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Correlation of the Atterberg Limits and the California Bearing Ratio Values for Soil-Cement Media

Vernon E. Kerr

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CORRELATION OF THE ATTERBERG LIMITS AND THE CALIFORNIA BEARING RATIO VALUES FOR SOIL-CEMENT MEDIA

By

Vernon E. Kerr

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

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This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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ABSTRACT

Tests were made on three different soils, using controlled amounts of Portland cement and water. All tests were made using a standard liquid limit device or a six-inch mold. The variables were amounts of Portland cement, degree and thoroughness of mixing, moisture content, curing, and compaction of samples.

The recommended procedures for performing the Plastic Limits Test, Liquid Limits Test, and the California Bearing Ratio Test were followed with very few exceptions. All values obtained from testing are entered in the report and no retesting was done.

ACKNOWLEDGMENT

The studies herein were made possible by a number of contributing factors, the foremost being the Civil Engineering Department, University of New Mexico, in whose Soil Mechanics Laboratory the tests were conducted.

Cement was furnished by the Ideal Cement Company plant near Albuquerque, New Mexico.

No alterations were required to the testing equipment available in the Soil Mechanics Laboratory, nor was there a need to supplement this equipment.

Appreciation is expressed to Sandia Corporation of Albuquerque, New Mexico, for printing this thesis; to Professor W. C. Wagner, Chairman, Civil Engineering Department, for suggestions in performing certain tests; and to J. P. Callahan, Instructor, Civil Engineering, for assistance through use of reference material and equipment.

This report was written as a thesis in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering under the direction of Professor J. E. Martinez. His assistance and helpful comments are gratefully acknowledged.

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CHAPTER I -- INTRODUCTION

General

Stabilization of soil through the use of varying amounts of cement and water, thorough mixing, and adequate curing, is a good definition of soil-cement.

During the last few years the use of soil-cement in construction has become popular in this country but the basic idea of soil stabilization is not new. Although the development of soil-cement is not credited to any one nation, it was used by the Chinese and later by the Japanese in highway construction[1] prior to World War II. The Germans, British, and French had also been using soil-cement to varying degrees, the Germans having developed special construction equipment for use with soil-cements.

The first example of the use of soil-cement for construction in the United States was near Johnsonville, South Carolina, in 1935.[2] Since that time, soil-cement has been used on an increasing number of projects each year. Several hundred million square yards of soil-cement roads and airfields have been built and are in service at the present time.

There has been considerable research on soil-cements as well as on other soil admixtures[3, 5, 9] and combinations of admixtures[4] in recent years, and in most cases the results have shown many possibilities for their use. Although there are few data available in sufficient detail to permit a comprehensive evaluation of the performance of soil-cement roads in service, results are encouraging for those cases where design, traffic, and performance data have been obtained. Soil-cement has been used to advantage in construction other than roads—mainly airfields—and it has shown great promise as hardstands for jet aircraft parks, car parks, and foundations for water storage tanks.[2]

Economics is a major factor facing all types of construction today, with labor prices and material costs at an all-time high. Some cost studies have been made on the use of soil-cement in different phases of construction, and in most cases it has proven desirable and very competitive with other materials.[1,4]

Although soil-cement is slowly coming into its own in this country, the American engineer is still reluctant to use it in lieu of regular concrete or bituminous materials because of his lack of knowledge of all aspects concerning design, use and behavior under load. What he knows about the design and behavior of a soil-cement structure as a whole has, in the large part, been derived from tests on individual projects and laboratory work. It is generally believed that a thorough understanding of the basic conditions and units that compose any structure is a prerequisite to any further knowledge we may gain of the structure as a whole.

Object and Scope of Investigation

Contemporary design philosophy has relied on the earliest concept, i. e., design based on ultimate strength in bearing. Then, in these terms, complete efficiency in soil-cement or admixture design becomes synonymous with a thorough and rational understanding of the effects of loading on such construction. At present, the total elimination of all non-exacting tests as used on soils and cements seems far in the future and dependent on more and better research and development of new methods.

A survey of the literature revealed only limited information on testing that appeared to be different from that applied to the more common items of construction material. This information appeared to be the experimentation involved as a side venture in radiation studies and construction involving the use of new equipment design.

From knowledge of ordinary flexible pavement design, it is known that failures are in most cases due to inadequate subgrade support and occur in more or less small, isolated areas. The slab strength possessed by

soil-cement mixtures, when compacted and allowed to harden, serves to reduce considerably the unit pressures applied to the subgrade by surface loads. In an operation involving a subgrade material that has proven completely inadequate and must either be replaced or stabilized before a surface course of either flexible material or concrete can be installed, the removal of much less subgrade material is made possible by the use of soil-cement and consequently reduces construction cost.[1]

The tests carried out in conjunction with this investigation were planned with the following objectives:

1. To determine the variations of strength obtained in the different soil samples through the use of variable quantities of cement.

2. To further the engineering knowledge on the abilities and use of soil-cement.

3. To correlate the Atterberg Limits tests and the California Bearing Ratio Method and establish a curve to this effect.

A total of three different soil samples were utilized. All were tested in individual tests using cement increments of 2 percent in the range of 0-20 percent by volume of the total sample. The properties of the soils are given in Table I.

Outline of Tests

In an effort to eliminate all variables other than amounts of cement and the actual soil samples, a special attempt was made to equalize mixing time for all samples, maximize pulverization of soils, accurately measure all constituents for the tests, establish a method for taking readings and counts, and, in general, try to minimize human error.

The equipment used in the tests is discussed in Chapter II. All equipment is basic to a soils laboratory or, in most cases, a field testing laboratory. For this reason, it is the intent of these tests to encourage the possible use of the California Bearing Ratio Method in the field with the

Atterberg Limits tests through a set of curves. All operations other than those involved for the Atterberg Limits tests[6, 7, 8, 10] can be performed in the field and were consistent with ASTM Standards throughout.

Definitions

Atterberg Limits is the moisture content of a soil at the upper and lower limits of the moisture range within which that soil exhibits the properties of a plastic solid. These tests for liquid limit and plastic limit are widely used to identify soils and give an indication of certain properties, such as plasticity, cohesiveness, and bonding characteristics.[8]

California Bearing Ratio is a test to determine the bearing ratio of a soil, the value of which is expressed as a percentage of a standard penetration value for crushed stone. The bearing value is used in conjunction with empirical design curves to determine the total thickness of base and wearing course required to protect the subgrade and base course of a road or airfield against failure.[8]

CHAPTER II -- MATERIALS, FABRICATION AND TESTING OF SAMPLES

Materials

Cements

Ideal Type I Portland cement, manufactured by the Ideal Cement Company, El Paso, Texas, was used in all Atterberg Limits and California Bearing Ratio samples.

Soils

All soils were obtained in the local Albuquerque area and in most cases were taken in their natural and undisturbed condition. The one exception was soil sample No. 1 which was obtained from in-place and compacted fill on the Coronado Freeway near the east side of the city. This sample is a well-graded sand and gravel with few fines. Sample No. 2 was obtained in a cultivated field in the North Valley of the city. It is a silty sand, poorly graded with clay mixture. Sample No. 3 was obtained from a cut bank on the edge of the North Valley of the city. This sample is an inorganic clay of high plasticity.

Description of Specimens

California Bearing Ratio

The soil-cement cylinders were 6 inches in diameter and 5 inches high. The soil samples, after being mixed with the different percentages of cement, were brought to optimum moisture content with the addition of distilled water and then compacted in a mold using 55 blows per layer of material and using the modified AASHO compaction hammer. The samples were compacted in five layers.

Atterberg Limits

The Plastic Limit and Liquid Limit tests were run concurrently on each mixture containing 2 percent increments of cement to total sample. Therefore, the samples were prepared in quantity to perform both tests from a common "batch" of mixture. The Plastic Limit test required 25 to 35 grams while the Liquid Limit test requires approximately 150 grams. Since the Plastic Limit test defines the lower moisture content of the mixture, this test was performed first, and, upon completion, water was added to the remaining mixture, and the Liquid Limit test was performed.

Preparation of Samples

Atterberg Limits

The Plastic Limit test is made by starting with a wet soil-cement and adjusting the moisture content until its plastic limit is reached.

Apparatus for Plastic Limit Test --

Evaporating dish
Four-inch flexible steel spatula
Glass plate on which to roll the sample
Watch glass
Triple-beam balance
Electric oven
Desiccator

Procedure, Plastic Limit Test -- All soil samples passed the No. 40 sieve. They were mixed while dry with cement in 2 percent increments by volume ranging from 0-20 percent. Distilled water was added to the sample in sufficient amounts to bring the mix to the proper moisture content. Twenty-five to thirty-five grams of the wetted mixture were taken from the mixing dish for the Plastic Limit test. The mixture was formed into a ball, and either more water was added or the sample was manipulated with the fingers to help dry it out. This was determined in part by the sample, in that the finer soils took more water than did the coarse grain samples.

A trial test was made after the sample had been thoroughly mixed. The sample was compacted into a dense ball in the hand and then placed on the glass plate and rolled into a thread under the palm of the hand. It was attempted to roll out a thread about 2 inches long and 1/8 inch in diameter. If the diameter reached 1/8 inch without the thread breaking, the sample was too wet, and if it broke or crumbled before reaching 1/8 inch, the sample was too dry. By continual manipulation of the moisture content of the sample, the desired thread was obtained. Pieces of this thread were placed in a pre-weighed watch glass and weighed before being placed in the electric oven for drying. After drying, the watch glass and contents were again weighed and the plastic limit was determined as follows:

$$\text{Percent moisture} = \frac{\text{wet weight - dry weight}}{\text{dry weight of the soil}} \times 100$$

The Liquid Limit test is the moisture content, expressed as a percentage of the over-dry weight, at which the soil will just begin to flow when dropped 25 times from a distance of 1 centimeter.

Apparatus for Liquid Limit Test --

Evaporating dish
Flexible spatula with 4-inch blade
Grooving tool
Mechanical liquid limit device
Triple-beam balance
Watch glasses
Electric oven
Desiccator

Procedure, Liquid Limit Test -- After adjusting the liquid limit device so that the brass cup fell exactly 1 centimeter, a sample weighing approximately 150 grams, prepared as outlined heretofore, was placed in an evaporating dish. Distilled water was slowly added and mixed until a consistency that required 30 to 35 drops of the cup to cause closure of a groove in the sample was produced. A portion of the mix was placed in the cup and spread out smoothly over the area where the cup rests on the base. The mix was smoothed off to about 3/8 inch thickness and the metal grooving tool was drawn through it. The grooving tool was normal to the surface of the cup at all times while forming the groove.

The crank handle of the liquid limit device was turned at the rate of two rotations per second. The number of drops required to close the groove for a length of 1/2 inch along the bottom of the cup was recorded, and about 25 grams of the mix at the closed groove was placed in a watch glass, weighed, and placed in the oven for determining the percentage of moisture. This same mix was used for a second trial, and, when there was a large variation in the number of drops required to close the groove, more trials were made until agreement was reached.

The mix remaining in the bowl was returned to the evaporating dish, and water was added and thoroughly mixed until a consistency was reached such that 20 to 25 drops were required to close the groove.

More water was added and thoroughly mixed into the remaining sample until a third consistency was reached such that the number of drops required to close the groove 1/2 inch was between 10 and 15.

After the percentage of moisture was determined for each of the tests, they were plotted as ordinates on an arithmetic scale against the number of drops as abscissa on a logarithmic scale. The Liquid Limit was then determined as that value of the curve corresponding to the 25 drop line.

Plasticity Index -- The plasticity index is merely the difference between the Liquid Limit and the Plastic Limit. The Plastic Limit will never be larger than the Liquid Limit. If the test indicated a Plastic Limit value higher than the Liquid Limit, the Liquid Limit value was also taken as the Plastic Limit of the sample.

California Bearing Ratio

The California Bearing Ratio is a measure of the shearing resistance of the soil-cement under controlled density and moisture conditions.

Apparatus --

Testing machine

Cylindrical mold 6 inches in diameter and 7 inches high with 2-inch collar extension and perforated base plate.

Disk 5.95 inches in diameter and 2 inches thick

Compaction hammer, modified AASHO

Adjustable stem, perforated plate, tripod and dial gauge reading to 0.001 inch.

Penetration piston 1.954 inches in diameter (3 square inches)

Annular weights of 5, 10 and 20 pounds

Scale, 30-pound capacity

Coarse filter paper, 6 inches in diameter

3/4-inch and No. 4 sieves

Water tank for immersion of samples

Ames dial reading to 0.001 inch and assembly for measuring penetration

Electric oven

Triple beam balance

Mixing bowl

Spatulas

Graduate

Watch glasses

Procedure -- An air-dried sample weighing about 100 pounds of soil was pulverized and screened through the 3/4-inch sieve. All material retained on the 3/4-inch sieve was replaced with material passing the 3/4-inch sieve but retained on the No. 4 sieve. Cement was mixed with the soil in proper amounts to give 2 percent increments of cement to total volume of the sample, a test being run on each increment from 0 to 20 percent. Distilled water was added in a predetermined amount to obtain the optimum moisture content of the mixture.

The compaction mold was assembled on its base with the 2-inch spacer disk in the bottom and the 2-inch collar on the top. The soil-cement mixture

was placed in the mold and compacted in 5 layers using 55 blows per layer with the compaction hammer. The 2-inch collar was removed and the cylinder of soil-cement was trimmed with a straight edge. Only one sample was made for each increment of cement as opposed to the four or five recommended for the test, because of the large number of samples required. A small sample of the material was taken for determination of the moisture content. The base plate and spacer disk were removed and a filter paper was placed on the base plate. The mold was turned upside down so that the top of the sample as compacted rested on the base plate. The sample was then ready for soaking.

To simulate field conditions, the sample was soaked under a surcharge weight of 10 pounds produced by the annular rings. A filter paper was placed on top of the sample, and the perforated plate with adjustable stem was placed on the paper. The annular ring of appropriate size was then placed on the perforated plate. A dial connected to a tripod clamp was adjusted to read zero on the mold and the perforated plate stem before soaking.

The sample was immersed in a tank of water and allowed to soak for four days or until it was thoroughly saturated and ceased to expand. The tripod clamp was placed on the mold each day during the soaking period to determine when saturation was reached.

After the soaking period, the mold was removed from the water and allowed to drain for 15 minutes. The surcharge weight, perforated plate, and filter paper were removed, and the specimen was ready for testing. The amount of swell and water absorbed by the sample was not considered pertinent for this experiment and was not recorded.

The sample with surcharge on top was placed directly under the penetration piston in the testing machine, and the penetration piston was brought into contact with the soil-cement. The Ames dial was adjusted so that its stem was bearing on the rim of the mold, and the initial reading was recorded.

Load was applied smoothly at the rate of penetration of 0.005 inch per minute. Loads were recorded at 0.025, 0.050, 0.075, 0.100, 0.200, 0.300, 0.400, and 0.500 inches of penetration. The load was released and the mold was removed from the testing machine. A 20- to 50-gram moisture sample was taken from the soil-cement cylinder.

For each penetration the load in pounds per square inch was determined and curves were plotted for each test. Only those curves that were uniform were used to determine the California Bearing Ratio values. The values for 0.1 inch penetration and 0.2 inch penetration were calculated from the loads shown on the curve.

The California Bearing Ratio for each sample was determined as the percentage of the unit load required to force the piston into the sample, divided by the unit load required to force the same piston to the same depth in a standard sample of compacted, crushed rock. The California Bearing Ratio was selected at 0.1 inch penetration.

CHAPTER III -- PRESENTATION AND ANALYSIS OF RESULTS

Cement As a Variable

As was expected, there is a definite correlation between the Plastic Index and the California Bearing Ratio of the soils tested. This is indicated by the results shown in Figures 7, 8, and 9 and Table IV. The values listed in Table IV would indicate that with cement as a variable, the Plasticity Index can be lowered to a more desirable value and, at the same time, will raise the California Bearing Ratio value to a very impressive figure.

Selection of Samples

At the time of selecting the three different soils for use in this experiment, the thought was to get soils as far removed from each other in their mechanical composition as possible. It was deemed desirable that a coarse, well-graded gravel, as opposed to an inorganic, high-plasticity clay, could be found, and then a soil found which fit about midway between these two. This was partially accomplished in that soil No. 1 is a well-graded, coarse gravel, and soil No. 3 is a high-plasticity clay, but soil No. 2 is of better quality than was intended, as far as its mechanical composition is concerned.

The fact that soils Nos. 1 and 2 are so close together makes possible an interesting analysis of the graphs plotted with the values obtained from the test. As will be noted, these values were plotted on three different combinations of logarithmic and arithmetic scales.

Interpretation of Results

Figure 8, using an arithmetic scale for both the Plasticity Index and the California Bearing Ratio, produces a straight line which would be easily interpreted by technicians with little or no previous instruction. Also, it will be noted that the cement curve becomes asymptotic with the California Bearing Ratio-Plasticity Index curve for soil No. 1. This would indicate that less desirable results are obtained from the coarse soils while very good results are obtained with fine-grained soils. Normally, a coarse, well-graded gravel needs nothing more than proper moisture and compaction for use on most construction projects, so that it is doubtful if any stabilization by use of additives would be considered.

Figure 9, using an arithmetic scale for the California Bearing Ratio and a logarithmic scale for the Plasticity Index, gives a less desirable set of curves, because the cement curve is almost parallel to the California Bearing Ratio lines at most values, indicating a variety of values for the Plasticity Index in each case. However, the figure does indicate asymptotic conditions of the cement curve as it nears the curve for soil No. 1.

Figure 7 is discussed last, because it appears to be the least desirable and has few or no apparent indications as found in Figures 8 and 9. There is no apparent family of curves indicated by the three soils when the values of tests run are plotted using a logarithmic scale for both the California Bearing Ratio and the Plasticity Index. The cement curve also fails to become asymptotic to the curve for soil No. 1 as in Figures 8 and 9.

The only feature that appears to be common to all three figures is that the curves for the three soil samples appear to approach a common point. This point theoretically would be the results obtained as the percent of cement approaches 100. This is clearly indicated on Figure 8 and less clearly on Figures 9 and 7, in that order.

The maximum percent of cement that could be used to advantage, neglecting the economic aspect, appears on Figure 8 to be in the range of 16 to 20 percent. As can be noted, the percent cement curve becomes more steep and is developing an asymptotic relationship to the curve for soil No. 3.

It is possible to correlate the California Bearing Ratio and the Atterberg Limits, using soil-cement as a media through the use of curves developed from data obtained from this experiment. By considering a hypothetical soil which has been visibly identified as a gravel, sand, silt, clay, or combination of these materials, Figure 8 can be entered on the curve pertaining to this classification, and the percent cement required to obtain the California Bearing Ratio-Plasticity Index desired can be determined. It is necessary to interpolate the location of a curve representing a particular soil classification not specifically plotted on the figure, but, at the intersection with the desired values, the percent cement can be read. It would be advantageous to code the soil classification curves as an aid to entering the figure.

CHAPTER IV -- SUMMARY, FUTURE TESTS, AND CONCLUSIONS

Summary

The objects of this investigation were stated to be the following:

1. To determine the variations of strength obtained in the different soil samples through the use of variable quantities of cement.

2. To further the engineering knowledge on the abilities and use of soil-cement.

3. To correlate the Atterberg Limits Test and the California Bearing Ratio Method and establish a curve to this effect.

A total of three soils were utilized. All were tested in individual tests using cement increments of 2 percent in the range of 0-20 percent by volume of the soil sample. An attempt was made to eliminate or minimize all variables other than amount of cement and the soils samples used, by standardizing the operations performed.

The tests have been described, and the results have been presented in both tabular and graphical form.

Future Tests

Since present knowledge of the mechanics of soil-cement is somewhat limited, and the apparent reluctance of its use in construction is evident, the following tests are recommended for future study:

1. Continuation and elaboration of the objectives of this particular experiment, with special emphasis placed on standardization of all operations performed and maximum reduction of error.

2. Testing for and preparation of design methods and graphic aids for highway, airport, and other construction design.

3. The use of combinations of additives for soils not particularly compatible to any certain additive because of organic content or chemical composition.

4. Economic studies on the stabilization of soils through the use of additives.

Conclusions

The following conclusions are based on the test results for the three soils used and the studies which are presented in the body of this report:

1. Fine-grained soils such as clays can be stabilized with the use of a cement additive. The following criteria has a direct relationship to the results obtained:

   a. Pulverization of soil

   b. Uniform mixing of additives and soil sample

   c. Moisture content and curing

   d. Compaction.

2. An arithmetic scale appears to give the best graphic results for plotting California Bearing Ratio, Plasticity Index, and percent cement values.

3. Several runs are required of each sample in all tests as a check of values obtained. This would help reduce errors as indicated in Chapter IV.

4. Soils from very fine, inorganic clays to silts, sands, and coarse gravels, can be stabilized through the use of Portland cement. However, more distinct results are obtained with the finer grain soils which is complementary to the known fact that coarser, well-graded materials require less effort for stabilization. It is apparent that soils with Plasticity Indexes of 5 or less, well-graded and clean, will act quite similar to concrete, i. e.,

the California Bearing Ratio Curve increases very rapidly with an increase in the proportion of cement, while the Plasticity Index remains very nearly constant.

TABLE I

Sieve Analysis

Soil No. 1 (Coronado Freeway Fill)

Sieve	Percent retained	Percent passing	
1 inch	0	100	
3/4 inch	0	100	
3/8 inch	2.6	97.4	
No. 4	14.5	85.5	
No. 8	33.4	66.6	Specific
No. 16	48.2	51.8	gravity
No. 30	58.4	41.6	2.626
No. 50	67.6	32.4	
No. 100	82.8	17.2	
No. 200	93.6	6.4	
Pan	100	0	

Soil No. 2 (North Valley)

1 inch	0	100	
3/4 inch	0	100	
3/8 inch	0	100	
No. 4	0.4	99.6	
No. 8	2.5	97.5	Specific
No. 16	5.7	94.3	gravity
No. 30	11.5	88.5	2.480
No. 50	28.7	71.3	
No. 100	54.0	46.0	
No. 200	71.0	29.0	
Pan	100	0	

Soil No. 3 (North Edith)

1 inch	0	100	
3/4 inch	0	100	
3/8 inch	0	100	
No. 4	0	100	
No. 8	0.16	99.84	Specific
No. 16	0.3	99.7	gravity
No. 30	0.5	99.5	2.668
No. 50	0.8	99.2	
No. 100	1.6	98.4	
No. 200	3.0	97.0	
Pan	100	0	

TABLE II

Moisture Content and Dry Unit Weight

(Coronado Freeway Fill)

Soil No. 1

Percent moisture to dry weight	Unit weight pounds/cubic foot
3.23	124.9
6.77	132.8
7.55	135.3
8.9	132.7

(North Valley)

Soil No. 2

Percent moisture to dry weight	Unit weight pounds/cubic foot
2.5	99.0
6.3	109.2
9.2	118.5
13.7	126.8
17.8	109.7

(North Edith)

Soil No. 3

Percent moisture to dry weight	Unit weight pounds/cubic foot
5.37	82.5
10.01	85.4
15.1	93.8
23.4	94.4
31.1	90.6
36.4	82.1

TABLE III

Soil Classification

Unified Soil Classification Method[7]

Sample	Group symbol
No. 1 (Coronado Freeway Fill)	SW
No. 2 (North Valley)	SM-SC
No. 3 (North Edith)	CH

Cement Data

Brand:	Ideal Cement Company
Type:	I
Normal Consistency:	26 percent
Gilmore Time of Set:	Initial - 3 hours, 20 minutes Final - 5 hours, 20 minutes
Vicat Time of Set:	3 hours

TABLE IV

California Bearing Ratio and Plasticity Index Values

Percent cement by volume	Soil No. 1		Soil No. 2		Soil No. 3	
	California Bearing Ratio	Plasticity Index	California Bearing Ratio	Plasticity Index	California Bearing Ratio	Plasticity Index
0	37	4.9	22	7.1	13.8	40.0
2	51	3.8	39	6.3	30	36.5
4	74	3.6	57.7	5.9	48	32.8
6	83.5	3.2	76	5.6	66.4	31.4
8	107	3.2	95	6.3	82.3	31.4
10	123	4.0	117	5.2	96.7	29.0
12	136.4	2.8	129	5.0	110	28.0
14	153	2.6	141.4	4.9	126.6	21.0
16	158.4	2.5	151.4	4.6	148.2	20.8
18	182.4	2.4	168	4.3	175	19.4
20	197	2.3	176.6	4.0	217.5	19.2

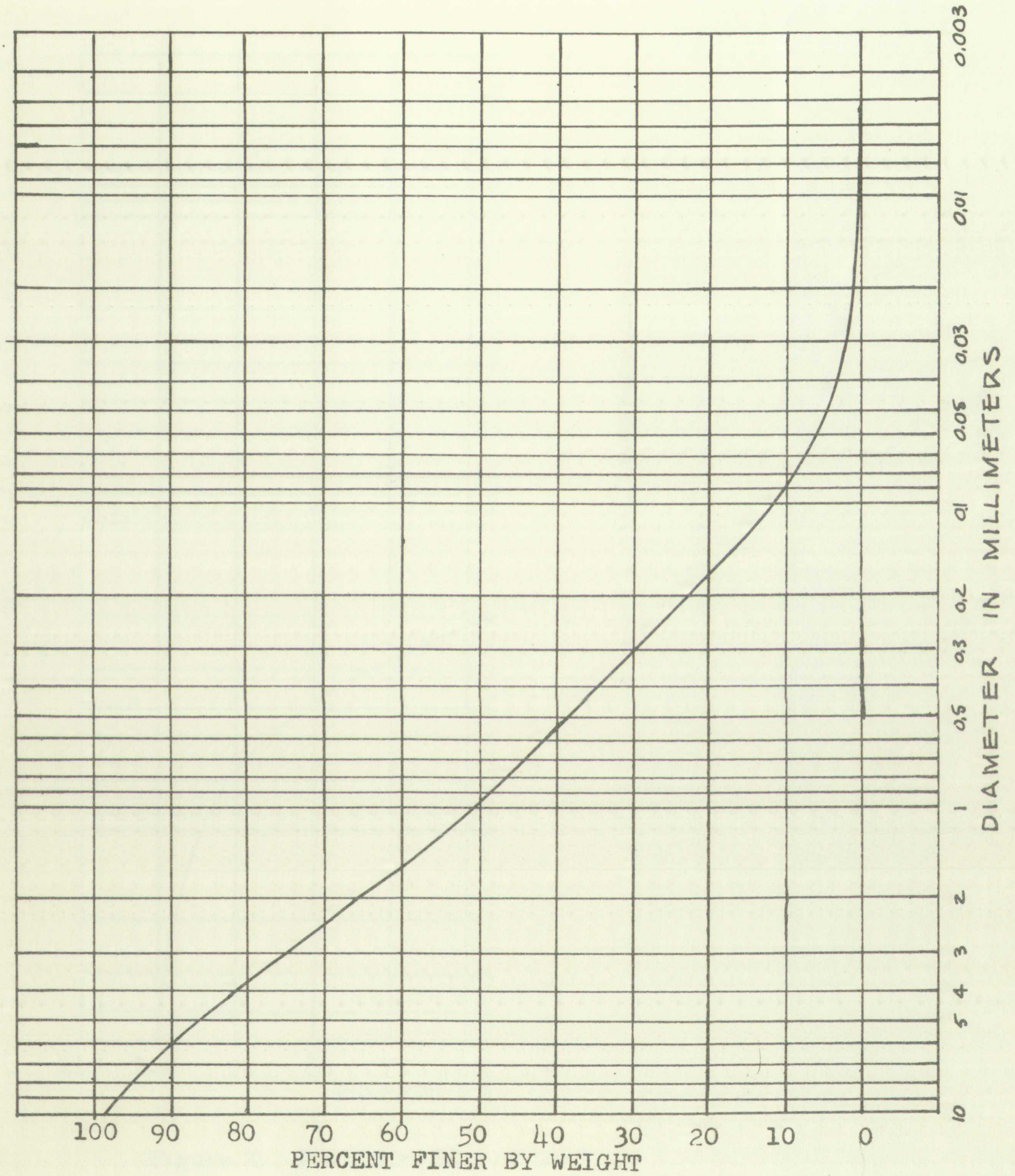

Figure 1. Grain Size Distribution, Soil Number 1

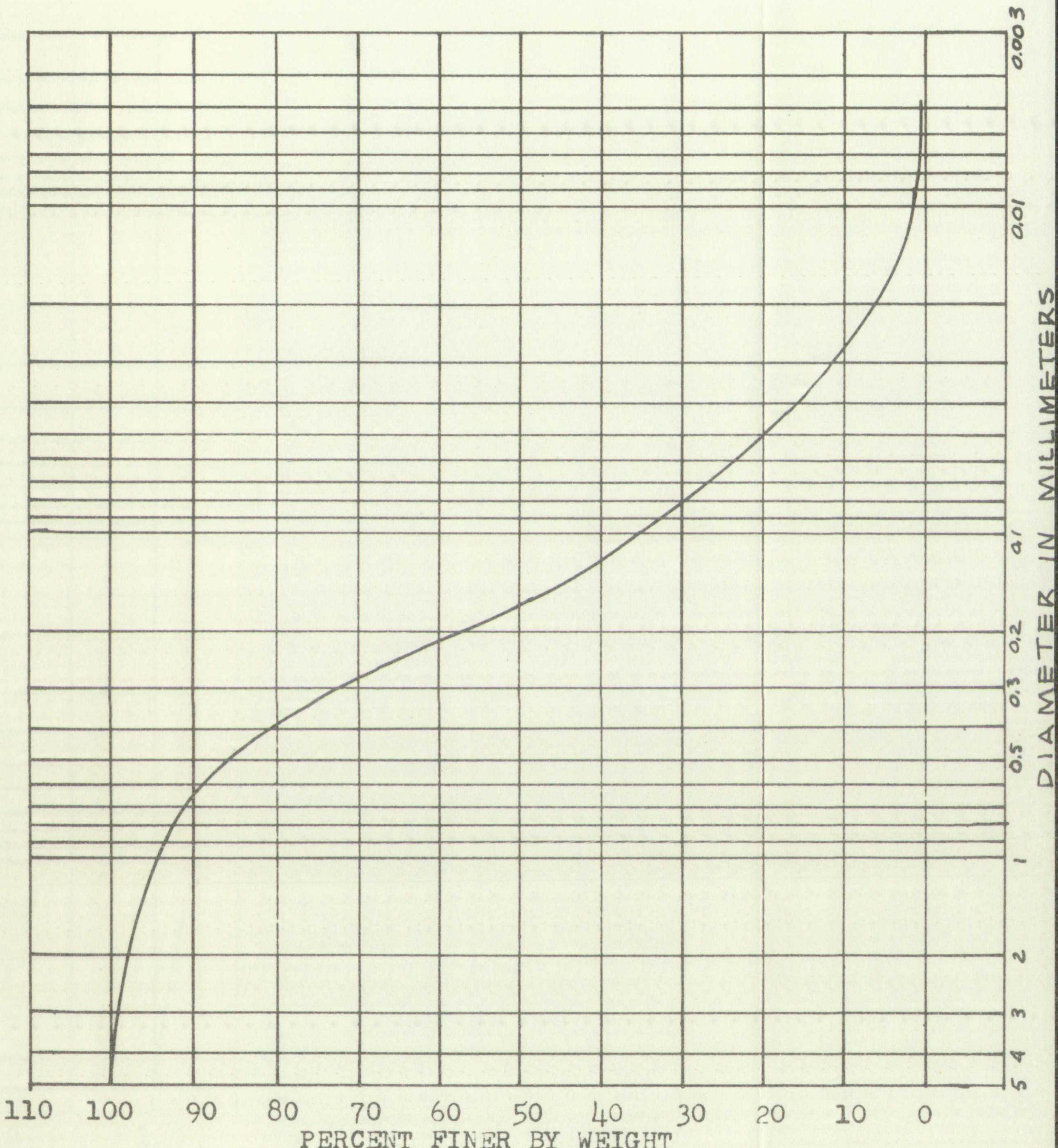

Figure 2. Grain Size Distribution, Soil Number 2

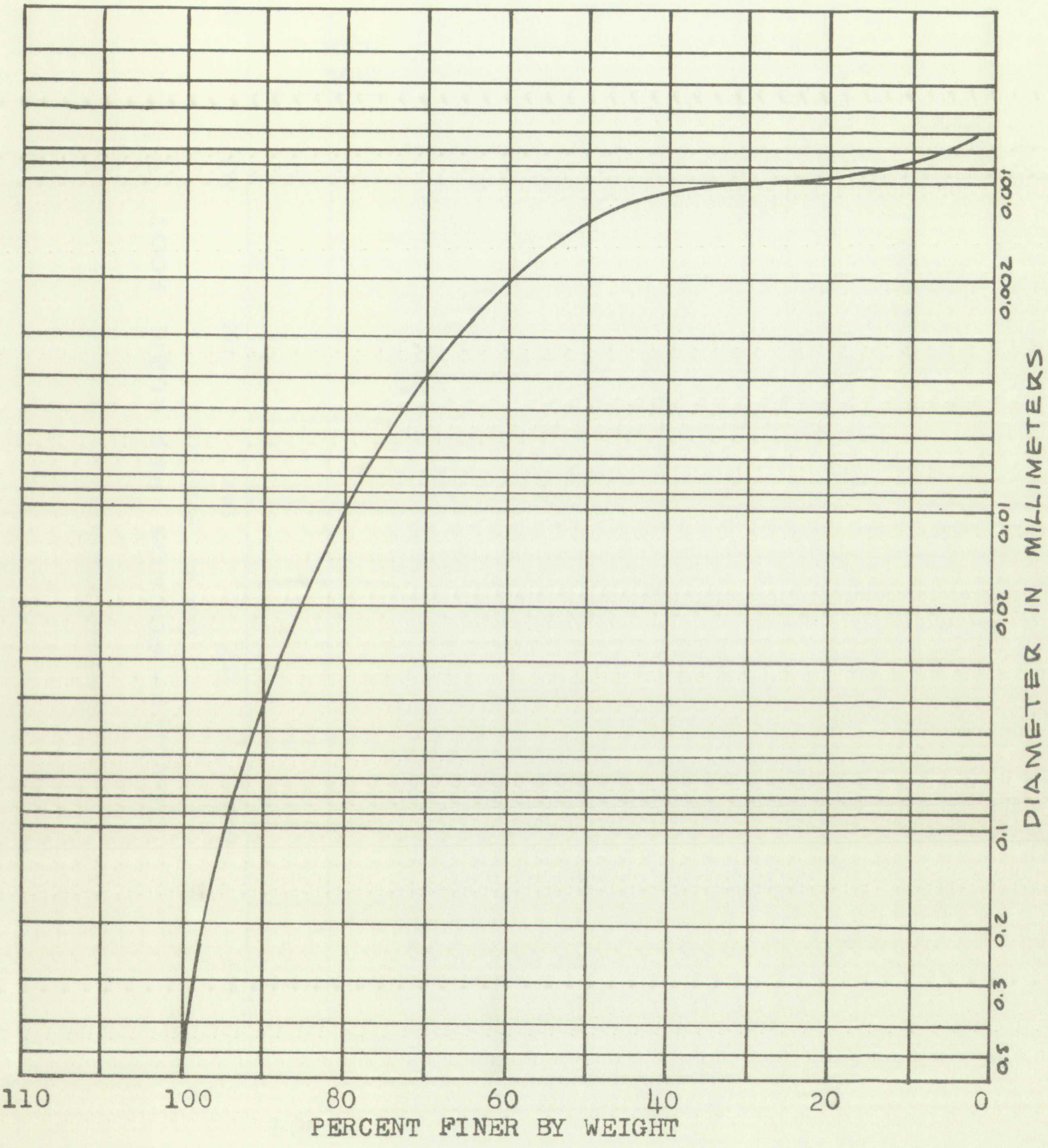

Figure 3. Grain Size Distribution, Soil Number 3

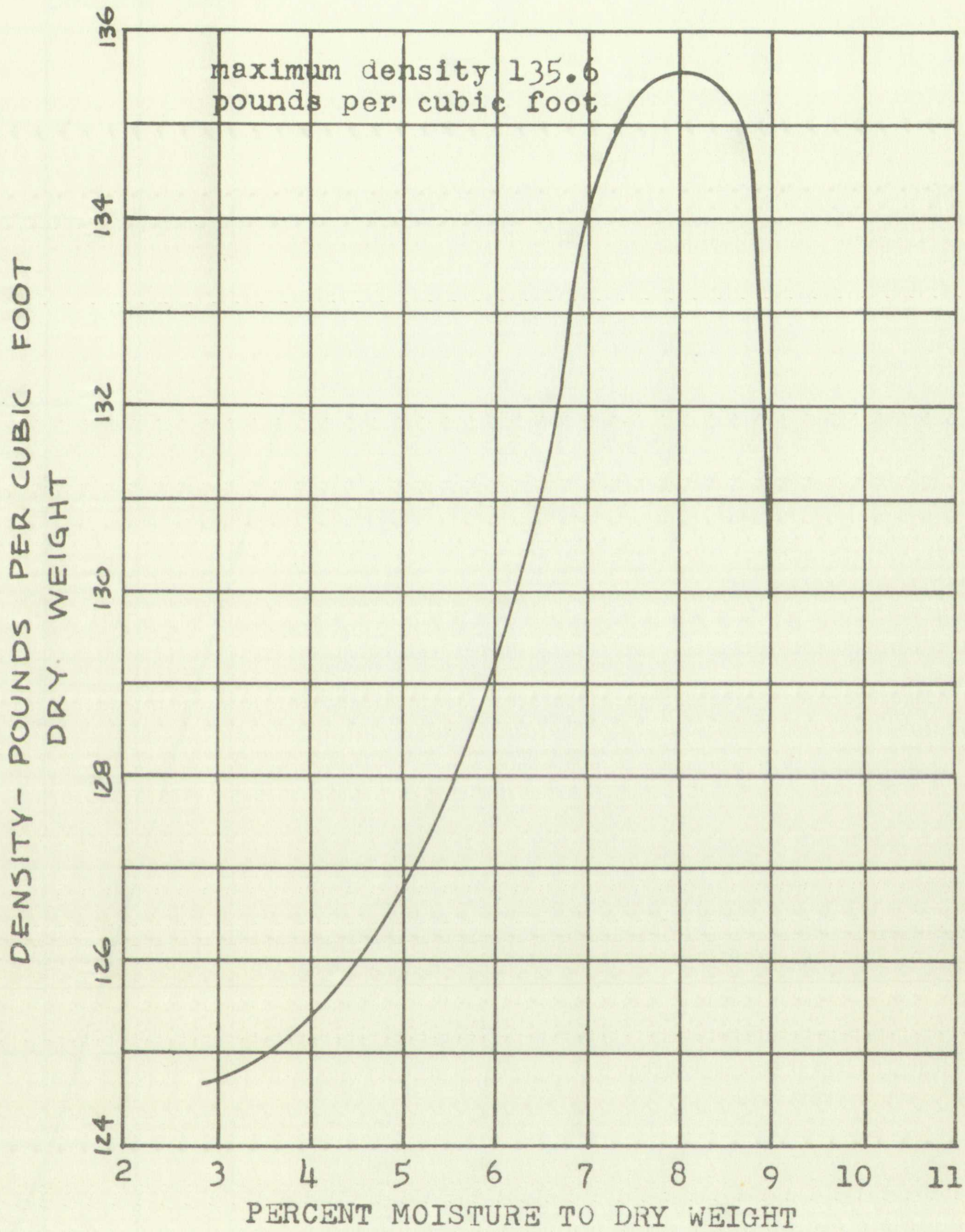

Figure 4. Moisture-Density Curve, Soil Number 1

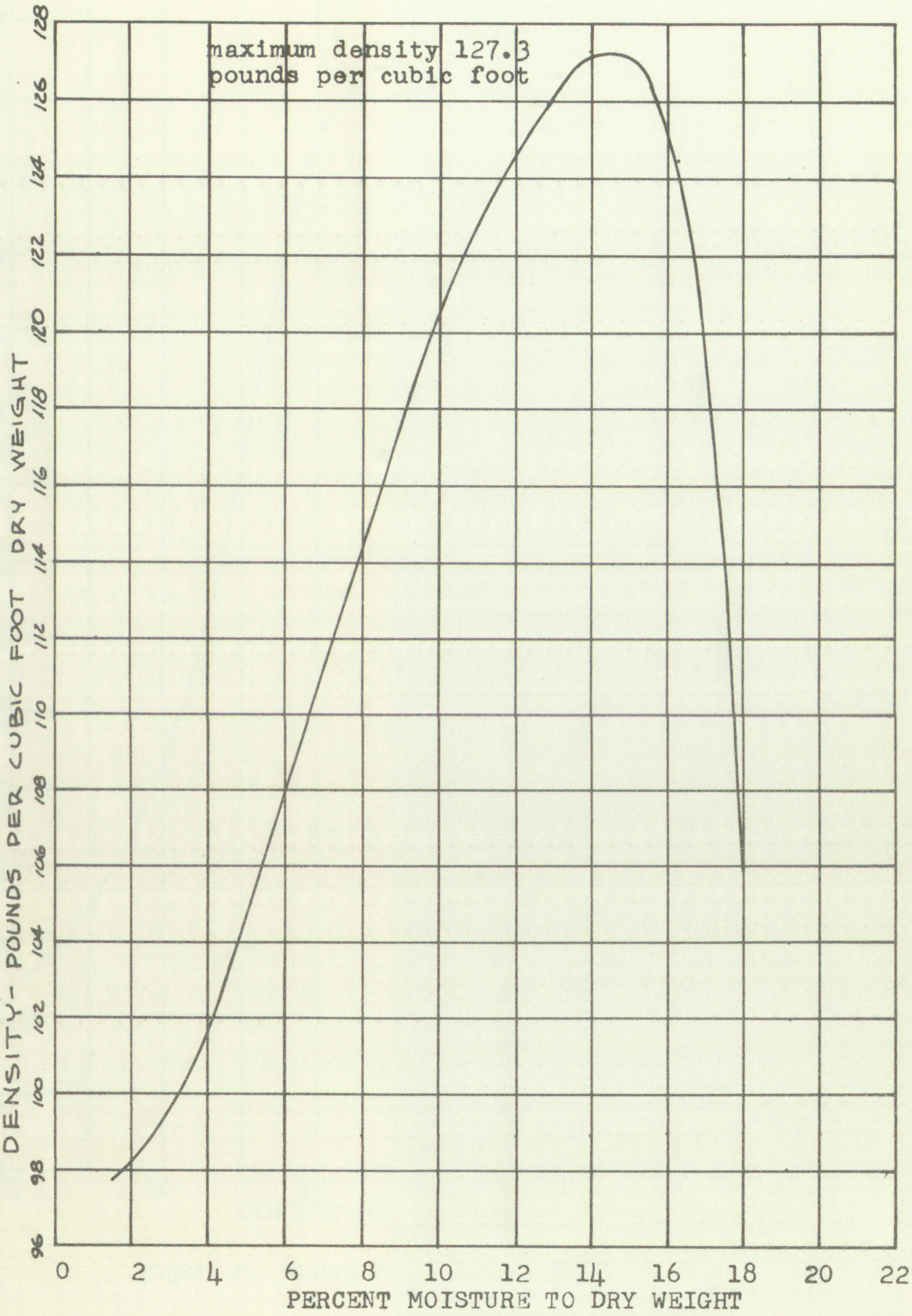

Figure 5. Moisture-Density Curve, Soil Number 2

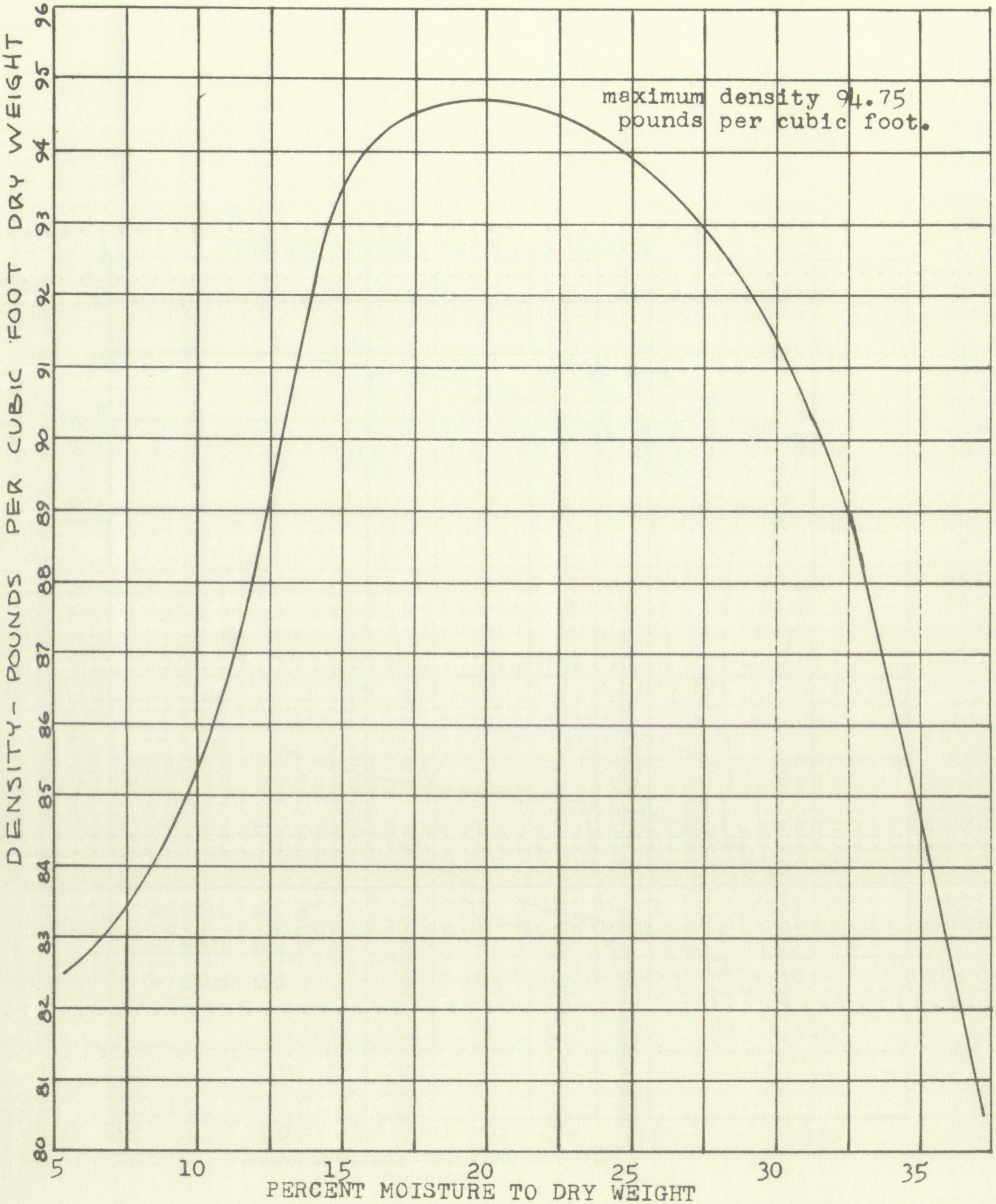

Figure 6. Moisture-Density Curve, Soil Number 3

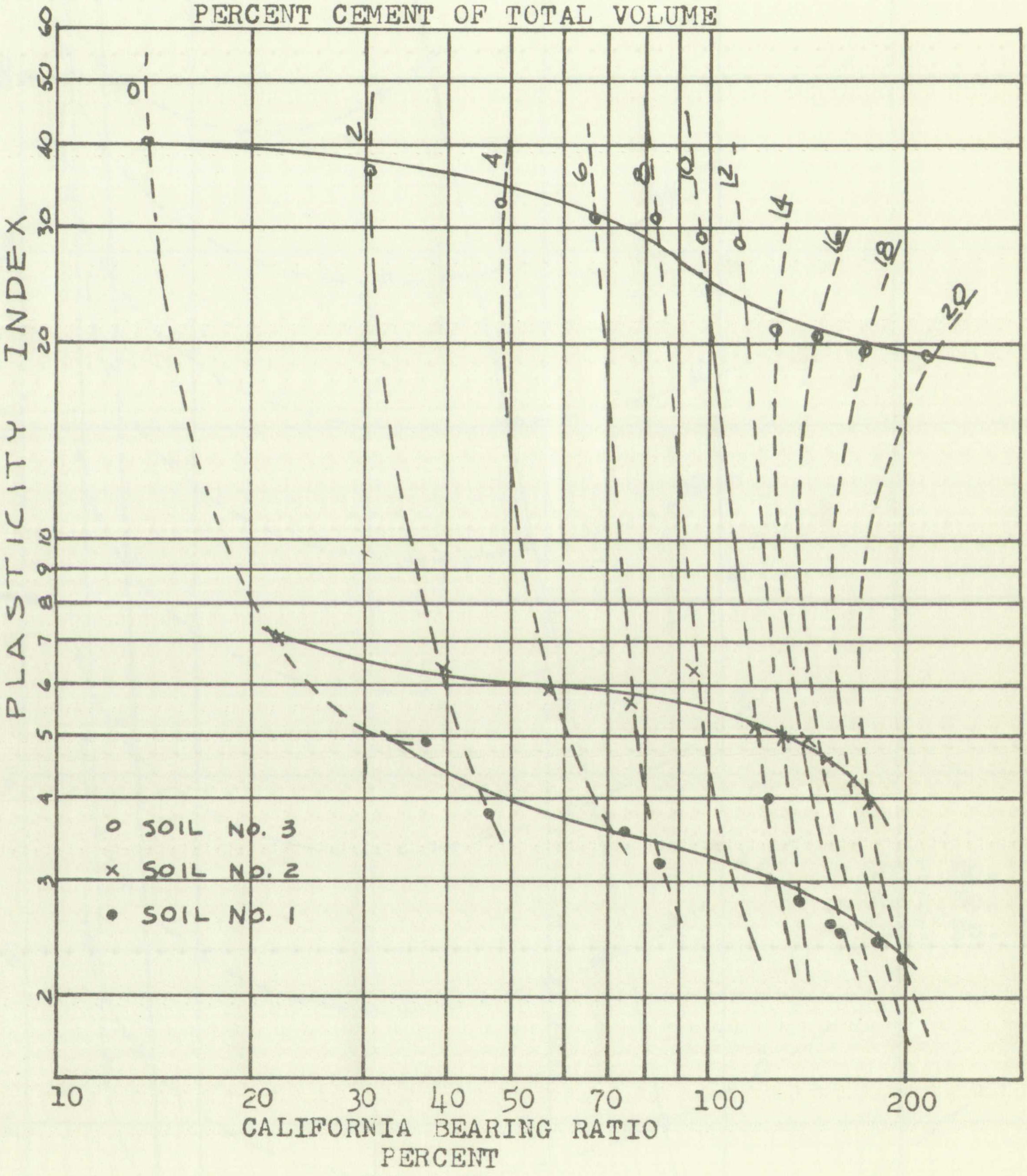

Figure 7. Plot of California Bearing Ratio Against Plasticity Index

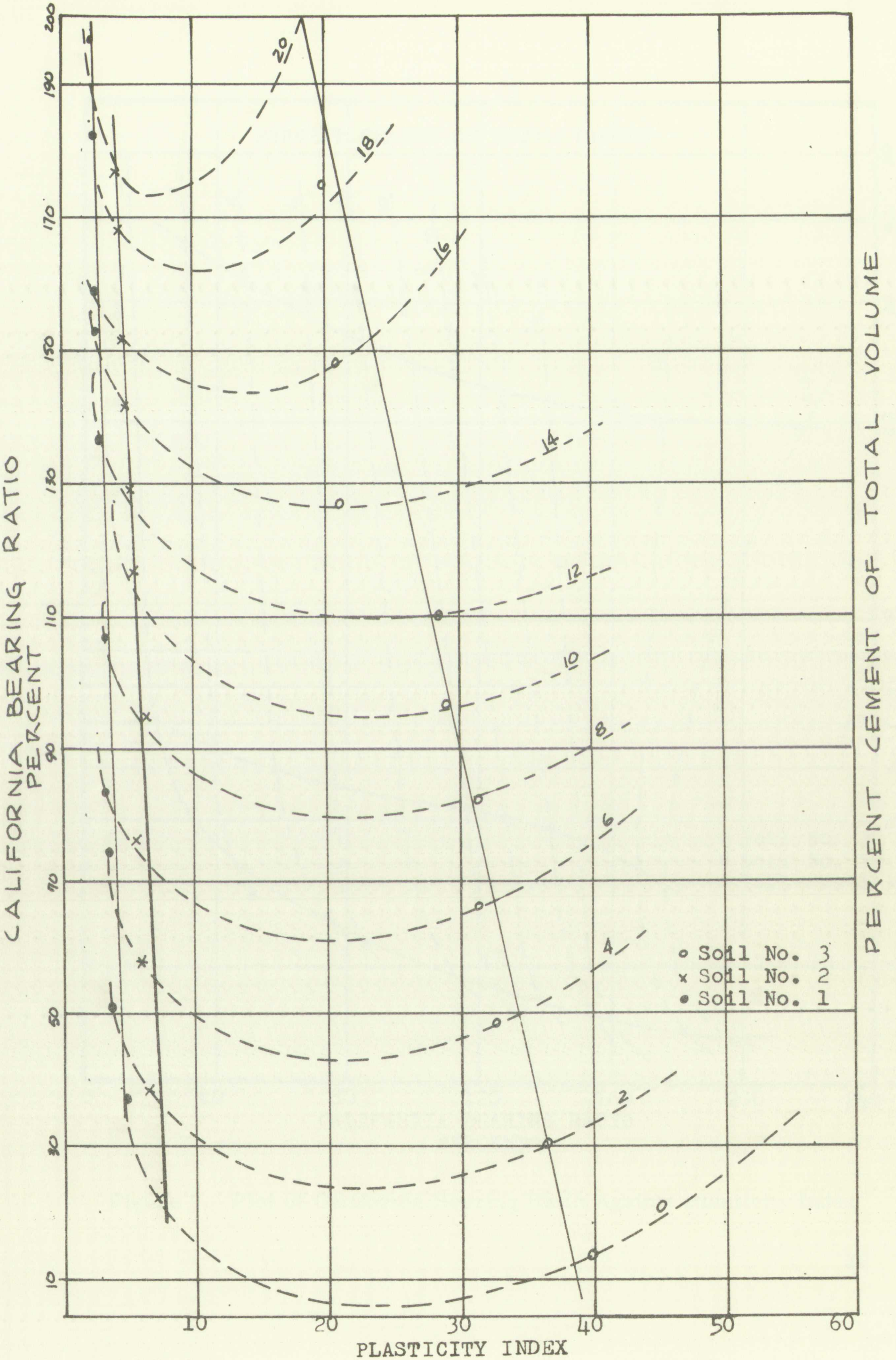

Figure 8. Plot of California Bearing Ratio Against Plasticity Index

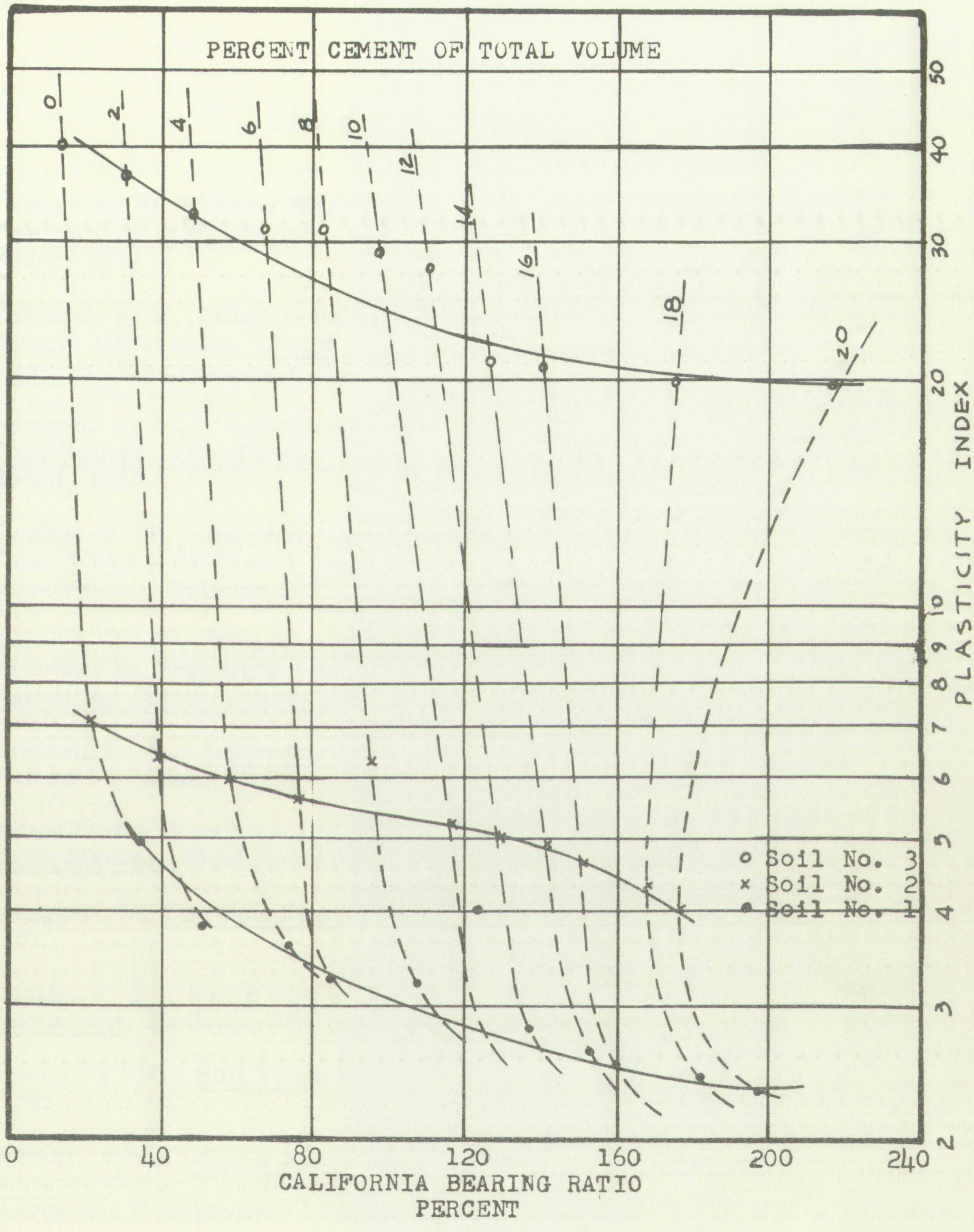

Figure 9. Plot of California Bearing Ratio Against Plasticity Index

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