THE EFFECT OF A VARYING MOISTURE CONTENT ON THE SETTLEMENT OF SOIL SUBJECTED TO A CONSTANT LOAD

Thesis by

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INTRODUCTION

It is surprising that while engineers have devoted so much time to the development and refinement of the theories of structures they have almost entirely neglected to consider the foundations upon which their structures must rest. Only recently has there been a general awakening to the importance of foundations in structural engineering.

Some fifteen years ago Dr. Charles Terzaghi began experimenting with sands at the American Robert College in Turkey. He later broadened his work to cover the field of soils in general. The work which Dr. Terzaghi has done is the outstanding contribution so far in the field of soil mechanics. The results which he published in 1925(1) attracted the attention of the entire engineering profession and impressed it with the importance of such studies. Investigators have shown an increasing interest in the subject ever since. A special department for soil research was created at the Massachusetts Institute of Technology under the personal supervision of Dr. Terzaghi. Other schools, notably Iowa State College, have taken up the work on a large scale. The United States Bureau of Public Roads has undertaken extensive work with reference to highway subsoils. The engineering literature has begun to carry articles on soil mechanics and foundations. Apparently the profession is beginning to do justice to this heretofore neglected science.

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(1) A series of articles in Engineering News-Record, November 5 to December 31.

One factor which has to a great extent been responsible for the neglect of soil mechanics is the inherent complexity of soil itself. There seems to be an almost unlimited number of variables that are involved in the behavior of soils. To make the science exact, all the laws governing these variables should be determined. On the surface this appears to be an almost hopeless task, not only because of the number of variables, but because of their inter-relation and effect on one another. However, some of the variables, such as density, permeability, cohesiveness, size of particles, coefficient of internal friction, void ratio, etc., are really functions of the type of soil. If soils are classified on the basis of clay, silt, and sand, it is found that for each type the above variables are constant - or at least nearly enough so for engineering purposes. If the study is to be the physics, chemistry, or geology of soils, the above mentioned variables - and many more - will have to be considered. However, for engineering purposes, where the emphasis is on the mechanics of soils, the type of soil may be considered as a single variable which is the sum total of all the others.

From the standpoint of foundations and footings the variables have to do with soil mechanics. Of course, the first and most important of these is the type of soil. The other variables are: the unit load applied, the settlement which occurs, the time of settlement, the shape of the loading plate, the diameter of the loading plate, (called d), the ratio of the depth at which load is applied to the diameter of the loading plate (called t/d), and the moisture content of the soil. Since in structural work the practice is to use settlement as a basis for determining allowable bearing values, it is desirable to know the relation of settlement to the other variables.

For given soils the time-settlement relation under a constant unit load, with fixed-values of d and t/d, and constant moisture content has been quite well determined.(1) Similarly, for given soils, the unit load - final settlement relation with fixed values of d and t/d and constant moisture content has been studied.(2) A variation of this relation is obtained by periodically removing the load during the test and observing the so-called "rebound" ability of the soil.(3) The relations between final settlement and such factors as the shape of plate, d, and t/d have been observed and are definitely known.(4)

There is one relation, however, which is much less understood than those mentioned above. It is the effect of moisture content on the final settlement of soil when all the other variables are constant. Terzaghi has observed the effect of moisture content on the deformation of small unconfined cylinders of clay subjected to constant unit load.(5)

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(1) Terzaghi in Engineering News-Record for November 12, 1925. Griffith in Bulletin 101 of Iowa State College, June 1931.

(2) Williams and Wing in Transactions, Am.Soc.C.E., 1929.

(3) Griffith in Bulletin 101 of Iowa State College, June, 1931.

(4) Terzaghi and Housel in Transactions, Am.Soc.C.E., 1929.

(5) Terzaghi in Public Roads for October, 1926.

His results, while not strictly applicable to foundation and footing conditions, indicate that the moisture content is an important consideration in any deformative test of soil. Apparently this fact has not been fully appreciated in connection with most tests for soil bearing values.

An example of the neglect of moisture considerations in load tests can be found in the various building codes. In the past the problem of safe bearing loads on foundations has been taken care of in the codes by giving arbitrary bearing values to different types of soils. The Los Angeles Code of 1923 and the Pasadena Code of 1926 have such provisions. Some of the newer and more advanced codes, such as the Uniform Building Code of the Pacific Coast and the proposed code for New York City, go a step further. They state that where the bearing capacity of the soil is not definitely known or is in question, load test shall be made. The procedure for conducting these tests is given in detail, but nothing is said concerning the moisture content of the soil at the time of test. The question immediately arises as to how much this important variable will affect the test. If a test is made in the spring the soil will be saturated from the winter rains, (in a California climate), and will probably not show the same results as one made in the fall after the summer drought. It was with the intent of determining the effect of moisture content on settlement, particularly as it may relate to tests for allowable bearing values, that the problem of this thesis was undertaken.

EXPERIMENTAL PROCEDURE

General Considerations

Most engineering soil research has been carried out in the field. For a test such as proposed in the Introduction to this thesis, work in the field is almost out of the question because of the enormous difficulty of realizing the main objective - moisture control. It was decided, therefore, to conduct the tests in the laboratory, while approximating as nearly as possible field conditions.

The nature of the sample used is one of the most important considerations in any laboratory test of soil. If the results of the test are to have any application to field conditions the soil in the sample should have the same structure and physical properties as that in the field. This means that the sample should be removed from the ground without being in any way disturbed, since it is almost impossible to take loosened dirt and reproduce the original granular arrangement by artificial means. It becomes a requirement, therefore, that the sample used in the proposed laboratory tests be of undisturbed natural soil.

The particular problem of these tests was that of varying the moisture content of the soil. Reduction of the percent moisture would require either the application of heat or the effect of evaporation over a long time. Such procedure would be both inconvenient and difficult to control. The moisture content can be increased comparatively easily, however, by merely introducing water to the sample. So for these tests it was decided to restrict the variation of moisture content to an increase.

Generally the footings used for structures have a soil surcharge of some height, t, above their bearing surface. Therefore the ratio t/d will usually have some value greater than zero. So if footing conditions are to be simulated in the laboratory tests there should be some method of providing a surcharge above the base of the bearing plate. Also, since the load applied to footings is due only to a stationary weight, there should be provisions for static loading of the soil in the proposed laboratory tests.

Soil Container

For the tests described in this thesis a container was built which made it possible to secure an undisturbed soil sample and furnished an easy means of creating a surcharge above the loaded surface. It was made from a piece of sixteen inch seamless steel tubing. The piece was cut into two sections, one to contain the soil sample and the other to accommodate the surcharge. The part which was made into the container proper was about twelve inches in length. A circular steel plate was welded on one end to make a bottom. In the center of this bottom a hole was bored and tapped for a half-inch pipe plug. A pair of handles was welded on the container for ease in lifting.

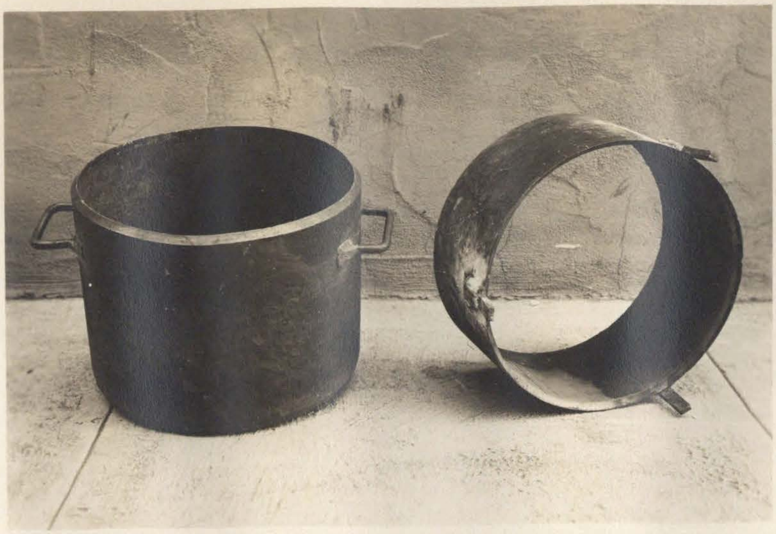


FIG. 1

FIG. 2

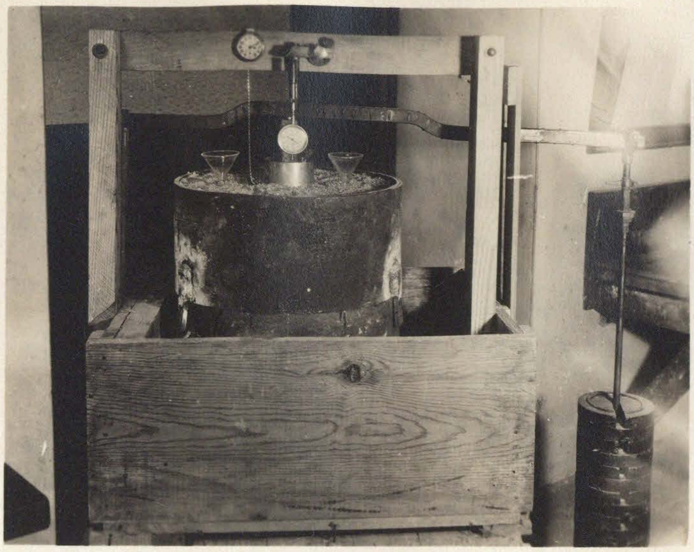


FIG. 3

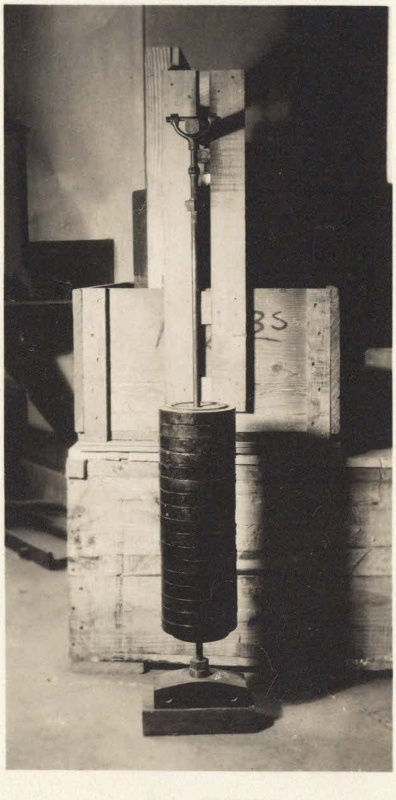


FIG. 4

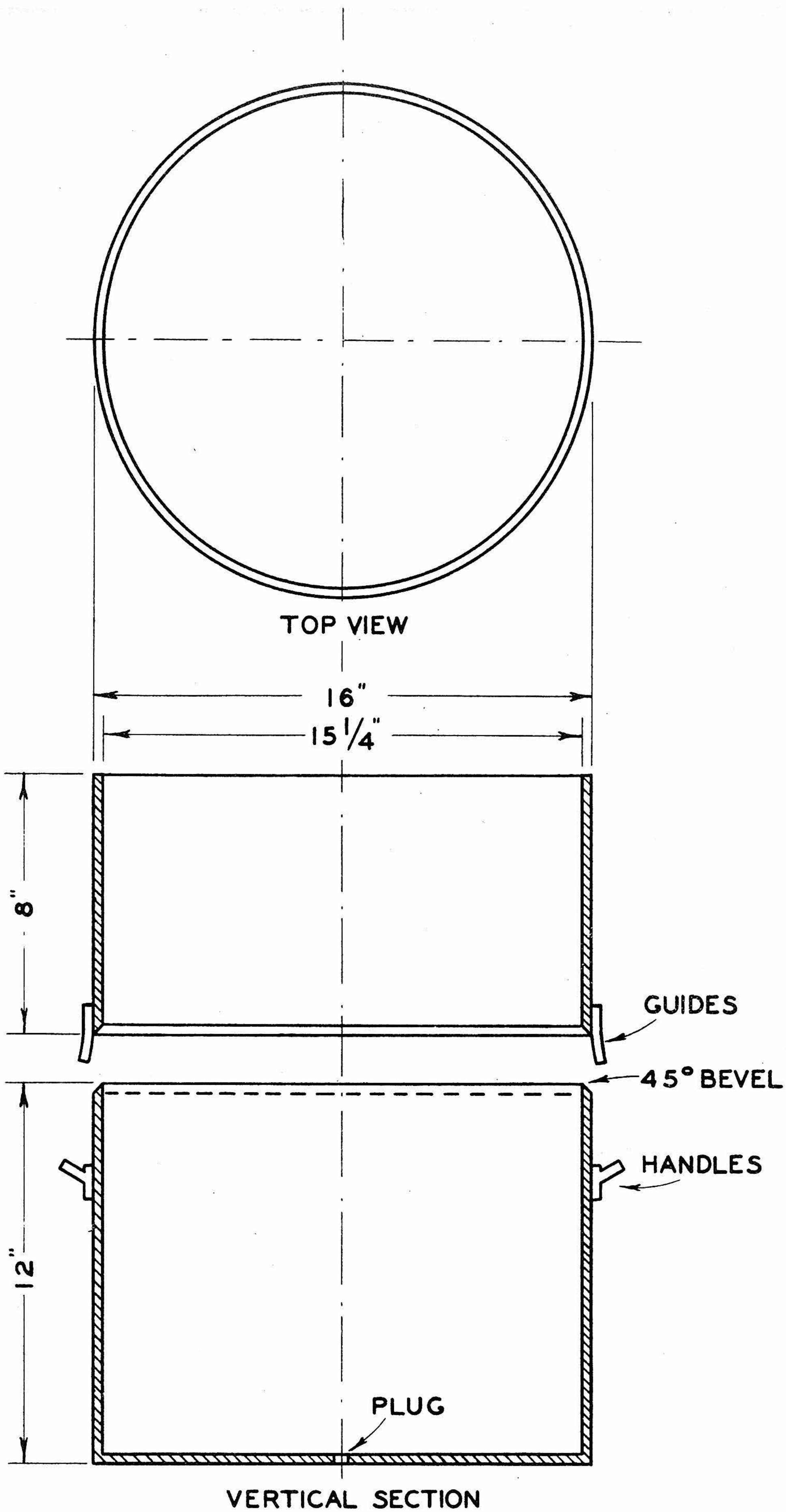


FIG. 5 - DETAIL OF CONTAINER

The remaining part of the tube, about eight inches, was made into a holder for the surcharge. Since this holder was to set upon the container proper, the contacting edges of both parts were machined to a forty-five degree bevel. This gave a nice fit, and rendered the two parts stable when set up. To facilitate setting the two parts together a few guides were welded on the surcharge holder.

Figure 1 is a photograph showing the two parts separated, while in Figure 2 they are assembled. The drawing in Figure 5 shows the container in detail with all dimensions.

Securing a Sample

Figure 6 shows the method of securing samples which was used for these tests. A hole about five feet in diameter was dug in the field at the place where the soil was to be investigated. After firm, undisturbed soil had been reached a cylindrical column of earth was allowed to remain standing in the center of the hole as digging continued. The hole was carried down until the height of the column was six inches or so greater than that of the container. As the work progressed the column was carefully trimmed so its diameter would be an inch or two greater than the diameter of the container.

When the excavation was finished the container was centered on the column in an inverted position. This brought the sharp bevel edge in contact with the soil. It was then a simple matter to drive the container down over the cylindrical column. A sledge hammer was used for

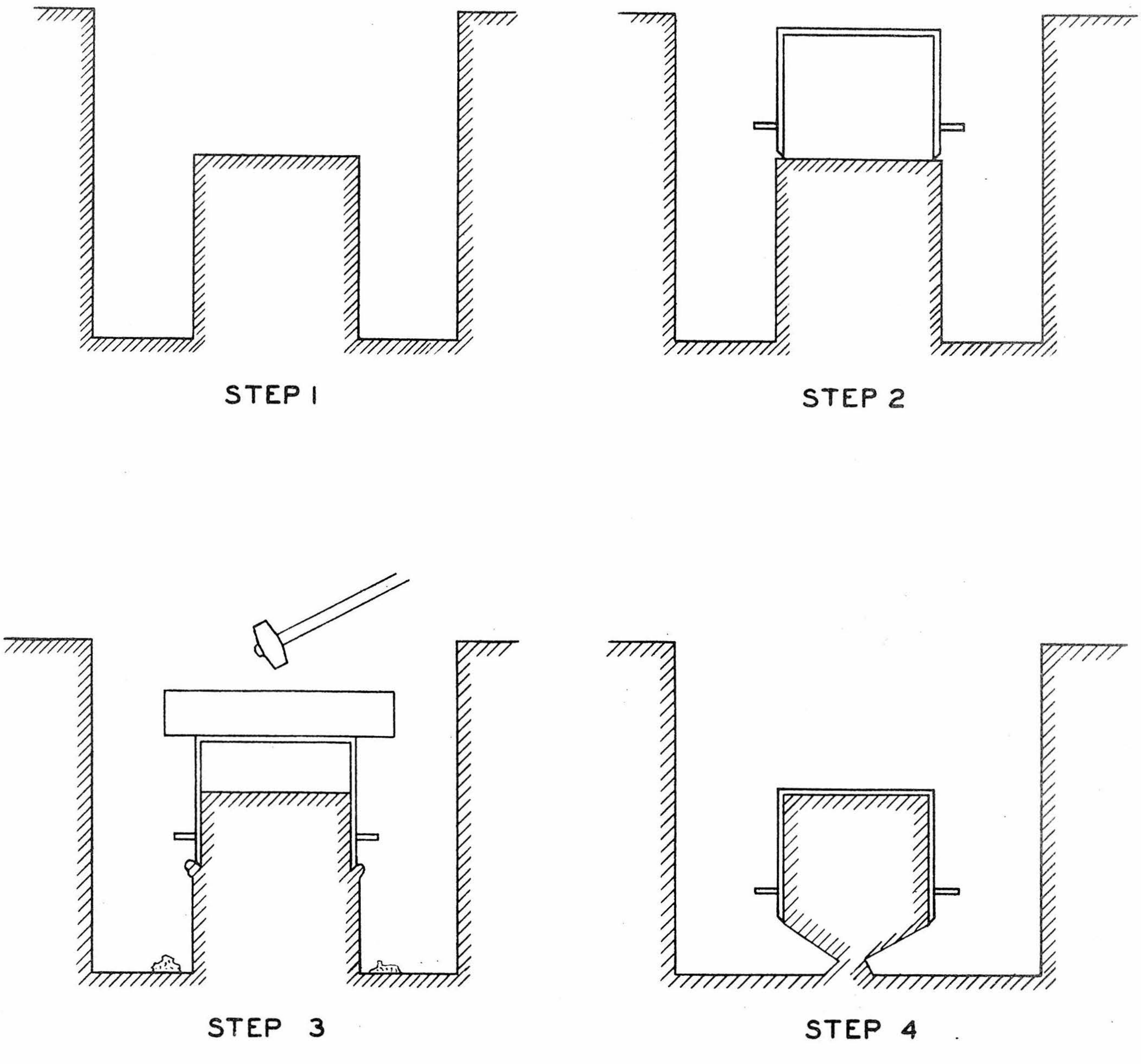


FIG 6 METHOD OF SECURING SAMPLE

the driving, and the blows were cushioned by a wooden plank. As the container worked its way down the soil directly below the cutting edge was trimmed away with a trowel so as to reduce the column approximately to size. It was possible by means of the hole in the base - which also served as an outlet for the air - to see when the container was full.

After the container had been completely driven down it was undercut, as shown in Figure 6, until it was completely detached. There then remained only the tasks of hoisting the sample out of the hole and squaring off the exposed soil surface.

There is considerable physical labor involved in getting a sample by the method outlined above. This is clearly shown by the fact that to secure a soil sample of approximately one cubic foot volume it is necessary to move a total of about three and a half cubic yards of dirt. Besides, the sample and container together are a good lift, since they weigh close to two hundred pounds.

This method of securing the soil sample is satisfactory in that the sample which goes to the laboratory is made up of soil in the identical state as that in the field. The only possible objection might be that the soil is inverted relative to what it would be in the field. However, soil is nearly enough homogeneous that inversion will probably not make an appreciable difference. Besides, a device for securing a sample which could be used without inversion would be considerably more complicated and expensive.

Moisture Control

In these soil tests, as has already been said elsewhere, the variation in moisture content was restricted to an increase which was secured by the direct addition of water. The moisture in soil can best be expressed as a percent of the dry weight. Therefore, in order to calculate the moisture content at any time during a test, it was necessary to know both the dry weight of the sample and the total weight of water present. The water added was measured by volume, so was easily expressed in pounds. The original weight of water in the sample was determined by making a special moisture test. A small sample for this purpose was taken at the same time as the large one and immediately adjacent to it. This special sample was heated in an oven at 105° C. until it reached constant weight. By noting the loss in weight the original moisture content could be calculated readily. The assumption was made that the same percentage existed originally in the large sample. Therefore, by noting the total weight of the big sample when it was taken, its dry weight and the original weight of water were easily figured.

Some difficulty was encountered in devising a method of introducing water to the sample. The first attempt was to pour water through funnels which were inserted directly into the soil. But it was found that in the stems of the funnels there was not sufficient area of soil available to permit rapid percolation, so the idea was given up.

A little further experimenting indicated that water could be readily introduced to the sample through funnels and a layer of sand spread over the soil surface. A sand was selected which passed the No. 8 Tyler Standard Sieve and was retained on the No. 10. Since some of the water introduced into the sand would undoubtedly remain, an experiment was conducted to ascertain the amount. A quantity of the sifted sand was dried in the oven to constant weight, and then placed in a large glass funnel on a piece of dampened filter paper. Water was poured through the funnel until volume measurements indicated that no more was being retained. Knowing the dry weight of the sand and the volume of water retained it was possible to figure out a "constant" for the sand. This constant gave the volume of water retained per unit weight of dry sand. So by drying and weighing the sand used in the test it was a simple matter to determine the excess water necessary to make up for that retained.

There was some question as to whether water introduced at the surface would percolate sufficiently to produce a uniform moisture content throughout the specimen. So an experiment was performed to clear up this point. A definite quantity of water was added to a sample of soil through a layer of sand at the surface. Twenty-four hours later tests were made for moisture content at a number of points across a diameter and at different depths. It was found that the percentage moisture was practically uniform throughout the specimen. There was a slight difference at different depths, but nothing to indicate a definite trend one way or the other. In fact, the variation with depth was no more than the variation across a diameter. So the assumption of uniformity of moisture content was made throughout these tests.

Preparation of Sample for Test

Figure 7 shows the sample as it was prepared for a test. The soil was removed down to a point about an inch below the top of the container. The new surface was smoothed and leveled. Then the bearing plate was centered on this new surface. A tin pipe which fit over the bearing plate was used to keep the surcharge in place. The pipe came down flush with the soil surface. It was 3-5/8 inches in diameter and about ten inches high.

The special sifted sand was placed in a layer about three quarters of an inch deep on the soil surface, after it had been dried and weighed. The stems of three glass funnels were inserted in the sand. The funnels were located as shown in Figure 7. Small vent pipes were provided to carry off the displaced air in the sand.

It was necessary to provide a water tight seal between the sand layer and the surcharge above, so there would be no loss of water through capillary action. This seal was furnished by a layer of paraffin which was applied in the molten state. Filter paper was placed on top of the sand to keep the hot paraffin from working into it. To keep the paraffin from leaking into the sand around the edges of the filter paper or through the funnel holes, special putty seals were provided at these places.

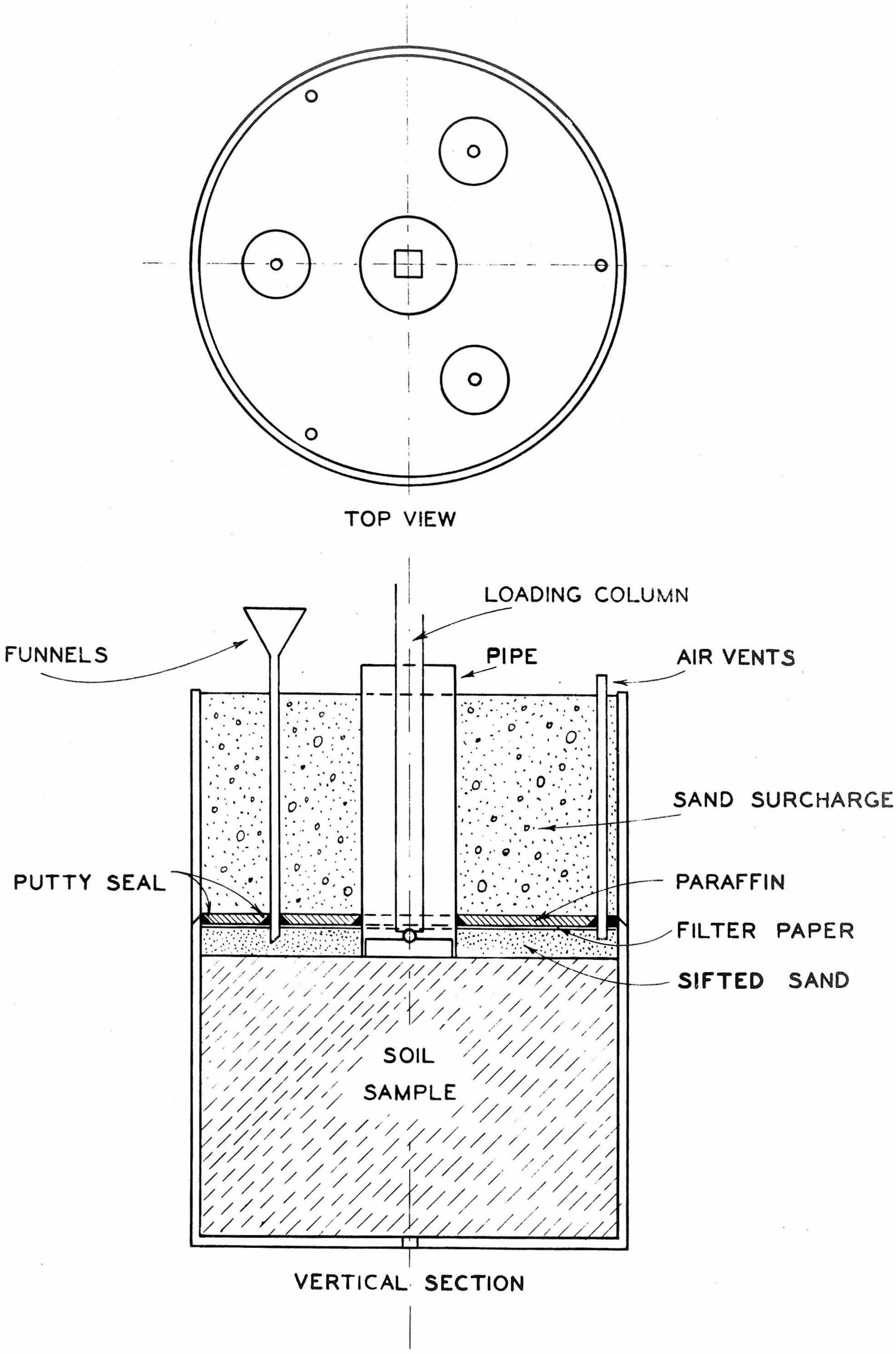


FIG. 7 - PREPARATION OF SAMPLE FOR TEST

After the paraffin had hardened the surcharge holder was set in place and the surcharge applied. The effect of weight is all that the surcharge supplies, so it does not have to be the same material as the test specimen. In these tests ordinary sand was used.

Loading System

Since a static load was necessary for the test it was out of the question to use an ordinary testing machine for the loading device. A lever system was finally adopted. The drawing in Figure 8 shows the details of the system.

The essentials of the system are: the lever, the weights, the loading column, and the bearing plate. The lever has an effective length of 36-3/4 inches, and is free to rotate about a knife edge at one end. Load was provided for the loading column, 12-1/4 inches from the knife edge, by means of weights suspended from the other end. Since the ratio of lever arms is 3 to 1, the effect of the weights is tripled. The load is carried through the column to the bearing plate, where it is distributed to the soil.

The lever was made from a one inch square reinforcing bar. In the region of the contact with the loading column the bar is offset an inch upwards to give more stability under the existing forces. The knife edge at one end bears against a rigid surface. The other end is V-notched to carry a holder for the weights.

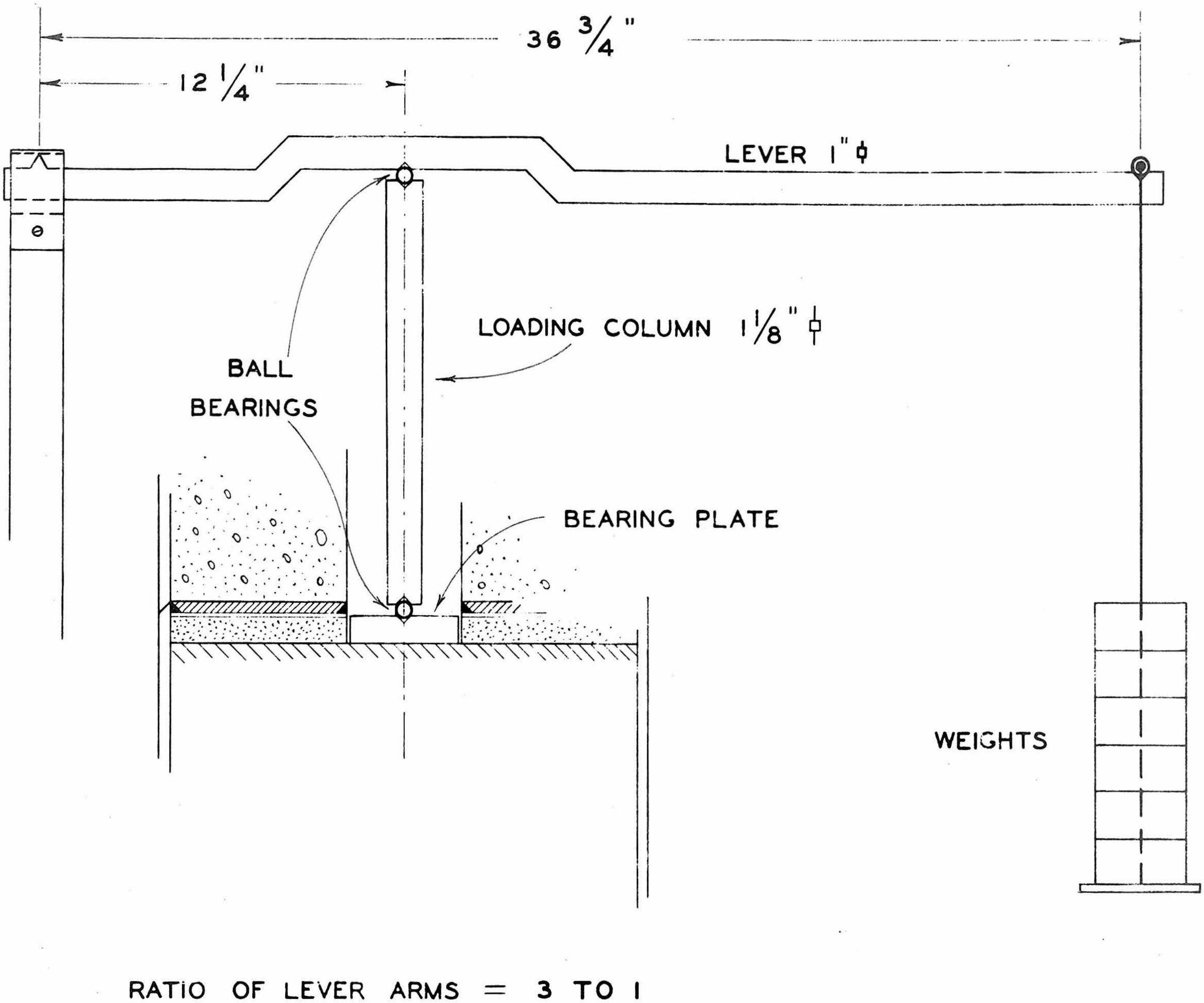


FIG. 8 DETAIL OF LOADING SYSTEM

The weights were of the type ordinarily used with platform scales. They weighed five pounds each and were slotted to fit around the holder. A short rod resting in the notch or the lever carried the holder.

The loading column was made from a piece of 1-1/8 inch reinforcing steel. It is about 12 inches long. Its contact with the lever arm and the bearing plate is through ball bearings which seat in conical holes.

The bearing plate is shown in detail in Figure 10. It is a steel disk 3-1/2 inches in diameter. The area is 0.066 sq. ft.. A unit load of 4000 lbs. per sq. ft. was desired on the soil so the total load transmitted to the bearing plate had to be 267 lbs.. Since the lever ratio is 3 to 1, 89 lbs. of weights were required at the end of the lever. Seventeen weights and the holder just made the 89 pounds.

A supplementary device used was the screw jack shown in Figure 11. This jack was placed under the weights, and whenever it was desired to relieve the load on the soil the weights were raised slightly.

Device for Measuring Settlement

The device consisted essentially of an Ames dial and a micrometer screw. The dial was rigidly attached to the loading column by means of brackets. The micrometer was located above the dial, and was carried from a fixed beam. Adjustments could be made so the piston of the micrometer contacted the buttom of the dial. Then as the bearing plate and loading column settled, the dial was carried down relative to the

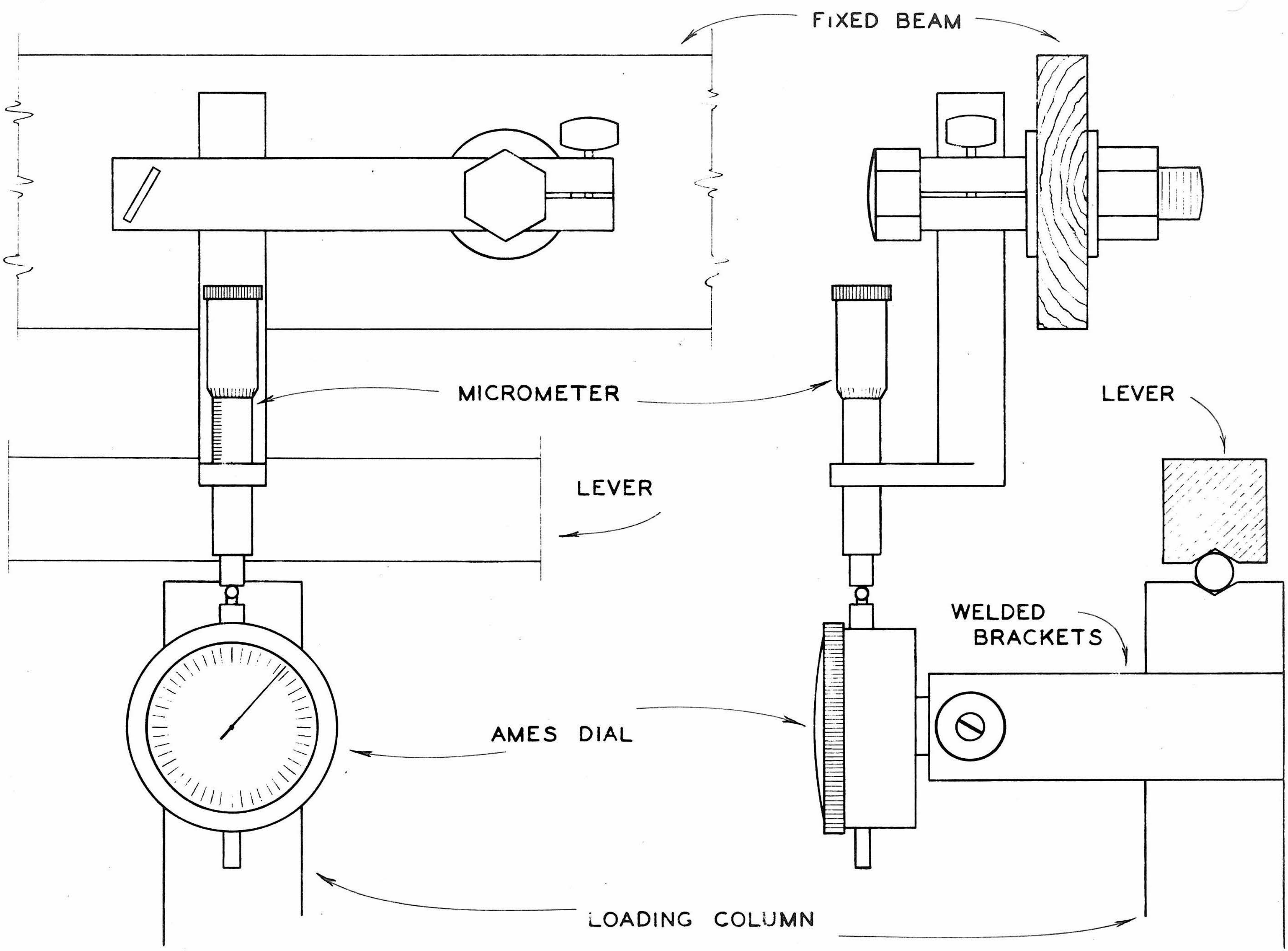
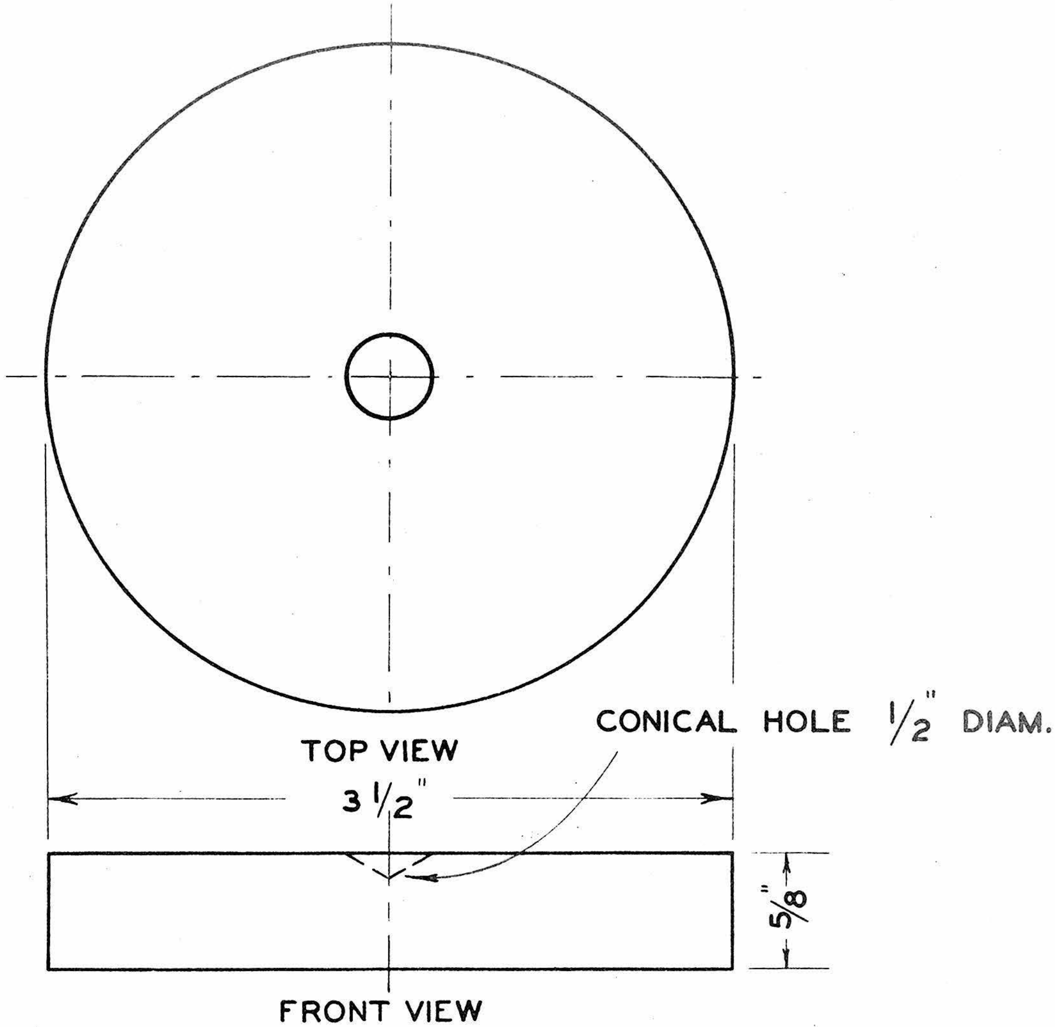


FIG. 9 DEVICE FOR MEASURING SETTLEMENT



AREA = 9.6 SQ. IN. = 0.0665 SQ. FT.

FIG. 10 - DETAIL OF BEARING PLATE

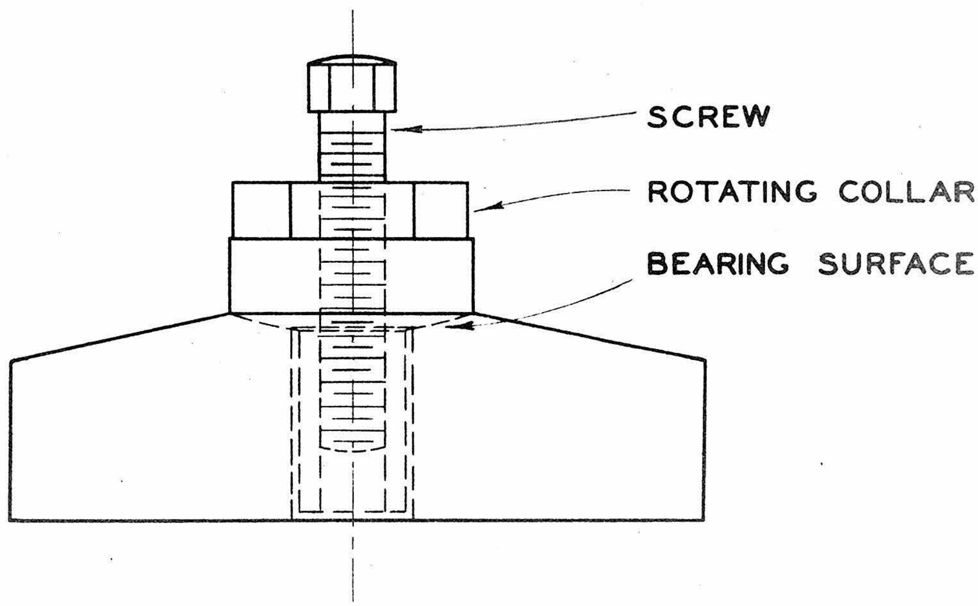


FIG. 11 - DETAIL OF JACKING DEVICE

micrometer, which remained fixed. Therefore, the dial recorded the settlement.

As the settlement neared the capacity of the dial, the button could be moved down by turning the micrometer, and the whole dial range again made available. This process could be repeated until the capacity of the micrometer was reached. The total range made available by this method was 1.3 inches.

The drawings in Figure 9 show the system in detail. The device for securing vertical and horizontal adjustment of the micrometer is shown clearly.

The Ames dial read directly to thousandths of an inch and had a capacity of .3 inch. The micrometer also read to thousandths of an inch directly, and its capacity was one inch.

Classification of Soil

It was noted in the Introduction to this thesis that the type of soil is one of the most important factors influencing any engineering soil test. This means that a definite basis of classification must be adopted if the tests are to mean anything.

The Bureau of Public Roads has evolved a method of classification based on mechanical analysis and rigid definition.[1] The analysis is

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(1) "Highway Subsoils". Transactions, Am.Soc.C.E., 1930.

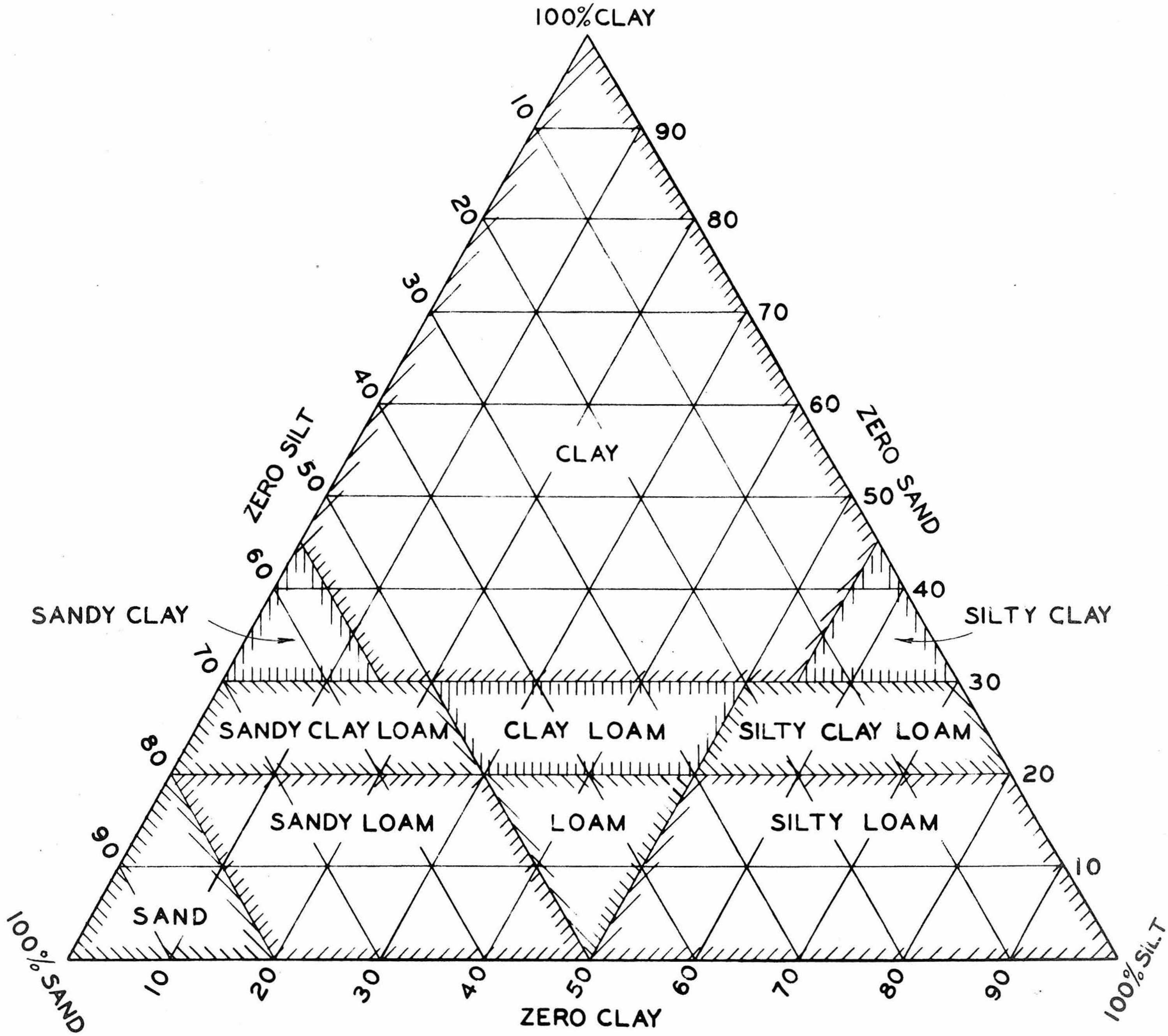

FIG. 12-TRILINEAR SOIL CLASSIFICATION CHART

made to determine the percentages by weight of sand, silt, and clay in the soil. These percentages are then plotted on a trilinear chart, such as shown in Figure 12. The plotted point will fall within one of the regions on the chart arbitrarily assigned to a certain kind of soil, and the classification is thereby made.

The mechanical analysis of the soil was based on the A.S.T.M. Standards.(1) Clay was taken as that part of the soil which would not settle out through 8 centimeters of water in 8 minutes. Of the soil which did settle out, that passing the 200 mesh Tyler Standard Sieve was taken as silt, and that retained on the sieve was taken as sand. The percentage of each constituent was based on the dry weight of the soil.

Test Procedure

The samples were secured and preparations made for tests as outlined above. The particular values wanted from the tests were the readings of final settlement for each moisture content. Since it required very little additional effort, it was decided to observe also the time rate of settlement.

Settlement was allowed to proceed and readings were taken only when the moisture content was uniform throughout the sample. So the

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(1) "Mechanical Analysis of Subgrade Soils". A.S.T.M., Serial D137-22T (1922).

tests had to be interrupted periodically while water was being added. During this period, and until uniform moisture conditions again existed, the load on the soil was relieved. The jack previously described was used to secure this effect. The weights at the end of the lever were gradually raised by the jack until a backward movement of about one thousandth of an inch was recorded on the Ames dial. When this point was reached sufficient load had been removed so no settlement would occur, yet enough remained to prevent rebound. The jack was left in place for twenty-four hours, which was sufficient time for percolation to produce a uniform distribution of moisture throughout the sample.

For each moisture content settlement readings were taken with time. The time interval was one minute at first, when the settlement was rapid, and was gradually lengthened as the settlement became slower and slower. The settlement was considered to be complete for a particular moisture content when not more than a thousandth of an inch occurred in twelve hours.

The first moisture content was, of course, that originally present in the sample. After settlement was complete for this first condition, the load was jacked up and the calculated increment of water added to the sample. In addition, enough water was added to allow for that retained by the sand layer. Twenty-four hours later the jack was lowered, and time settlement data were taken for the second moisture content. Then when settlement was complete the jack was inserted, the water added, and the whole procedure repeated. The process was carried on until the limit of the micrometer and Ames dial was approached, or until time warranted the cessation of the test.

The water was added to the sample slowly, usually in doses spaced about fifteen minutes apart. Each dose consisted of approximately 50 c.c. per funnel.

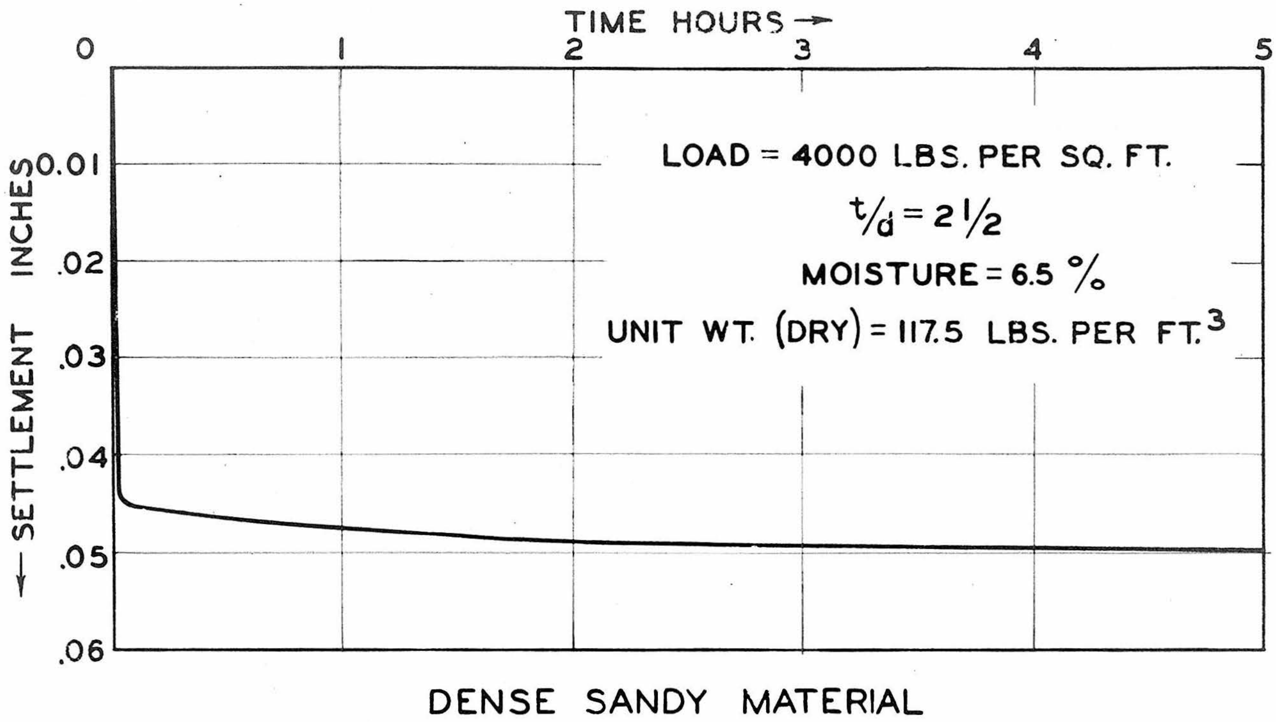
Time settlement data were usually taken starting at one o'clock in the afternoon. By 6:00 P.M. the settlement had usually slowed down sufficiently to permit of taking the next reading the following morning.

EXPERIMENTAL RESULTS

Two complete tests were conducted, one on a sandy loam and the other on a clay loam. It was found that in general settlement took place more rapidly with the former than with the latter. Figure 13 shows comparative time-settlement curves for the two materials. It can be seen that for sandy loam the greatest part of the settlement takes place during the first five minutes, and that after that time settlement is almost negligible. In the case of clay loam a large part of the settlement also takes place during the first five minutes, but not such a large percentage as was true for sandy loam. It can also be seen that for clay material the settlement continues at an appreciable rate for an hour or so after the very fast settlement of the first five minutes. At the higher moisture contents the difference in settlement rates for the two materials is more marked.

Curves were plotted to show the relation of time, settlement, and moisture. The curve for sandy loam is shown in Figure 14, and that for clay loam in Figure 15. Due to the limitation of space, it was possible to plot only the first hour's settlement for the lower moisture contents. Of course in all cases there was some settlement after the first hour. It was neglected for these curves, however, since they were only intended to aid in visualizing the time-settlement relation for progressively greater moisture contents.

The curve for sandy loam, Figure 14, shows that a considerable settlement occurs when the load is applied at the first moisture con-



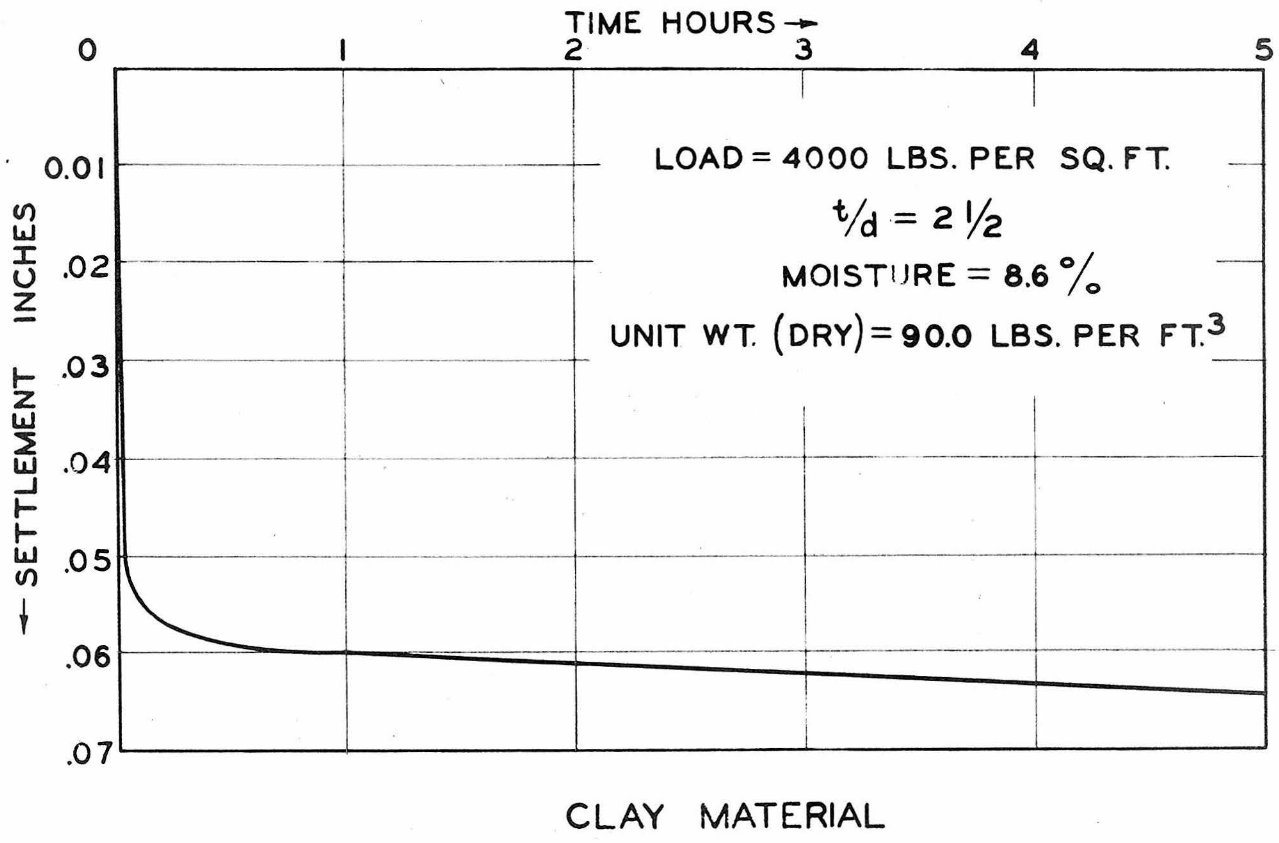


FIG. 13 TYPICAL TIME SETTLEMENT CURVES

tent. For the succeeding moisture contents the settlement increases in small but nearly uniform steps. More settlement seems to take place after the first few minutes for the higher moisture contents than for the lower. This is probably due to the small amount of clay in the material being rendered plastic by the moisture.

Figure 15 shows that for clay material the amount of settlement gets larger for each successive moisture content. For the last moisture content - 13% - the amount of settlement is much greater than for any other, being, in fact, nearly twice the entire previous settlement. The curve also shows that as the moisture content increases more settlement tends to take place after the first few minutes, until at 13% more than half the settlement takes place after the first ten minutes. This greater but less rapid settlement is due to the increased plasticity of the clay at the higher moisture contents.

The moisture-final settlement curves are shown in Figures 16 and 17. For the sandy material it is seen that over the range of the test the settlement was proportional to the moisture, thereby giving a straight line. The clay material, on the other hand, shows an entirely different behavior. The curve is concave downward from the start, indicating that greater than proportional settlement occurs for succeedingly higher moisture contents. At about 12% the curve begins to drop down rapidly, indicating a rather sudden softening of the material. Terzaghi observed a similar phenomenon in his tests of clay cylinders.[1] He calls the moisture content at which the material begins to deform rapidly the "plastic limit".

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(1) Terzaghi in Public Roads, October, 1926.

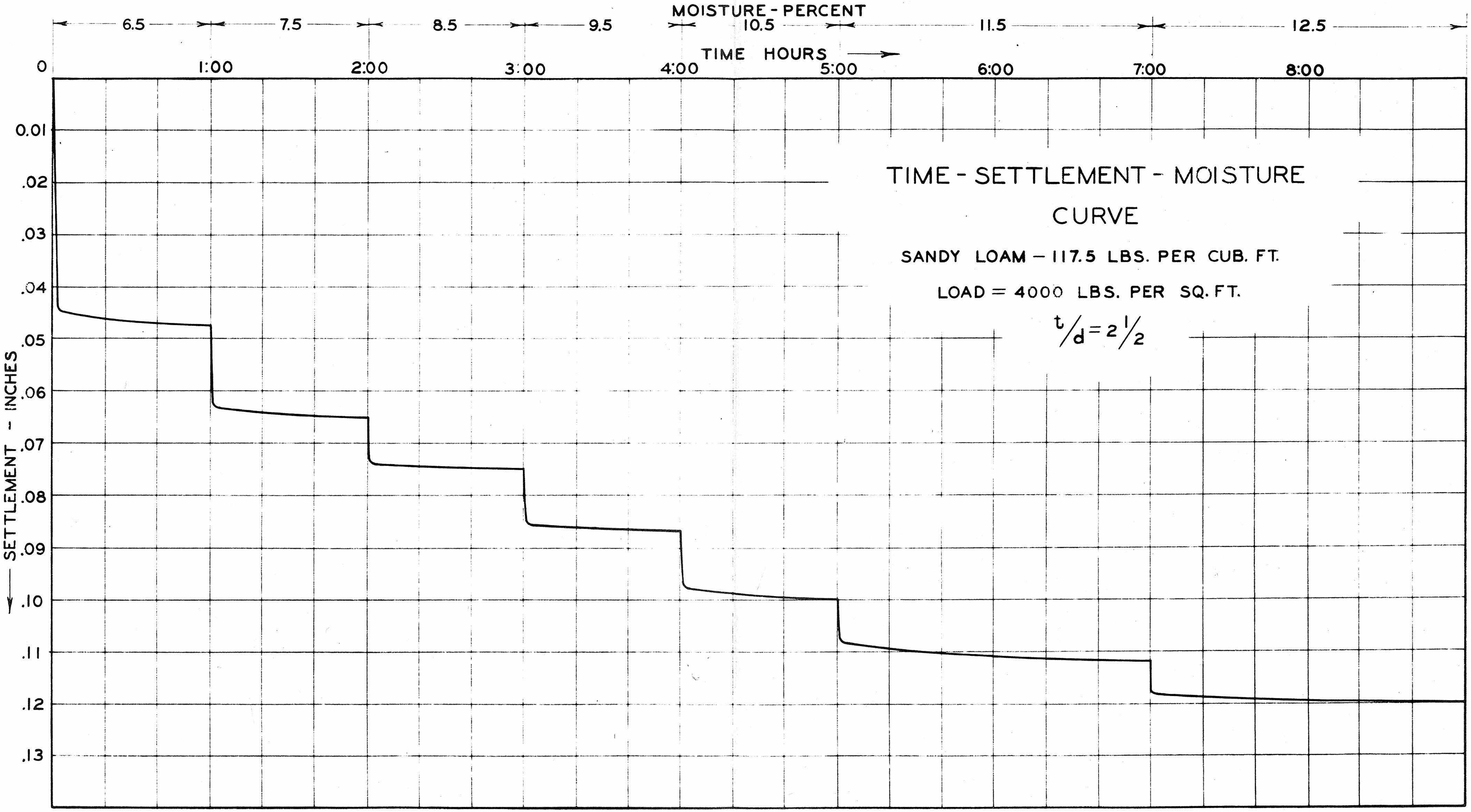
MOISTURE - PERCENT
6.5
7.5
8.5
9.5
10.5
11.5
12.5
TIME HOURS
0
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
0.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11
.12
.13
SETTLEMENT - INCHES
TIME - SETTLEMENT - MOISTURE CURVE
SANDY LOAM — 117.5 LBS. PER CUB. FT.
LOAD = 4000 LBS. PER SQ. FT.
t/d = 2 1/2

FIG. 14

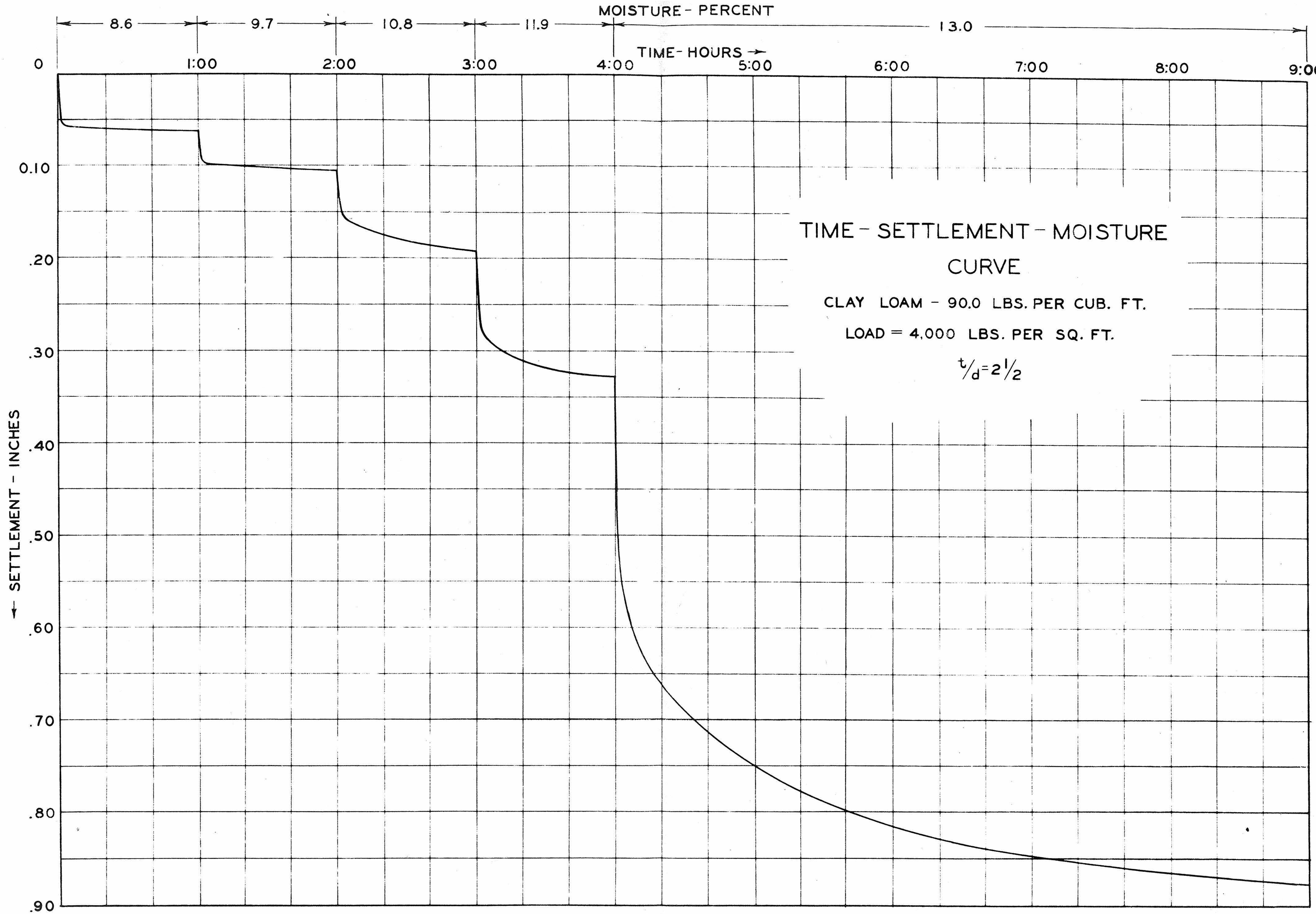
MOISTURE - PERCENT
8.6
9.7
10.8
11.9
13.0
TIME - HOURS
0
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
SETTLEMENT - INCHES
0.10
.20
.30
.40
.50
.60
.70
.80
.90
TIME - SETTLEMENT - MOISTURE CURVE
CLAY LOAM - 90.0 LBS. PER CUB. FT.
LOAD = 4,000 LBS. PER SQ. FT.
t/d = 2 1/2

FIG 15

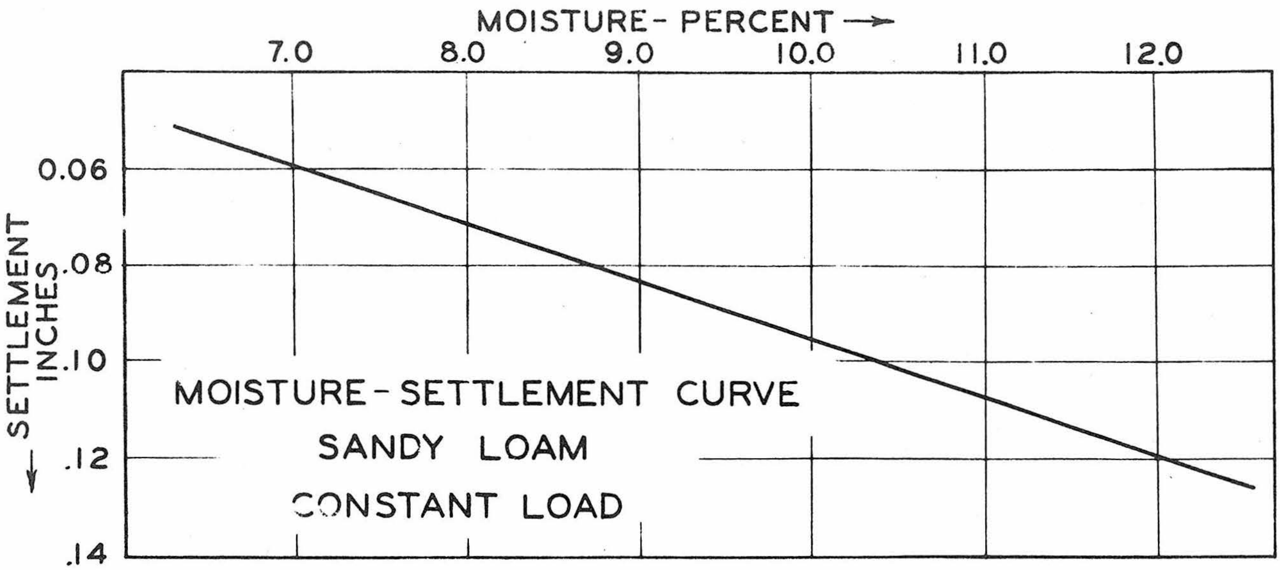
MOISTURE- PERCENT →
7.0
8.0
9.0
10.0
11.0
12.0
0.06
.08
.10
.12
.14
← SETTLEMENT INCHES
MOISTURE - SETTLEMENT CURVE
SANDY LOAM
CONSTANT LOAD

FIG. 16

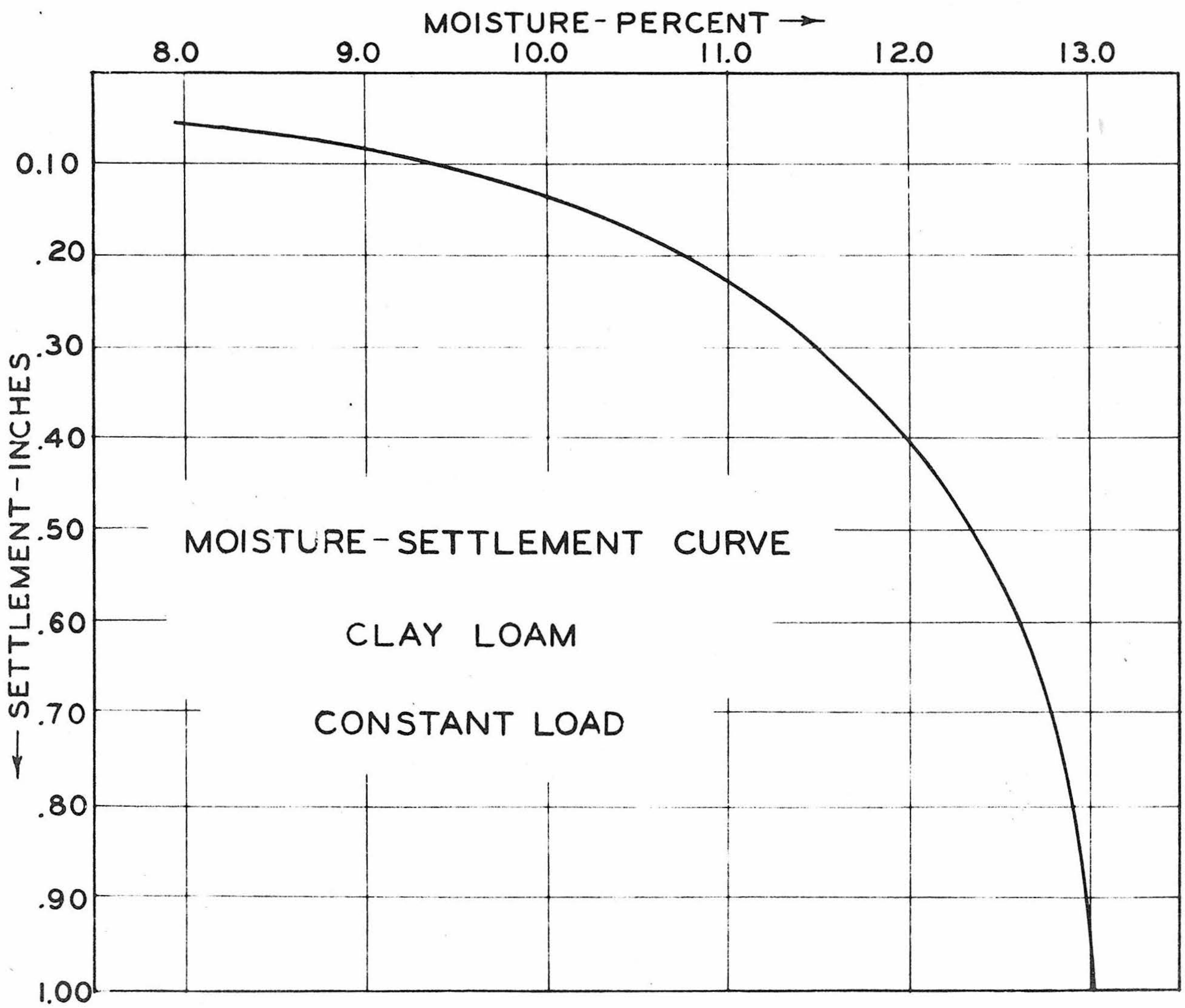
MOISTURE- PERCENT →
8.0
9.0
10.0
11.0
12.0
13.0
0.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
← SETTLEMENT - INCHES
MOISTURE - SETTLEMENT CURVE
CLAY LOAM
CONSTANT LOAD

FIG. 17

CONCLUSIONS

From the results of these tests the following conclusions can be drawn:

1. The moisture content of soil has an important effect on settlement of the soil under load.

2. An increased moisture content causes an increased settlement under a constant load.

3. For sandy soil the increase in settlement is approximately proportional to the increase in moisture content.

4. For clay soil the settlement increases at a rate more rapid than the increase in moisture content.

5. A moisture content is finally reached for clay soils where settlement increases enormously. This is called the "plastic limit". A one percent increment in moisture content near this point will result in an increase in settlement which may be double the entire previous settlement.

6. Settlement in general takes place very rapidly in sandy soil. Most of it occurs during the first five minutes.

7. In clay soil settlement is less rapid than in sand. More settlement takes place after the first five minutes, and as the moisture content increases this effect becomes more pronounced.

The results of this thesis show that the moisture content of soil is of considerable importance in soil testing. Tests performed in strict accordance with building codes could give widely different results for a particular soil, depending upon the moisture content. For instance, it was found that with clay soil a load of 4000 lbs. per sq. ft. would produce almost three times as much total settlement at 13% as at 12%. According to the proposed New York Code, which rules out a soil that settles more than an inch under the specified load, it would be entirely possible for a clay soil to be satisfactory at one moisture content and quite unsatisfactory at one a little higher. In the light of the above facts, it would seem wise to require moisture determinations in connection with all tests for allowable bearing values of soils. The moisture content at the time of test should then be compared to the maximum likely to occur before arriving at a bearing value.

A foundation condition could easily occur under a completed building that approximates closely that of the tests described in this thesis. The footings of the building might easily be placed during the summer or fall months. A certain initial settlement would take place corresponding to the existing moisture content. Then during the winter and spring months the moisture content of the soil under the exterior footings would be increased by the rains and additional settlement would occur. Since the soil under the interior footings would not be so affected, the additional settlement would not take place at such places. The final result would be differential settlement of interior and exterior footings. This condition will cause considerable moments in the building frame above. Mr. M. P. White in a thesis[(1)] has found that differential settlement of 1/4 inch produces moments in the frame approximately of the same magnitude as dead or wind loads. So the effect of moisture in the soil is not negligible.

The possibilities in the field of soil research have barely been touched up to the present. Under the leadership of such men as Terzaghi a start has been made, and it is to be hoped that in the future work will be continued.

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(1) "Primary and Secondary Moments in a Building Bent Due to Footing Settlement", California Institute of Technology, 1932.

MISCELLANEOUS INFORMATION

General

Weight of container	=	73.1 lbs.
Volume of container utilized	=	1.11 cu. ft.
Area of bearing plate	=	9.6 sq. in. = 0.066 sq. ft.
Unit load on soil	=	4000 lbs. per sq. ft.
Total load on soil	=	267 lbs.
Load at end of lever	=	89 lbs.
Ratio of lever arms	=	3:1
Sifted sand used		Passes #8 sieve, Retained on #10.
Constant for sand	=	28.4 c.c. water per pound.
Capacity of Ames dial	=	.3 inch.
Smallest scale division of Ames dial	=	.001 inch.
Capacity of micrometer	=	1 inch.
Smallest scale division of micrometer	=	.001 inch.

Oven used was thermostatically controlled to within one degree Centigrade.

Temperature for all moisture reduction tests was 105° C.

Constant weight was assumed when the loss of weight in one hour was less than 0.1%.

Tyler Standard Sieves were used with Ro-Top Machine, which was operated ten minutes for a test.

Test of Sample No. 1.

Analysis:

Clay	=	15%
Silt	=	8%
Sand	=	77%
Classification		Sandy loam.
Unit weight dry	=	117.5 lbs. per cu. ft.
Original weight of sample	=	139.0 lbs.
Original moisture content	=	6.5%
Final moisture content	=	12.5%
Increment of moisture	=	1% = 600 c.c.
Weight of sifted sand used	=	5.3 lbs.
Excess water added	=	150 c.c.
Unit load applied	=	4000 lbs. per sq. in.
Shape of bearing plate		circular.
Diameter of bearing plate	=	3-1/2 inches.
Value of t/d	=	2-1/2
Total settlement	=	.122 inches.

Test of Sample No. 2.

Analysis:

Clay	=	29.2%
Silt	=	30.3%
Sand	=	40.5%
Classification		Clay loam.
Unit weight dry	=	90 lbs. per cu. ft.
Original weight of sample	=	108.6 lbs.
Original moisture content	=	8.6%
Final moisture content	=	13.0%
Increment of moisture	=	1.1% = 500 c.c.
Weight of sifted sand used	=	5.3 lbs.
Excess water added	=	150 c.c.
Unit load applied	=	4000 lbs. per sq. in.
Shape of bearing plate		circular.
Diameter of bearing plate	=	3-1/2 inches.
Value of t/d	=	2-1/2.
Total settlement	=	.966 inches.