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MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

INVESTIGATION OF THE INFLUENCE OF SOIL PARTICLES PASSING THE NUMBER 200 SIEVE (0.074 mm.) ON THE STABILIZATION OF GRAVEL

Roy J. Leonard

Conducted by Testing and Research Division in
Cooperation with the Civil Engineering Department
Michigan State University

Highway Research Project 54E-14
Progress Report No. 1

Research Laboratory
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W. W. McLaughlin
Testing and Research Engineer

This is a progress report of an investigation to determine the influence of soil particles passing the No. 200 sieve on the stabilization of gravel. The investigation was suggested by Mr. Olaf Stokstad of the Michigan State Highway Department.

The report presents the history and nature of the problem and discusses the results of tests performed on two types of "B" horizon soils which were treated to vary the characteristics and quantity of the organic material contained in the 200 plus fraction.

The work was performed by Mr. Roy J. Leonard, a graduate student, as a partial requirement for his Master's Degree. Mr. Leonard resigned from his assignment on June 10, 1955 to enroll at Iowa State College and thus was only able to complete a portion of the originally planned work.

The project was under the supervision of the Highway Research Laboratory in cooperation with the Civil Engineering Department of Michigan State University. Dr. J. R. Snell, head of that department, generously agreed to furnish the necessary laboratory space and soil testing equipment. Dr. T. H. Wu, Mr. Leonard's major professor, was assigned to the project to act in a consultatory capacity on various phases of the academic and laboratory work.

E. A. Finney
Ass't. Testing & Research Engineer
in Charge of Research

INVESTIGATION OF THE INFLUENCE OF SOIL PARTICLES PASSING THE NUMBER 200 SIEVE (0.074 mm.) ON THE STABILIZATION OF GRAVEL

This is a progress report of an investigation to determine the effect of natural organic material passing the Number 200 Sieve on mineral soil passing the Number 200 Sieve.

Principal Objectives:

1). The determination of the effect of natural organic material on the Atterberg limits and indices, compaction and various strength characteristics of a soil.

2). Establish a criterion for allowable amounts of organic material in soil binders.

3). Investigate testing procedures for the determination of the amount and presence of organic matter in the soil.

Discussion of Problem and History -

The "B" horizon of most soil series offers a ready source of material for the mechanical stabilization of gravel. However, due to leaching, the "B" horizon may contain organic material which, generally, is thought to be detrimental to the strength of the stabilized soil mass.

Since most laboratory specifications require oven drying of the soil, which may destroy all of the effects of the organic material on the physical properties of the soil, the presence of organic material is frequently not detected. If organic matter is detected its exact effect on the properties of the soil is uncertain.

Soil organic matter consists of any substance or organic origin, living or dead, encountered in the soil. Frequently soil organic matter is spoken of as humus, although technically humus is only a portion of the total organic matter of the soil.

According to Joffe (20), "Humus is the dark brown-black organic matter that has undergone decomposition to such an extent that one can no longer determine by inspection the nature of the material from which it was derived." For the most part humus is of the greatest concern in the investigation of soil organic matter in connection with the physical properties of soil. Humus consists essentially of: 1) Waxes and resins; 2) Humic acids; 3) Fulvic acids, also called crenic and apocrenic acid; and 4) Residual organic matter which represent humic acids that are more oxidized and appear in the form of stable combinations with the mineral portions of the soil--this group is frequently termed humin. Humic acids are the most characteristic group of soil organic matter.

Strahan (37), (38), reported on some of the construction factors of "top soil", or soil containing organic matter. The work of Strahan, however, was done before the advent of modern soil classification and testing procedures. Reports on the investigations of the physical relationships of mineral-organic matter soils are meager. Actually the reports of only two investigators are worth note. Baver (5) (6) investigated the effect of organic matter upon mineral soil in connection with the Atterberg consistency constants and various physical tests used in Agronomy. Baver's conclusions were:

> "It has been observed in a study of the plasticity constants of different soil profiles that the upper and lower plastic limits of the surface horizons are always fairly high on the moisture scale when compared with the other horizons of the profile. The presence of organic matter with a relatively high absorptive capacity for water was responsible for these high plastic limits..............It is evident that organic matter raises both plastic limits on the moisture scale. Removal of organic matter, however, does not affect the plasticity number to any great extent, although there is a tendency towards a decrease in plasticity."

Baver used various soils containing natural organic matter in his tests, the amounts being determined by the oxidation of the organic matter with hydrogen peroxide. The nature of the organic matter in the individual soils was not determined. According to Puri and Sarup (29) the hydrogen peroxide method for the determination of the amount of organic matter is ineffective and, hence, is unreliable. Casagrande (8) also investigated various factors effecting the Atterberg indices by complying test results for various types of soils. Casagrande (8) presented his results in the graph shown in Figure 1.

Various relationships between organic matter and mineral soils have been investigated by soil scientists, but invariably, they are of little direct consequence to the engineering properties of organic soils. Some of the work on the analyses and determination of organic matter found in the soil is of much interest, however.

Procedure -

Essentially the procedure was to separate the mineral soil constituents less than 0.074 mm. diameter from several "B" horizon soils, add various percentages of a natural organic material and to test them using various engineering testing procedures.

Two types of "B" horizon material were used, the terms 1H-2H and 1K-2K were used for convenience of identification. One of the "B" horizon soils was altered by adding a bentonite with a sodium ion complex, this mixture was termed 1M-2M.

The organic material used throughout the test was a humic acid ($C_{12}H_8O_6 + H_2O$) produced from a peat. The procedure for producing humic acid is as follows: Place the peat in a container and saturate with a 2 % sodium hydroxide solution. Stir the suspension well, allow to stand overnight, heat and then filter off the soluble organic matter slowly, add 0.1N HCl until flocculation occurs. Filter off the flocculated suspension and wash with water until free of chlorides. The gelatinous colloid is humic acid. Humic acid should not be allowed to become dry during or after the filtering. Humic acid was used since it is characteristic of natural organic matter found in the soil, it is of colloidal size and can be easily dispersed in a mineral soil and it can easily be reproduced for use in different mineral soils.

The "B" horizons soils were wet-sieved to obtain the material passing the Number 200 Sieve (0.074 mm.). The fine material was air-dried to a plastic consistency before mixing. The grain size distribution curves for the soils used are shown in Figure 2.

The bentonite used in one soil sample was obtained from the American Colloid Company of Chicago, Illinois, the trade name used for the bentonite used is 325 Volclay.

Due to the nature of the material tested, all samples were mixed in a semi-saturated state, this also facilitates the mixing of the materials. After athorough mixing, the mixtures were allowed to air-dry to a plastic consistency.

The mixtures were subjected to the following tests:

1). Atterberg limits, all samples

2). Moisture-density, as indicated

3). Tri-axial shear, as indicated

4). Infrared spectra study, as indicated

5). Oxidization with various chemical compounds, as indicated

The results from the above tests have been summarized in Table I.

It will be noted from the grains size distribution curves in Figure 2 that the two soils tested are in the same range, the silt range of grain sizes, however the manner in which they are distributed are far different. The 1H-2H is well distributed over the silt range. The 1K-2K soil consists of predominately the same grain size, consider 60 percent of the grains being about 0.02 mm. in diameter. The difference in the initial Atterberg limits of these two soils may be noted in Table I. The differences between the Atterberg limits of the two soils thus is due to the surface characteristics and grain size distribution of the grains.

Infra-red Studies

From infra-red spectra studies it was concluded that the mineral constituents of the two soils were essentially the same.

Infra-red spectra studies of the two soils, to determine the organic content were performed, but due to the high iron oxide content of the soils the presence of organic matter could not be determined.

TABLE 1

SUMMARY OF TEST RESULTS ON SOIL SAMPLES

SOIL 1H-2H - ATTERBERG LIMITS AND INDICES

Assumed % Organic	Computed % Organic	Liquid Limit	Plastic Limit	Plasticity Index	Shrinkage Limit
0	0	26.5	22	4.5	18.8
1/4	0.24	30	23	7	21.9
1/2	0.49	32	24	8	22.0
1	1.07	35	25.5	9.5	25.0
2	2.14	39	27.5	11.5	22.9
4	3.98	43.5	31	12.5	23.5
8	6.68	54	34.5	19	25.5
8	8.85	58.5	35	23.5	27.1

1K-2K + ORGANIC MATERIAL - ATTERBERG LIMITS AND INDICES

Assumed % Organic	Computed % Organic	Liquid Limit	Plastic Limit	Plasticity Index	Shrinkage Limit
0	0	47	21.5	25.5	12.0
1/2	0.55	48.5	23.0	25.5	12.5
1	1.39	49	25.0	24.0	12.5
2	2.21	52	26.5	25.5	14.0
4	4.50	64.5	27.5	37.0	16.5
8	8.87	76.5	35.0	41.5	15.5

1H-2H + ORGANIC MATERIAL - STRUCTURAL TESTS

Assumed % Organic	Computed % Organic	Max. Density #/Ft.^{3}	Opt. Moisture %	Internal Friction Degrees	Cohesion #/Ft.^{2}
0	0	110.7	17	30	17
1/4	0.24	110.5	17	28	17.5
1/2	0.49	110	17	26	16
1	1.07	109	17	24	16
2	2.14	108	17.5	25	18
4	3.98	101.8	20	--	--
8	8.95	94.5	24.5	22	19

Note: Harvard test used for density test - 5 layers, 25 blows/layer.

1M-2M + ORGANIC MATERIAL (1M-2M = 1K-2K + 20% BENTONITE) ATTERBERG LIMITS AND INDICES

Assumed % Organic	Computed % Organic	Liquid Limit	Plastic Limit	Plasticity Index	Shrinkage Limit
0	0	81	24.5	56.5	8.0
1/2	0.48	75	24.0	51.0	9.0
1	1.00	74	24.5	49.5	9.5
2	1.99	76	26.5	49.5	13.0
4	3.99	81	30.0	51.0	12.5
8	8.06	87	35.0	52.0	12.0

1H-2H + 6.68% ORGANIC MATERIAL, TREATED

Method Used	Liquid Limit	Plastic Limit	Plasticity Index
None	54	35	19
Oven-dried, 110°C.	36.5	29.5	7
6% $H_2 O_2$	37.0	27.5	9.5
HCl	47.0	32.0	15.0

DISCUSSION OF RESULTS

Atterberg Limits 1H-2H Soil

The toughness index, slopes of the liquid limit curves, remained essentially the same although over 8 percent, by weight, of humic acid was added to the soil, this may be seen in Figure 3. The liquid limit increased with increasing amounts of organic material. The constancy of the toughness index seems to indicate that the addition of organic material did not result in a change in the material itself but only in its surface.

The 1H-2H soil plus a percent assumed organic (6. 68% true) was treated by various chemical and physical methods to determine a means of calculating the amount of organic content from the limits. The results of these trials are shown in Figure 3. Treatment with hydrochloric acid has little effect on the liquid limit. Heating the sample to 110 degrees Centrigrade has the same effect as treatment with hydrogen peroxide, a decrease in liquid limit of about 20. The hydrogen peroxide and oven-drying treatment resulted in a liquid limit slightly less than the limit represented by a 2 percent organic content. Therefore, complete oxidization of the organic matter is not accomplished by oven-drying or treatment with hydrogen peroxide. A strong possibility exists that oxidation did not take place by oven-drying, but that a physical reaction took place that was irreversible. Grim (14) mentions the irreversibility of various clay minerals when subjected to heat; this may also take place in the humic acid. Hydrogen peroxide is an oxidizer, although not a very good one. At the most, only two-thirds of the organic matter was oxidized. It will be noted that the toughness index of the soil was not changed by the various treatments, thus strengthening the theory that the toughness index is determined by the mineral soil.

The relation between the plasticity index and the liquid limit for various percentages of organic material in 1H-2H soil is shown in Figure 4. The relationship is essentially a straight line relationship for the extent of the mixtures tested. The line

"A" from Casagrande's plasticity chart is plotted on the graph, and it will be noted that the initial point, the zero percent point, lies on the "A" line. The slope of the 1H-2H line is less than the "A" line slope and hence the points lie to the right of the "A" line, in the organic area of Casagrande's plasticity chart.

The relation between the plasticity index and the liquid limit for samples of a 1H-2H with 6.68 percent humic acid treated by various methods is shown in Figure 5. The treatment line is parallel to the "A" line; the slope is greater than the 1H-2H line. The treatment line indicates that the treatments may have some effect on the mineral soil or they may alter the physical properties of the organic matter. The latter is believed to be the case.

The liquid, plastic and shrinkage limits for the various percentages of organic matter used in 1H-2H soil are plotted on the graph shown in Figure 6. These curves show that the relationship between each limit and the organic content is an epotential one. The exact relationship would be meaningless at the present time. The plasticity index for a given organic content is the difference between the liquid limit curve and plastic limit curve. Hence, the plasticity index is essentially constant for an organic content less than two percent only. The organic matter has the greatest effect on the liquid limit. The shrinkage limit increases with increasing organic content, although the increase is not extensive.

Atterberg Limits 1K-2K and 1M-2M Soils

The liquid limit curves for various mixtures of organic material and 1K-2K mineral soil are shown in Figure 7. It will be noted that there is a gradual change in the toughness index, slope of the curve, between zero and two percent and then the index remains essentially the same for the remaining organic contents. The exact nature of this phenomenon is not known at the present time.

The plasticity index, liquid limit relation line for 1K-2K soil containing various percentages of organic material is shown in Figure 8. The line is to the left of "A" line, thus indicating an inorganic soil according to Casagrande. The line is very near the "A" line, however, and the slope indicates that at higher organic contents the 1K-2K line will eventually cross the "A" line.

The liquid limit curves for 1K-2K soil containing 20 percent bentonite (1M-2M) and various percentages of organic material are shown in Figure 7. It is interesting to note that the liquid limit values decrease with low percentages of organic material, reach an optimum point, and then increase in value. The liquid limit at four percent (3.99%) equals the liquid limit at zero percent. The slopes of the curves increase until the four percent curve is reached. Some investigators feel that there is a chemical reaction between the bentonite and the humic acid. However, the answer cannot be found from these curves, it is believed.

The 1M-2M line on the plasticity index vs. liquid limit graph shown in Figure 9 is to the left of the "A" line. This indicates an inorganic soil according to Casagrande. The slope of the 1M-2M line indicates that it will eventually cross the "A" line. Apparently, if the plasticity index and liquid limit are such that the zero organic point is far to the left of the "A" line, it takes a considerable amount of organic matter to indicate the presence of organic matter by the use of the "A" line.

The liquid, plastic and shrinkage limit curves for 1K-2K soil shown in Figure 10 are of the same character as those for 1H-2H soil. The plasticity index, the difference between the liquid limit and the plastic limit, remains essentially constant until a 2 percent organic content is reached, after which it increases with increasing amounts of organic material. The shrinkage limit increases with increasing organic content until an organic content of approximately six percent is reached. It then apparently decreases with increasing organic content. This decrease in shrinkage limit cannot be explained. Perhaps with further testing at increased organic contents, the explanation can be obtained for this phenomenon. The shrinkage due to organic content is not excessive in any case.

The liquid, plastic and shrinkage limits of 1M-2M soil for various percentages of organic content are shown in Figure 11. The decrease in the liquid limit by the addition of humic acid will be noted. This may be explained by the physical decrease in the amount of expansion of the montmorillionite lattice by the entrance of organic colloids. Whether any chemical reaction takes place is a matter of conjecture. The plastic limit curve is of the same nature as the curves for the 1H-2H and 1K-2K soils. Due to the nature of the liquid limit curve, the plasticity index decreases with increasing organic content until a one percent organic content is reached. It then remains essentially constant with increasing organic content. The shrinkage limit increases until a two percent organic content is reached. It then decreases. The decrease in shrinkage limit may be due to the clogging of the soil pore spaces with organic material.

Moisture-Density Relationships 1H-2H Soils

The moisture density relationships for 1H-2H soil containing various percentages of organic matter are shown in Figures 12 and 13. In general, the maximum density decreases with increasing percentages of organic material. The optimum moisture also increases with increasing percentages of organic material. The maximum density curve shown in Figure 13 is practically a mirror image of the plastic limit curve shown in Figure 6.

Triaxial Test Results 1H-2H Soil

The results of the triaxial tests on the 1H-2H soil with various percentages of organic material at maximum density are also shown in Figure 13. It will be noted that there is a gradual decrease in internal friction due to increased organic content. The decrease due to an organic content of 8.85 percent is approximately 30 percent. The cohesion of the soil increases gradually with increasing organic content although the increase in cohesion is negligible.

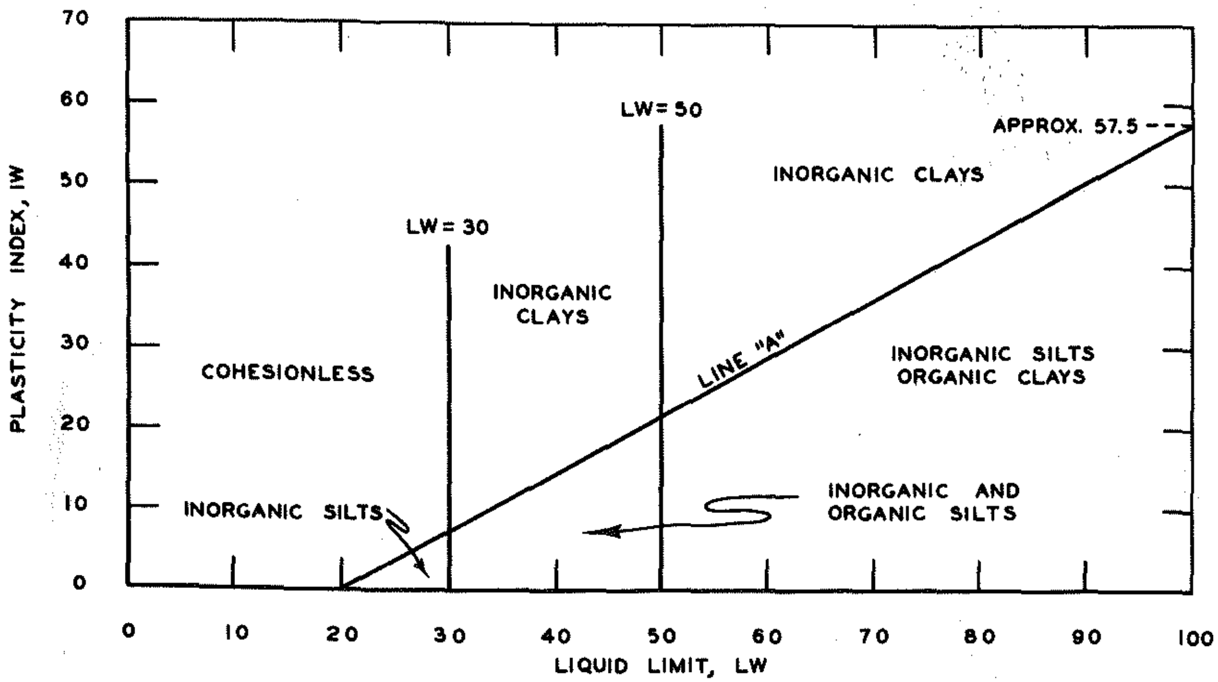
CONCLUSIONS

The conclusions reached to date are few in number due to the limited amount of testing and the magnitude of the problem. The conclusions may be listed as follows:

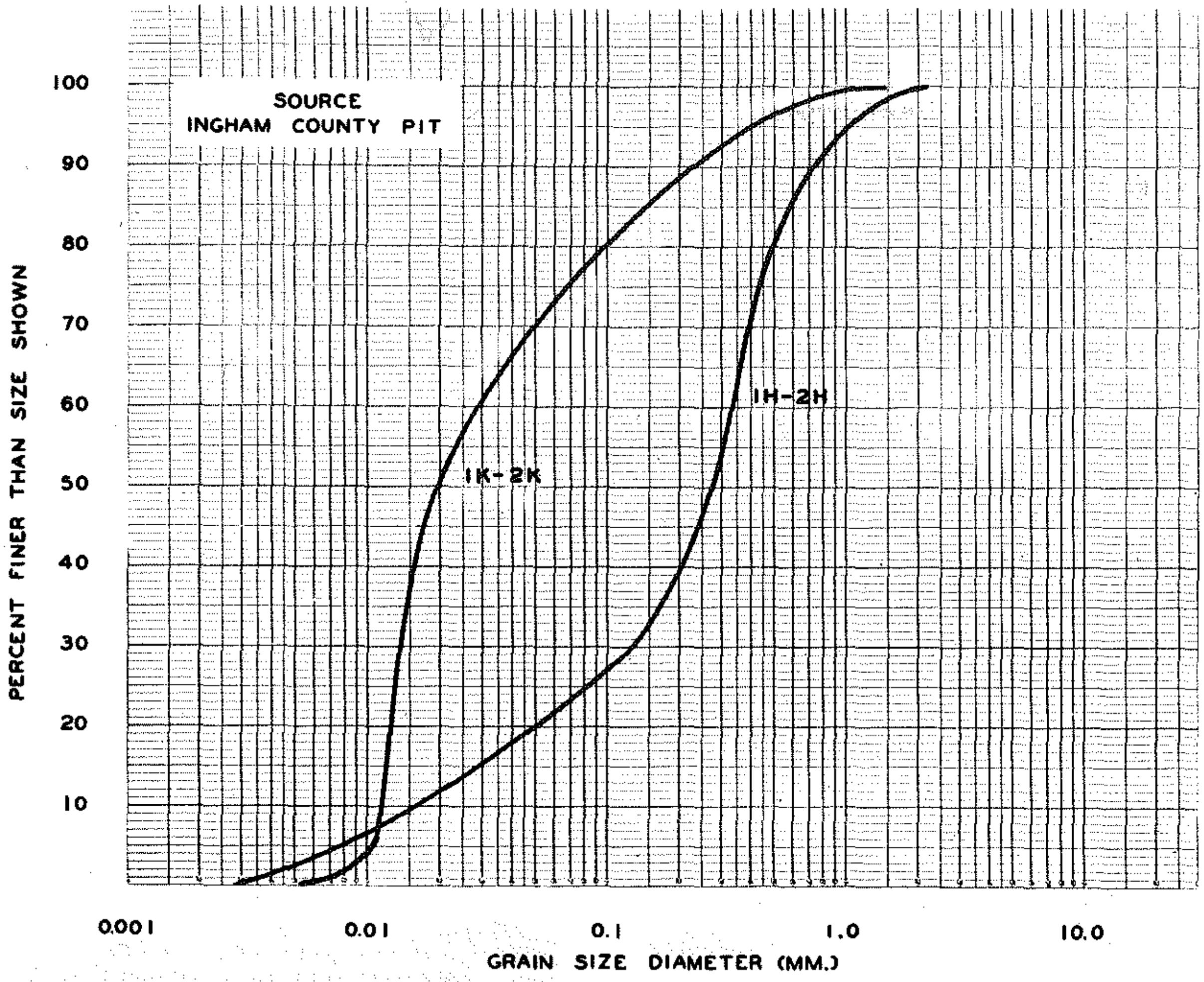
1. Organic material in general increases the liquid, plastic and shrinkage limits of a mineral soil.
2. The character of the mineral soil, especially its gradation and clay content, is a major factor in determining the amount of influence of the organic material.
3. Heat decreases the influence of the organic material. Samples should not be heated before testing if organic material is suspected.
4. Organic material decreases the maximum density obtainable, increases the optimum moisture, and decreases the internal friction of a mineral soil.
5. The plasticity index does not remain constant with increasing amounts of organic material.
6. Less than two percent organic content has little effect upon the physical characteristics of the soil.
7. Casagrande's "A" line may not indicate the presence of organic material.

SUGGESTED PHASES TO BE INVESTIGATED

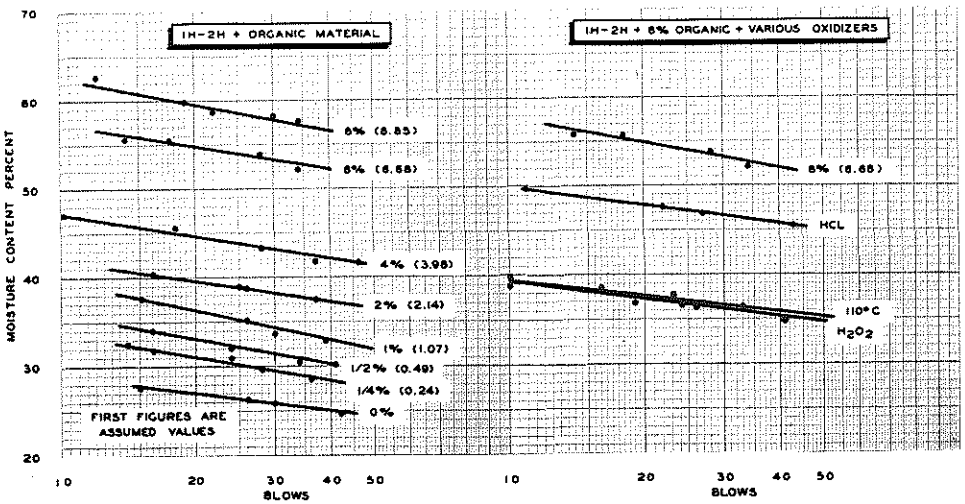
1. Determination of a satisfactory oxidizing agent that will oxidize the organic matter but not altering the mineral soil properties.
2. Investigate the effect of grain size distribution and grain shapes on the properties of the soil.



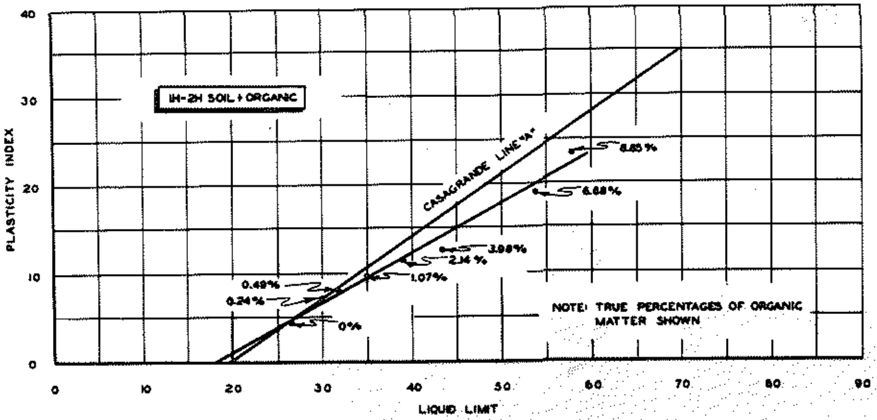
CASAGRANDE'S PLASTICITY CHART
FIGURE 1



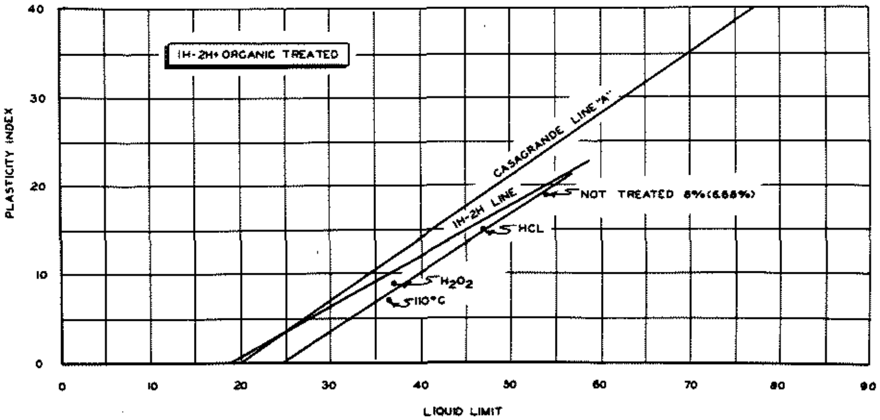
GRAIN SIZE DISTRIBUTION CURVES
FIGURE 2



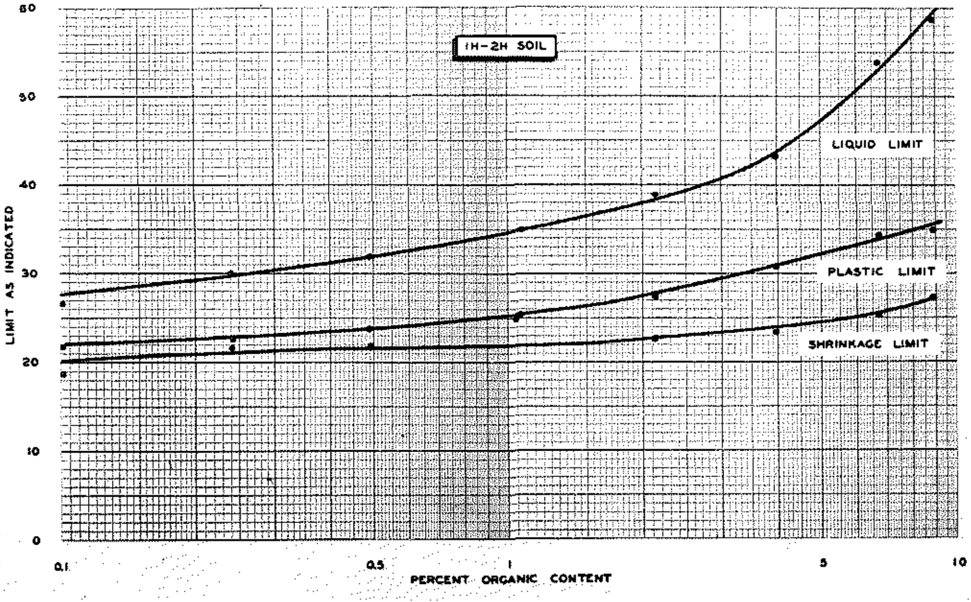
LIQUID LIMIT CURVES
FIGURE 3



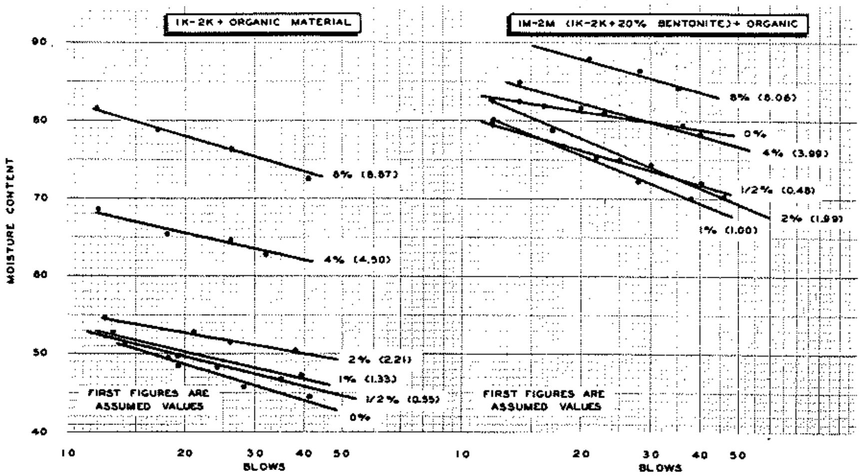
PLASTICITY INDEX VS. LIQUID LIMIT
FIGURE 4



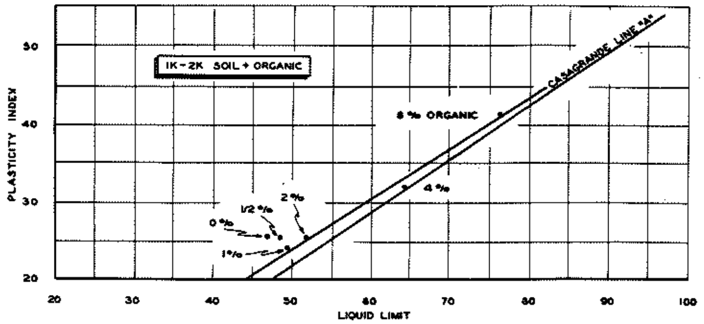
PLASTICITY INDEX VS. LIQUID LIMIT
FIGURE 5



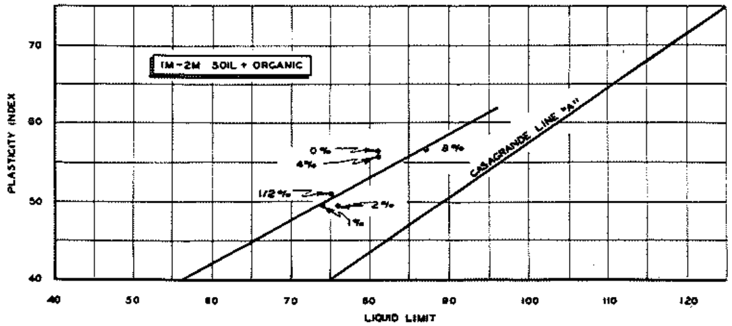
LIQUID, PLASTIC AND SHRINKAGE LIMITS
VS. ORGANIC CONTENT
FIGURE 6



LIQUID LIMIT CURVES
FIGURE 7

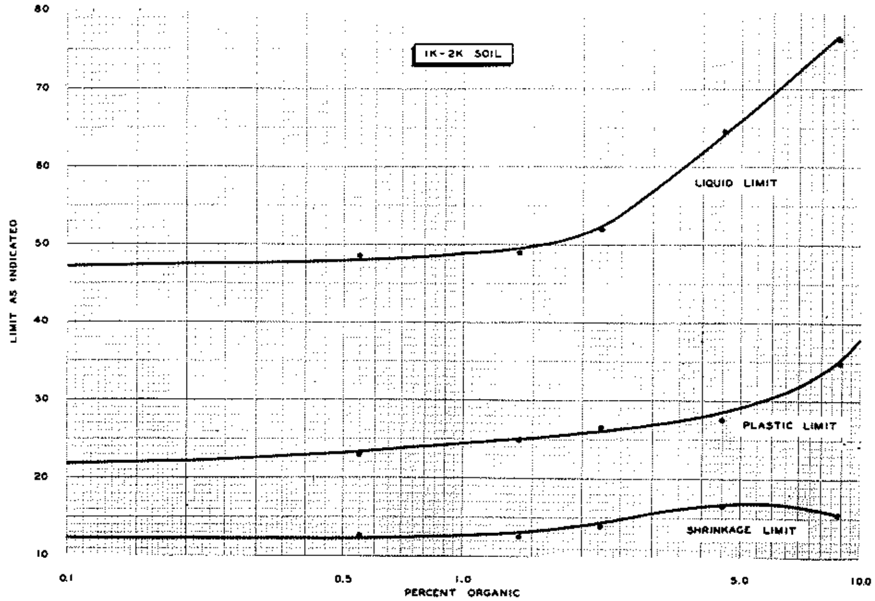


PLASTICITY VS LIQUID LIMIT
FIGURE 8

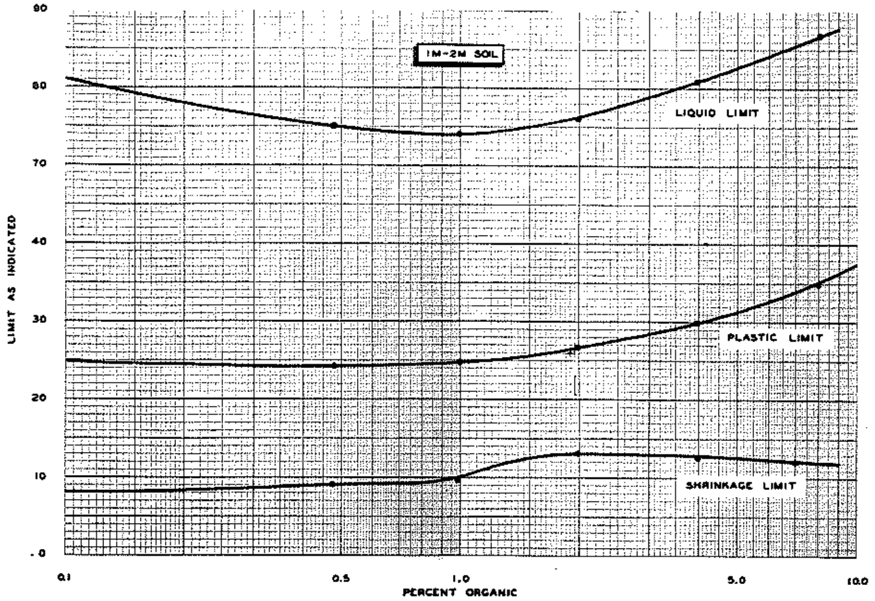


PLASTICITY INDEX VS. LIQUID LIMIT

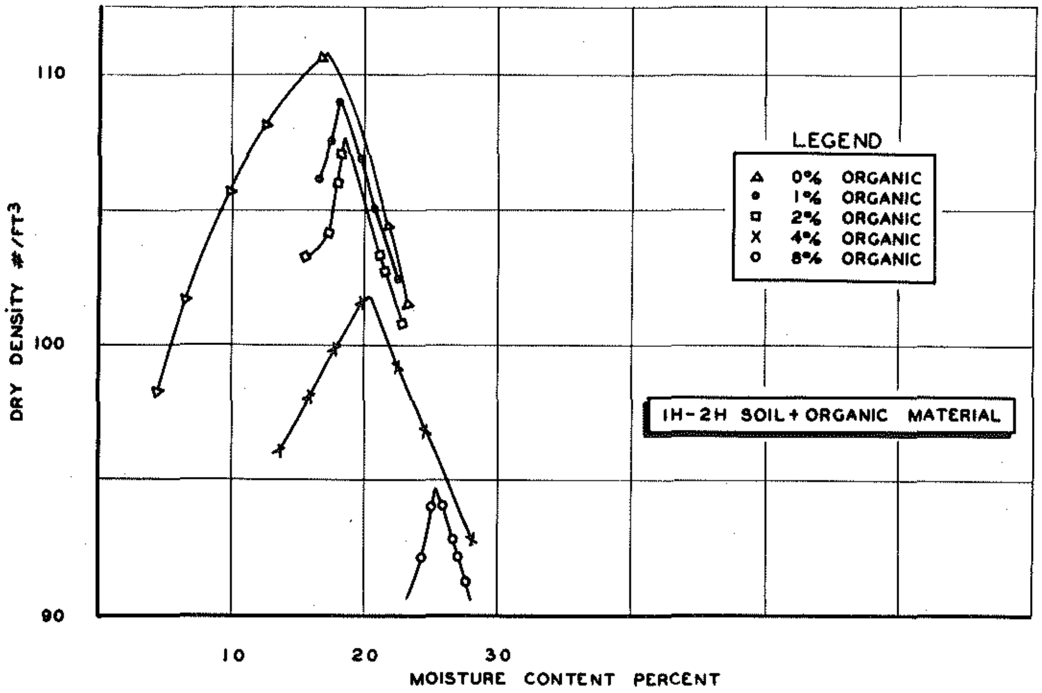
FIGURE 9



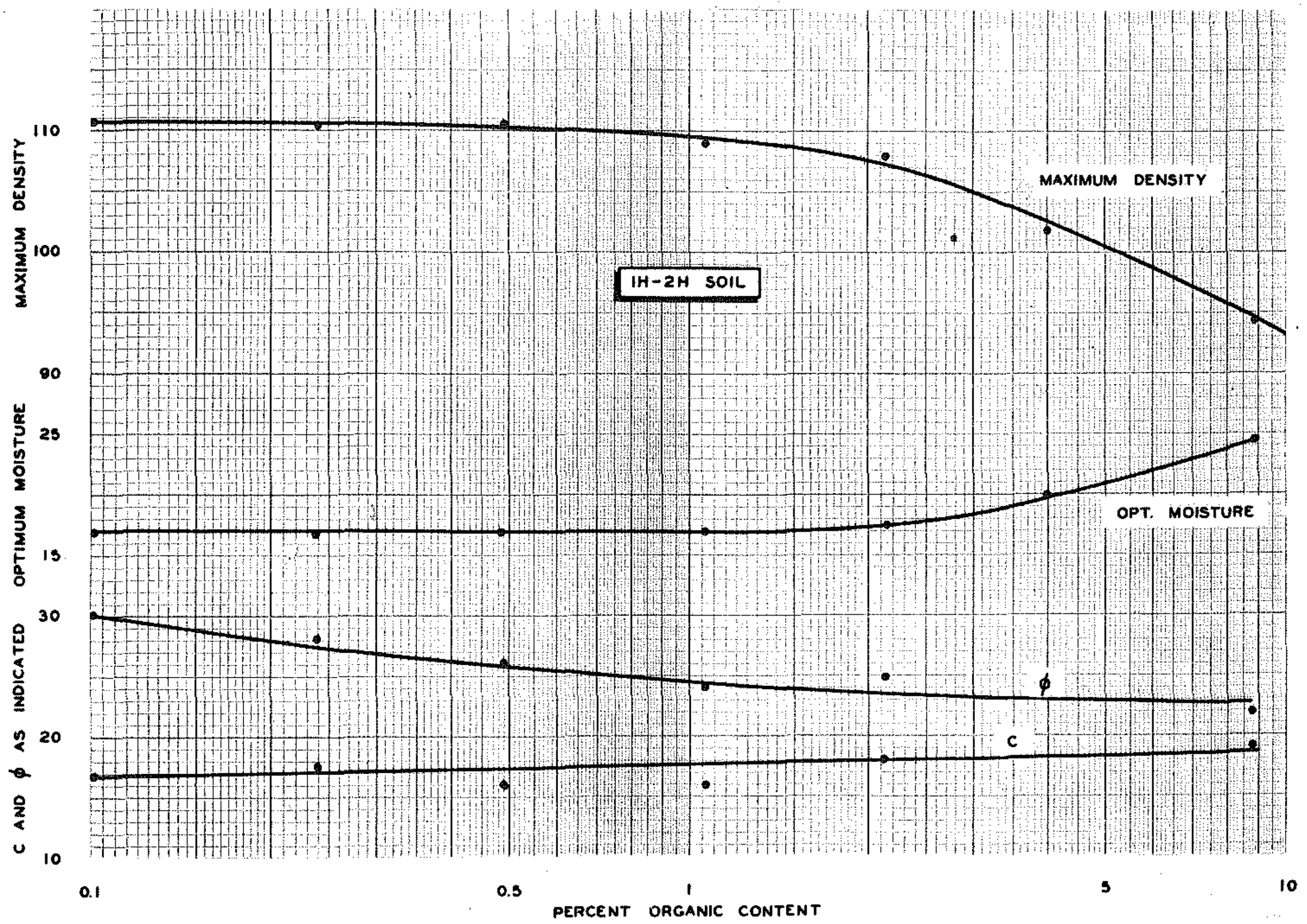
LIQUID, PLASTIC AND SHRINKAGE LIMITS
VS ORGANIC CONTENT
FIGURE 10



LIQUID, PLASTIC AND SHRINKAGE LIMITS
VS ORGANIC CONTENT
FIGURE 11



MOISTURE - DENSITY RELATIONSHIP
FIGURE 12



MOISTURE - DENSITY RELATIONS
FIGURE 13

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