EFFECT OF DISPERSING AGENTS ON THE COMPACTION CHARACTERISTICS OF DIFFERENT KINDS OF SOILS

by

ONDER EVRENOL

B. S., Robert College, Istanbul, Turkey, 1957

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1959

TABLE OF CONTENTS

INTRODUCTION

Every structure must be founded on soil or ledge. Since most structures rest on soil, it is necessary to investigate and improve the properties of the foundation material.

Most of the time it is necessary to improve the stability of soils to make it more resistant to heavy loads and climatic conditions. Compaction is a way of artificially densifying the soil by expelling air or water in a short time. This process depends on the amount of water in soil, the type of soil, and the compactive effort. Compaction increases the bearing capacity and the shearing strength of soils; on the other hand, it decreases the porosity. In 1934, Proctor developed a standard method of compaction. (4). Proctor compaction may be viewed as a laboratory procedure designed to bring soils to approximately the same state of density as is obtained when in the field, they are compacted by rolling equipment. This thesis describes the effects of dispersing agents on the compaction characteristics of different kinds of soils. This investigation shows that the small amounts of dispersion agents, which were used in this research, increase the degree of compaction. However, there is an optimum percent for each dispersing agent, that can be added to a known kind of soil, to get a maximum increase in density.

This investigation is an extension of a project commenced by Remzi Tekguc (8) the results of his study being the starting point of this research.

PROPERTIES OF CLAY

The soil samples used for this research are from the vicinity of Manhattan, Kansas. These same samples were used by Tekguc. The geologic test results of the clay minerals in the four samples used are shown in Table 1, which is taken from Tekguc's thesis (8).

Table 1. Test results of clay minerals* (8).

Sample	Clay major mineral groups	Amount %
A, B, and D	Montmorillonite	60
	Illite	20
	Kaolinite	20
C	Inter stratified	
	Montmorillonite - Illite	60
	Illite	20
	Kaolinite	20

Many of the physical properties of soils are affected by the nature of the adsorbed ions. The amount of ions adsorbed per unit mass is known as the exchange capacity, and the energy with which they are held is known as ease of replacement. The exchange capacity is different for different kinds of clays, because it depends on the chemical as well as the mineralogical composition of the soil or of colloid in a colloidal solution. In addition to the type of clay, the adsorbtion of cations is also affected by the type of cation adsorbed. This depends on both the valance and the size of the ion. Ionic size increases with hydration. Colloidal suspensions carry a charge which is either negative or positive; clays, however, are mostly negatively charged. If placed between two electrodes they migrate to the anode with a certain velocity known as the migration velocity or negative potential, but usually termed as zeta potential. Since clays are negatively charged, and they adsorb cations, they are sometimes known by the name of the cations they have adsorbed. Thus a clay particle is a negatively charged ion surrounded by positively charged ions, as shown in the figure below (Baver, 2).

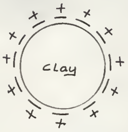

Fig. 1. A charged soil particle.

This shows an electrical double layer around clay particles, and this electrical double layer is known as Helmholt's Double Layer. Since the outer positive layer is composed of the adsorbed cations, they are often replaced during ionic exchange. Zeta potential for a given type of clay will thus vary with the nature of the adsorbed cation. This will be governed by ionic radii and the valence of the cations (2)

$$Z = \frac{4\ ed}{D} \qquad \text{——————————} \quad I.$$

where

Z = zeta potential in volts,
e = electric charge in coulombs/sq.in.,
d = thickness of the double layer,
D = dielectric constant of solution.

Coulomb's Law states that force of attraction between two ions in a given dielectric varies inversely as the square of the distance between them (2).

$$F = \frac{k\, e_a\, e_c}{d^2}$$

where e_a, e_c are the charges of the anion and cation, d is the distance between them, k is a constant.

For colloidal clays (Lambe, 5),

$$F = \frac{k\, e_a\, e_c}{(r_a + r_c)^2} \qquad \text{- II.}$$

PROCEDURE

For this project, four kinds of soil were used. Each sample of soil was classified and tested according to the American Association of State Highway Officals designation. After the classification and simple tests were completed, the maximum density and optimum moisture content of each sample with distilled water was found.

Another series of compaction tests was completed with each sample, using different percentages of dispersing agents added to the distilled water. The dispersing agents used for this research were sodium tripolyphosphate, tetrasodium pyrophosphate and calgon + sal soda (sodium hexametaphosphate buffered with sodium carbonate). Tekguc (8) used the same soils and the same dispersing agents. The amount of dispersing agents used by Tekguc were 0.1 and 0.25 percent by weight of each dispersing agent. In this research, 0.5 and 0.75 percent by weight of each dispersing agent was used for compaction tests. The graphs that show the maximum density variation with the percent of dispersant added also include the results of Tekguc's thesis in order to get clearer and more exact curves.

Classification and simple tests are tabulated below.

The AASHO Designations referred to for the laboratory tests are (4),

Specific Gravity test	AASHO	Des.	T-100-54
Field Moisture Equivalent	"	"	T-93-54
Atteberg Limits:			
Liquid Limit	"	"	T-89-54
Plastic Limit	"	"	T-90-54
Shrinkage Limit	"	"	T-92-54
Hydrometer Analysis	"	"	T-88-54*
Compaction Tests	"	"	T-99-49**

For each of the four soil samples, seven compaction tests were made as follows:

1. Distilled water
2. 0.5 percent Sodium Tripolyphosphate Granular I
3. 0.75 " " " " "
4. 0.5 " Tetrasodium Pyrophosphate Granular
5. 0.75 " " " "
6. 5 gm. Calgon + 0.952 gm. Sal soda added to 1000 cm^3 distilled water
7. 7.5 gm. Calgon + 1.428 gm. Sal soda added to 1000 cm^3 distilled water.

DISCUSSION

The results of this research show that small amounts of dispersing agents added to the water used in the compaction tests, increase the density and decrease the optimum moisture content. When the amount of dispersion agent is increased gradually, the density reaches a peak point and then drops down. At the same time, optimum moisture content begins to increase.

When small amounts of dispersing agents with distilled water are added to the soil, the cations are hydrated and ionic radii increase. The proportional amount of this increase varies with different cations (6). Thus, in considering ionic radii, we have to consider their hydrated ionic radii. According to coulomb's law, when ionic radii increase the force of attraction decreases. As a result, a dispersed system which is needed for compaction is obtained. At the same time, small amounts of dispersing agents increase zeta potential (Baver, 2) because the thickness of the double layer reaches its maximum value. This is a good condition for compaction because particles have less attraction and internal friction is reduced. So, they can be compacted more. This can be explained by this simple example: If one of two similar size boxes is filled with neutral iron particles and the other filled with the same but magnetized iron particles, the box which was filled with the neutral iron particles will have a greater bulk density, because the magnetized particles are not free to move and fill their small pores; they stick to each other like space frames.

When the amount of dispersing agent was increased in the solution, the maximum limit of cation adsorbtion was reached. By dontinuing to increase the amount of dispersant agent, the cations in the clay were increased. This decreases the thickness of the double layer which causes decrease in the zeta potential, and consequently flocculation occurred. Flocculation of soils makes them difficult to compact, and as a result density decreased and optimum moisture content increased.

CONCLUSIONS

As has been pointed out, action of the proper amount of dispersant decreases the soil cohesion.

In many soil problems only a small improvement in a soil property is required. The cheap methods of improvement save us money and time. Dispersion of soils with chemicals is an easy method, and it does not cost much, if the best kind and amount of dispersants are known. To date, no one has been able to find an exact formula or method for using dispersing agents in the soils that will give us the best results. The stabilization process depends on the ion exchange capacity of soils which varies with chemical and physical properties of different kinds of clays.

The conclusions of this research are based on the results of compaction tests which are shown on Table 4. So, on an actual field job, it is recommended that compaction tests be made with the soil samples taken from the job. A small portion of the soil should be sent to a soil chemistry laboratory for analysis. After analyzing the soil, the soil chemist must recommend the kind of dispersing agent to be used for each particular type of soil. Then the compaction tests must be completed, and the optimum amount of dispersing agent which will give the maximum dispersion obtained. For example, the results of this research gave an idea about the best kind of dispersing agent that can be added to each of the four kinds of soil samples from the vicinity of Manhattan, Kansas (Figs. 2 to 5 incl.).

The dispersed system of a soil will give maximum percent of compaction, but, at the same time, shearing strength will decrease. It might be possible to prevent this decrease in cohesion by adding some more dispersing agent after the compaction process is completed. This means that, first, the soil is dispersed and compacted. Next, more dispersing agent in powder form is sprayed on the surface of the compacted layers. The powder dispersant disolves in the surface moisture and penetrates into the soil. This will cause flocculation of soil after compaction, and flocculation increases the cohesion of soil.

ACKNOWLEDGMENT

The author wishes to express his sincere thanks to Professor Harold H. Munger for his most helpful suggestions, and for spending his valuable time in the preparation of this thesis.

LITERATURE CITED

(1) Aron, H.
Report of Committee on Lime Soil Stabilization.
Am. Road Builders Association, Tech. Bull. No. 147.

(2) Baver, L. D.
Soil Physics. New York: John Wiley and Sons, Inc., 3rd ed., 1956.

(3) Davidson, D. T.
Large Organic Cations as Soil Stabilizing Agents.
Iowa State College Bull. No. 168, 1949.

(4) Highway Materials, Part II
Standard Specifications for Highway Materials and Methods of Sampling and Testing. Washington, D. C.: American Association of State Highway Officials, 7th ed.

(5) Lambe, W. T.
Stabilization of Soils with Calcium Acrylate.
Journal of the Boston Society of Civil Engineers, No. 2, April 1952.

(6) Symposium on Exchange Phenomena in Soils.
American Society for Testing Materials. Bull. No. 142, 1952.

(7) Taylor, D. W.
Fundamentals of Soil Mechanics. New York: John Wiley and Sons, Inc., 1956.

(8) Tekguc, R.
The Effect of Dispersion Agents on the Compaction Characteristics of Different Kinds of Soils.
Unpublished Master's Thesis, Kansas State College, 1958.

APPENDICES

Table 2. Location of soil samples used in this research project.

Sample	Location
A	Sec. 1, T 10S, R 7E South backslope of township road, 1/8 mi. NW of Radio Tower of Station KSAC.
B	SW 1/4 of SE 1/4, Sec. 2, T 10S, R 8E 600 ft. north of Highway US 24.
C	NW 1/4 of Sec. 28, T 10S, R 8E, East backslope of Highway K-13, 6 ft. above the centerline grade, 1/4 mi. south of NW corner of Sec. 28.
D	NE 1/4 of Sec. 28, T 10S, R 7E, South backslope of old Golden Belt Road, 1/4 mi. east of entrance to I.O.O.F. Home.

Table 3. Summary of the classification tests.

Simple Tests	Sample			
	A	B	C	D
Specific Gravity	2.54	2.75	2.73	2.87
Field Moisture	39.8	36.84	53.10	33.3
Classification Tests:				
Liquid Limit	38.2	40.1	33.7	30.5
Plastic Limit	21.8	20.7	42.3	45.4
Shrinkage Limit	21.2	24.3	23.7	25.0
Hydrometer Analysis:				
Sand, %	2.0	3.5	21.0	48.0
Silt, %	50.5	49.0	33.0	26.0
Clay, %	47.5	47.5	46.0	26.0
Colloids, %	43.0	41.0	27.0	16.0

Classification of the Soil Samples

Sample	U. S. Bu. of Public Roads	Description of Soil
A	Silty Loam	Reclaimed by tile drainage 45 yr. previous to sampling.
B	Silty Loam	Swamp, subjected to intermittent flooding.
C	Clay Loam	Formed by disintegration of marine shale of Permien age.
D	Sandy Loam	Alluvium, flood plain deposit of Kansas River.

Table 4. Summary of optimum values obtained from the compaction tests.

Dispersing Agent	Sample A	Sample B	Sample C	Sample D
Ordinary Distilled Water:				
Optimum Moisture, %	22.0	21.0	23.2	18.0
Maximum Density, pcf	93.0	91.5	96.0	97.8
Sodium Tripolyphosphate:				
0.5% by weight,				
Optimum Moisture, %	18.5	21.0	20.0	17.0
Maximum Density, pcf	99.5	93.0	99.0	100.0
0.75% by weight,				
Optimum Moisture, %	19.0	25.0	19.0	18.8
Maximum Density, pcf	98.0	85.0	100.5	101.0
Tetrasodium Pyrophosphate:				
0.5% by weight,				
Optimum Moisture, %	19.0	23.0	23.0	17.0
Maximum Density, pcf	96.5	90.0	97.5	99.0
0.75% by weight,				
Optimum Moisture, %	18.5	27.0	24.0	18.0
Maximum Density, pcf	97.6	84.0	94.5	96.8
Calgon + Sal Soda:				
0.5% by weight,				
Optimum Moisture, %	19.0	16.5	21.5	18.0
Maximum Density, pcf	97.1	96.0	99.0	100.2
0.75% by weight,				
Optimum Moisture, %	18.6	15.0	23.0	14.3
Maximum Density, pcf	97.5	96.5	100.5	102.0

Table 5. The relation of percent dispersing agent to change in maximum density.

Sample	% Colloids	% Dispersing Agent (by weight)	Maximum Density pcf
A	43.0		93.0
		0.1 Sodium Tripolyphosphate	93.6
		0.25 " "	95.5
		0.50 " "	99.5
		0.75 " "	98.0
		0.10 Tetrasodium Pyrophosphate	93.8
		0.25 " "	95.5
		0.50 " "	96.5
		0.75 " "	97.6
		0.10 Calgon + Sal Soda	94.0
		0.25 " "	96.0
		0.50 " "	97.1
		0.75 " "	97.5
B	41.0		91.5
		0.10 Sodium Tripolyphosphate	93.0
		0.25 " "	94.7
		0.50 " "	93.0
		0.75 " "	85.0
		0.10 Tetrasodium Pyrophosphate	92.4
		0.25 " "	94.0
		0.50 " "	90.0
		0.75 " "	84.0
		0.10 Calgon + Sal Soda	92.5
		0.25 " "	94.5
		0.50 " "	96.0
		0.75 " "	96.5

Table 5. (concl.)

Sample	% Colloids	% Dispersing Agent (by weight)	Maximum Density pcf
C	27.0		96.0
		0.10 Sodium Tripolyphosphate	97.0
		0.25 " "	98.0
		0.50 " "	99.0
		0.75 " "	100.5
		0.10 Tetrasodium Pyrophosphate	96.0
		0.25 " "	97.0
		0.50 " "	97.5
		0.75 " "	94.5
		0.10 Calgon + Sal Soda	96.5
		0.25 " "	97.5
		0.50 " "	99.0
		0.75 " "	100.0
D	16.0		97.8
		0.10 Sodium Tripolyphosphate	98.0
		0.25 " "	99.0
		0.50 " "	100.0
		0.75 " "	101.0
		0.10 Tetrasodium Pyrophosphate	98.5
		0.25 " "	99.0
		0.50 " "	99.0
		0.75 " "	96.8
		0.10 Calgon + Sal Soda	98.0
		0.25 " "	99.5
		0.50 " "	100.2
		0.75 " "	102.0

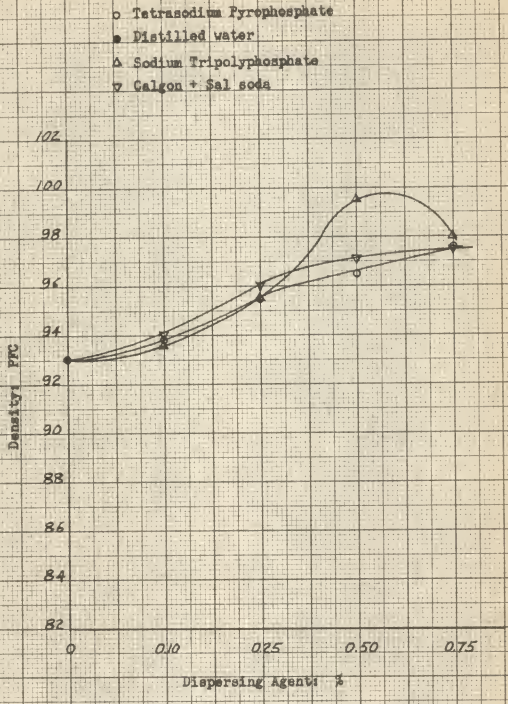

Fig. 2. Sample A: Change in maximum density.

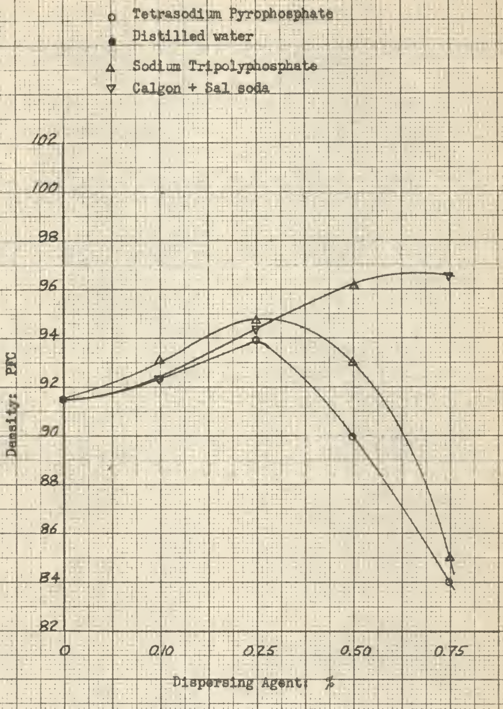

Fig. 3. Sample B: Change in maximum density.

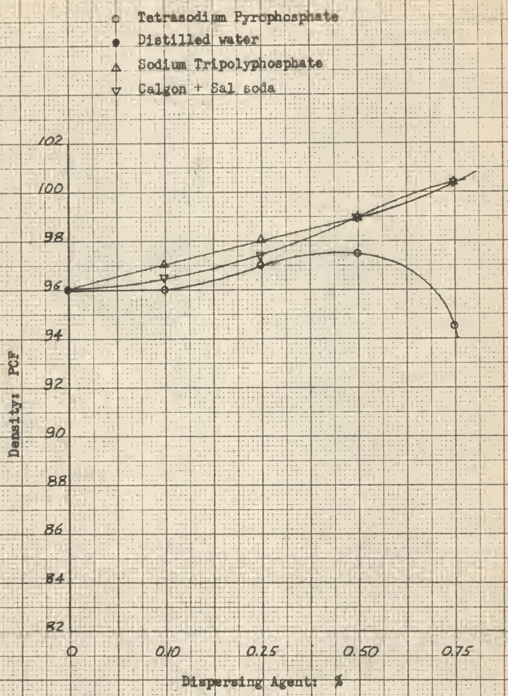

Fig. 4. Sample C: Change in maximum density.

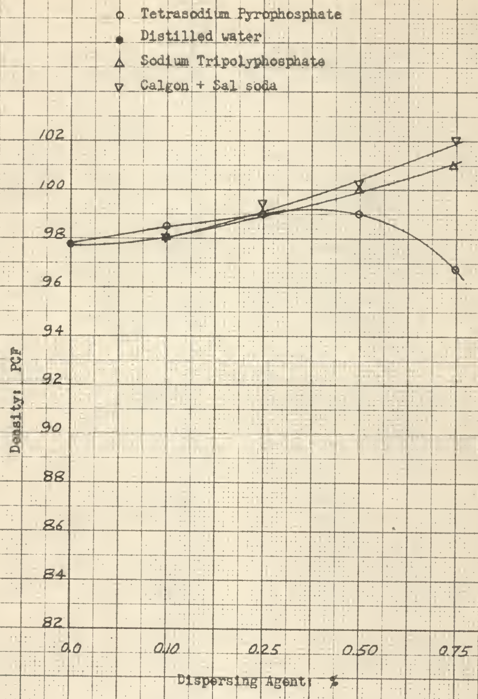

Fig. 5. Sample D: Change in maximum density.

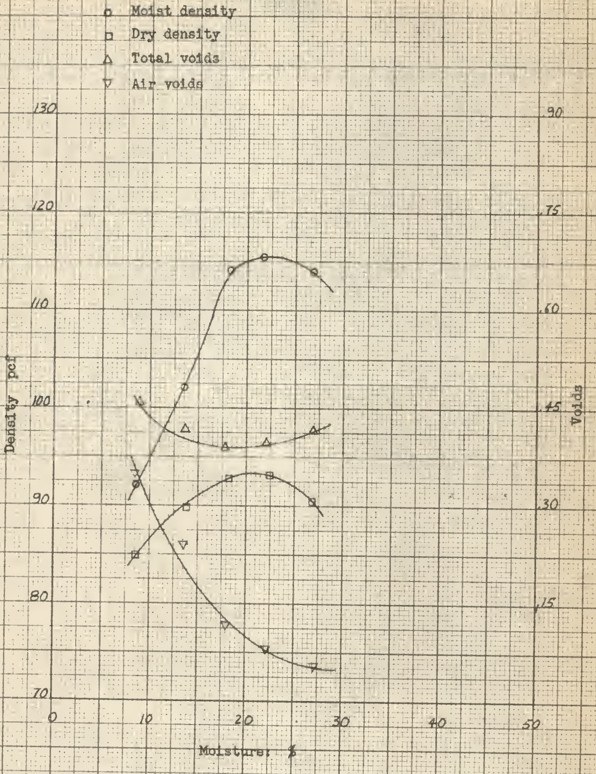

Fig. 6. Sample A: Ordinary distilled water.

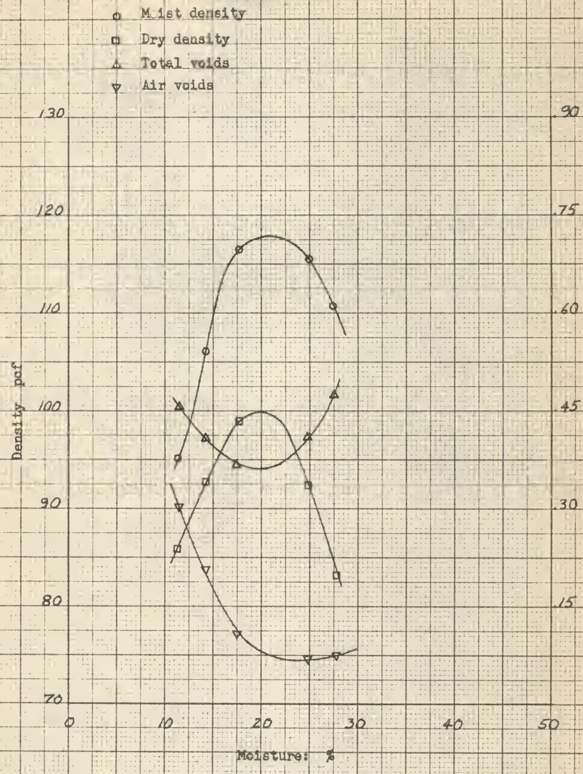

Fig. 7. Sample A: 0.5% of sodium tripolyphosphate added to distilled water.

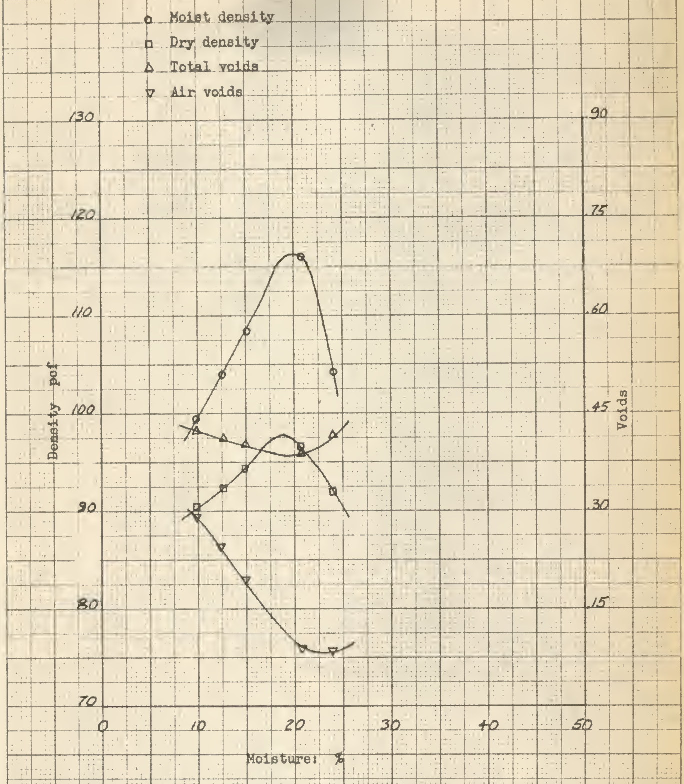

Fig. 8. Sample A: 0.75% of sodium tripolyphosphate added to distilled water.

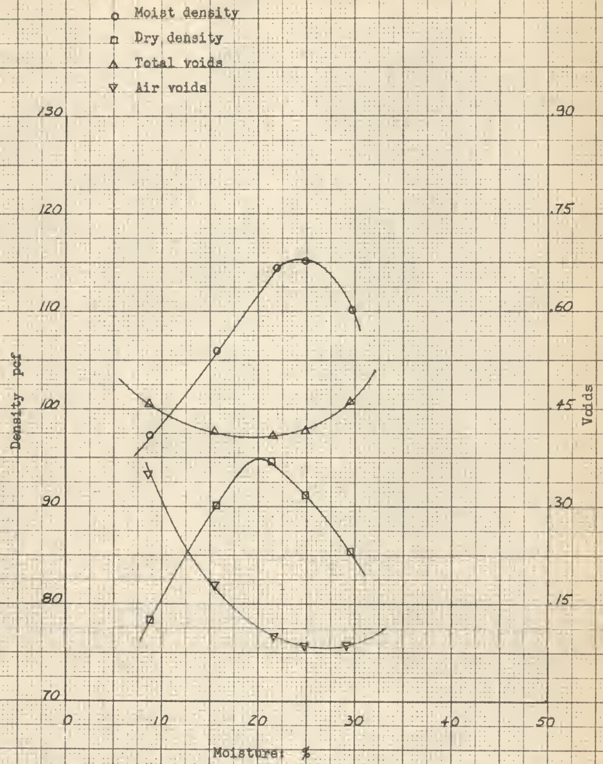

Fig. 9. Sample A: 0.5% tetrasodium pyrophosphate added to distilled water.

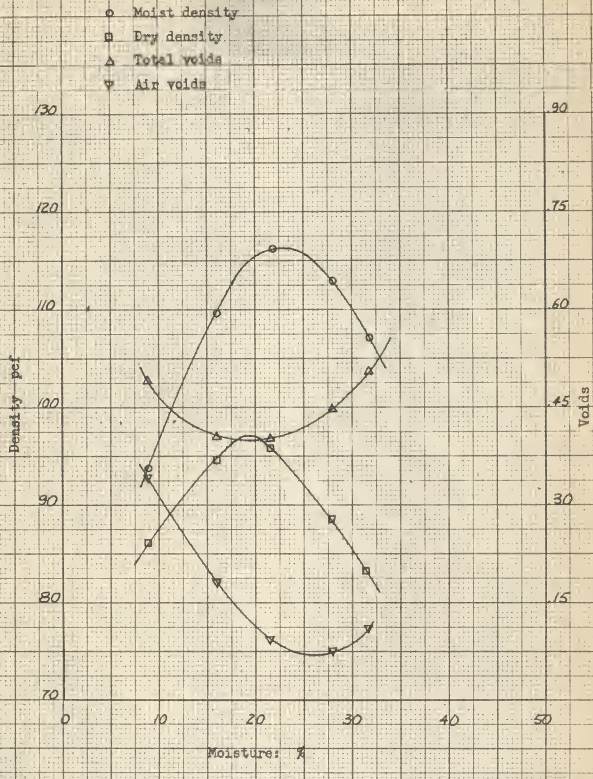

Fig. 10. Sample A: 0.75% tetrasodium pyrophosphate added to distilled water.

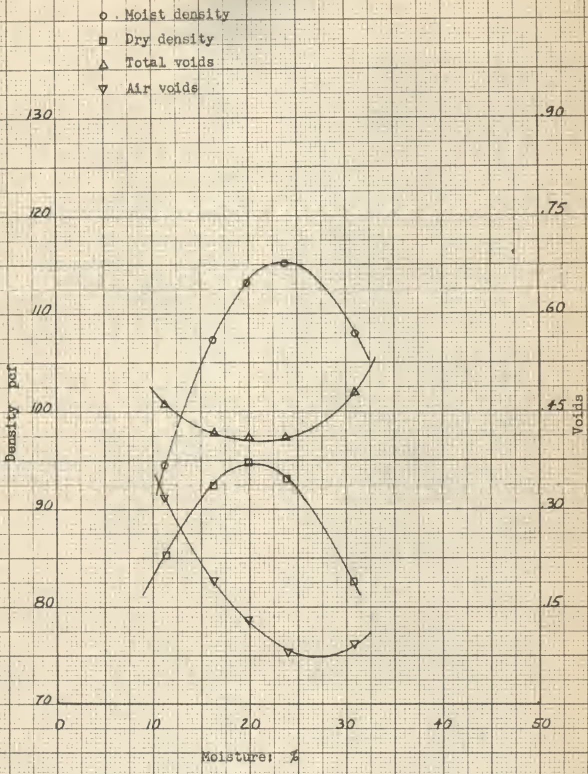

Fig. 11. Sample A: 0.5% calgon + sal soda added to distilled water.

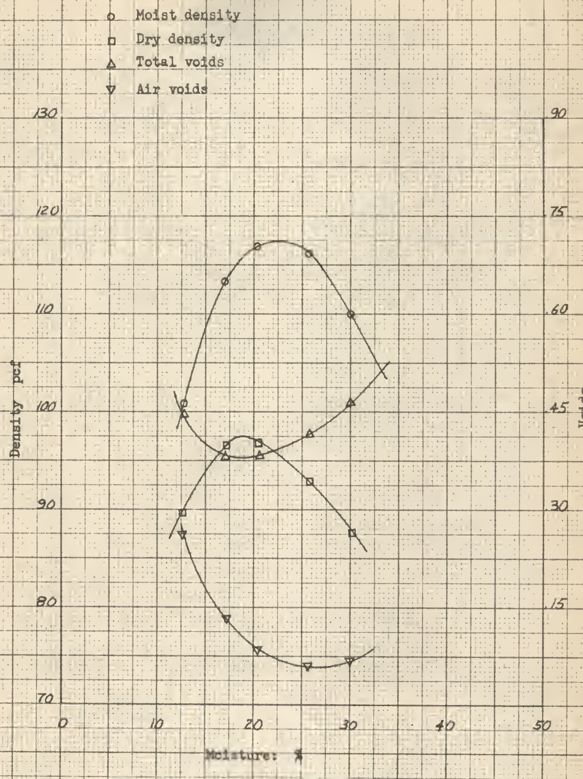

Fig. 12. Sample A: 0.75% calgon + sal soda added to distilled water.

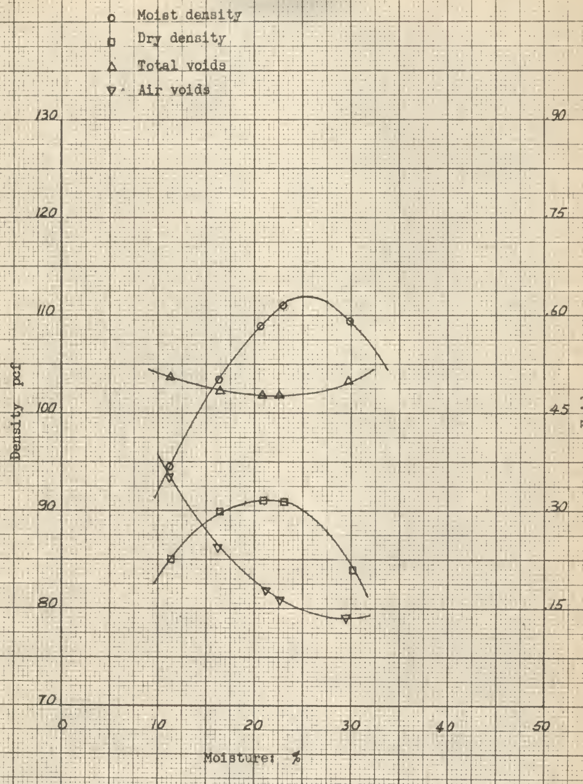

Fig. 13. Sample B: Ordinary distilled water.

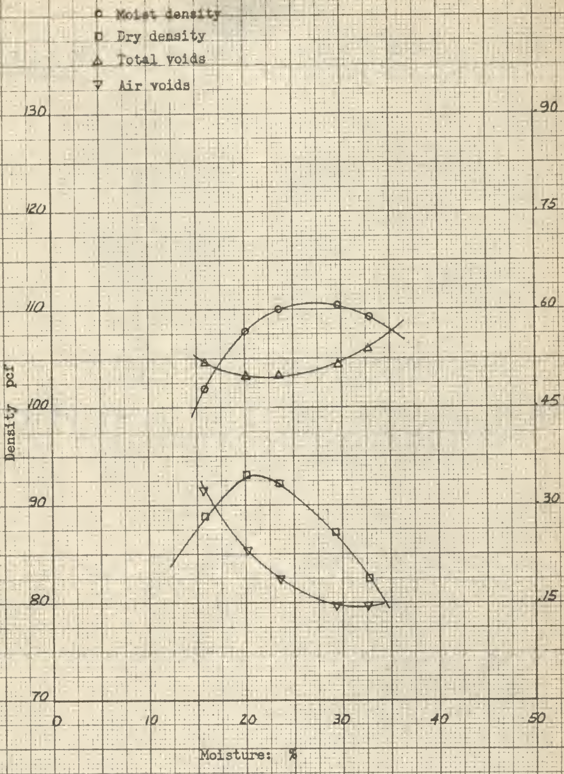

Fig. 14. Sample B: 0.5% sodium tripolyphosphate added to distilled water.

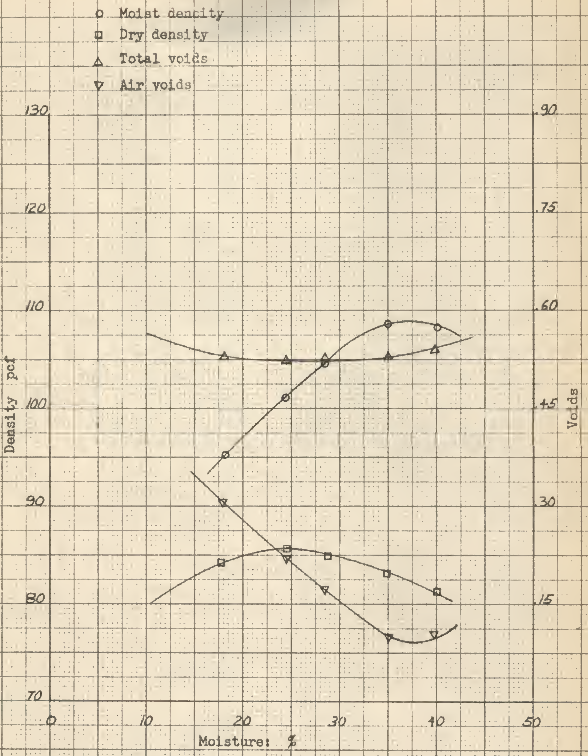

Fig. 15. Sample B: 0.75% sodium tripolyphosphate added to distilled water.

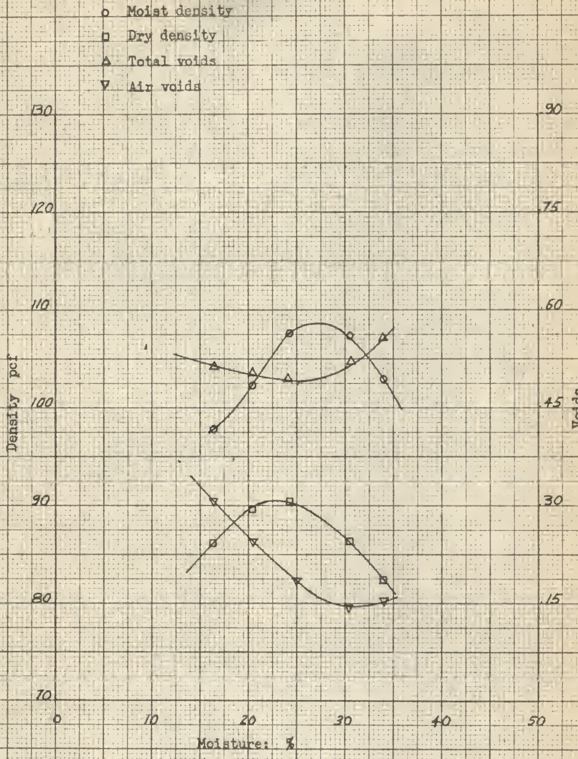

Fig. 16. Sample B: 0.5% tetrasodium pyrophosphate added to distilled water.

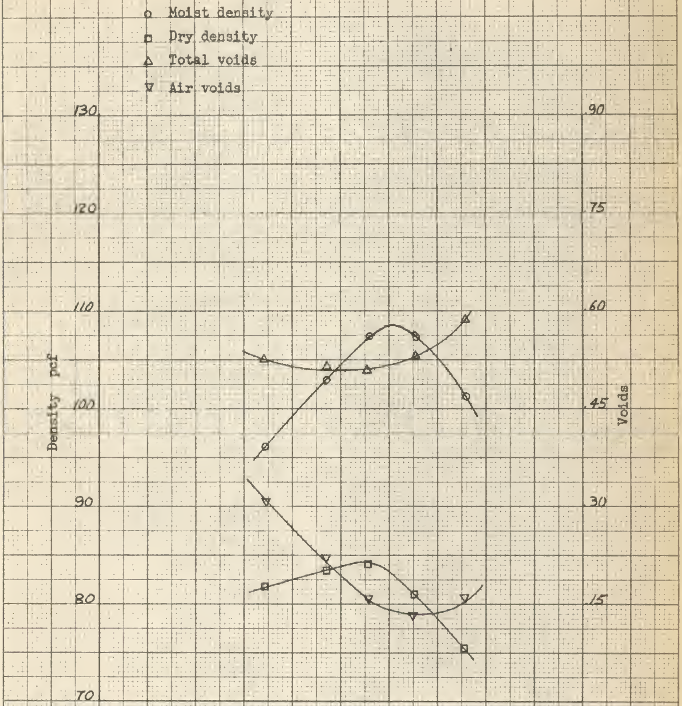

Fig. 17. Sample B: 0.75% tetrasodium pyrophosphate added to distilled water.

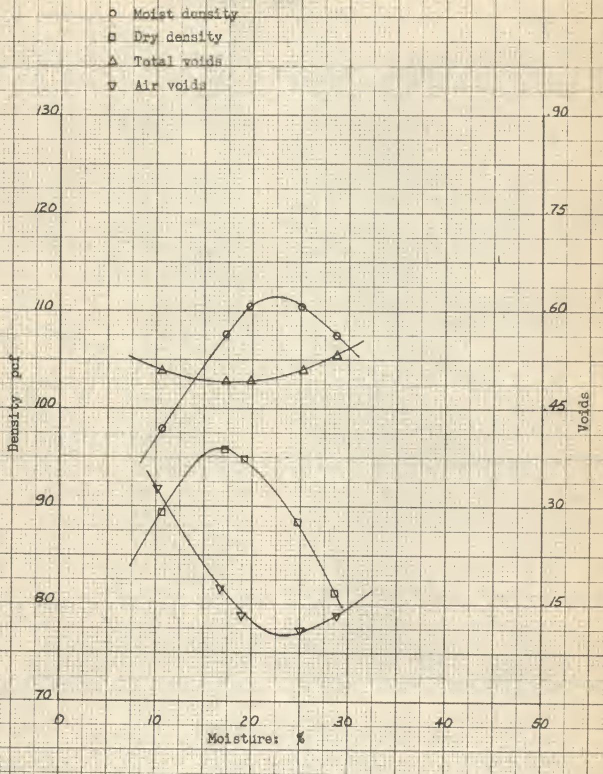

Fig. 18. Sample B: 0.5% calgon + sal soda added to distilled water.

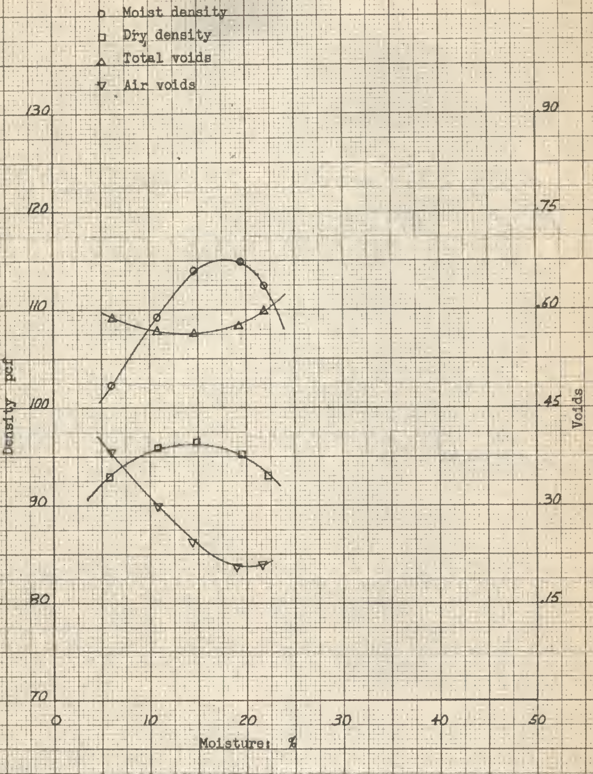

Fig. 19. Sample B: 0.75% calgon + sal soda added to distilled water.

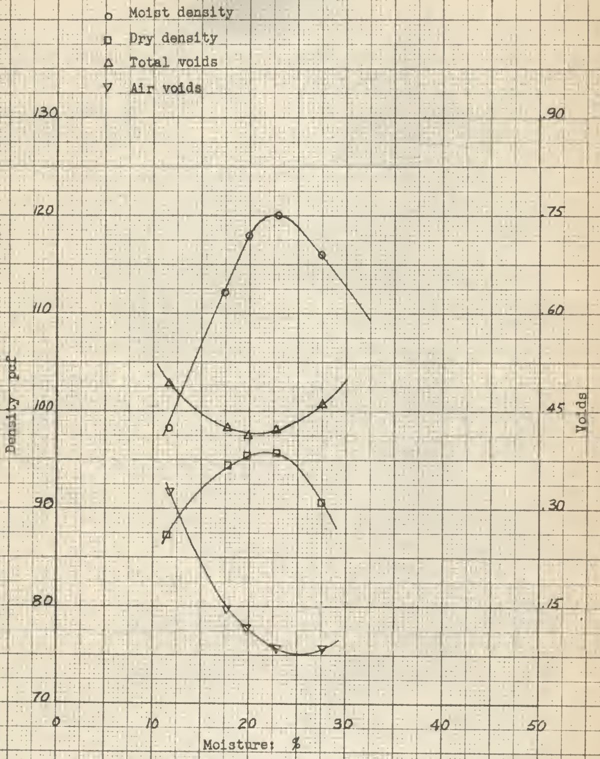

Fig. 20. Sample C: Ordinary distilled water.

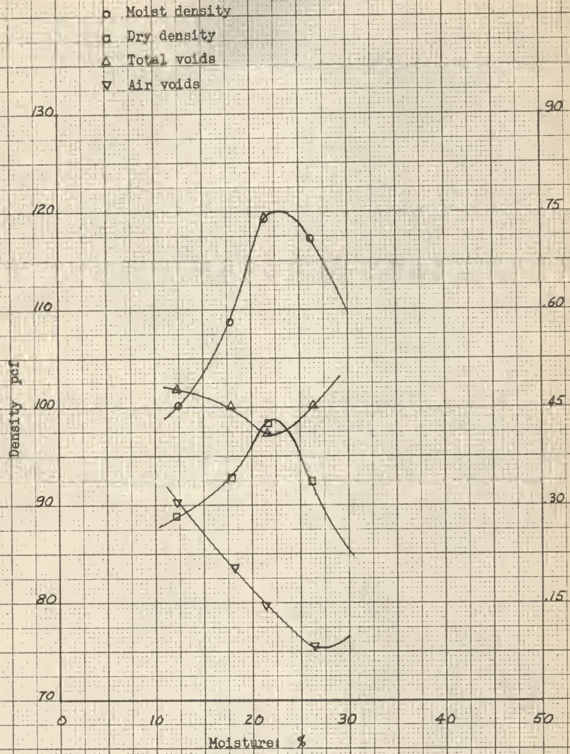

Fig. 21. Sample C: 0.5% sodium tripolyphosphate added to distilled water.

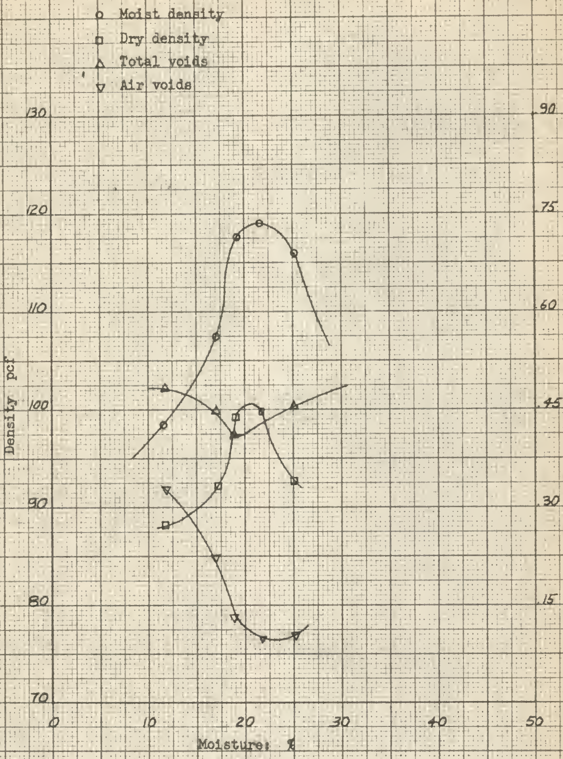

Fig. 22. Sample C: 0.75% sodium tripolyphosphate added to distilled water.

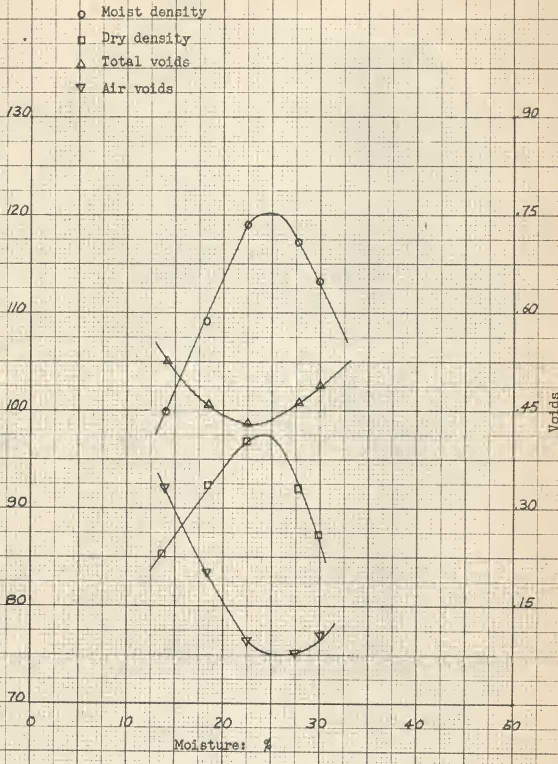

Fig. 23. Sample C: 0.5% tetrasodium pyrophosphate added to distilled water.

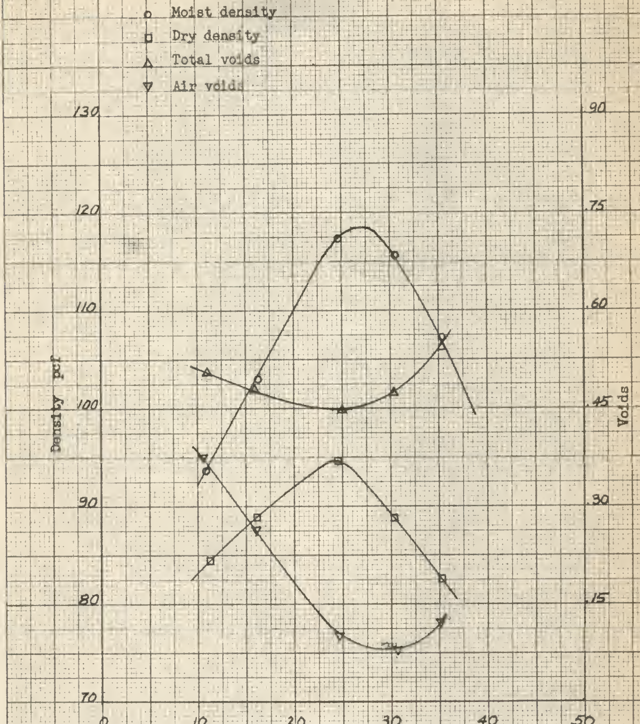

Fig. 24. Sample C: 0.75% tetrasodium pyrophosphate added to distilled water.

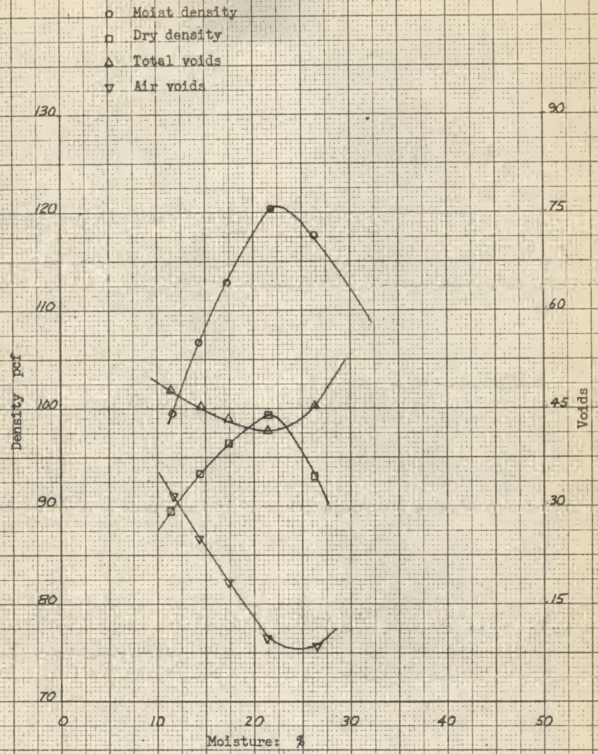

Fig. 25. Sample C: 0.5% calgon + sal soda added to distilled water.

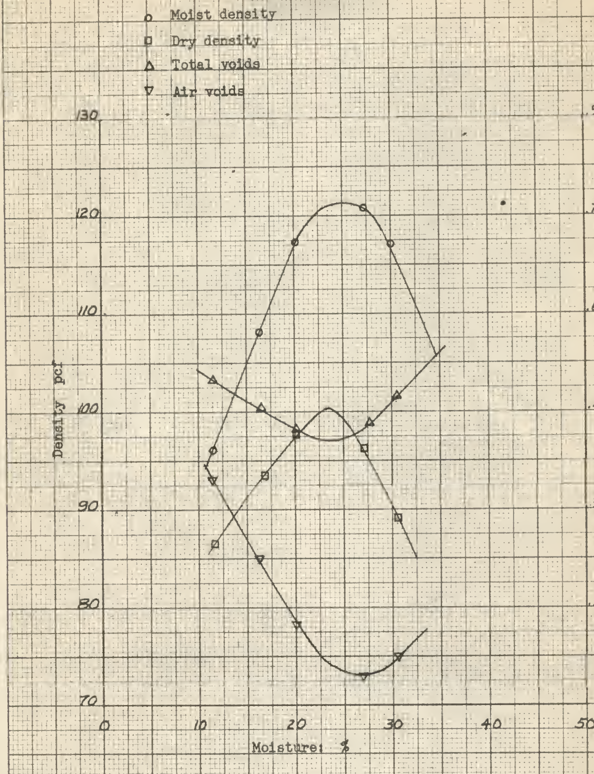

Fig. 26. Sample C: 0.75% calgon + sal soda added to distilled water.

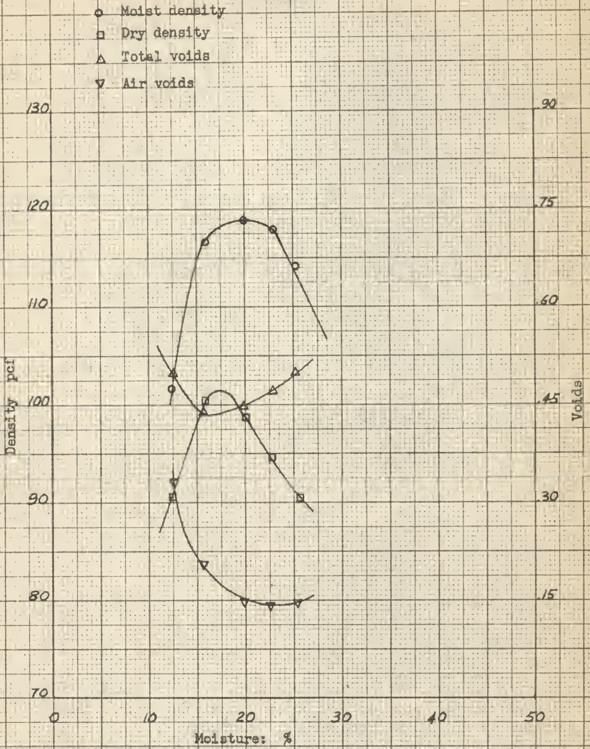

Fig. 27. Sample D: Ordinary distilled water.

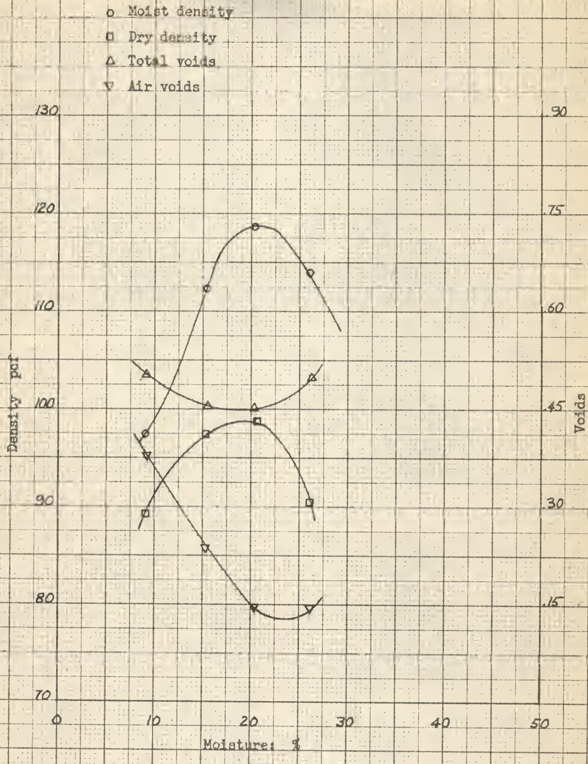

Fig. 28. Sample D: 0.5% sodium tripolyphosphate added to distilled water.

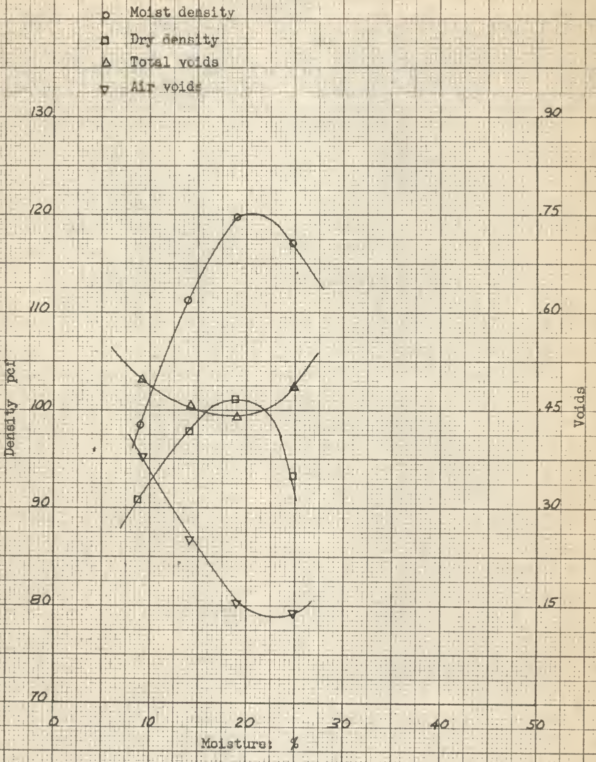

Fig. 29. Sample D: 0.75% sodium tripolyphosphate added to distilled water.

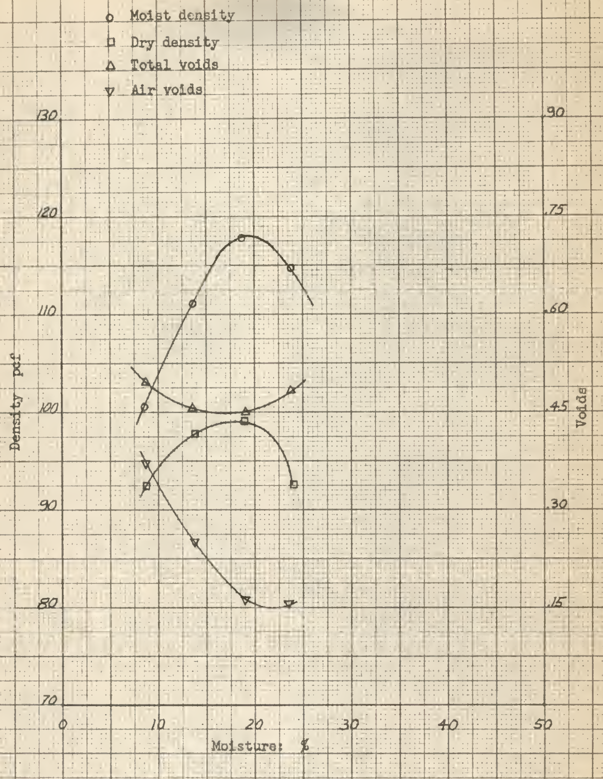

Fig. 30. Sample D: 0.5% tetrasodium pyrophosphate added to distilled water.

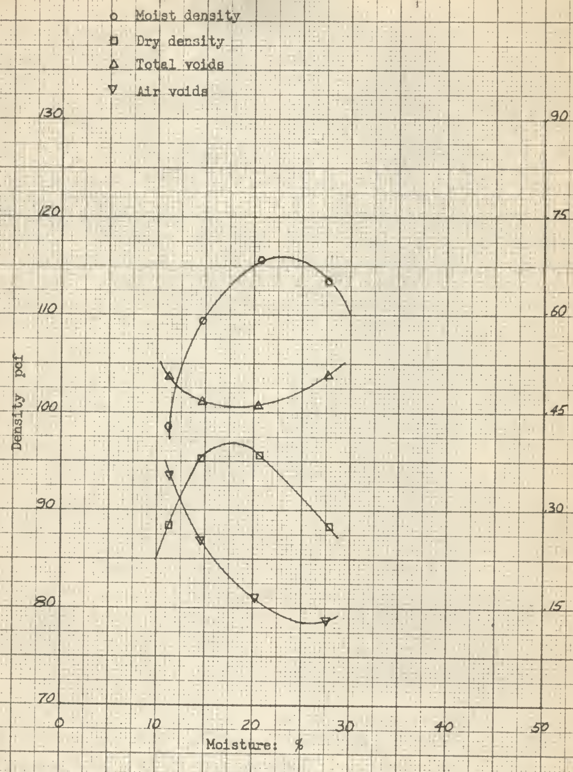

Fig. 31. Sample D: 0.75% tetrasodium pyrophosphate added to distilled water.

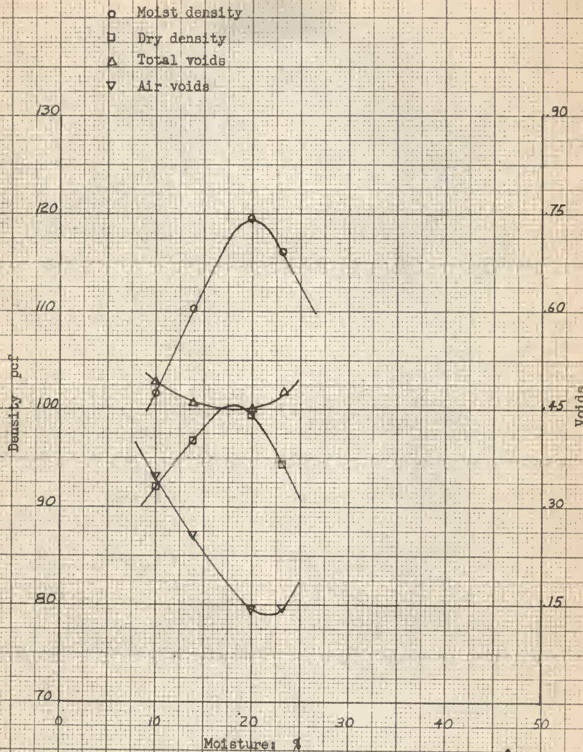

Fig. 32. Sample D: 0.5% calgon + sal soda added to distilled water.

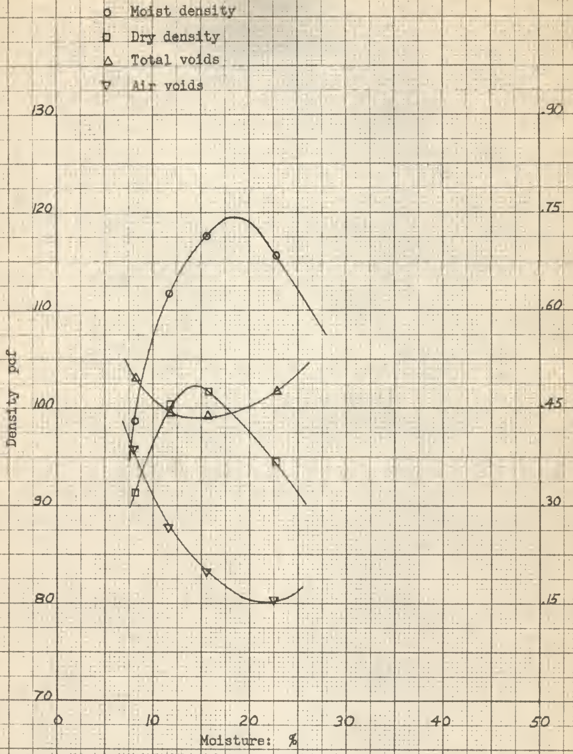

Fig. 33. Sample D: 0.75% calgon + sal soda added to distilled water.

EFFECT OF DISPERSING AGENTS ON THE COMPACTION CHARACTERISTICS OF DIFFERENT KINDS OF SOILS

by

ONDER EVERNOL

B. S., Robert College, Istanbul, Turkey, 1957

AN ABSTRACT OF
A THESES

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1959

The work described in this thesis is the second part of a soil mechanics research project conducted by Professor Harold H. Munger of the Department of Applied Mechanics of Kansas State College.

The purpose of this research project was to find the effect of commercial dispersing agents on the compaction characteristics of different kinds of soils.

The first part of this project was completed by Tekguc. He used three different kinds of dispersing agents in four kinds of soils from the vicinity of Manhattan, Kansas. Tekguc used 0.1 and 0.25 percent by weight of each dispersing agent. For the second part of this research project the same soils and the same dispersing agents were used. The only difference was that the percent of dispersing agent was different. The dispersants and their percents used for the second part are as follows:

0.50 percent Sodium Tripolyphosphate Granular I
0.75 " " " " "
0.50 " Tetrasodium Pyrophosphate Granular
0.75 " " " "
5 gm. Calgon + 0.952 gm Sal soda added to 1000 cm^3 distilled water
7.5 gm. Calgon + 1.428 gm Sal soda added to 1000 cm^3 distilled water.

For the laboratory tests, AASHO Designations were used, except that for hydrometer analyses the stirring time was five minutes, and the Rainhardt compaction machine was used for the compaction tests. After the classification and simple tests were completed, the compaction tests were made with distilled water. Then another series of compaction tests were made with dispersing agents.

As may be seen from tables and graphs of this research, small amounts of dispersing agents increase the maximum dry density of soils. When small amounts of dispersing agents are added to the soil, the ion exchange process takes place. Colloids of the soil adsorb cations and they become neutral. This process increases the zeta potential and decreases the force of attraction. In this form, the soil can be compacted to higher degrees. If some more dispersing agents are added to the soil flocculation takes place because of extra cations. In this condition, soil can not be compacted to a high degree.

The results of this research show that if the exchange capacity of the soil is obtained, it is easy to determine the amount of dispersion agent that will give the highest degree of compaction for that particular kind of soil. The kind of dispersing agent to be used for a given kind of soil is obtained by a chemical analysis of that soil, or by trial method.