.68		
) = 1 (	2	12.6	117.8	490	0.47	4	11.4	120.9	957	0.96		
Wet-Dry	3	12.4	118.5	952	0.46	7	11. 1	120.9	1644	0.96		
4 Cycles	4	12.3	118.6	961	0.64	8	11.4	120.6	1571	0.79		
Freeze-Thaw	5	12.0	119.4	654	0.43	5	11.3	119.9	777	0.64		
4 Cycles	6	12.5	118.1	654	0.54	6	10.8	120.9	975	0.61		
Wet-Dry	7	12.0	118.6	1380	0.91	13	10.7	121. 3	1870	0.99		
8 Cycles	В	11, 6	119.7	1440	0.67	14	10.9	121.3	1705	1. 11		
Freeze-Thaw	9	12. 1	119.4	694	0.56	9	10.6	121, 1	863	0.69		
8 Cycles	10	12.6	117.7	635	0.61	10	11, 1	120.6	796	0.76		
Wet-Dry	11	12,5	118.1	1288	0.68	15	11.0	120.2	20 20	1.04		
12 Cycles	12	12. 1	118.4	1338	0.75	16	11.0	120.9	1985	1. 34		
Freeze-Thaw	13	12, 2	118. 1	654	0.55	11	11.3	120.2	755	0.79		
12 Cycles	14	12.0	119.0	675	0.42	12	10.8	121. 1	866	0.76		

TABLE 10

MAXIMUM COMPRESSIVE STRENGTH AND MAXIMUM STRAIN OF SANDY LOAM SOIL-CEMENT SPECIMENS

Specimens Molded at Approximate Optimum Water Content

Type of Dur- ability Test after 28 days curing.	TREATED WITH TDA SOLUTION								UNTREATED							
	5% Cement		7% Cement		9% Cement		11% Cement		5% Cement		7% Cement		9% Cement		11% Cement	
	C. S. *	Strain**	C. S.	Strain	c. s.	Strain	c. s.	Strain	C. S.	Strain	c. s.	Strain	C. S.	Strain	c. s.	Strain
									4 10	0.64	541	0.64	804	0.75	970	0.83
28-Day Curing									424	.61	522	. 79	674	.86	922	.95
Period Only	197	0.70	267	0.43	357	0.59	616	0.59	400	.59	509	.81	693	. 72	949	.68
	216	.62	216	.84	433	.52	490	. 47	382	.71	528	.80	716	.84	957	.96
Wet-Dry	442	.52	490	.58	645	. 79	952	. 46	643	. 79	1100	.72	1446	. 84	1644	.96
4 Cycles	357	.56	471	.75	635	.57	961	.64	574	. 64	935	.96	1170	.78	1571	. 79
Freeze-Thaw	197	.62	277	.54	481	.46	654	. 43	331	.62	554	. 79	713	.72	777	. 64
4 Cycles	175	.37	256	.42	471	. 47	654	. 54	309	.93	518	.68	751	. 76	975	.61
Wet-Dry	267	.82	694	.90	869	. 75	1380	.91	446	.83	1050	1.04	1372	.83	1870	.99
8 Cycles	501	.95	705	1.00	931	.82	1440	, 67	462	.69	802	. 75	1438	.94	1705	1. 11
Freeze-Thaw	175	.51	267	0.56	401	. 67	694	.56	274	.64	431	.66	674	. 64	863	0.69
8 Cycles	146	.56	277	.55	481	. 49	635	.61	289	.68	477	.87	696	.71	796	. 76
Wet-Dry	442	.76	563	1.01	922	.92	1288	. 68	809	.98	896	.90	1975	1.12	2020	1.04
12 Cycles	616	. 73	554	0.91	1011	.59	1338	. 75	696	.90	1069	. 78	1680	1.06	1985	1. 34
Freeze-Thaw	156	.51	288	. 67	554	.43	654	.55	223	.85	490	.81	581	0.73	755	0.79
12 Cycles	127	. 47	277	.54	512	.32	675	.42	121	.92	452	. 65	440	.96	866	. 76

<sup>\*</sup> Compressive strength in pounds per sq. in.;

NOTE: Cement in per cent dry wt. of soil.

<sup>\*\*</sup> In per cent.

TABLE 11

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESS STRENGTH OF SANDY CLAY LOAM SOIL-CEMENT SPECIMENS

Cement Content — 5% of Dry Wt. of Soil

Specimens Molded at Approximate Minus 2% Optimum Water Content

		TREA	TED WITH TDA	SOLUTION				UNT	REATED	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	13.8	109.5	360	0.38
28-Day Curing						14	14.3	108.0	426	0.37
Period Only	1	14.6	106.9	277	0.40	15	14. 2	108. 2	296	0.54
	2	14.5	106.1	299	0.38	16	13.5	107.7	376	0.43
	3	14.0	105.9	95	0.81	7	13. 1	105.9	127	0.69
Wet-Dry 4 Cycles	4	14.0	106.2	127	0.94	8	12, 8	106.1	99	0.70
Francis Them	5	13.7	105.5	137	0.57	1	13.4	107.8	147	0.58
Freeze-Thaw 4 Cycles	6	14. 5	105.7	137	0.43	2	13. 2	104.9	180	0.60
Mat On	7	14. 4	107.0	156	0.92	9	12.7	106.9	121	1. 20
Wet-Dry 8 Cycles	8	14.0	105.2	146	0.92	10	14.8	109.0	148	1. 19
	9	14.5	107.0	186	0.52	3	13.7	108.9	147	0.94
Freeze-Thaw 8 Cycles	10	14. 6	10 6. 4	146	0.44	4	14. 1	10 7. 7	137	0.82
Wat Day	11	15. 2	107.3	175	1.00	11	13.8	107.6	149	1. 12
Wet-Dry 12 Cycles	12	13.9	105.2	166	0.78	12	14. 1	108.9	153	1. 24
	13	14. 3	106.3	146	0.42	5	13.9	108.4	89	1. 49
Freeze-Thaw 12 Cycles	14	13.7	105.1	127	0.48	6	13.9	109.9	143	1.58

TABLE 12

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF SANDY CLAY LOAM SOIL-CEMENT SPECIMENS

Cement Content — 7% of Dry Wt. of Soil

Specimens Molded at Approximate Minus 2% Optimum Water Content

		TRE	ATED WITH TOA	SOLUTION				UNT	REATED	
Type of Dur- ability Test after 28 days curing	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	14.0	108.7	529	0.63
8-Day Curing						14	13. 4	106.8	566	0.57
Period Only	1	15.0	108.5	625	0.44	15	13. 2	108.6	596	0.40
	2	14.3	107.6	481	0.36	16	13.3	107.6	472	0.58
Wet-Dry	3	13. 1	106.7	328	1. 12	7	_	_	4 20	1.03
4 Cycles	4	14.6	109.3	401	1. 18	8	13. 7	106.9	248	1, 21
reeze-Thaw	5	14. 2	107.4	422	0.56	1	13.3	107.5	414	0.54
4 Cycles	6	13.7	106.0	318	0.52	2	13.9	107.0	363	0.54
Wet-Dry	7	13.6	10 6. 7	357	1.08	9	13.8	107.2	283	1. 29
8 Cycles	8	13.8	107.3	462	0.99	10	13.5	109.5	363	1.37
reeze-Thaw	9	13. 1	105.6	318	0.38	3	13.7	109.1	366	0.66
8 Cycles	10	13.4	107.2	379	0.45	4	13.3	108.9	395	0.63
Net Day	11	14. 2	105, 2	337	0.96	11	13.9	107.6	280	1, 40
Wet-Dry 12 Cycles	12	13.6	105. 2	267	1.02	12		=	334	1. 22
	13	13.3	104.3	237	0.48	5	13.6	107.6	290	0.64
reeze—Thaw 12 Cycles	14	13. 1	105.3	309	0.49	6	13.4	108.3	351	0.77

TABLE 13

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF SANDY CLAY LOAM SOIL-CEMENT SPECIMENS

Cement Content --- 9% of Dry Wt. of Soil

Specimens Molded at Approximate Minus 2% Optimum Water Content

		TREAT	ED WITH TDA	SOLUTION				UNTREA	TED	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 165/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	13.5	108.0	524	0.60
28-Day Curing						14	13.9	107.7	361	0.49
Period Only	1	14.0	106.3	543	0.43	15	13.6	108.5	567	0.54
	2	13.7	104.7	543	0.41	16	13. 2	108.3	516	0.53
Wet-Dry	3	13.5	105.0	390	0.94	7	13.8	109.6	30.5	1. 27
4 Cycles	4	12.9	10 4. 8	347	1.06	8	13.6	106.7	388	1. 17
Freeze-Thaw	5	14. 1	107.4	501	0.58	1	13. 4	106.9	516	0.57
4 Cycles	6	14. 1	107.6	5 2 2	0.45	2	13.6	108.0	506	0.52
Wet-Dry	7	13.7	107.4	433	0.78	9	13.9	110.1	420	0.87
8 Cycles	8	13. 2	108.0	347	0.72	10	13. 8	109.9	411	1. 15
Freeze-Thaw	9	13. 3	107.1	357	0.46	3	14. 2	108.8	558	0.61
8 Cycles	10	14. 2	106.8	368	0.58	4	13. 5	107.9	455	0.64
Wet-Dry	11	14.0	106.5	433	0.76	11	14. 1	111.0	506	1. 31
12 Cycles	12	13.6	106.5	433	1.01	12	14.3	108.9	538	1. 16
Freeze-Thaw	13	14.0	108.1	543	0.52	5	13.5	108.4	462	0.74
12 Cycles	14	13. 7	106.2	390	0.42	6	13.7	110.1	5 10	0.56

TABLE 14

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF SANDY CLAY LOAM SOIL-CEMENT SPECIMENS

Cement Content -- 11% of Dry Wt. of Soil

Specimens Molded at Approximate Minus 2% Optimum Water Content

		TREAT	TED WITH TOA	SOLUTION				UNTREAT	rED	
Type of Dur- ability Test after 28 days curing	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	13.6	107.7	592	0.61
8-day Curing						14	13.8	108.1	657	0.63
Period Only	1	13.7	106.9	7.26	0.54	15	14.0	107.9	612	0.66
reriod omy	2	14.4	107.8	778	0.48	16	13.7	106.3	507	0.69
Wet-Dry	3	14.0	107.7	586	0.99	7	13.9	108.0	567	1.09
4 Cycles	4	13.7	105.7	471	0.74	8	14. 2	107.0	574	1. 24
Cranan Thaw	5	13.9	107.3	737	0.72	1	13.6	109.4	563	0.65
Freeze-Thaw 4 Cycles	6	14.0	107.5	6 25	0.59	2	-	_	5 38	0.62
Web Day	7	15.4	108.3	645	0.95	9	13.7	108.3	593	1.08
Wet-Dry 8 Cycles	8	15. 1	107.9	7 26	0.82	10	13.8	107.4	533	1. 16
	9	14.8	108.3	635	0.60	3	13.9	108.5	573	0.74
Freeze-Thaw 8 Cycles	10	14.8	108.2	664	0.45	4		-	648	0.76
Link David	11	14.9	107.2	563	0.76	11	13.9	108.8	717	1.07
Wet-Dry 12 Cycles	12	14.6	106,5	645	0.84	12	13. 7	108.2	694	1. 13
Fronzo Thom	13	15. 3	108.0	684	0.48	5	14.0	107.9	648	0.75
Freeze-Thaw 12 Cycles	14	14. 4	107.2	616	0.47	6	14.0	108.8	669	0.71

TABLE 15

MAXIMUM COMPRESSIVE STRENGTH AND MAXIMUM STRAIN OF SANDY CLAY LOAM SOIL CEMENT SPECIMENS

Specimens Molded at Approximate Minus 2% Optimum Water Content

Type of Dur-			TRE	ATED WITH	TDA SO	LUTION						UNTREAT	ED			
ability Test after 28	c	5% ement		7% ment		9% ment		1% ment		5% ment		7% ment		9% ment		1% ment
days curing.	c.s.*	Strain**	C. S.	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain	C. S.	Strain	c. s.	Strain	C. S.	Strain
									360	0.38	529	0.63	524	0.60	592	0.61
28-Day Curing									426	.37	566	.51	361	. 49	657	.63
Period Only	277	0.40	625	0.44	543	0.43	726	0.54	296	.54	596	.40	567	-54	612	. 66
	299	.38	481	. 36	543	.41	778	. 48	376	. 43	472	.58	516	.53	507	. 69
Wet-Dry	95	.81	3 28	1. 12	390	.94	586	.99	127	. 69	420	1.03	305	1. 27	567	1.09
4 Cycles	127	. 94	401	1. 18	347	. 74	99	. 70	99	. 70	248	1. 21	388	1. 17	574	1. 24
Freeze-Thaw	137	.57	422	0.56	501	.58	737	. 72	147	.58	414	0.54	516	0.57	563	0.65
4 Cycles	137	. 43	318	.52	522	. 45	625	. 59	180	. 60	363	.54	506	.52	538	. 62
Wet-Dry	156	.92	357	1.08	433	.78	645	.95	121	1. 20	283	1. 29	420	.87	593	1.08
8 Cycles	146	.92	462	0.99	347	.72	726	.82	148	1. 19	363	1.37	411	1. 15	533	1. 16
Freeze-Thaw	186	.52	318	. 38	357	. 46	635	.60	147	0.94	366	0.66	558	0.61	573	0.74
8 Cycles	146	* ##	379	. 45	368	.58	664	. 45	137	.82	395	. 63	455	. 64	648	.76
Wet-Dry	175	1.00	337	.96	433	.76	563	. 76	149	1. 12	280	1.40	506	1.31	717	1.07
12 Cycles	166	0.78	267	1.02	433	1.01	645	.84	153	1. 24	334	1, 22	538	1. 16	694	1. 13
Freeze-Thaw	146	.42	237	0.48	543	.52	648	. 48	89	1.49	290	0.64	462	0.74	648	0.75
12 Cycles	127	. 48	309	. 49	390	. 42	616	. 47	143	1.58	351	.77	5 10	.56	669	.71

<sup>\*</sup> Compressive strength in pounds per sq. in.;

<sup>\*\*</sup> In per cent.

TABLE 16

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF CLAY LOAM SOIL-CEMENT SPECIMENS

Cement Content — 5% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

			TREATE	D WITH TDA SOLU	TION			UNTREATED	)	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	_	_	242	1. 52
28-Day Curing						14	18.3	104.2	224	1.32
Period Only	1	17.7	102.5	137	0.55	15	17.7	104.5	153	0.87
	2	17.3	102.5	118	0.54	16	17.4	103.1	105	1. 17
Wet-Dry	3	18.7	10 2. 4	64	0.87	7	17.4	104.1	111	111
4 Cycles	4	18. 7	102.4	54	0.65	8	17.3	103.1	111	111
reeze-Thaw	5	20.8	99.8	33	1,53	1	-	- 41	1	i
4 Cycles	6	18. 1	10 2. 9	43	1. 39	2	17.7	103.0	1	i
Wet-Dry	7	18.8	103.0	vi	vi	9	17.8	104.5	111	111
8 Cycles	8	19.1	102.6	viii	vili	10	17.9	103.9	٧	٧
reeze-Thaw	9	18.5	103.4	viii	viii	3	18.5	104,0	111	111
8 Cycles	10	19.2	102.3	viii	viii	4	17.8	103.9	iii	111
Wet-Dry	11	18. 7	102.3	iv	iv	11	17.9	103.3	111	111
12 Cycles	12	18.5	103.9	iv	iv	12	17.8	103.6	111	111
reeze-Thaw	13	18.5	102.7	33	1. 41	5	18. 2	103.7	111	111
12 Cycles	14	18.0	102.9	14	0.94	6	17.4	103.4	V	V

TABLE 17

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF CLAY LOAM SOIL-CEMENT SPECIMENS

Cement Content -- 7% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

			TREAT	ED WITH TDA SOL	UTION			UNTREATED		
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	17.3	103.5	274	1. 11
3-Day Curing						14	17.4	103.6	286	1. 18
Period Only	1	19.8	10 1. 2	175	0.50	15	17.3	104.0	153	0.98
	2	18,6	10 2. 2	166	0.53	16	17.0	104.6	143	0.88
Wet-Dry	3	20.0	10 2. 3	127	0.82	7	17.3	104.5	111	111
4 Cycles	4	19.7	10 1. 3	127	0.81	8	16.8	105.2	111	111
reeze-Thaw	5	19.8	10 1. 6	64	1, 36	1	17.0	104.3	121	0.85
Cycles	6	20.0	10 1. 4	64	1.12	2	17.6	103.3	127	0.93
Wet-Dry	7	19.4	101.9	146	0.83	9	17.5	104.3	vi	vi
8 Cycles	8	19.6	102.2	175	0.90	10	17.0	103.7	11	11
reeze-Thaw	9	20.1	102.7	viii	viii	3	17.8	104.1	162	1.81
3 Cycles	10	19.5	103.2	viii	viii	4	17.6	104.0	130	2. 20
Wet-Dry	11	19.6	103.7	186	0.98	11	16. 7	104.2	111	111
12 Cycles	12	19.5	103.4	166	1.01	12	17.8	103.6	ix	ix
reeze-Thaw	13	18. 7	103. 7	xII	xii	5	17.3	104.0	×	×
12 Cycles	14	18.6	103.5	xii	xii	6	17.5	104.3	×	×

TABLE 18

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF CLAY LOAM SOIL CEMENT SPECIMENS

Cement Content -- 9% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

			TRE	ATED WITH TOA S	OLUTION			UNTREAT	ED	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density lbs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	17. 2	104.3	188	0.82
28-Day Curing						14	17.1	104.5	161	0.84
Period Only	1	18.6	104.1	256	0.54	15	16.9	103.0	151	0.86
	2	18.0	102, 2	216	0.49	16	16.5	10 2, 8	175	0.83
Wet-Dry	3	18. 2	103. 2	197	0.63	7	17.9	104.4	236	1.04
4 Cycles	4	18.9	102.8	216	0,97	8	17.3	103.2	254	1, 14
Freeze-Thaw	5	18.7	103.8	137	0.82	1	17. 1	104.4	161	0.66
4 Cycles	6	18.5	10 2. 9	137	0.82	2	17. 7	103.7	151	0.71
Wet-Dry	7	15. 1	105.6	228	0.73	9	17.5	104.0	vi	vi
8 Cycles	8	18.8	103. 1	197	0.87	10	17. 2	104.1	30 6	1, 15
reeze-Thaw	9	18.3	103.7	viii	viii	3	17.8	103.3	151	2, 44
8 Cycles	10	17.8	10 2. 7	viii	viii	4	17.8	10 4. 9	146	1. 74
Wet-Dry	11	18.4	10 2. 0	186	0.87	11	17. 6	103.3	344	1. 43
12 Cycles	12	18.3	102.5	245	0.93	12	17. 4	103.2	318	1.32
Freeze-Thaw	13	19. 1	102.0	54	1. 62	5	17.8	103.5	xii	xii
12 Cycles	14	18.3	101.8	54	1.62	6	17.7	103.4	xii	×ii

TABLE 19

EFFECT OF DURABILITY TESTS ON UNCONFINED COMPRESSIVE STRENGTH OF CLAY LOAM SOIL CEMENT SPECIMENS

Cement Content -- 11% of Dry Wt. of Soil

Specimens Molded at Approximate Optimum Water Content

			TREA	TED WITH TDA SO	LUTION			UNTREATE	.D	
Type of Dur- ability Test after 28 days curing.	Sample No.	Molded Water Content Per Cent	Molded Dry Density 1bs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent	Sample No.	Molded Water Content Per Cent	Molded Dry Density lbs/cu ft	Maximum Compressive Strength 1bs/sq in	Maximum Strain Per Cent
						13	17.8	104.3	197	0.81
8-Day Curing						14	18.0	105.6	235	0.86
Period Only	1	20.4	101.2	245	0.44	15	17.5	104.6	272	0.97
	2	21. 4	100.6	228	0.62	16	16.8	104.9	206	0.91
Wet-Dry	3	20.8	101.5	379	1. 20	7	18.0	103.8	280	1. 16
4 Cycles	4	21. 2	10 1. 6	379	1.08	8	17. 7	103.9	308	1. 25
reeze-Thaw	5	20.8	10 1. 5	166	0.80	1	17. 7	105.0	197	0.85
4 Cycles	6	21.0	10 1. 7	137	0.57	2	17. 2	105.0	207	0.73
Wet-Dry	7	21, 3	10 1. 7	390	0.94	9	17. 7	105.0	459	1. 29
8 Cycles	8 ,	20.9	10 2. 2	368	0.84	10	18. 2	104.3	363	1. 21
reeze-Thaw	9	18. 1	102.9	viii	viii	3	17. 7	104.7	146	1.92
B Cycles	10	21.6	100.9	viii	viii	4	17. 5	105. 2	235	1.06
Wet-Dry	11	18. 1	103.3	347	0.85	11	17.8	103.8	xii	xii
12 Cycles	12	17.8	10 2. 7	228	1.07	12	17. 5	105.1	xii	×ii
reeze-Thaw	13	18.7	102.5	xii	xii	5	14. 6	106.6	xii	xii
12 Cycles	14	20.1	102.3	54	1.84	6	17. 6	10 4. 0	xii	xii

TABLE 20

MAXIMUM COMPRESSIVE STRENGTH AND MAXIMUM STRAIN OF CLAY LOAM SOIL-CEMENT SPECIMENS

Specimens Molded at Approximate Optimum Water Content

Type of Dur-			TR	EATED WIT	H TDA S	OLUTION						UN	TREATED			
ability Test after 28		5% Cement		7% ment		9% ment		1% ment		5% ment		nent		ent		1% ment
days curing.	c.s.*	Strain**	C. S.	Strain	C. S.	Strain	c. s.	Strain	C. S.	Strain	C. S.	Strain	C. S.	Strain	C. S.	Strai
									242	1.52	274	1. 11	188	0.82	197	0.81
8-Day Curing									224	1.32	286	1. 18	161	.84	235	.86
Period Only	137	0.55	175	0.50	256	0.54	245	0.44	153	0.87	153	0.98	151	.86	27 2	. 9
	118	.54	166	.53	216	. 49	2 28	, 62	105	1. 17	143	.88	175	.83	20 6	.9
Wet-Dry	64	.87	127	.82	197	.63	379	1. 20	111	111	111	111	236	1.04	280	1. 1
4 Cycles	54	.65	127	.81	216	.97	379	1.08	iii	111	111	111	254	1. 14	308	1. 2
Freeze-Thaw	33	1. 53	64	1. 36	137	.82	166	0.80	1	i	121	0.85	161	0.66	197	0.8
4 Cycles	43	1. 39	64	1. 12	137	.82	137	.57	i	i	127	.93	151	.71	207	.7
Wet-Dry	vi	vi	146	0.83	2 28	.73	390	.94	111	111	vi	vi	vi	vi	459	1. 2
8 Cycles	viii	viii	175	.90	197	.87	368	.84	٧	٧	ii	11	306	1. 15	363	1. 2
Freeze-Thaw	viii	viii	viii	viii	viii	viii	viii	viii	111	111	162	1.81	151	2. 44	146	1. 9
8 Cycles	viii	viii	viii	viii	viii	viii	viii	viii	III	iii	130	2. 20	146	1.74	235	1. 0
Wet-Dry	iv	īv	186	0.98	186	0.87	347	0.85	111	111	111	111	344	1. 43	xii	×i
12 Cycles	iv	iv	166	1.01	245	.93	2 28	1.07	iii	iii	ix	ix	318	1.32	xii	×i
Freeze-Thaw	33	1. 44	×ii	xii	54	1.62	xii	xii	111	111	×	×	×II	×ii	xii	хi
12 Cycles	14	0.94	xii	xii	54	1.62	54	1.84	٧	٧	×	×	xii	xii	xii	xi

<sup>\*</sup> Compressive strength in pounds per square inch.

<sup>\*\*</sup> In per cent.

TABLE 21

AVERAGE MAXIMUM COMPRESSIVE STRENGTH AND AVERAGE MAXIMUM STRAIN OF SANDY LOAM SOIL-CEMENT SPECIMENS

Turn of Due			TREAT	ED WITH T	DA SOLU	TION						UNTE	REATED			
Type of Dur- ability Test after 28		5% ment		7% ment		9% ment		1% ment		5% ment		7% ment		9% ment		1% ment
days curing.	c. s. *	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain
28—Day Curing Period Only	206	0.66	241	0.64	395	0.56	553	0.53	40 4	0.64	5 25	0.76	7 2 2	0.79	949	0.86
Wet-Dry 4 Cycles	399	.54	480	. 67	640	. 68	956	.55	608	.72	10 17	.84	1308	.81	1607	.88
Freeze-Thaw 4 Cycles	186	.50	266	. 48	476	. 47	654	. 49	320	.78	536	.74	732	.74	876	. 63
Wet-Dry 8 Cycles	384	.89	699	.95	900	.79	1410	.79	454	.76	9 26	.90	1405	.89	1787	1.05
Freeze-Thaw 8 Cycles	160	.54	27 2	.56	441	.58	664	. 59	28 1	.66	454	.77	685	.68	8 29	0.73
Wet-Dry 12 Cycles	5 29	75	558	.96	966	.76	1313	.72	752	.94	982	.84	18 27	1.09	2002	1. 19
Freeze-Thaw 12 Cycles	141	. 49	28 2	. 61	533	. 38	664	. 49	172	.89	471	.73	5 10	0.85	8 10	0.78

<sup>\*</sup> Compressive strength in 1bs. per sq. in.

<sup>\*\*</sup> In per cent.

TABLE 22

AVERAGE MAXIMUM COMPRESSIVE STRENGTH AND AVERAGE MAXIMUM STRAIN OF SANDY CLAY LOAM SOIL-CEMENT SPECIMENS

Type of Dur-	1 -		TREAT	ED WITH T	DA SOLU	TION							UNTREAT	TED		
ability Test after 28		5% Cement		7% ment		9% ment		1% ment		5% ment		7% ment		ment		1% ment
days curing.	C.S.*	Strain**	c. s.	Strain	c. s.	Strain	C. S.	Strain	C. S.	Strain	C. S.	Strain	c. s.	Strain	C. S.	Strain
28—Day Curing Period Only	288	0.39	553	0.40	543	0.42	752	0.57	364	0.43	541	0.53	492	0.54	592	0.65
Wet-Dry 4 Cycles	111	.88	364	1. 15	368	1.00	5 28	.87	113	. 70	334	1, 12	346	1. 22	570	1. 17
Freeze-Thaw 4 Cycles	137	.50	370	0.54	511	0.52	681	. 66	163	.59	368	0.54	511	0.55	550	0.64
Wet-Dry 8 Cycles	151	.92	409	1.04	390	.75	685	.89	134	1. 20	323	1. 33	415	1.01	563	1, 12
Freeze-Thaw B Cycles	166	. 48	348	0.42	362	.52	649	.53	142	0.88	380	0.65	506	0.63	610	0.75
Wet-Dry 12 Cycles	170	. 89	302	.99	433	.89	604	. 80	151	1. 18	307	1.31	522	1. 24	705	1. 10
Freeze-Thaw 12 Cycles	136	. 45	273	. 49	466	.47	650	. 48	116	1.54	3 20	0.71	486	0.65	658	0.73

<sup>\*</sup> Compressive strength in pounds per square inch.

<sup>\*\*</sup> In per cent.

TABLE 23

AVERAGE MAXIMUM COMPRESSIVE STRENGTH AND AVERAGE MAXIMUM STRAIN OF CLAY LOAM SOIL-CEMENT SPECIMENS

Type of Dur- ability Test after 28 days curing.	TREATED WITH TDA SOLUTION							UNTREATED								
	5% 7% Cement Cement			9% tCement		11% Cement		5% Cement		7% Cement		9% Cement		11% Cement		
	c.s.*	Strain**	c. s.	Strain	c. s.	Strain	c.s.	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain	c. s.	Strain
28—Day Curing Period Only	127	0.55	170	0.52	236	0.52	236	0.53	181	1. 22	214	1.04	169	0.84	227	0.89
Wet-Dry 4 Cycles	59	.76	127	.82	206	. 80	379	1. 14	111	111	111	111	245	1, 09	294	1. 21
reeze—Thaw 4 Cycles	38	1.46	64	1. 24	137	.82	151	0.69	i	i	124	0.89	156	0.69	20 2	0.79
Wet-Dry 8 Cycles	vii	vii	160	0.87	212	.80	379	. 89	īv	iv	iv	iv	306	1. 15	411	1. 25
reeze—Thaw 8 Cycles	viii	viii	viii	vili	viii	viii	viii	vIII	111	111	146	2.01	148	2.09	190	1.49
Wet-Dry 12 Cycles	īv	iv	176	1.00	215	0.90	287	0.96	111	111	vi	vi	331	1.38	×ii	×ii
reeze_Thaw 12 Cycles	23	1. 18	xii	xii	54	1.62	54	1.89	iv	īv	×	×	xii	xii	xii	xii

<sup>\*</sup> Compressive strength in pounds per square inch.

<sup>\*\*</sup> In per cent.

TABLE 24

## RELATIVE EFFECTS OF CURING PERIODS AND WET-DRY CYCLES ON UNCONFINED COMPRESSIVE STRENGTH SANDY LOAM SOIL-CEMENT SPECIMENS

Cement Content — 9% of Dry Wt. of Soil

Proctor's Optimum Water Content = 11.2%

Maximum Dry Density = 119.8 lb. per cu. ft.

Type of Test	Sample		r Content Wt. Soil		y, Dry Wt. er cu. ft.	Maximum — Compressive	Maximum Strain Per Cent
Or Curing Period	No.	Molded	Diff. in Optimum and Molded	Mo1ded	Diff. in Maximum and Molded	Strength  1bs. per sq. in.	
10 4	17	13.28	+ 2.08	115.9	- 3.8	288	0.42
28-day curing period	18	13.12	+ 1.92	115.8	- 3.9	309	0.51
36-day curing period	19	12.95	+ 1.75	116.8	- 2.9	318	0.50
	20	12.78	+ 1.58	116,6	- 3.1	328	0.39
28-day curing period	21	12.01	+ 0.81	117.7	- 2.0	675	0.90
plus 4 cycles wetting & drying test	22	12. 15	+ 0.95	117.8	- 1.9	684	0.91
	23	12.49	+ 1.29	117.4	- 2.3	348	0.73
4-day curing period	24	11.90	+ 0.70	118.9	- 0.8	442	0.89
28-day curing period	25	11.67	+ 0.47	119.4	- 0.3	1001	1.09
plus 8 cycles vetting & drying test	26	11.33	+ 0.13	119.4	- 0.3	1084	1.00
	27	11. 17	- 0.03	119.2	- 0.5	543	0.53
2-day curing period	28	11.34	+ 0.14	118.3	- 1,4	50 1	0.52
28-day curing period	29	11.16	- 0.04	119.5	- 0.2	1227	0.97
plus 12 cycles wetting & drying test	30	10.67	- 0.53	119.5	- 0.2	1410	0.77

TABLE 25

RELATIVE EFFECTS OF CURING PERIODS AND WET-DRY CYCLES
ON UNCONFINED COMPRESSIVE STRENGTH SANDY CLAY LOAM SOIL-CEMENT SPECIMENS

Cement Content -- 9% of Dry Wt. of Soil

Proctor's Optimum Water Content = 16.2%

Maximum Dry Density = 109.1 lb. per cu. ft.

Type of Test	Sample		r Content Wt. Soil	- Carrie and Carrie an	y, Dry Wt. er cu. ft.	Max imum	Maximum Strain Per Cent
Or Curing Period	No.	Molded	Diff. in Optimum and Molded	Mo1ded	Diff. in Maximum and Molded	Strength  1bs. per sq. in.	
nn day and a castad	17	15.09	- 1, 11	104.2	- 4.9	390	0.30
28-day curing period	18	14.11	- 2.09	104.2	- 4.9	471	0.33
36-day curing period	19	14. 26	- 1.94	107.2	- 1.9	595	0.38
	20	14.98	- 1.22	106.3	- 2.8	586	0.39
28-day curing period	21	15.28	- 0.92	108.3	- 0.8	379	1. 18
plus 4 cycles of wetting & drying	22	14.63	- 1.57	10.6.9	- 2.2	379	0.95
	23	14.74	- 1.46	106.8	- 2.3	605	0.75
44-day curing period	24	14.81	- 1.39	108.2	- 0.9	532	0.43
28-day curing period	25	15.47	- 0.73	105.9	- 3.2	412	1.00
plus 8 cycles of wetting & drying	26	16.01	- 0.19	106.9	- 2.2	390	1.30
	27	14.71	- 1.49	106.8	- 2.3	471	0.43
52-day curing period	28	15.91	- 0.29	106.8	- 2.3	625	0.49
28-day curing period plus 12 cycles	29	15.81	- 0.89	106.9	- 2.2	532	0.98
of wetting & drying	30	15.80	- 0.40	107.5	- 1.6	401	0.87

TABLE 26

RELATIVE EFFECTS OF CURING PERIODS AND WET-DRY CYCLES
ON UNCONFINED COMPRESSIVE STRENGTH CLAY LOAM SOIL-CEMENT SPECIMENS

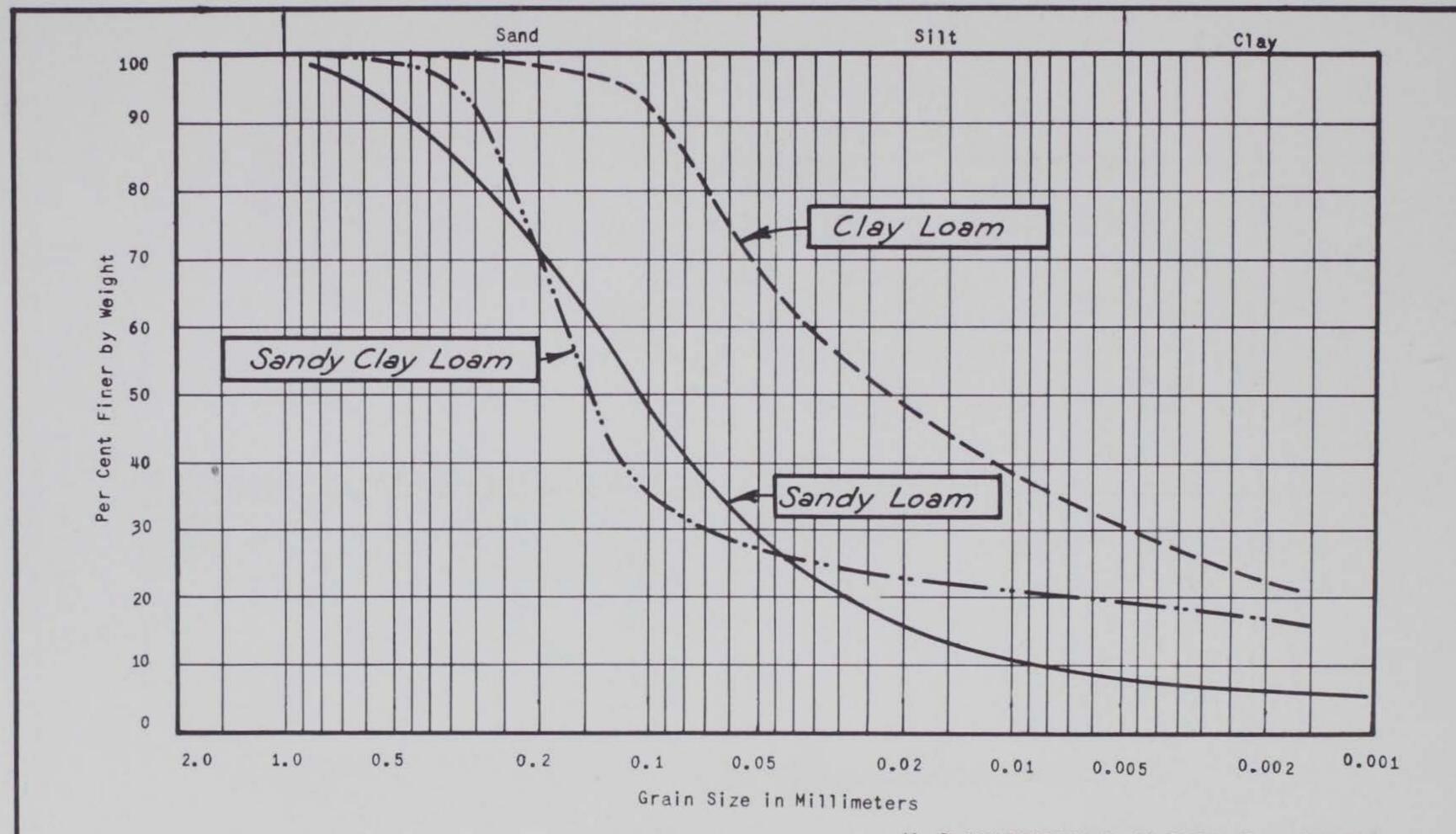
Cement Content -- 9% of Dry Wt. of Soil

Proctor's Optimum Water Content = 18.7%

Maximum Dry Density = 103.4 lb. per cu. ft.

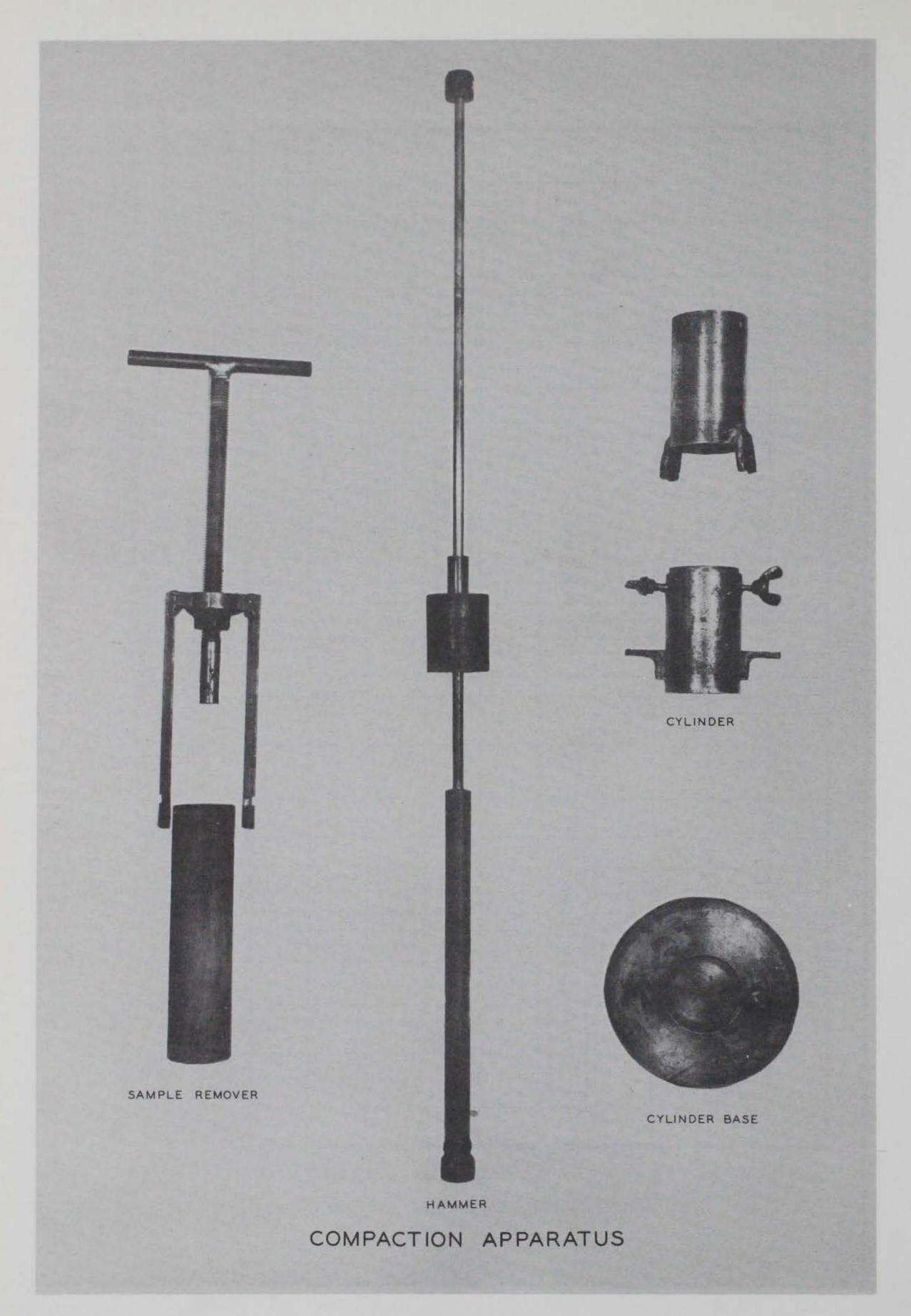
Type of Test	Sample		Wt. Soil		y, Dry Wt. er cu. ft.	Maximum - Compressive	Maximum Strain Per Cent
or Curing Period	No.	Molded	Diff. in Optimum and Molded	Mo1ded	Diff. in Maximum and Molded	Strength lbs. per sq. in.	
20 d	17	20.60	+ 1.90	99.3	- 4. 1	146	0.81
28—day curing period	18	20.21	+ 1.51	99.7	- 3.7	156	0.77
	19	22.80	+ 4.10	96.2	- 7.2	137	0.56
36—day curing period	20	20.99	+ 2.29	98.0	- 5.4	137	0.70
28-day curing period plus 4 cycles	21	21.75	+ 3.05	95.8	- 7.6	54	1.39
of wetting & drying	31	20.94	+ 2.24	102.4	- 1.0	137	1. 44
ww. a	23	20.96	+ 2.26	101.9	- 1.5	228	0.85
44—day curing period	24	20.72	+ 2.02	101.0	- 2.4	186	0.66
28-day curing period	25	20.48	+ 1.78	102.8	- 0.6	186	1.37
plus 8 cycles of wetting & drying	26	20.98	+ 2.28	101.8	- 1.6	118	1. 19
** 400 000 000	27	19.99	+ 1.29	102.6	- 0.8	207	0.71
52-day curing period	28	19.86	+ 1.16	103.5	+ 0.1	207	0.59
28-day curing period plus 12 cycles	29	20.29	+ 1.59	102.3	- 1.1	127	1. 26
of wetting & drying	30	21.40	+ 2.70	101.1	- 2.3	156	1. 23

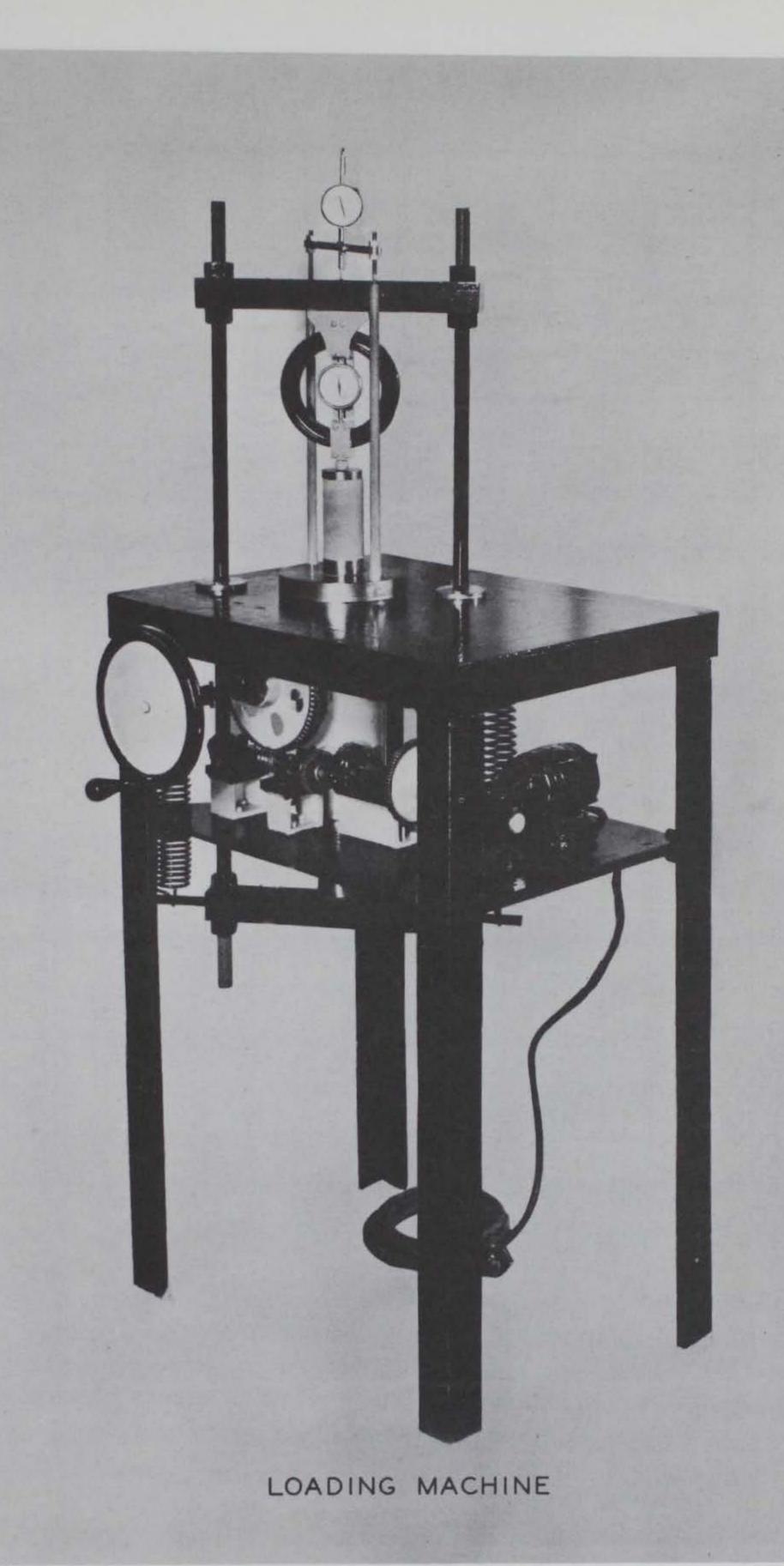
<u>FI GURES</u>

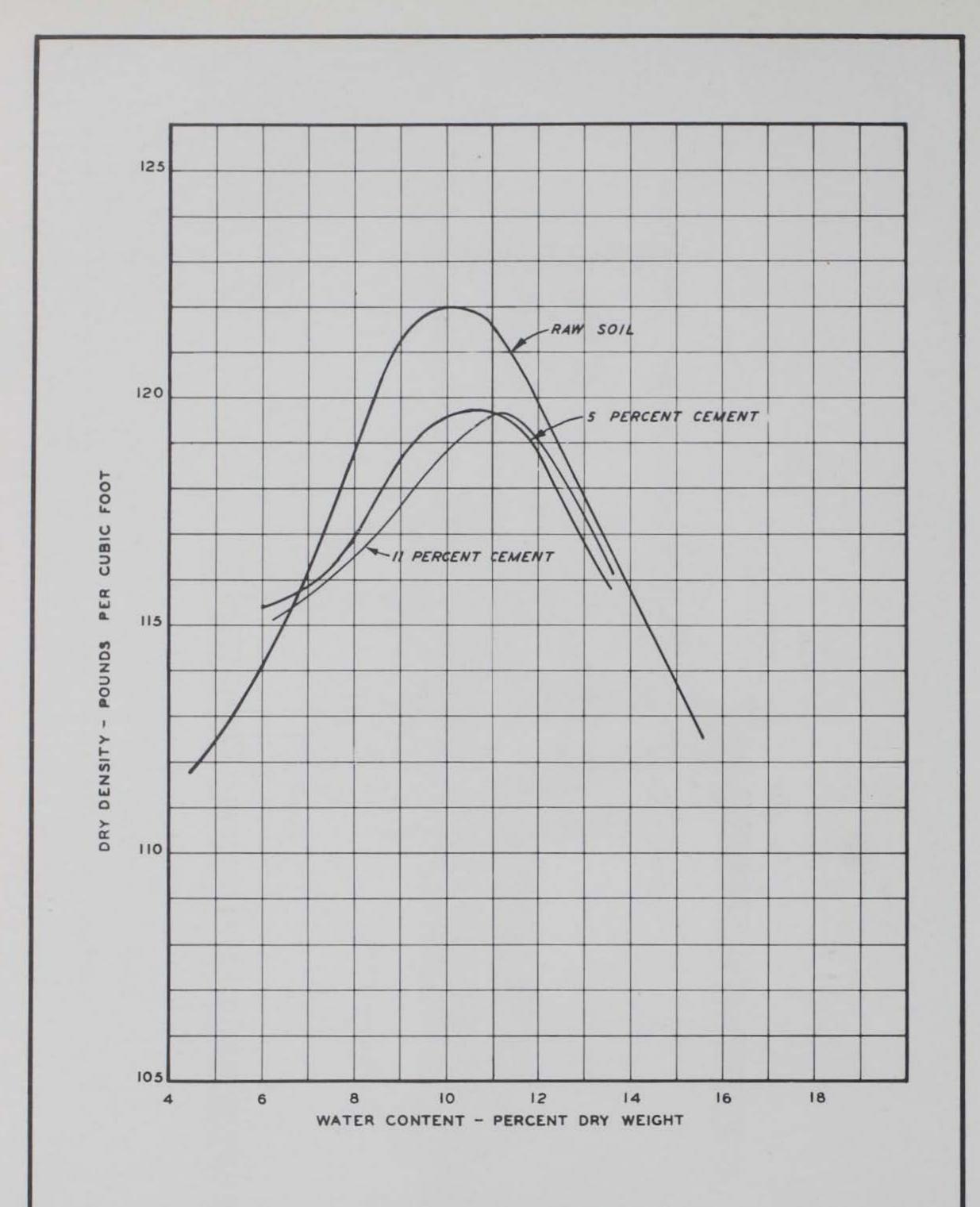


U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

GRAIN SIZE CURVES

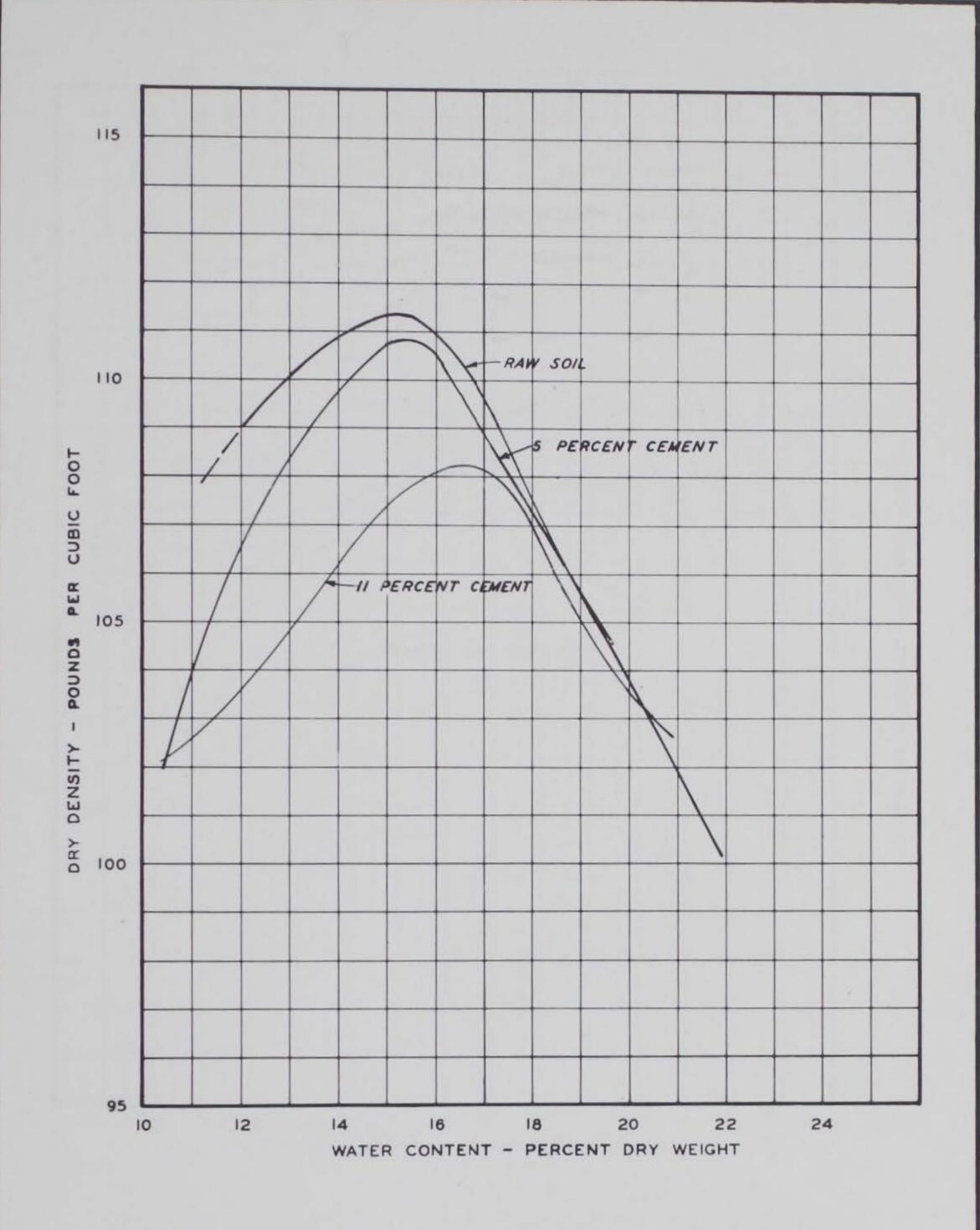




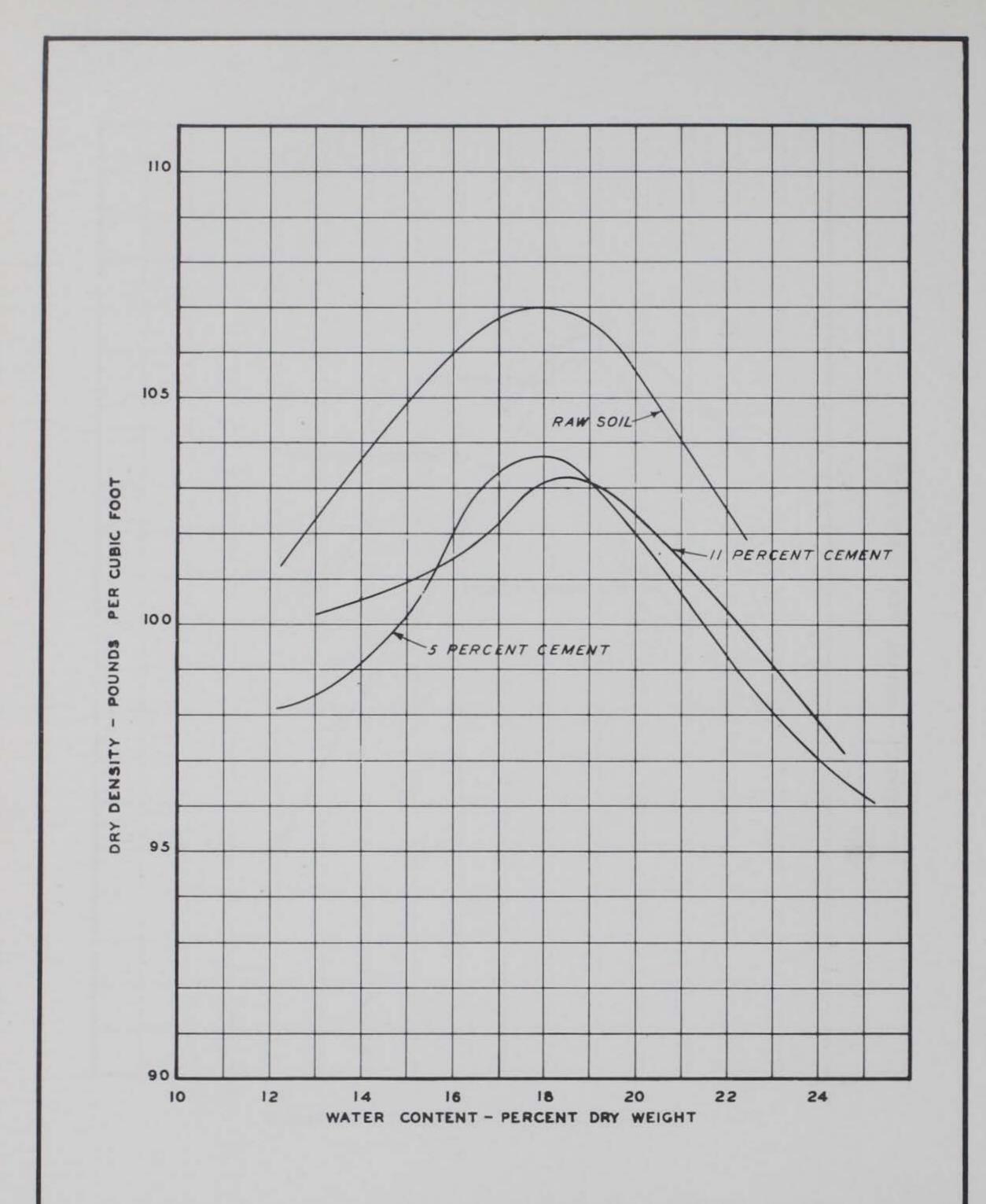


U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

MOISTURE DENSITY CONTROL FOR SANDY LOAM

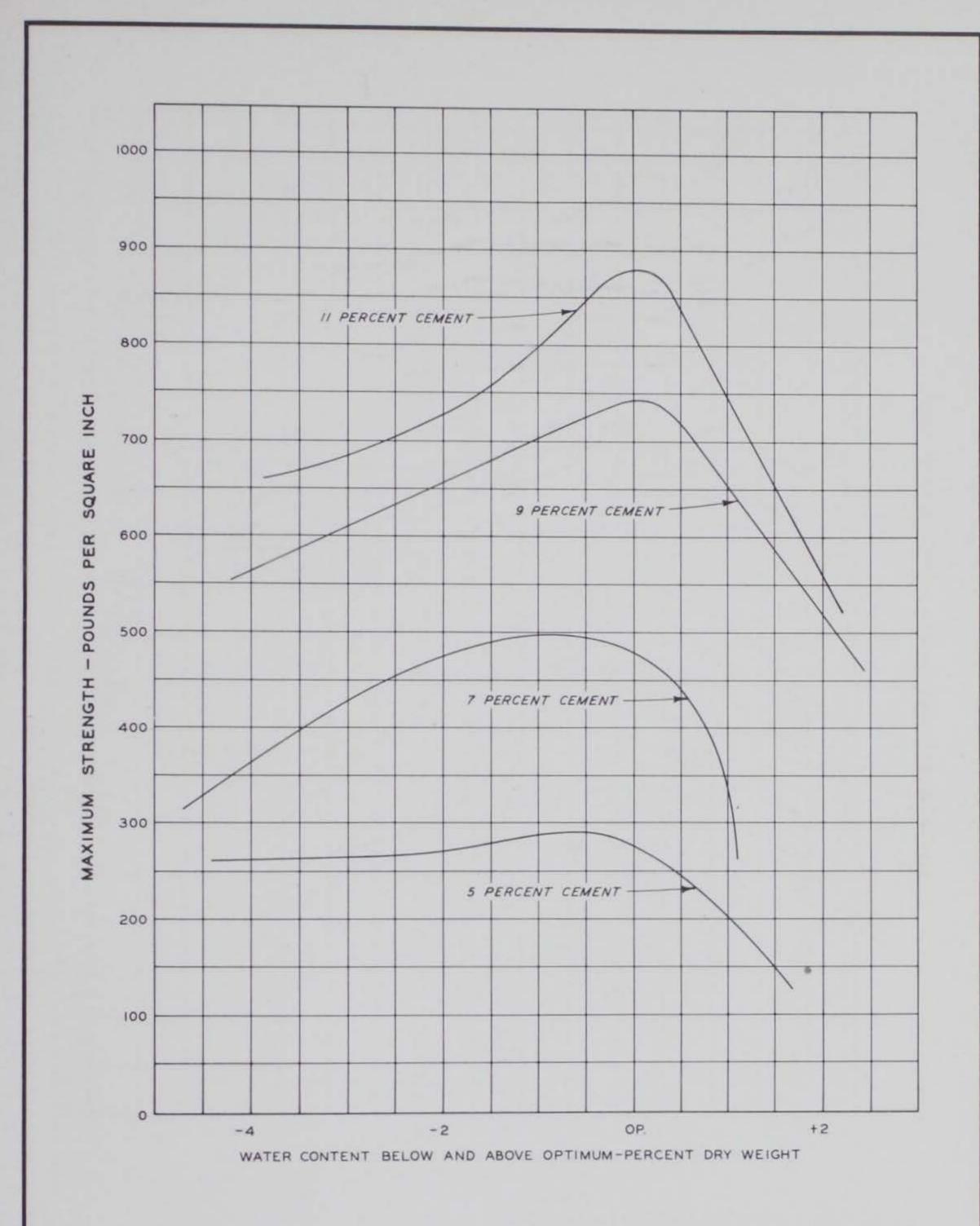


U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES
MOISTURE DENSITY CONTROL FOR
SANDY CLAY LOAM



U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

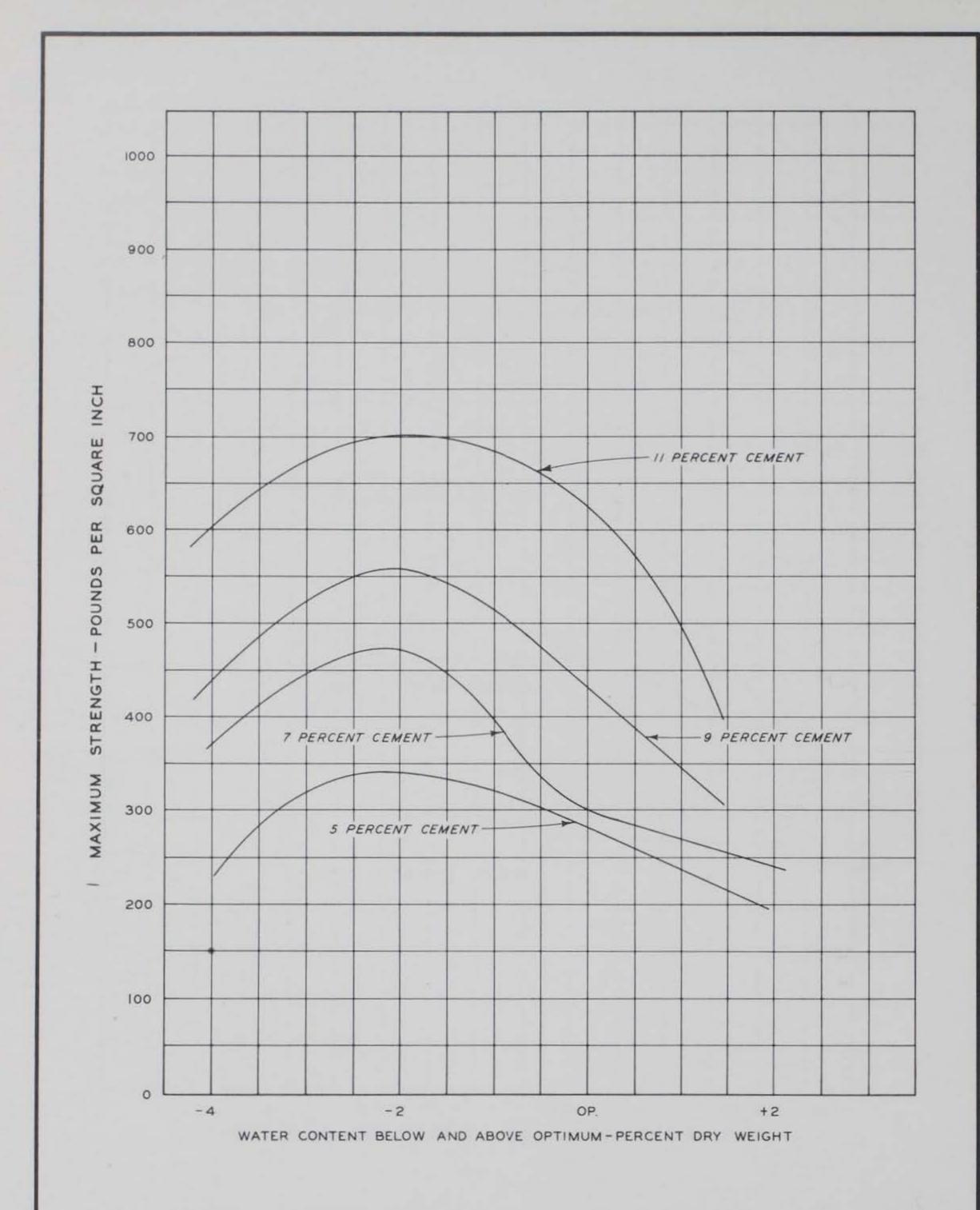
MOISTURE DENSITY CONTROL FOR CLAY LOAM



U. S. WATERWAYS EXPERIMENT STATION

INVESTIGATION OF UNCONFINED COMPRESSIVE STRENGTH OF SOIL CEMENT MIXTURES

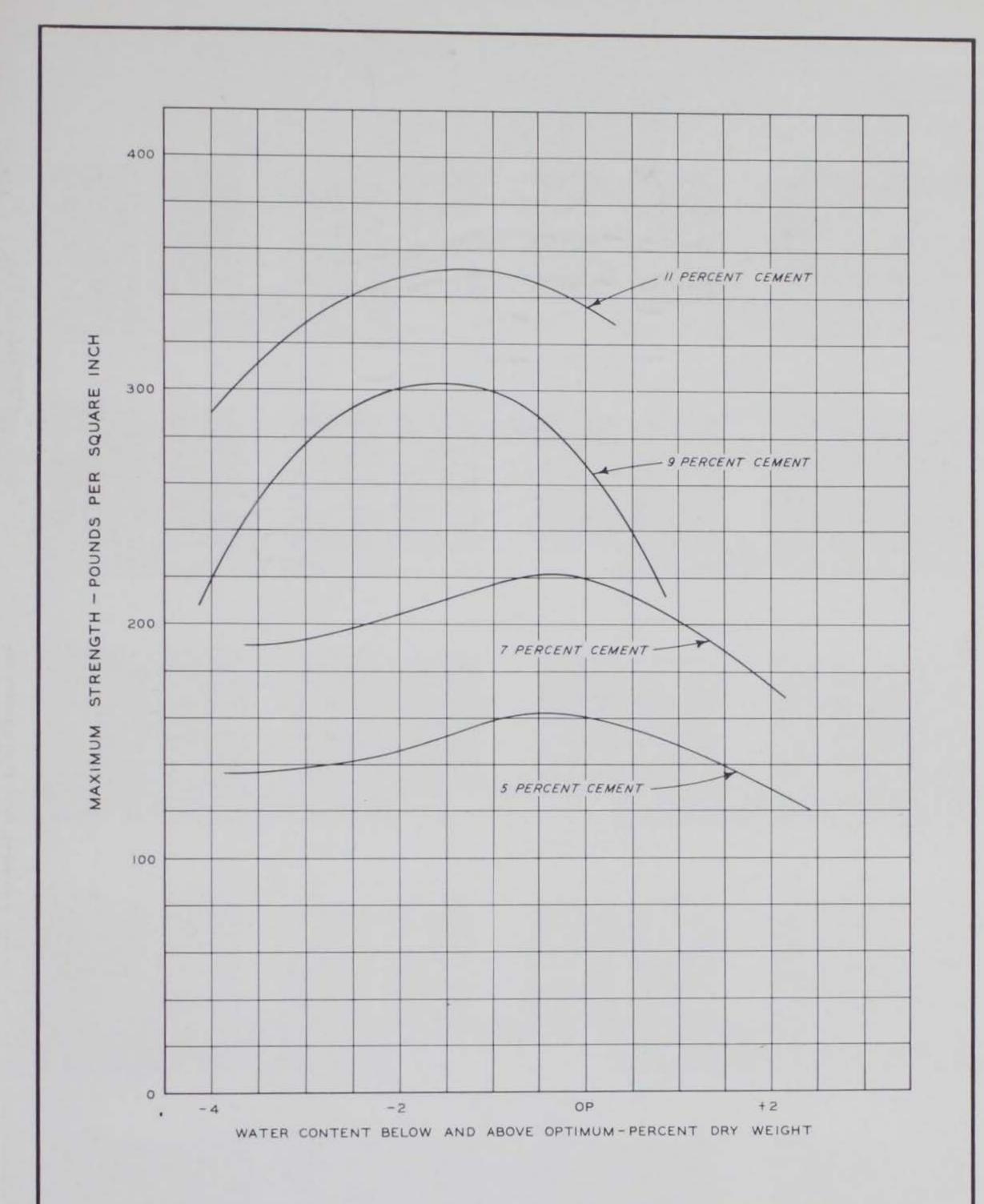
STRENGTH VERSUS WATER CONTENT SANDY LOAM



U. S. WATERWAYS EXPERIMENT STATION

INVESTIGATION OF UNCONFINED COMPRESSIVE STRENGTH OF SOIL CEMENT MIXTURES

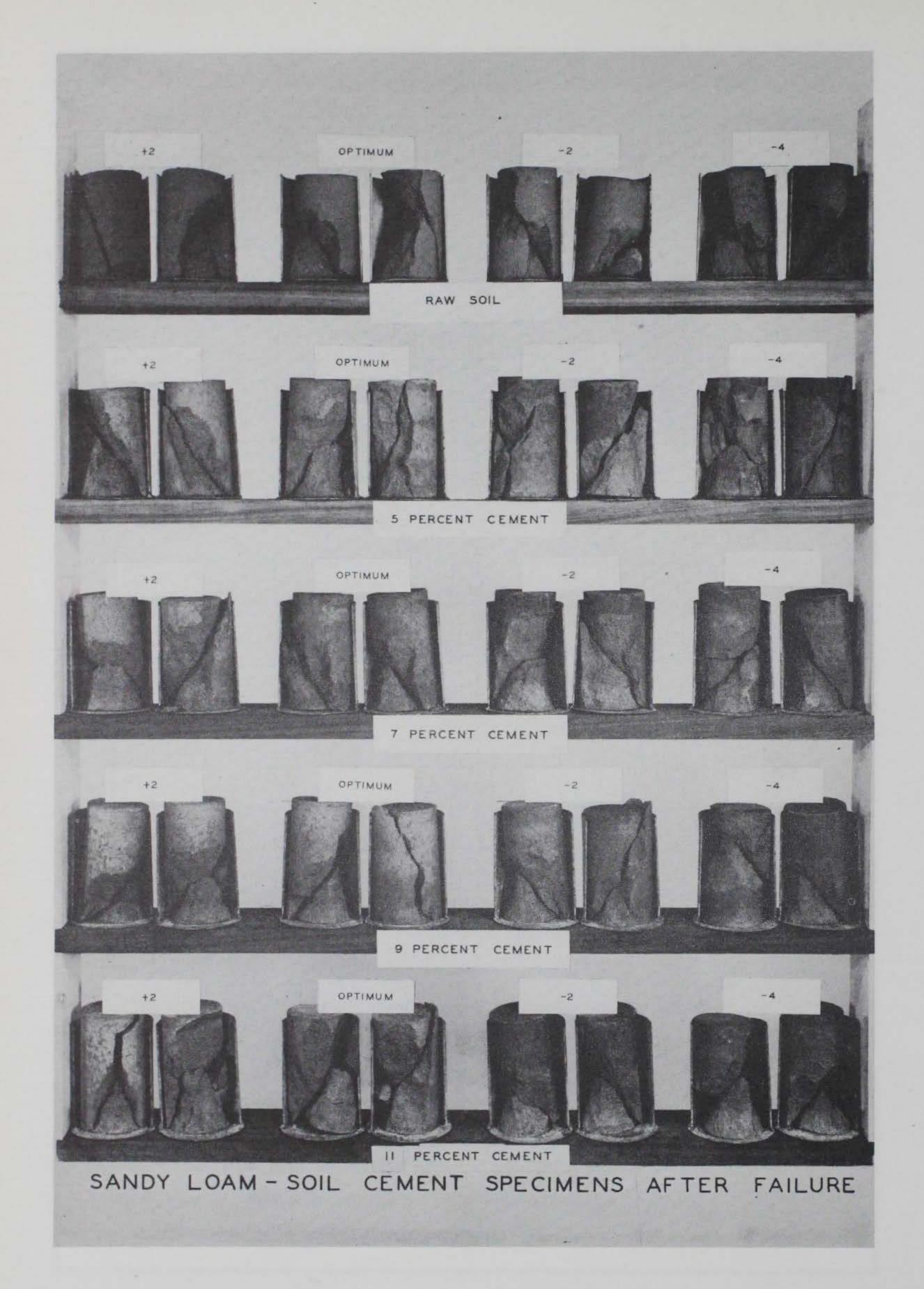
STRENGTH VERSUS WATER CONTENT SANDY CLAY LOAM

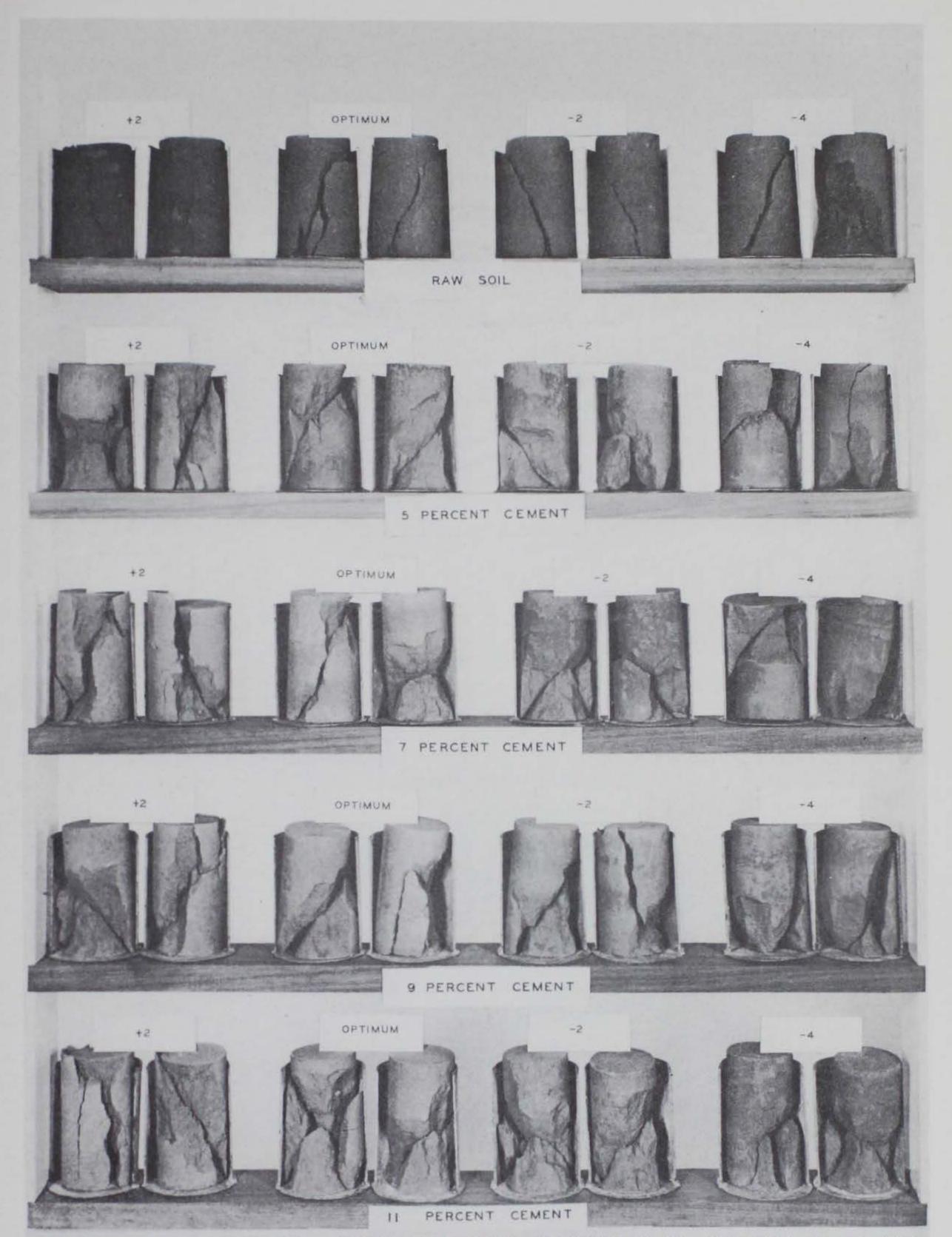


U. S. WATERWAYS EXPERIMENT STATION

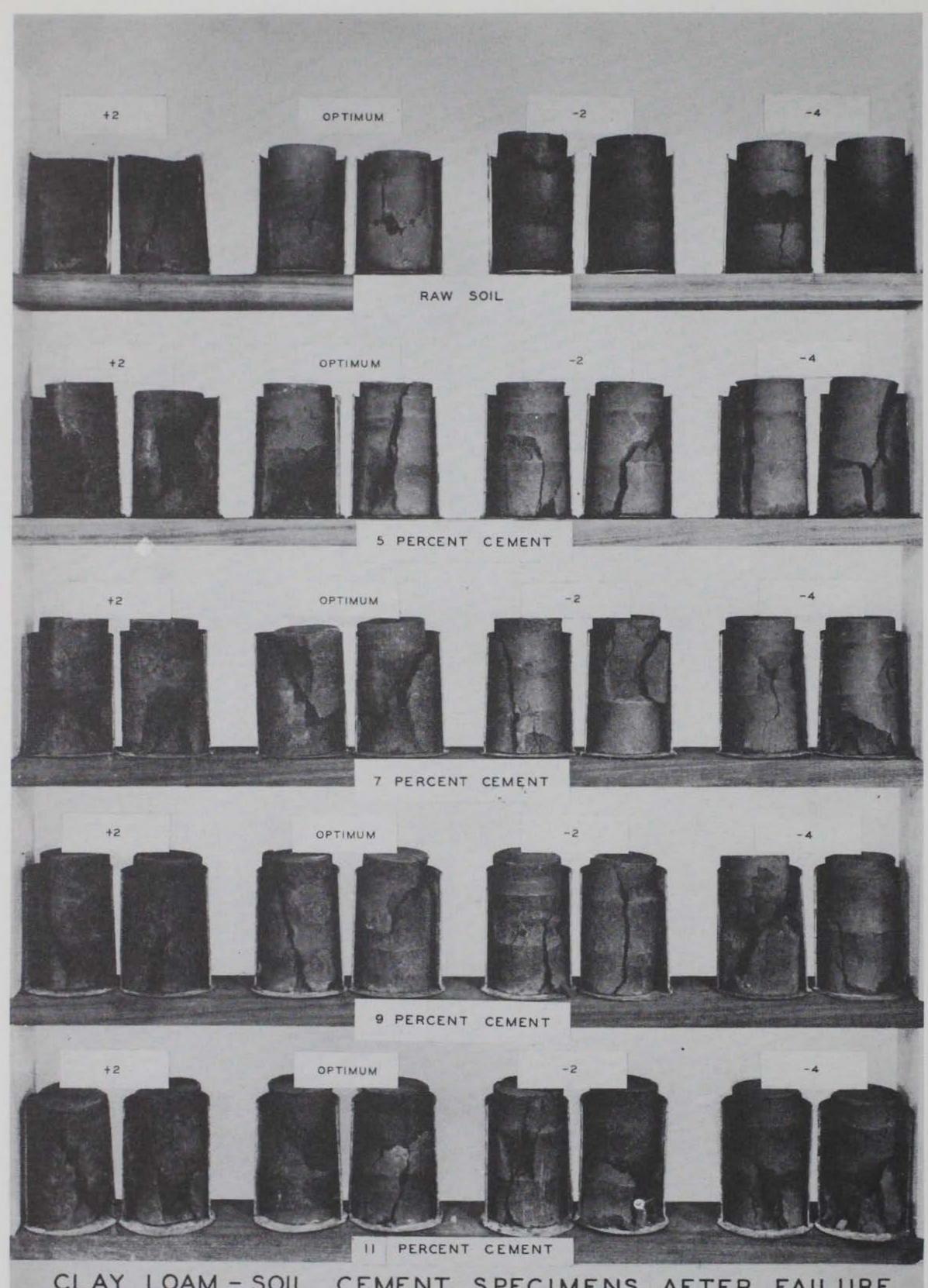
INVESTIGATION OF UNCONFINED COMPRESSIVE STRENGTH OF SOIL CEMENT MIXTURES

STRENGTH VERSUS WATER CONTENT CLAY LOAM

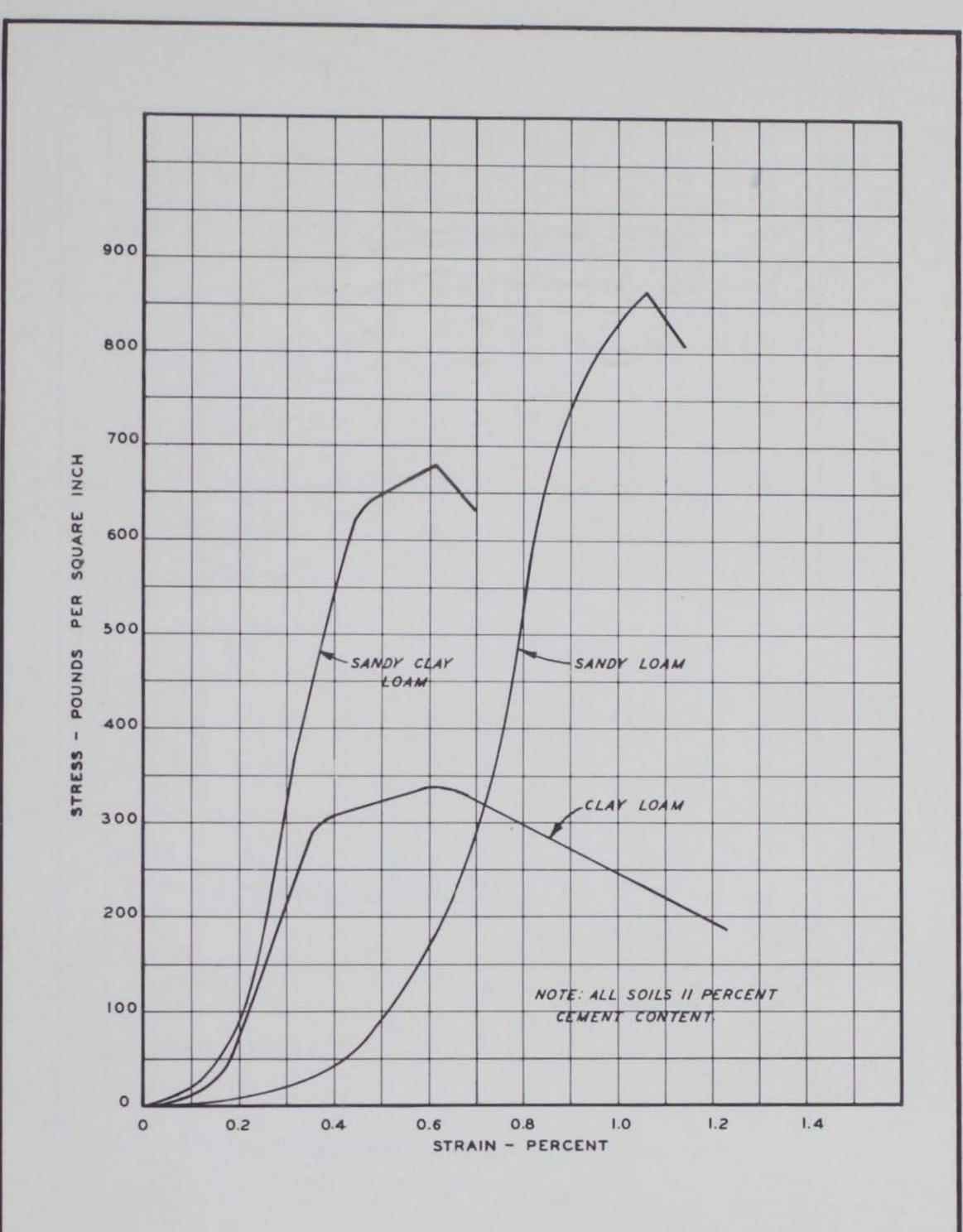




SANDY CLAY LOAM - SOIL CEMENT SPECIMENS AFTER FAILURE

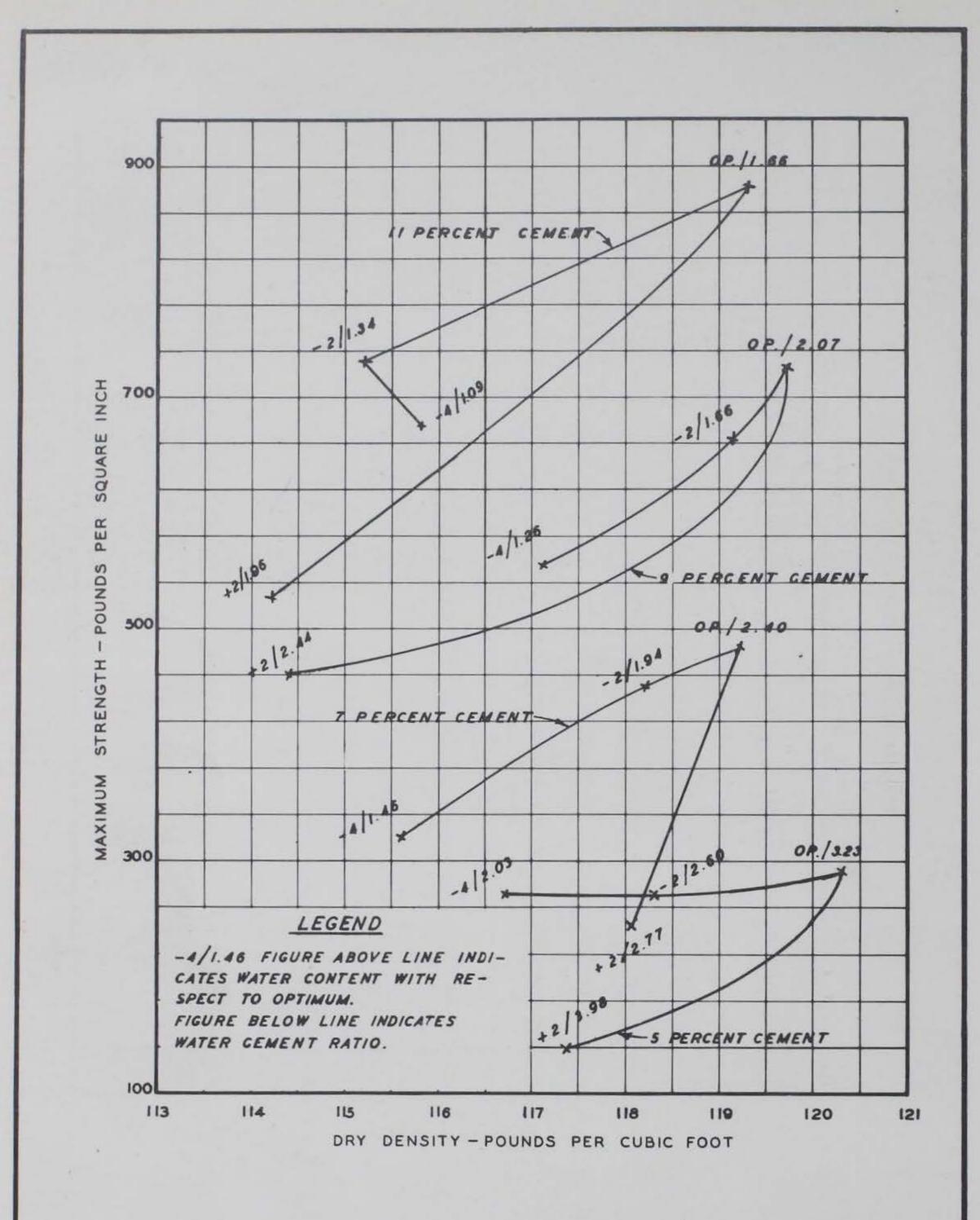


CLAY LOAM - SOIL CEMENT SPECIMENS AFTER FAILURE



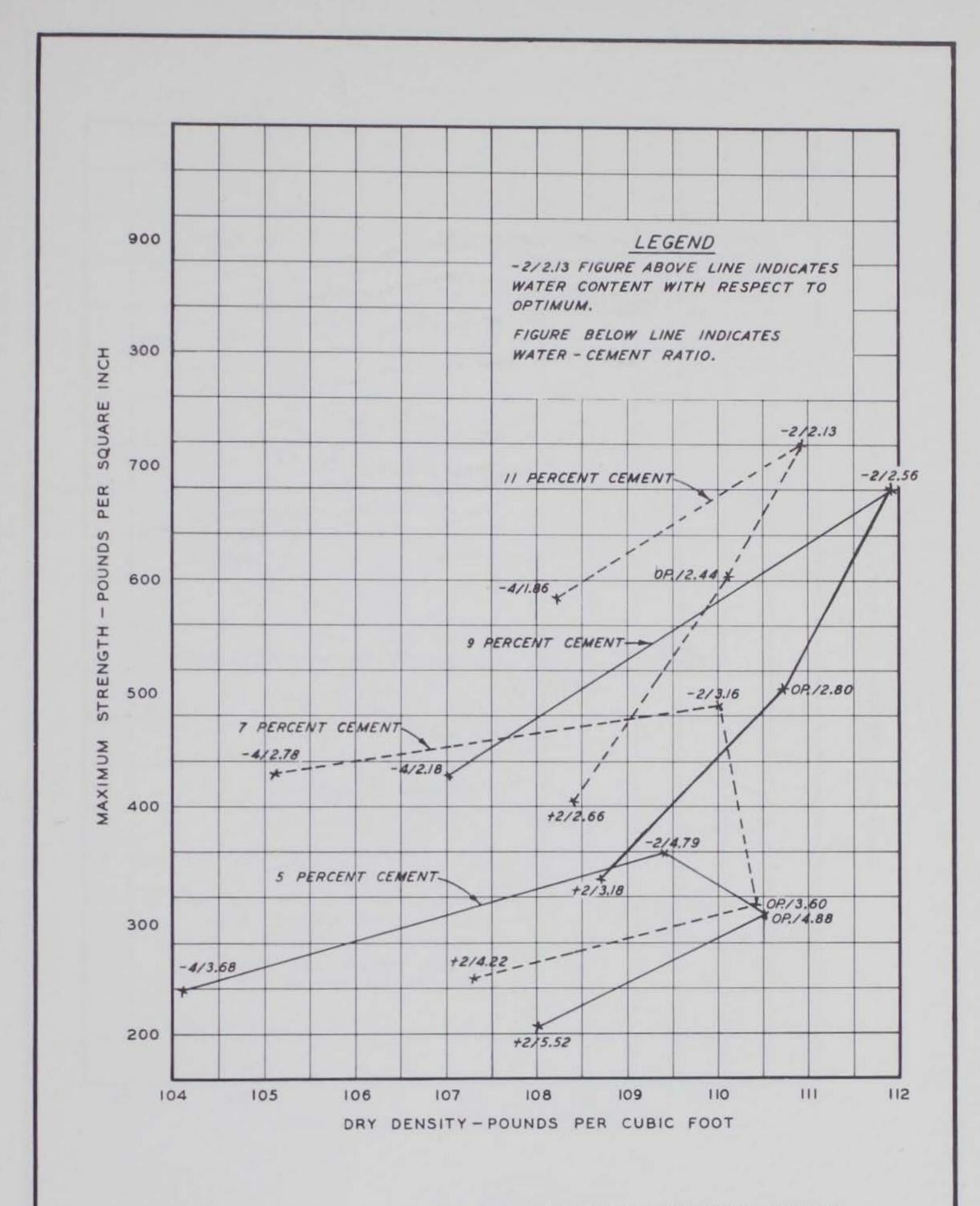
U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

STRESS - STRAIN CURVES FOR COMPARISON OF MAXIMUM STRENGTHS



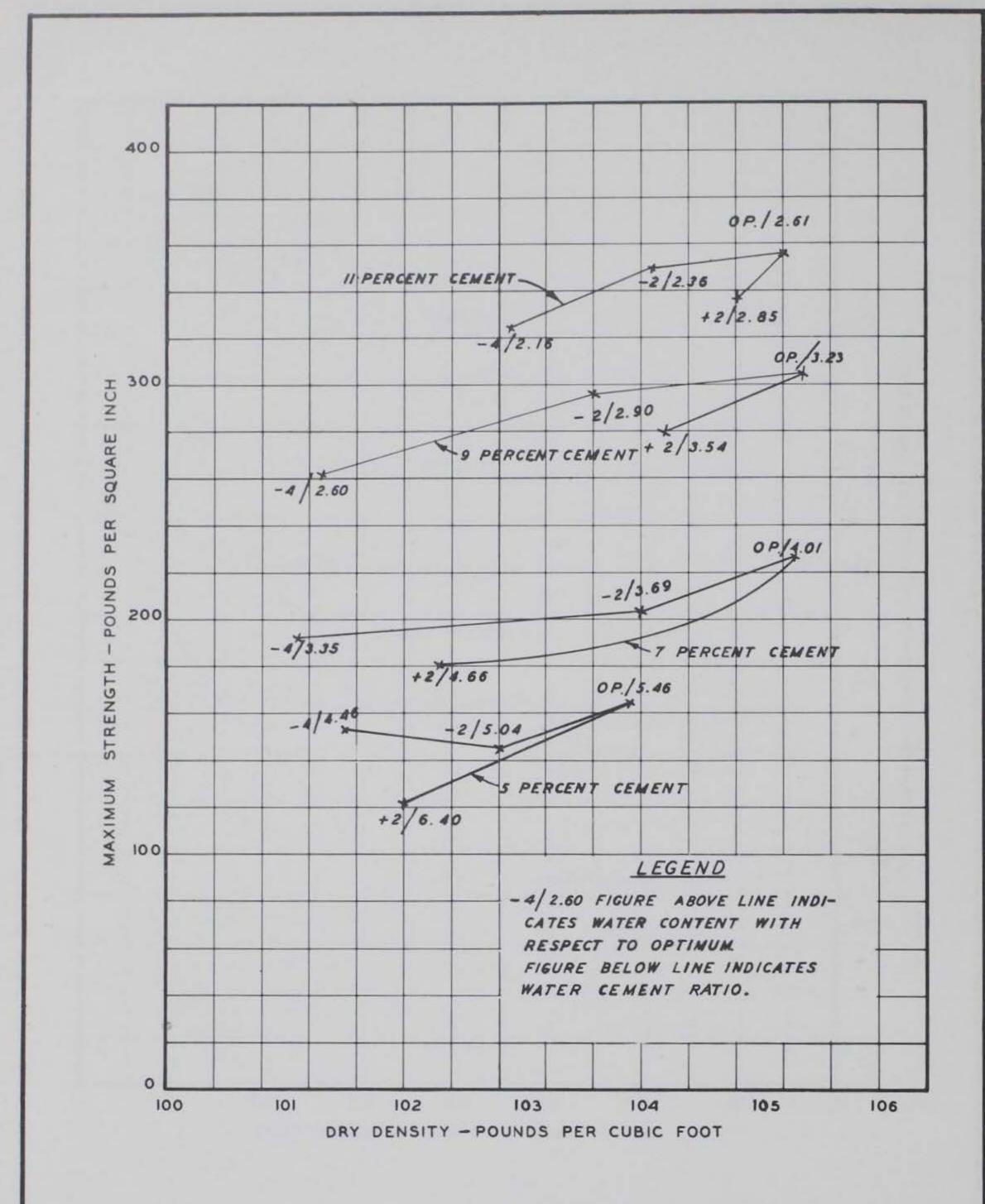
U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

STRENGTH VERSUS DENSITY FOR



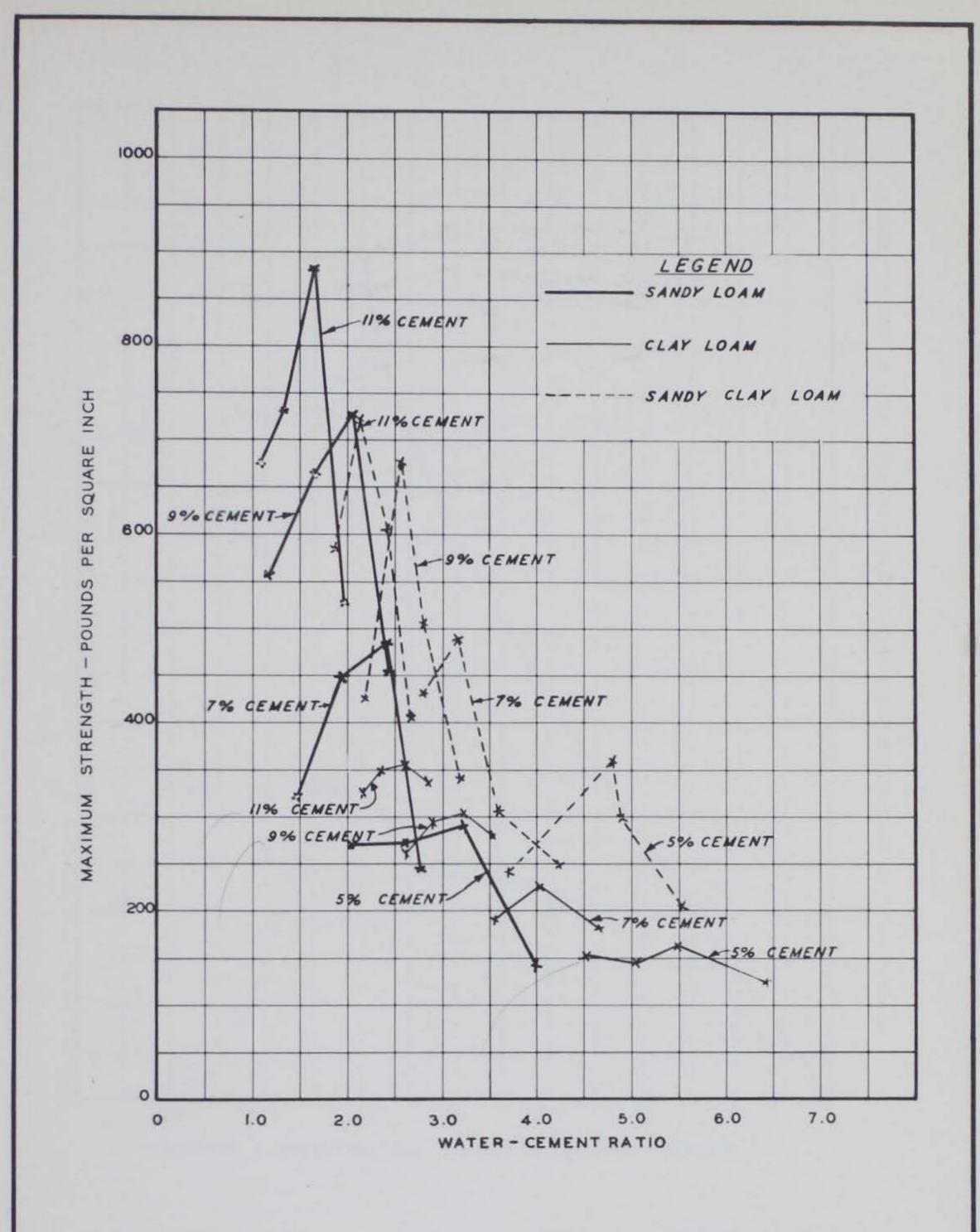
U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

STRENGTH VERSUS DENSITY FOR SANDY CLAY LOAM



U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

STRENGTH VERSUS DENSITY FOR CLAY LOAM

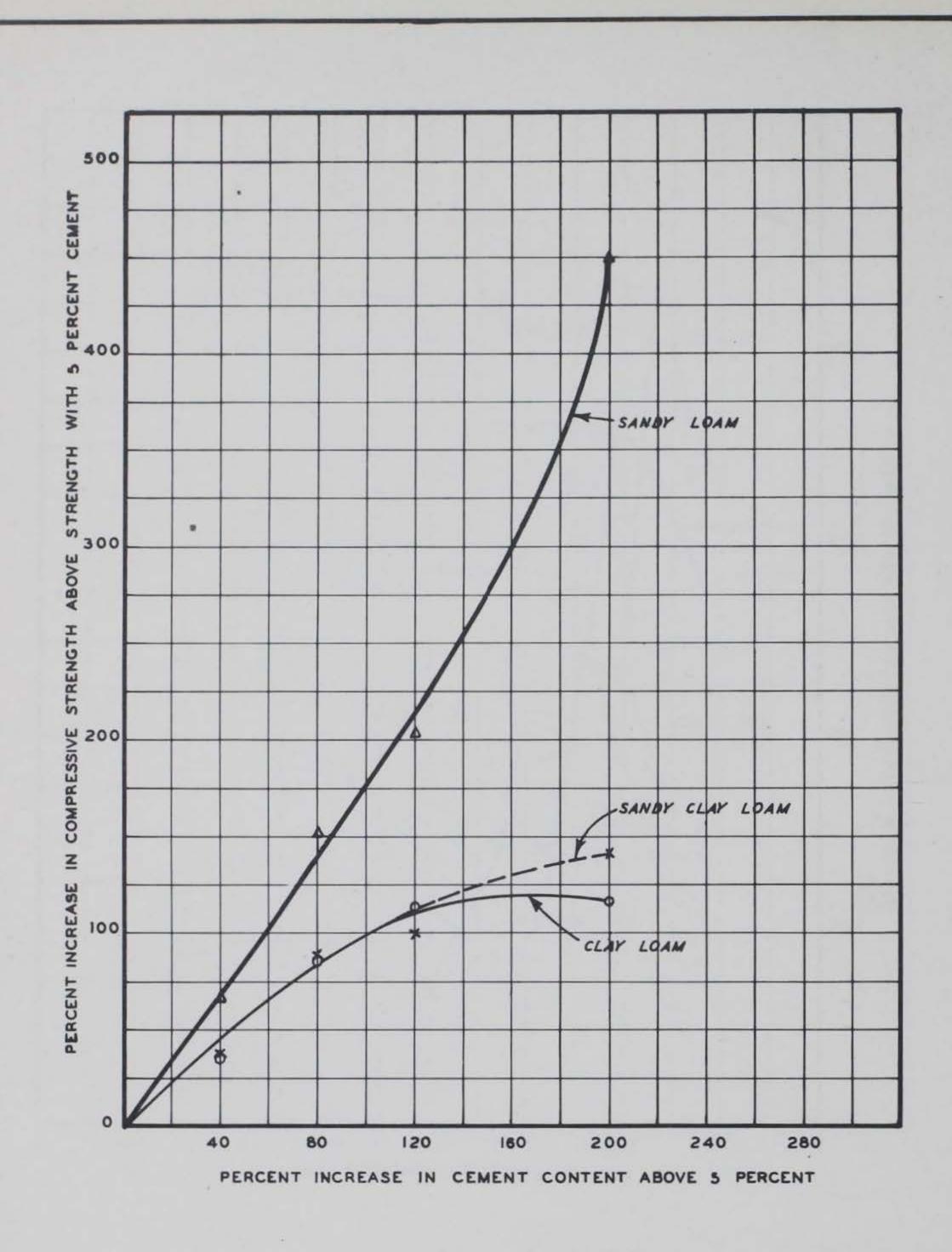


U. S. WATERWAYS EXPERIMENT STATION

INVESTIGATION OF UNCONFINED COMPRESSIVE

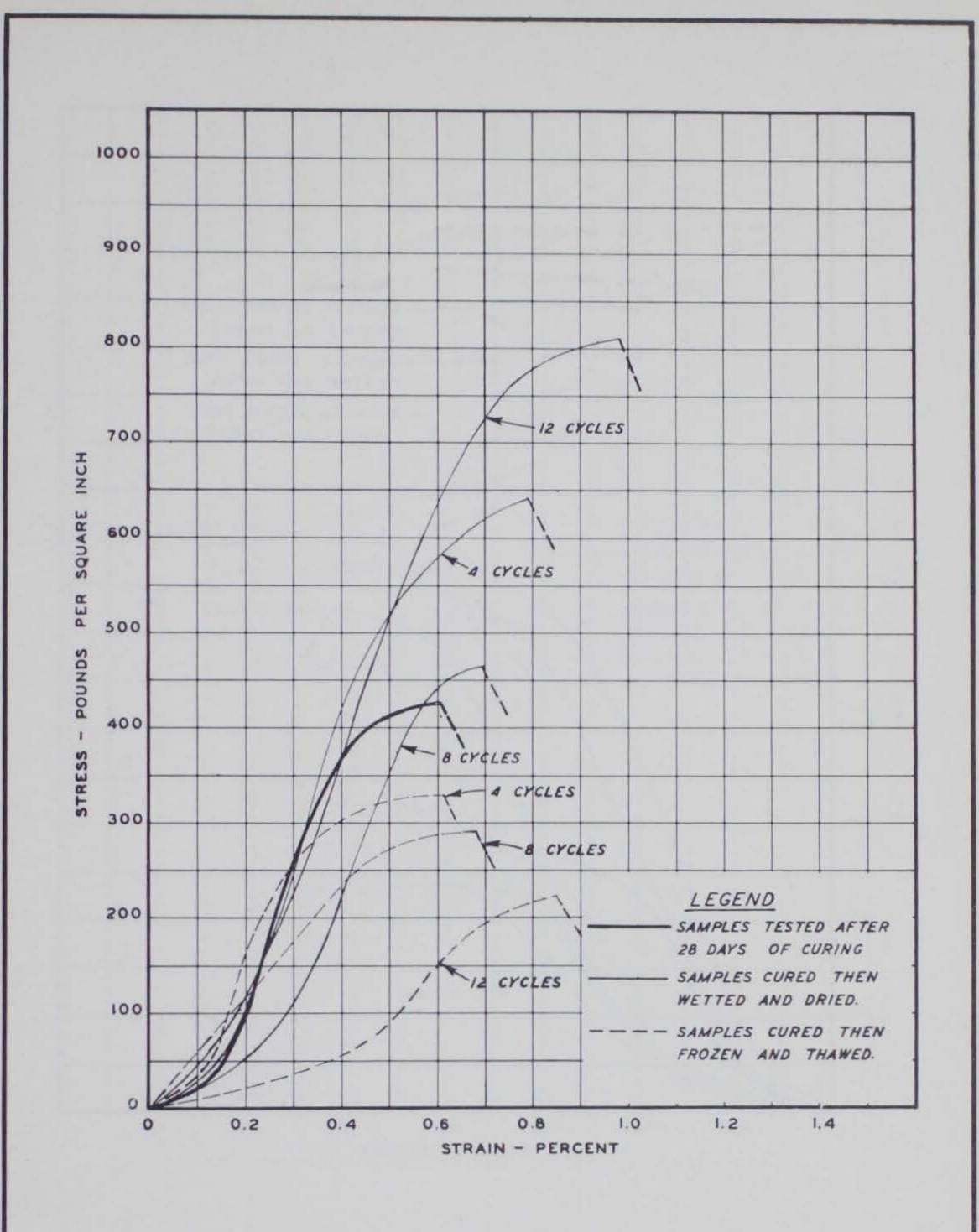
STRENGTH OF SOIL CEMENT MIXTURES

WATER-CEMENT RATIO VERSUS MAXIMUM STRENGTH



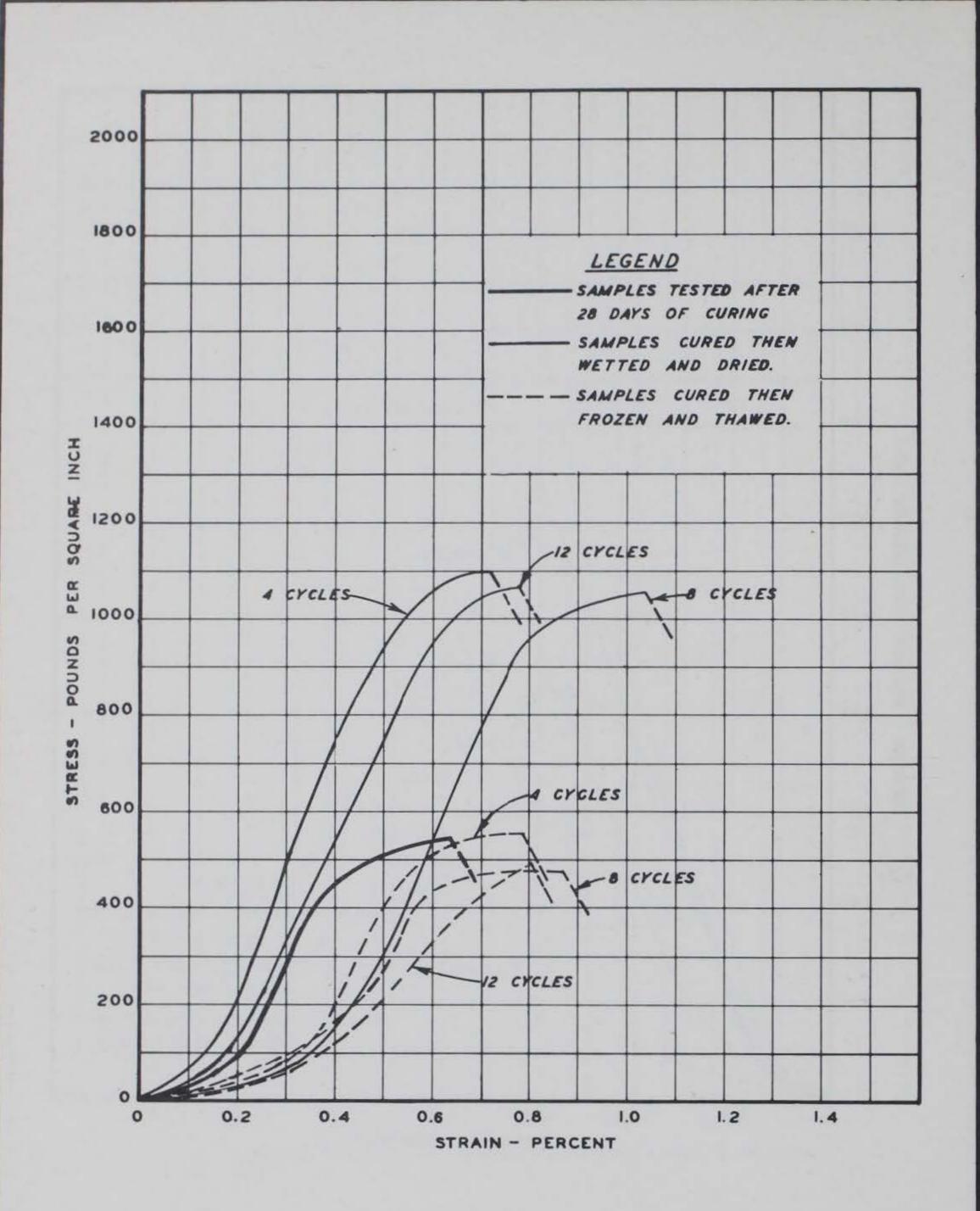
U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

PERCENT INCREASE IN STRENGTH VERSUS
PERCENT INCREASE IN CEMENT

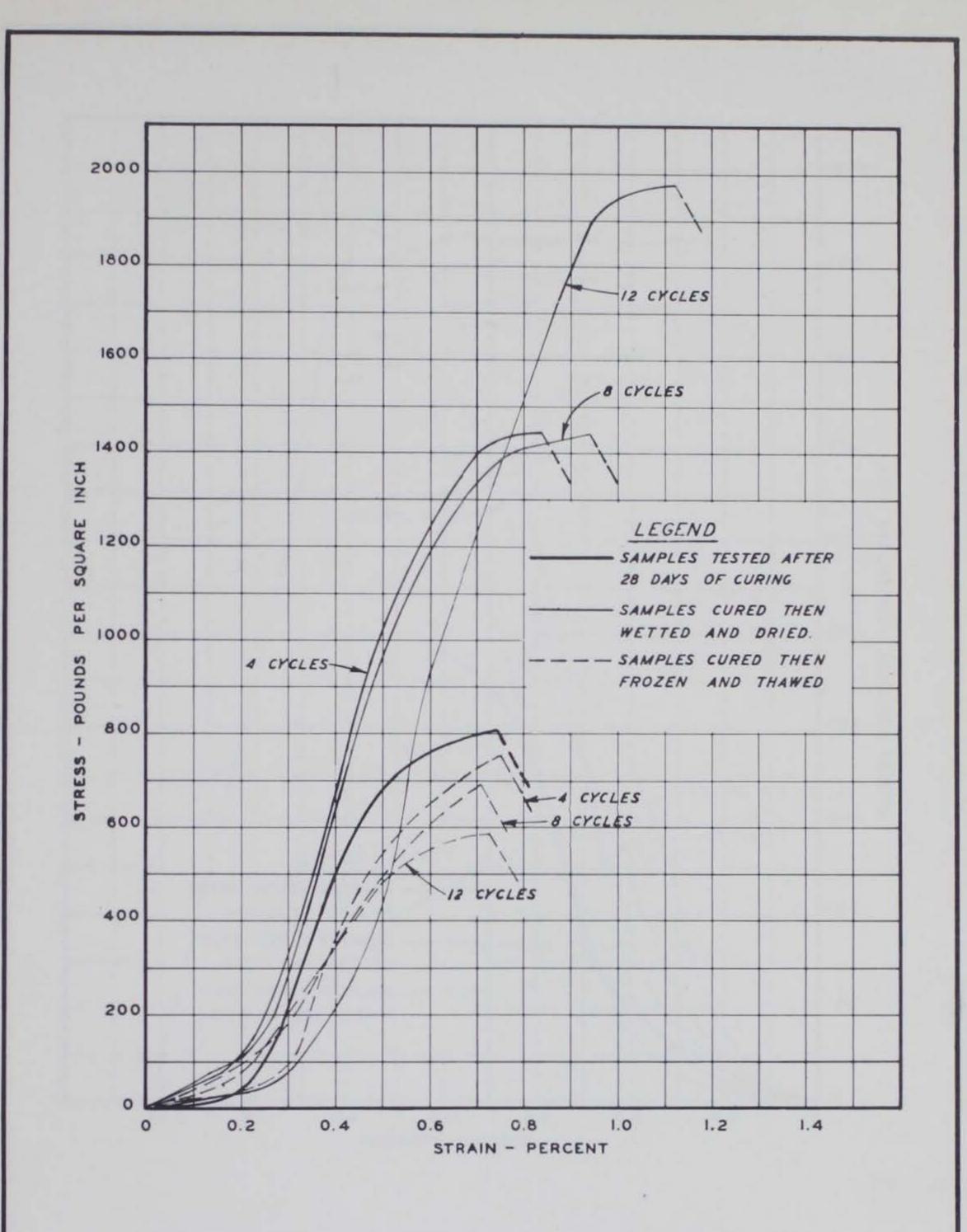


U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

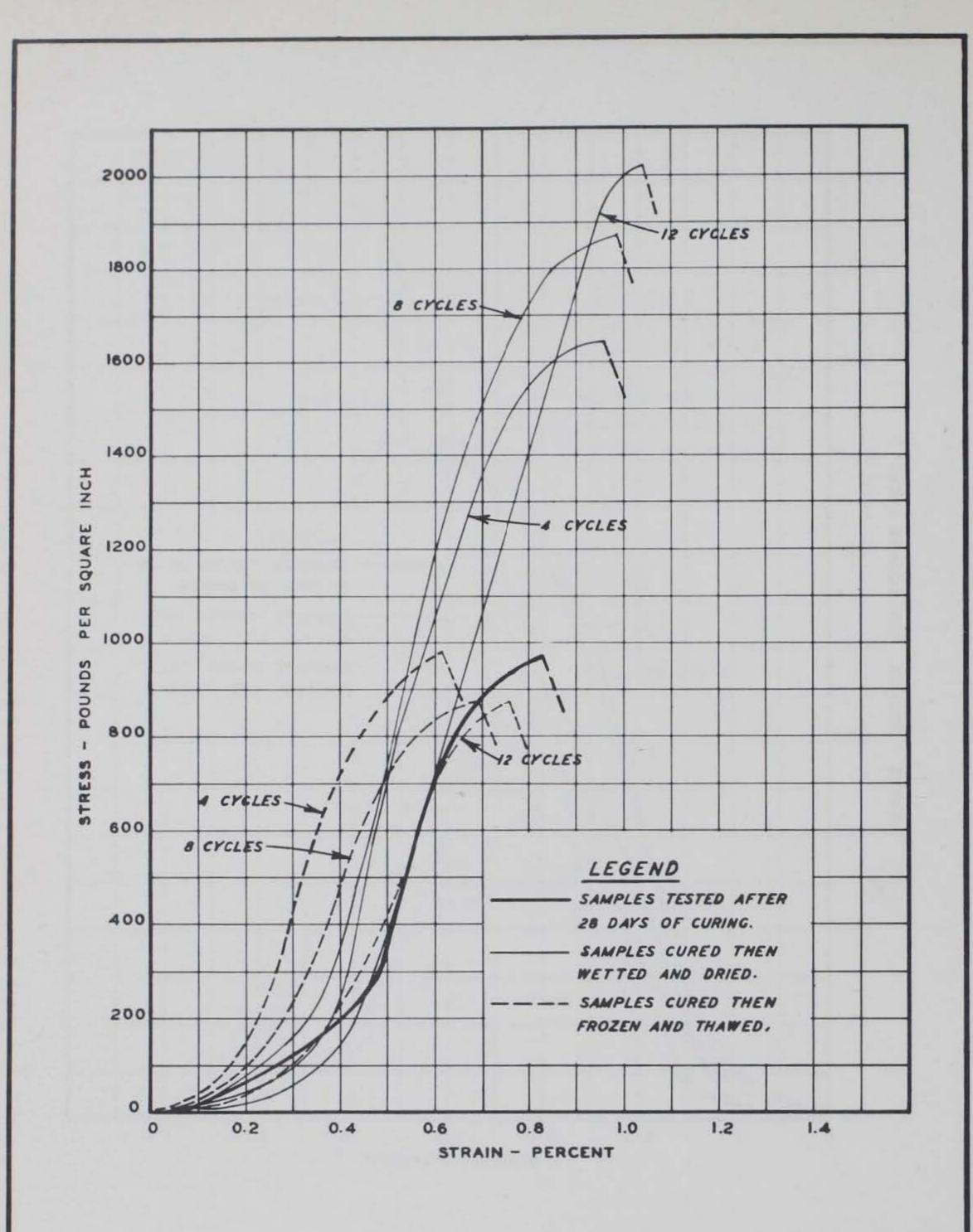
STRESS - STRAIN CURVES FOR SANDY LOAM 5 PERCENT CEMENT



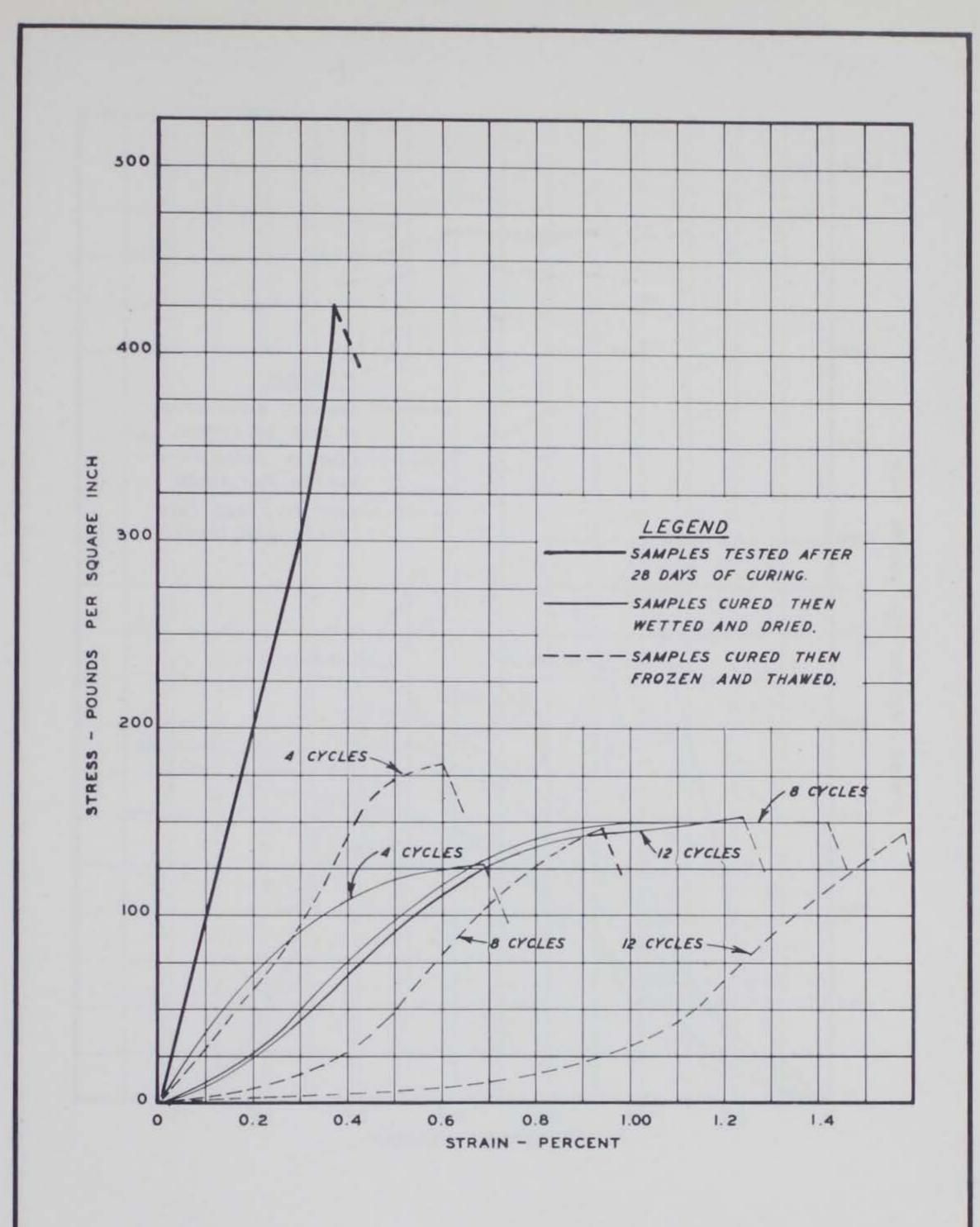
STRESS - STRAIN CURVES FOR SANDY LOAM 7 PERCENT CEMENT



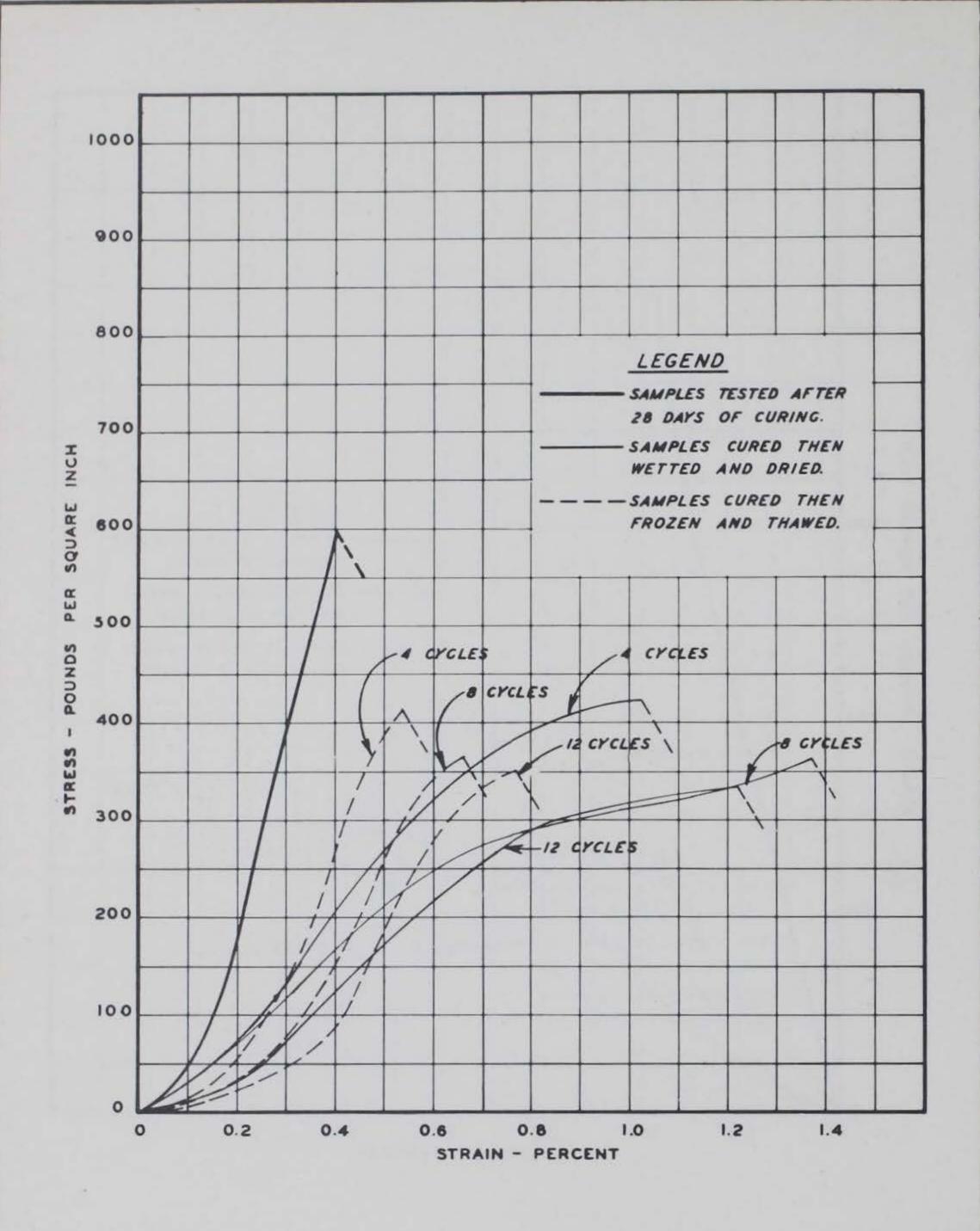
STRESS - STRAIN CURVES FOR SANDY LOAM 9 PERCENT CEMENT



STRESS - STRAIN CURVES FOR SANDY LOAM II PERCENT CEMENT

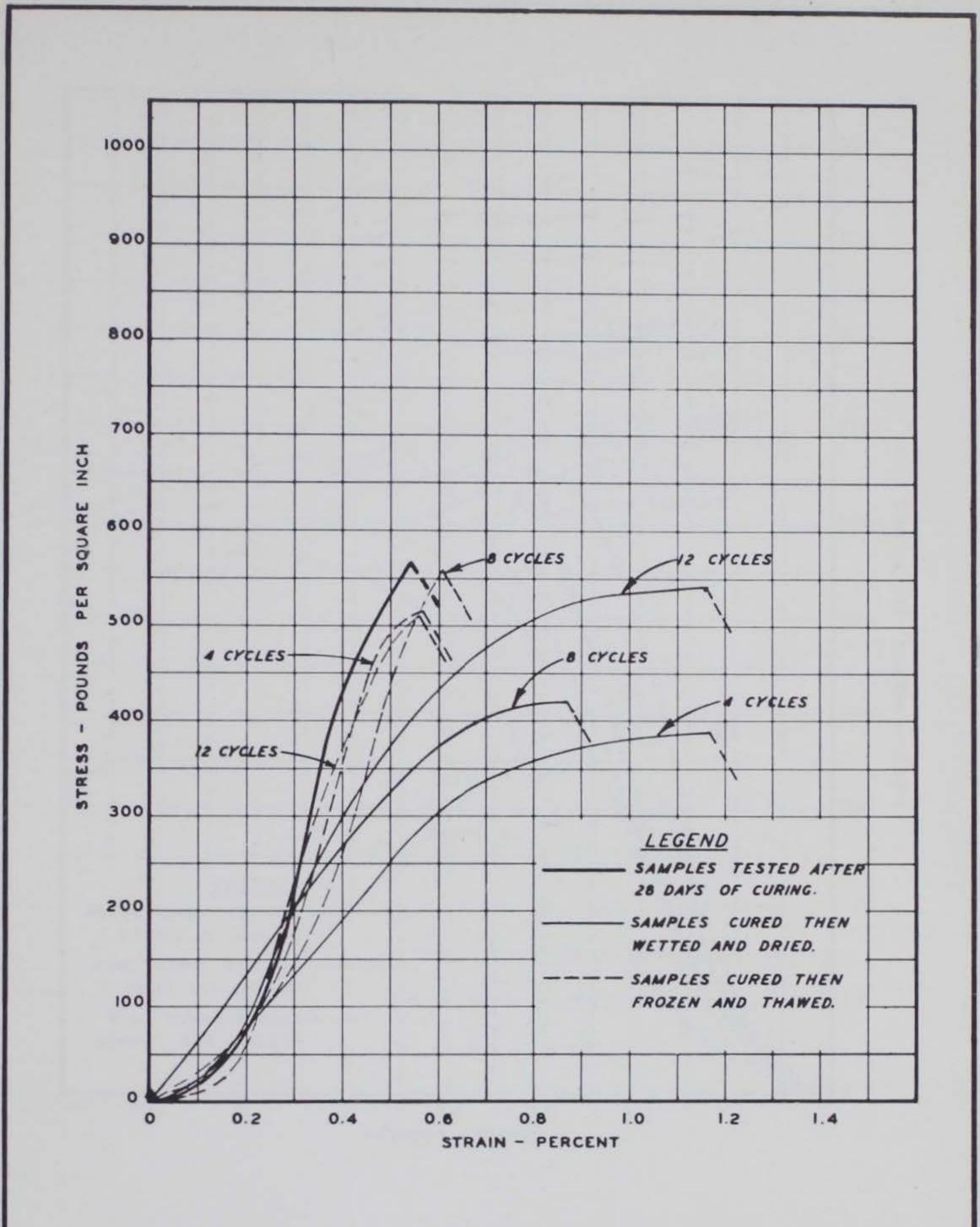


STRESS - STRAIN CURVES FOR SANDY CLAY LOAM 5 PERCENT CEMENT

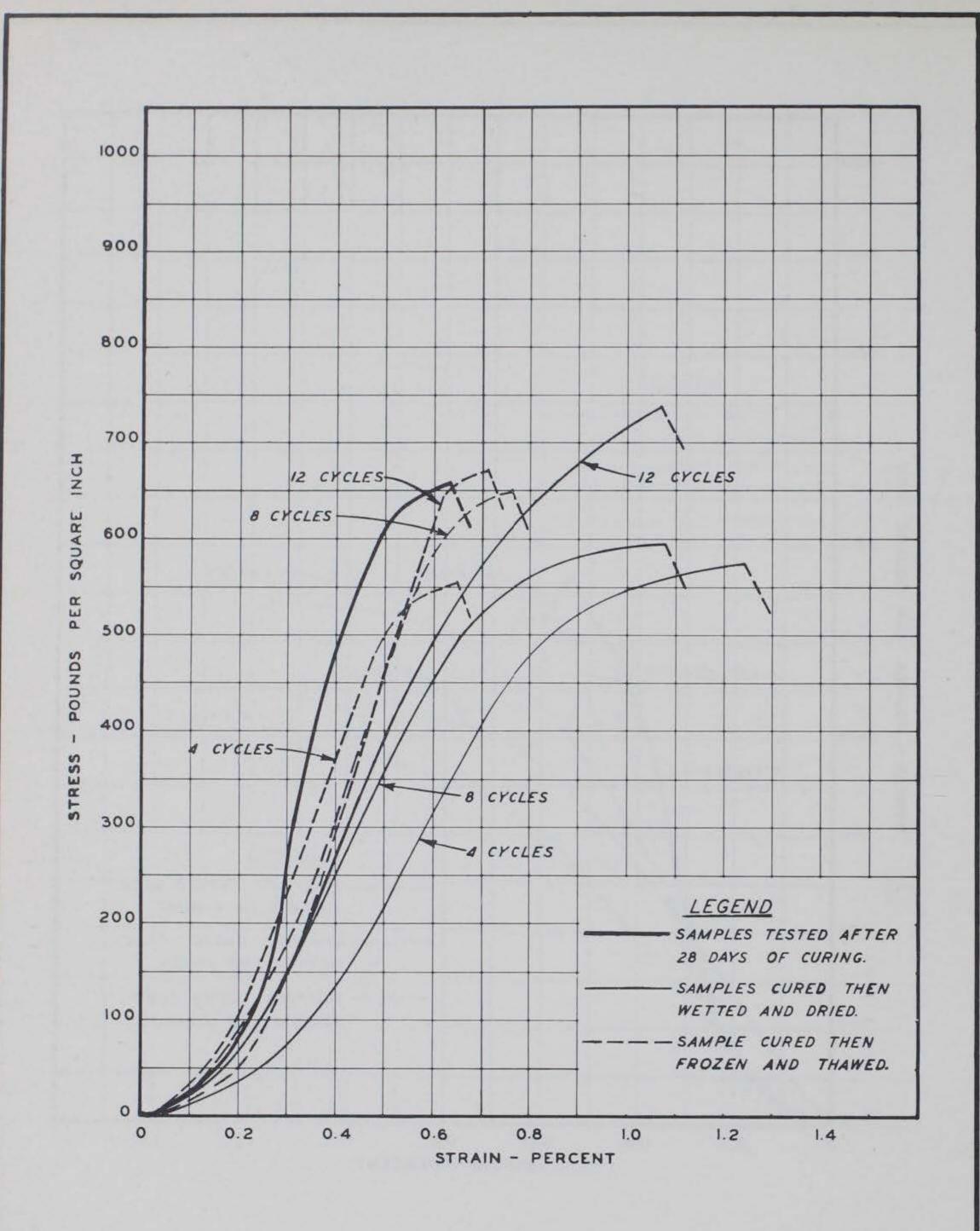


U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

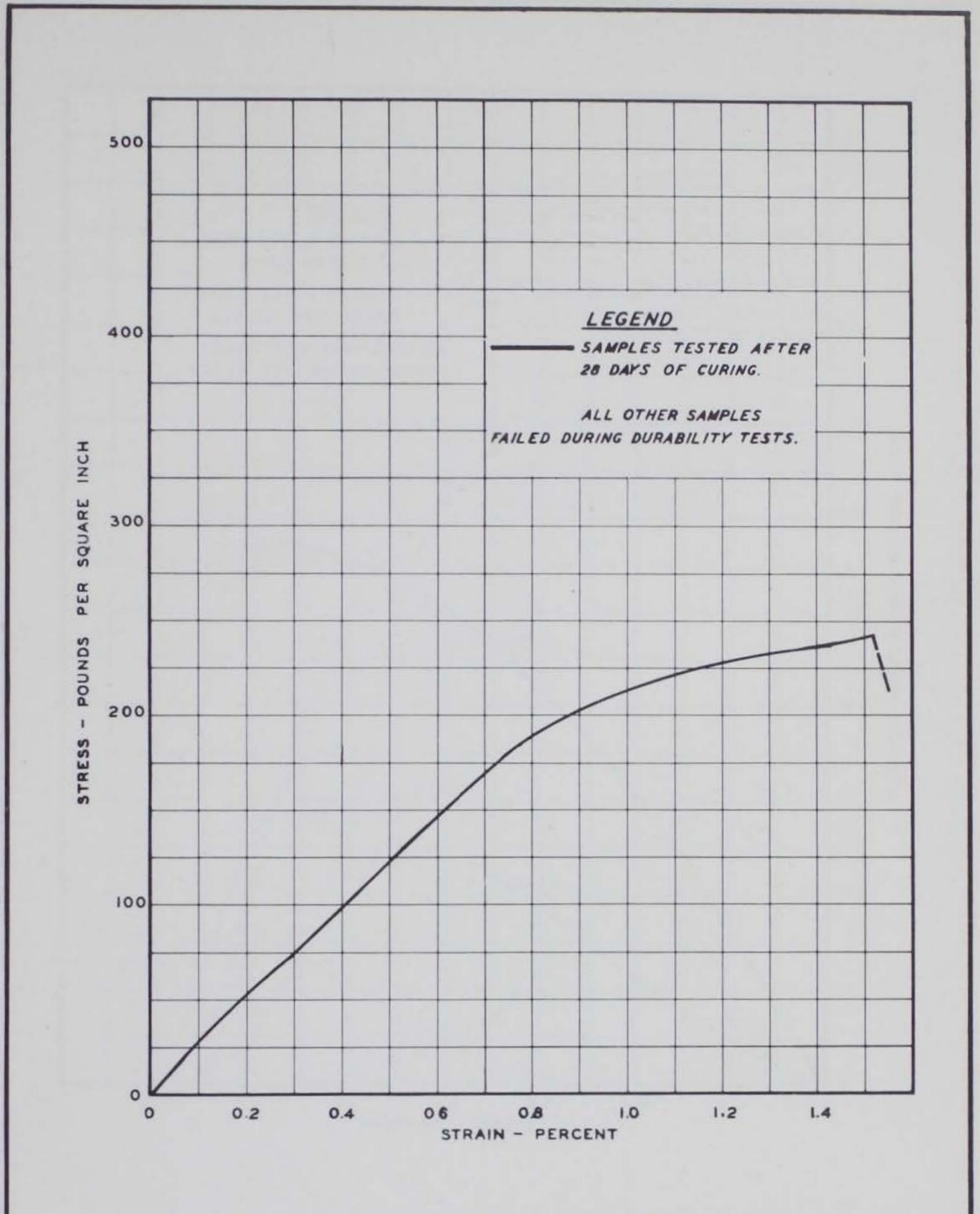
STRESS - STRAIN CURVES FOR SANDY CLAY LOAM 7 PERCENT CEMENT



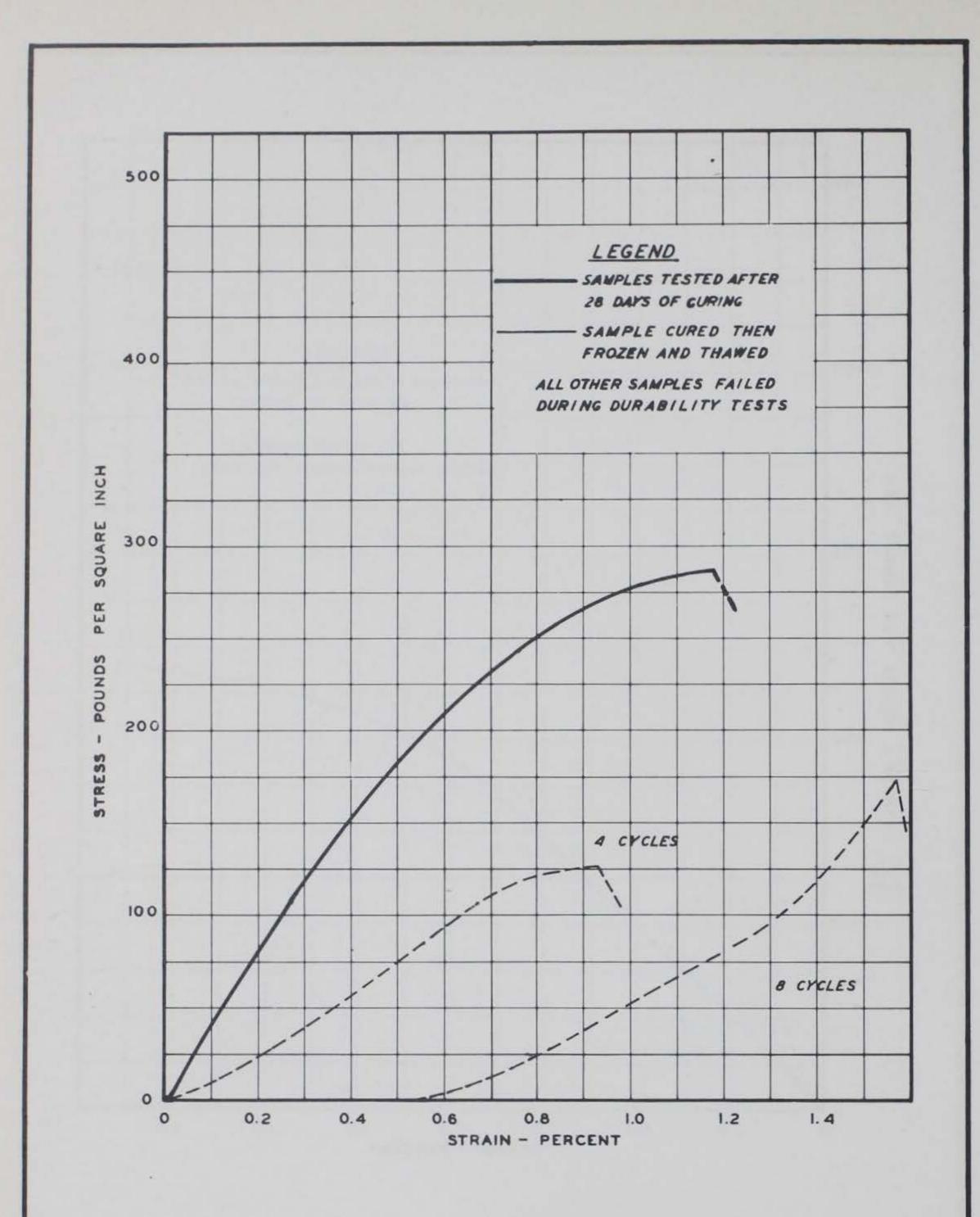
STRESS - STRAIN CURVES FOR SANDY CLAY LOAM 9 PERCENT CEMENT



STRESS - STRAIN CURVES FOR SANDY CLAY LOAM II PERCENT CEMENT

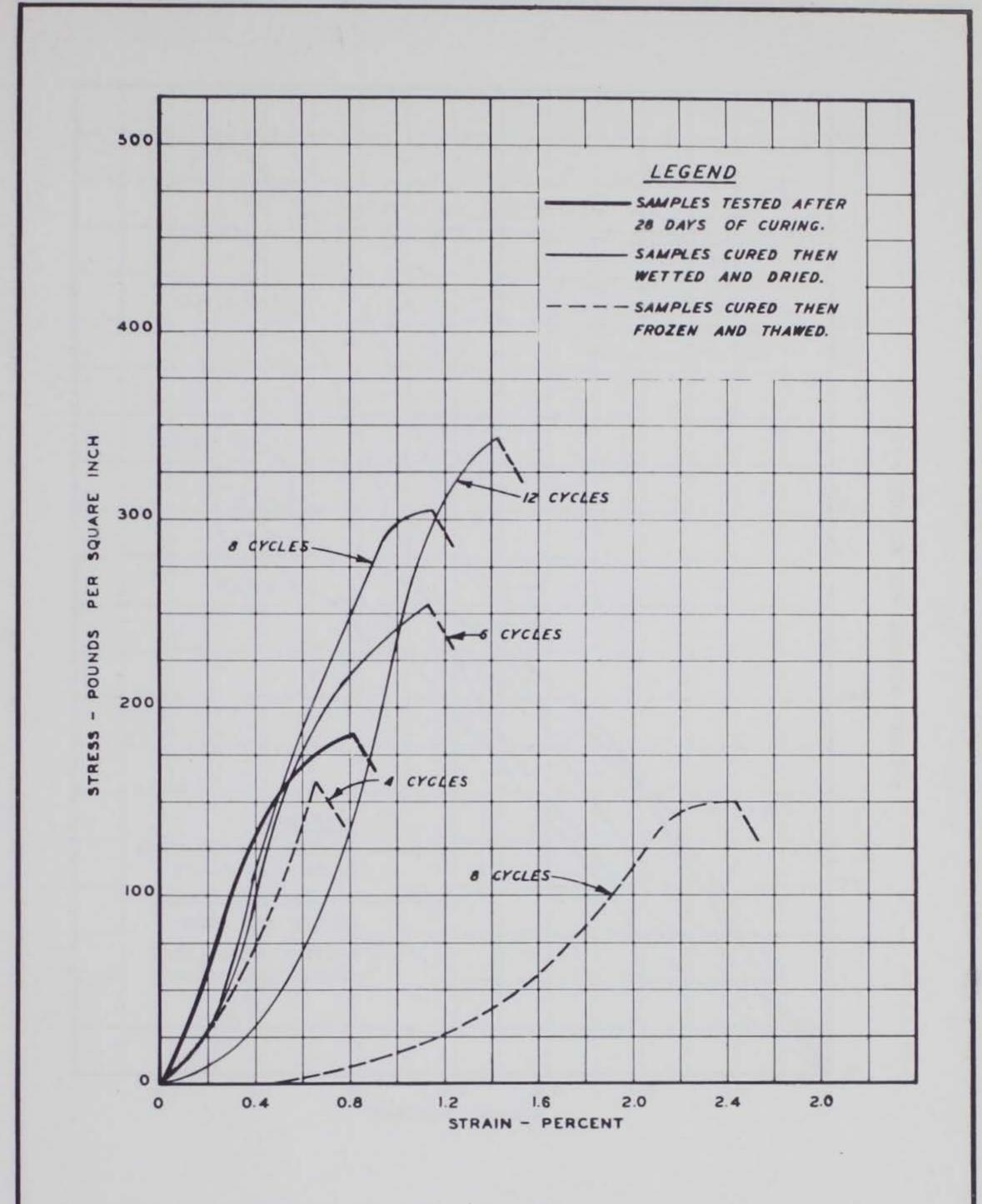


STRESS - STRAIN CURVES FOR CLAY LOAM 5 PERCENT CEMENT

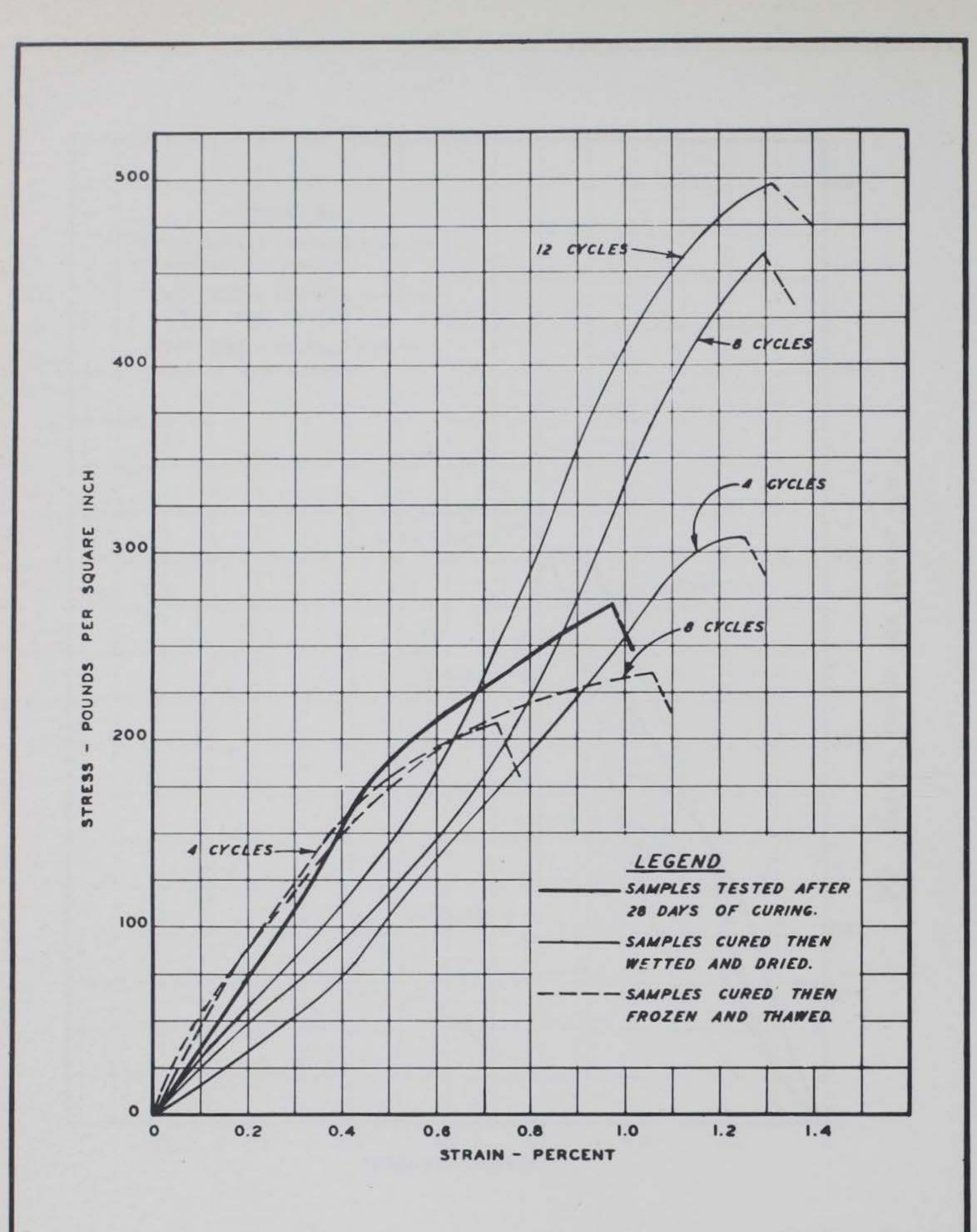


U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

STRESS - STRAIN CURVES FOR CLAY LOAM 7 PERCENT CEMENT

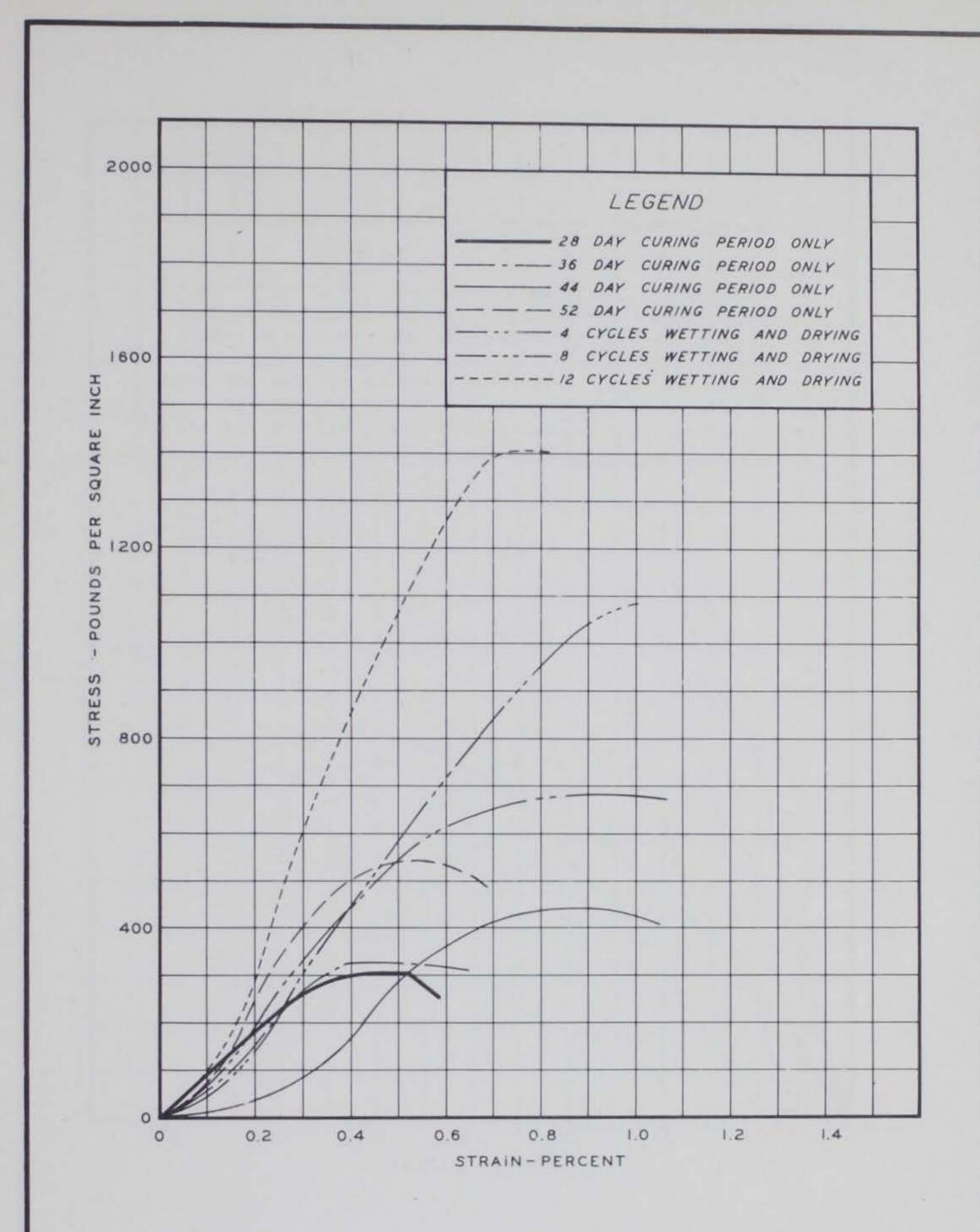


STRESS - STRAIN CURVES FOR CLAY LOAM 9 PERCENT CEMENT



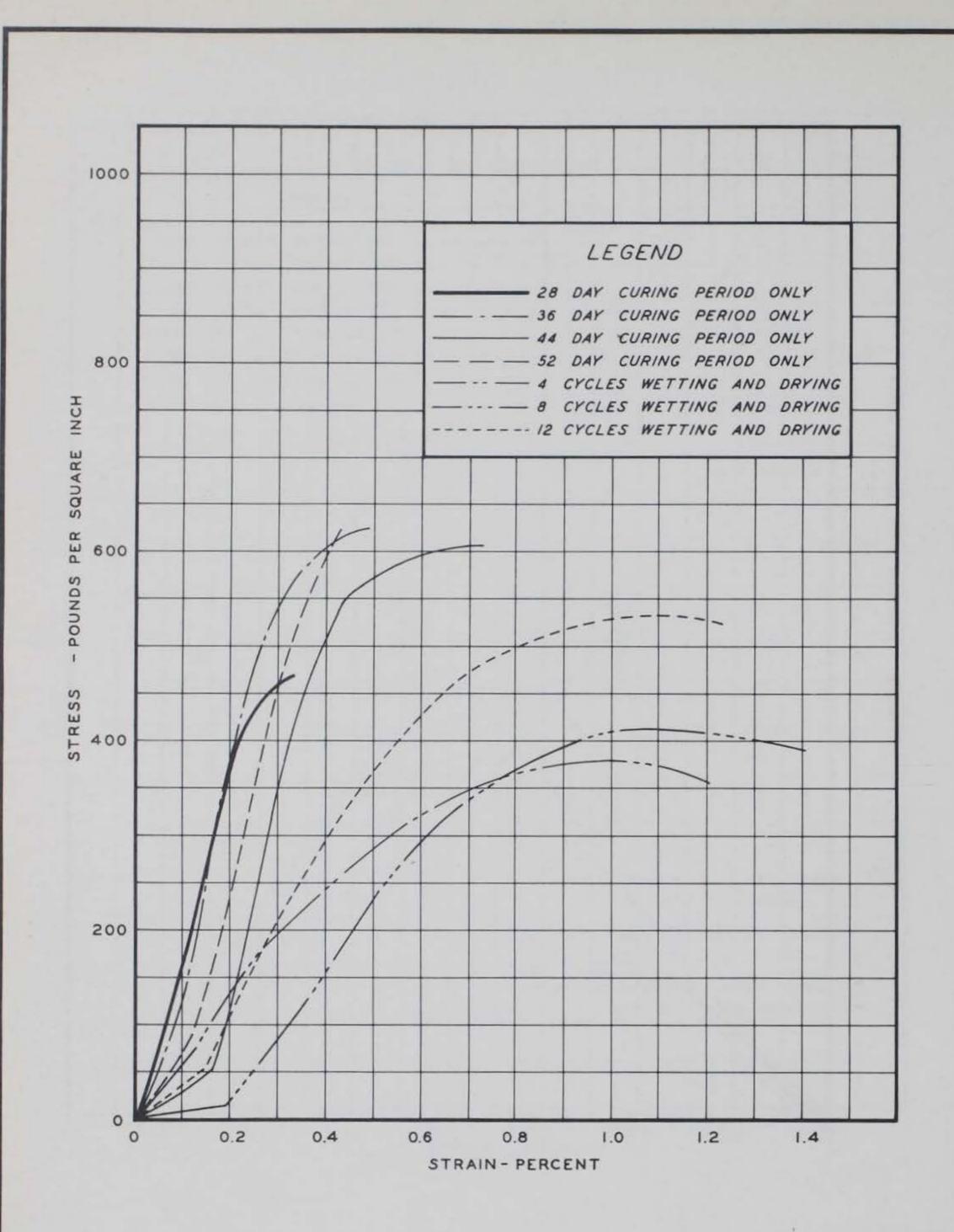
U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

STRESS - STRAIN CURVES FOR CLAY LOAM II PERCENT CEMENT



U. S. WATERWAYS EXPERIMENT STATION
INVESTIGATION OF UNCONFINED COMPRESSIVE
STRENGTH OF SOIL CEMENT MIXTURES

STRESS - STRAIN CURVES FOR SANDY LOAM 9 PERCENT CEMENT WET - DRY TEST INVESTIGATION

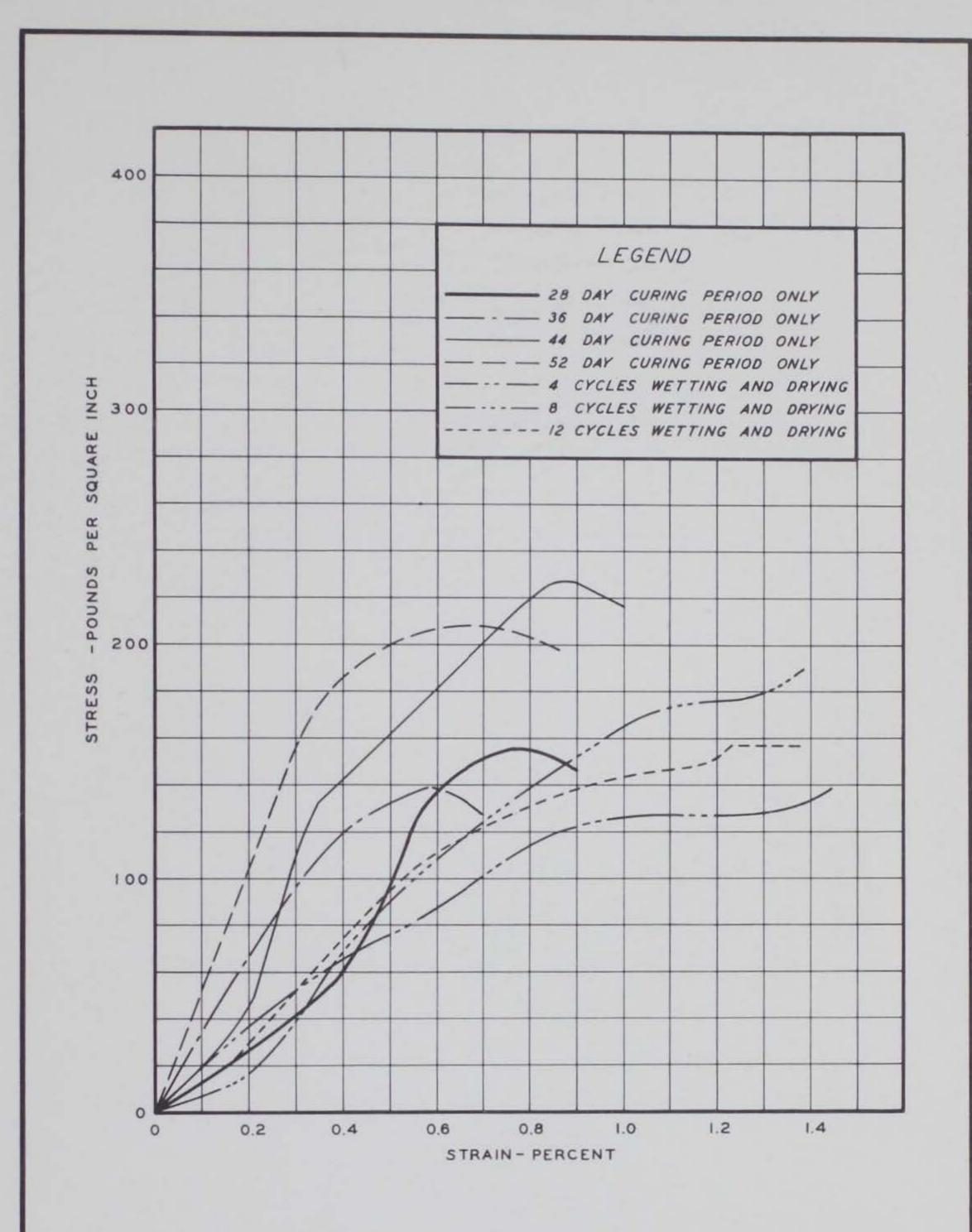


U. S. WATERWAYS EXPERIMENT STATION

INVESTIGATION OF UNCONFINED COMPRESSIVE

STRENGTH OF SOIL CEMENT MIXTURES

STRESS - STRAIN CURVES FOR SANDY CLAY LOAM 9 PERCENT CEMENT WET - DRY TEST INVESTIGATION



STRESS-STRAIN CURVES FOR CLAY LOAM 9 PERCENT CEMENT WET-DRY TEST INVESTIGATION