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

by

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B. S., Robert College, Istanbul, Turkey, 1951

A THESIS

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INTRODUCTION

The purpose of the compaction of soil is to increase interlocking of soil particles, to increase cohesion, and also to expel air from the pores. The immediate result of compaction is the reduction of porosity. Generally, granular soils have a tendency to compact, whereas clays never lose the tendency to displace under load.

The work of Proctor in 1934 helped to show the influence of soil moisture on the density which can be obtained during compaction. On earthwork construction it is now standard practice to establish a control over moisture content while compaction is in progress. The laboratory compaction-test results are graphically represented by diagrams, which are often referred to as Proctor curves. All Proctor curves are generally alike in respect to developing a peak point. This peak clearly indicates that with a given compaction effort, maximum density will be obtained at a particular water content which is called optimum.

On some occasions it might be advisable to use some admixture, such as dispersion agents, to reduce the thickness of adhesive water film on soil particles, and thus provide stabilized soil with greater density. After such a treatment the soil will be less sensitive to climatic effects; that is, it will be more stable as to condition, and will have a lowered optimum water content. Solutions of dispersion agents, such as sodium products, have lower vapor pressures than water has, so the evaporation of moisture from soil mixtures wetted with these solutions will be definitely slower than similar mixtures moistened with water. These dispersion agents, in a stabilized road mixture, therefore tend to conserve its moisture content.

PROPERTIES OF CLAY MINERALS IN THE VICINITY OF MANHATTAN, KANSAS

The soil samples for this research project were taken from various points near Manhattan, Kansas, and their mineral properties determined. Davidson (2) stated that, generally, all clays have the same organization. Clays are made up of a complex, negative radical and a miscellany of adsorbed inorganic cations. A cation is a positively charged ion: Adsorbed cations are usually rather easily displaced, so they are spoken of as exchangeable ions. This replacement, called ionic exchange, or more commonly base exchange, is one of the most important of all soil phenomena especially when admixtures are used.

The geologic test results of the clay minerals in the four samples used are shown in Table 1.

Table 1. Test results of clay minerals.*

Sample	Clay major mineral groups	Amount, %
A, B, & D	Montmorillonite	60
	Illite	20
	Kaolinite	20
C	Interstratified Montmorillonite-Illite	60
	Illite	20
	Kaolinite	20

* The mineral subgroups are the same as major groups.

PROCEDURE

The American Association of State Highway Officials Designations listed below were used for the laboratory tests in this research project. First, all the simple and classification tests for each sample were completed; next, the compaction tests, first with ordinary distilled water and then with three dispersion agents, were run. In the compaction tests, two different percents by weight of water from each dispersion agent were used. The dispersion agents and their percents used in this research are as follows,

0.1 percent Sodium Tripolyphosphate Granular 1

0.25 " " " "

0.1 " Tetrasodium Pyrophosphate Granular

0.25 " " " "

1 gm. Calgon + 0.192 gm. Salsoda added to 1000 cm3 distilled water

2.5 gm. Calgon + 0.476 gm. Salsoda added to 1000 cm3 distilled water.

The AASHO Designations referred to for the laboratory tests are,

Specific Gravity Test	AASHO	Des.	T-100-54	
Field Moisture Equivalent	"	"	T-93-54	
Atterberg Limits:				
Liquid	"	"	T-89-54	
Plastic	"	"	T-90-54	
Shrinkage	"	"	T-92-54	
Hydrometer Analysis	"	"	T-88-54	Except stirring time is used 5 min.
Compaction Tests	"	"	T-99-49	Except Rainhardt compaction machine is used.

DISCUSSION

The transportation and placing of earth is an important part of engineering construction. There are more tons of earth used in engineering construction than all other materials. Approximately half of the total cost of highway construction is the cost of moving and compacting earth. Therefore any improvement in earth-working practice is the subject of very careful investigation.

According to Hough (5), Krynin (6), and Spangler (11), compaction of the soil is a kind of stabilisation process. This compaction requires a judicious use of water and strict control of the rolling operation. The amount of water which will produce adequate compaction varies with the character of the soil. Due to changes in climatic conditions, keeping the moisture content at the desired level during the construction period is quite expensive. So, the lower the desired moisture content can be kept, the more money saved.

Professor Lambe (7) has sponsored some investigations at the Massachusetts Institute of Technology searching the effect of calcium acrylate on the characteristics of soils. Lambe and Davidson (2),each in a small book, indicate improved conditions of compaction, but mostly they declared only the effect of calcium acrylate on the Atterberg limits.

Because of the great importance of the compaction characteristics of soil, it was decided to initiate this research project.

CONCLUSIONS

Conclusions of this research are based mostly on the results of the physical tests. As may be seen from Table 3, the dispersion agents seem to have more effect on the first and second soil samples, which had high colloid content. The higher the colloid content, the greater the reduction in optimum moisture content. By adding a dispersion agent to the water which is used to moisten the soil, the greater the increase in density obtained.

The last sample was more sandy, and the dispersion agent had less effect on it than on the other three samples which contained a higher percent of colloids.

All of these results are tabulated in Table 3 which shows the relation of percent dispersion agent to change in density and optimum moisture content.

One part of the explanation of the effect the dispersion agent had on the soil samples could be due to the ion or base exchange process in the colloids of the clay samples. According to Spangler (11), a clay has the ability to adsorb ions on its colloids, and this process is known as the ion exchange or the base exchange. First, without the dispersion agent in the water, the clay colloids were holding hydrogen ions, and when we added the dispersion agent of sodium or calcium some of the hydrogen ions were released and replaced by the sodium or by the calcium ions. Adding the dispersion agents to a soil may also cause some electro-chemical forces. Due to all of these factors, a change occurs in the optimum moisture content, and in maximum density.

SUMMARY

This Master of Science Thesis describes research work showing the effect of dispersion agents on the compaction characteristics of soils. The project was sponsored by Kansas State College of Agriculture and Applied Science under the administration of the Department of Applied Mechanics. Professor H. H. Munger, a member of the staff of this department, was in direct charge of the project, guiding the work and acting as technical advisor.

ACKNOWLEDGMENTS

In particular, thanks to Professor H. H. Munger for his intelligent and sympathetic support of this research work. Also, recognition should be given to Mr. Carl F. Crumpton, Research Geologist for the State Highway Commission of Kansas, for information given concerning the mineral properties of clays from the vicinity of Manhattan, Kansas.

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APPENDICES

LOCATION OF SOIL SAMPLES USED IN THIS RESEARCH PROJECT

Sample A: Sec. 1, T 10S, R 7E
South backslope of township road, 1/8 mile NW of Radio Tower of Station KSAC.

Sample B: SW 1/4 of SE 1/4, sec. 2, T 10S, R 8E,
600 ft north of Highway US 24.

Sample C: NW 1/4 of sec. 28, T 10S, R 8E,
East backslope of Highway K-13, 6 ft above the center line grade, 1/4 mile south of NW corner of sec. 28.

Sample D: NE 1/4 of sec. 28, T 10S, R 7E,
South backslope of old Golden Belt Road,
1/4 mile east of entrance to I.O.O.F. Home.

Table 2. Summary of the classification tests.

Simple Tests	Sample A	Sample B	Sample C	Sample D
Specific Gravity	2.53	2.76	2.75	3.00
Field Moisture	43.50	37.90	52.80	34.60
Classification Tests:				
Liquid Limit	36.9	38.2	34.6	31.1
Plastic Limit	25.4	23.4	41.2 ?	46.3 ?
Shrinkage Limit	21.9	23.4	22.6	24.2
Hydrometer Analysis:				
Sand percent	2.0	4.0	20.0	50.0
Silt percent	50.0	50.0	32.0	24.0
Clay percent	4.0	6.0	20.0	8.0
Colloids percent	44.0	40.0	28.0	18.0

Classification of the Soil Samples:

Sample	U.S. Bu. of Public Roads	Description of Soil
A	Silty Loam	Reclaimed by tile drainage 45 years 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 3. Summary of the optimum values obtained from the compaction tests

Ordinary Distilled Water	Sample A	Sample B	Sample C	Sample D
Optimum Moisture, %	23.0	20.5	23.5	18.0
Maximum Density, pcf	92.0	91.5	96.0	97.5
Sodium Tripolyphosphate:				
0.1% (by weight), Optimum Moisture, %	21.0	17.5	22.0	17.0
Maximum Density, pcf	93.6	93.0	97.0	98.0
0.25% (by weight), Optimum Moisture, %	19.0	16.5	20.0	16.0
Maximum Density, pcf	95.5	94.7	98.0	99.0
Tetrasodium Pyrophosphate:				
0.1% (by weight), Optimum Moisture, %	21.5	18.5	23.0	17.0
Maximum Density, pcf	93.8	92.4	96.0	98.5
0.25% (by weight), Optimum Moisture, %	20.0	18.0	20.0	15.0
Maximum Density, pcf	95.5	94.0	97.0	99.0

Table 3. (concluded)

	Sample A	Sample B	Sample C	Sample D
Calgon + Sal Soda				
1 gm. Calgon + 0.192 gm. Sal Soda added to 1000 cm3 distilled water:				
Optimum Moisture, %	20.5	18.5	22.0	17.5
Maximum Density, pcf	94.0	92.5	96.5	98.0
2.5 gm. Calgon + 0.467 gm. Sal Soda added to 1000 cm3 distilled water:				
Optimum Moisture, %	19.5	18.0	20.5	16.0
Maximum Density, pcf	96.0	94.5	97.5	99.5

Table 4. The relation of percent dispersion agent to change in density and optimum moisture content.

Sample	% Colloids	% Increase in Maximum Density		% Decrease in Optimum moisture	
		% Dispersant		% Dispersant	
		0.1	0.25	0.1	0.25
A	44.0	1.96	4.70	8.70	15.20
B	40.0	1.20	3.20	6.70	14.60
C	28.0	0.52	1.60	5.10	14.00
D	18.0	0.31	1.50	4.50	12.60
Av.	-	1.00	2.25	6.25	14.10

Notes: (1) Changes in density and optimum moisture content are computed in percent of values obtained with ordinary distilled water.

(2) Since there was no significant difference among the changes in density and optimum moisture content obtained with the three dispersion agents used, the data in Table 4 show average values of all three.

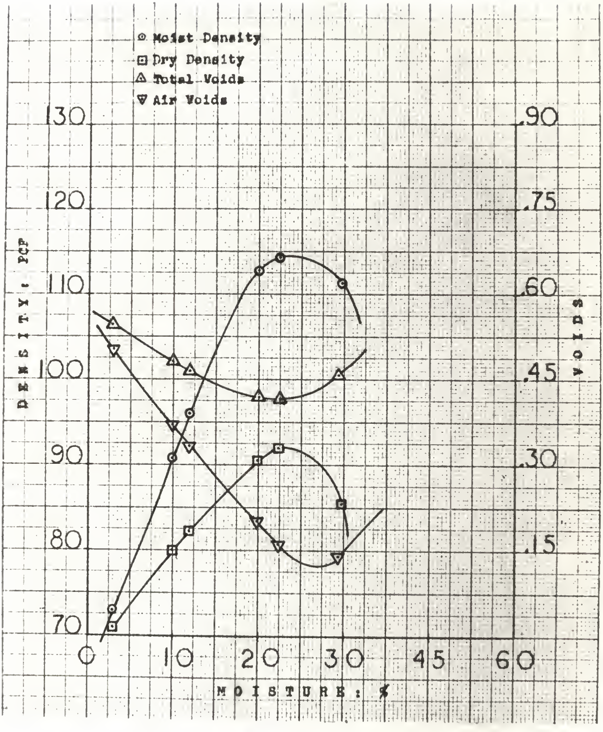

Fig. 1-A. Sample A: Ordinary distilled water.

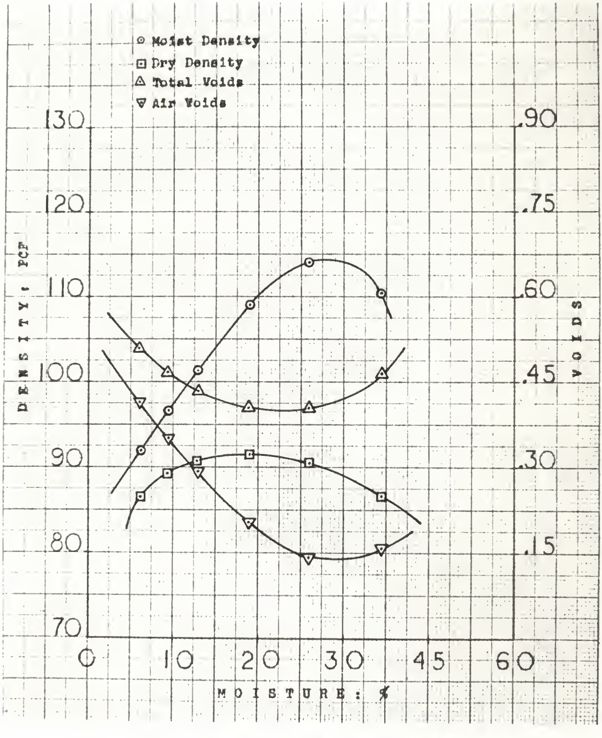

Fig. 1-B. Sample B: Ordinary distilled water.

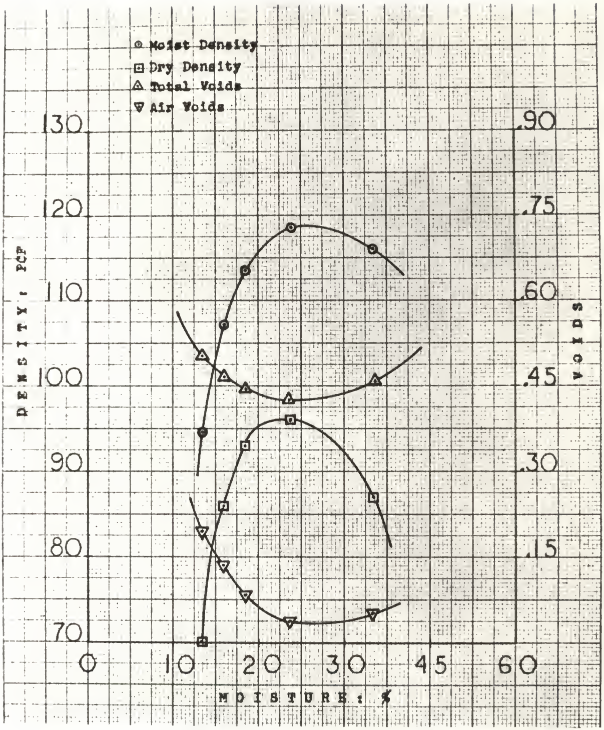

Fig. 1-C. Sample C: Ordinary distilled water.

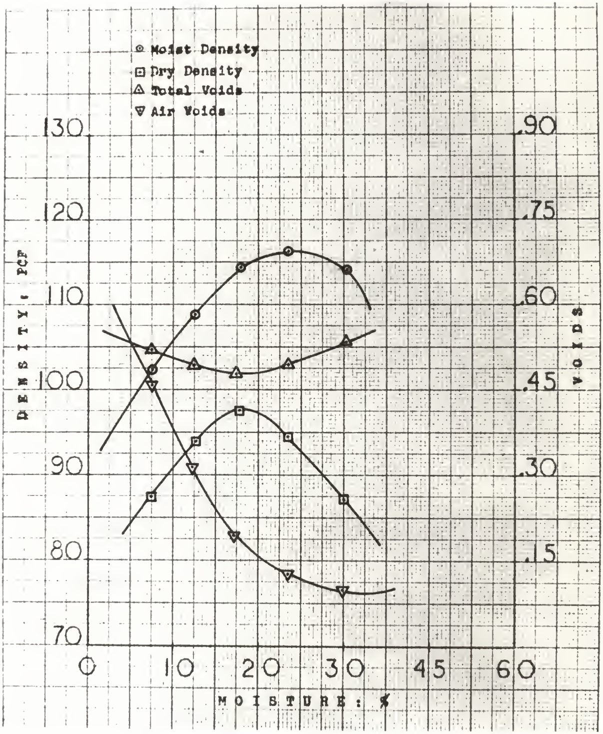

Fig. 1-D. Sample D: Ordinary distilled water.

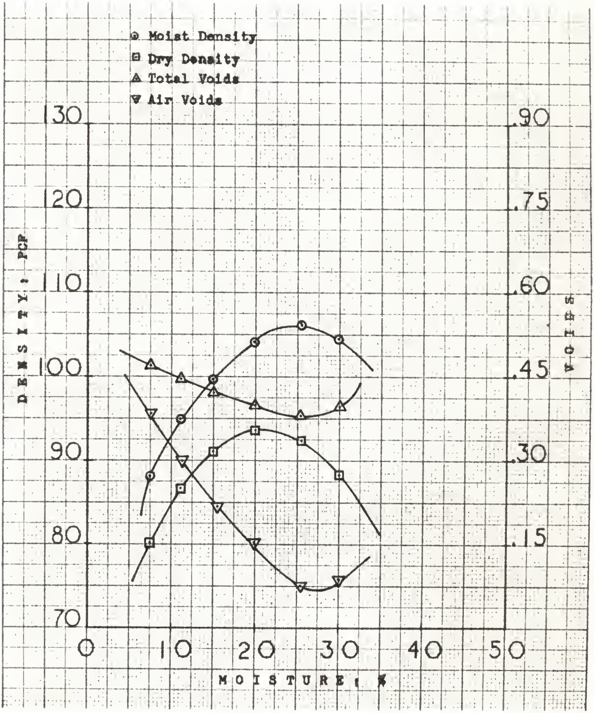

Fig. 2-A. Sample A: 0.1% (by weight) of sodium tripolyphosphate granular 1 added to distilled water.

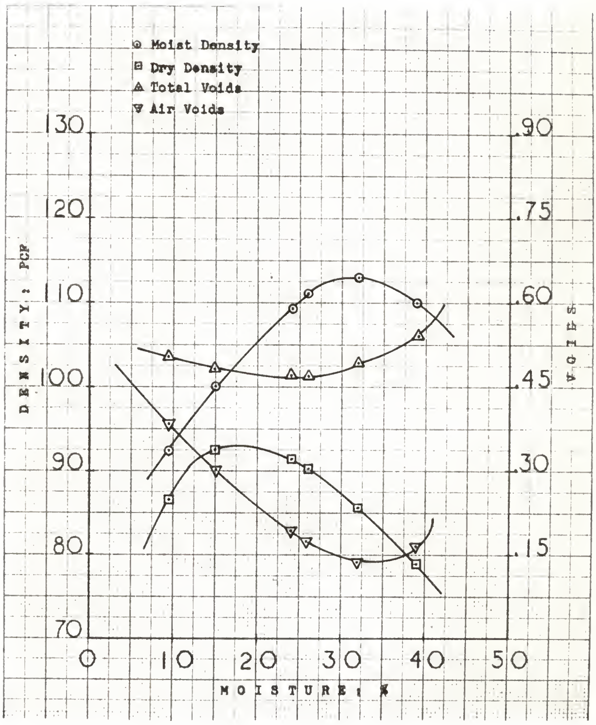

Fig. 2-B. Sample B: 0.1% (by weight) sodium tripolyphosphate granular 1 added to distilled water.

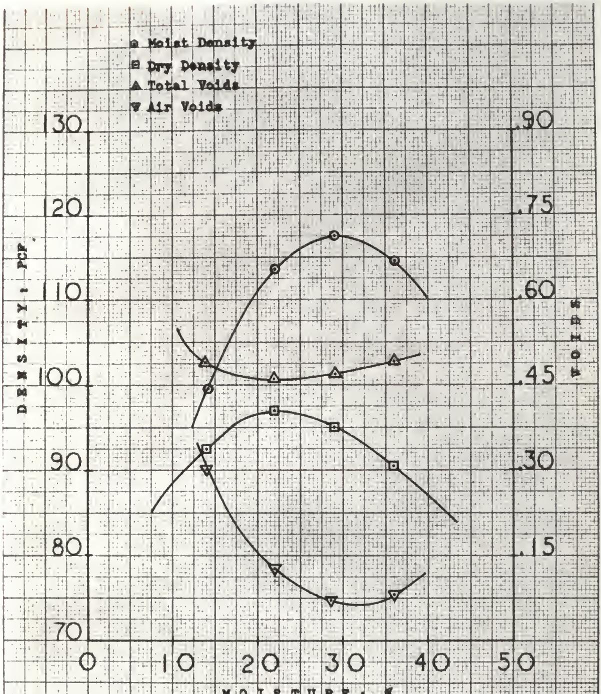

Fig. 2-C. Sample C: 0.1% (by weight) of sodium tripolyphosphate granular 1 added to distilled water.

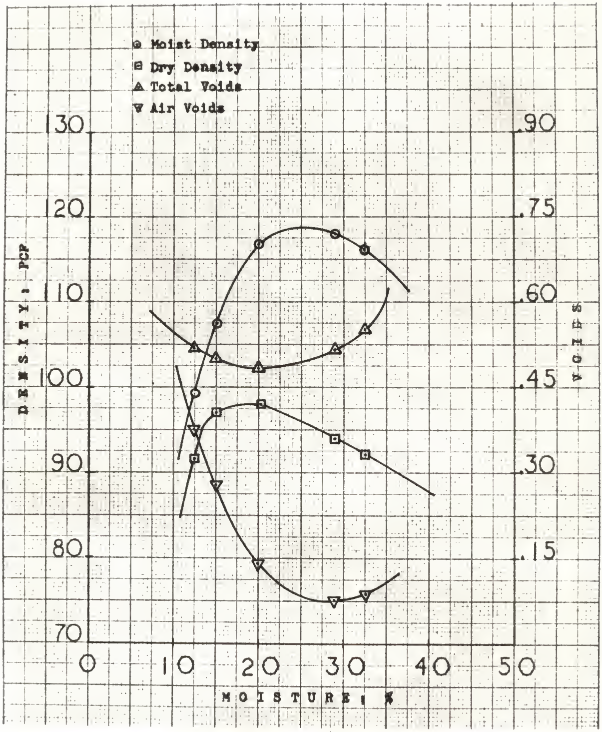

Fig. 2-D. Sample D: 0.1% (by weight) of sodium tripolyphosphate granular 1 added to distilled water.

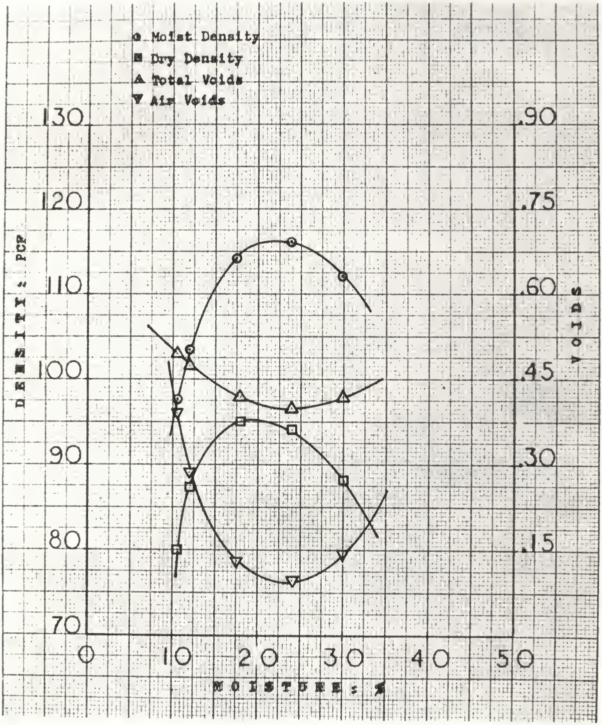

Fig. 3-A. Sample A: 0.25% (by weight) of sodium tripolyphosphate granular 1 added to distilled water.

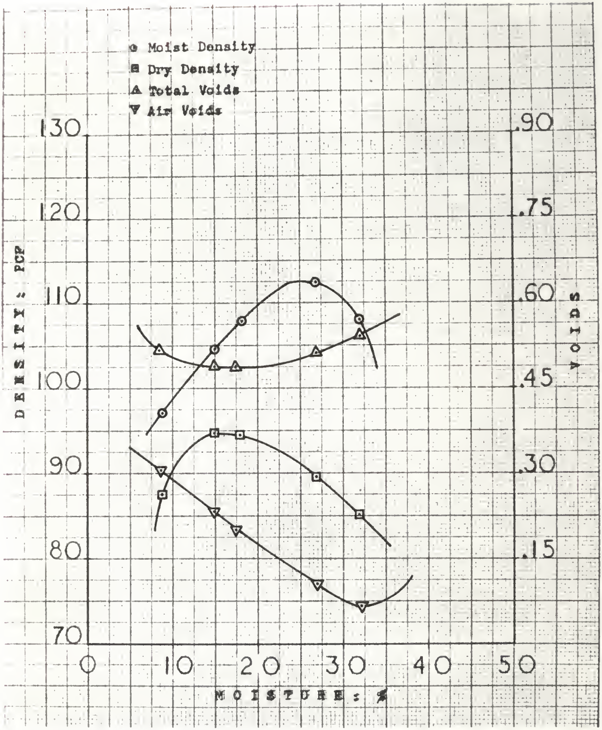

Fig. 3-B. Sample B: 0.25% (by weight) of sodium tripolyphosphate granular 1 added to distilled water.

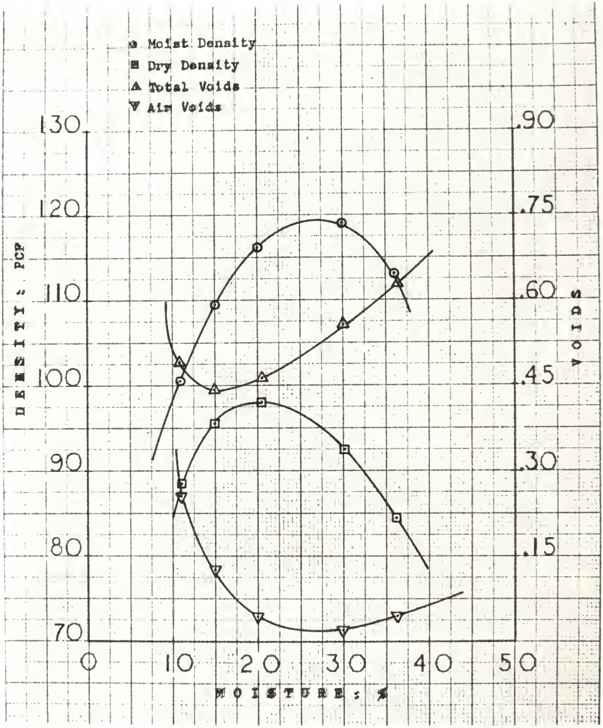

Fig. 3-C. Sample C: 0.25% (by weight) of sodium tripolyphosphate granular 1 added to distilled water.

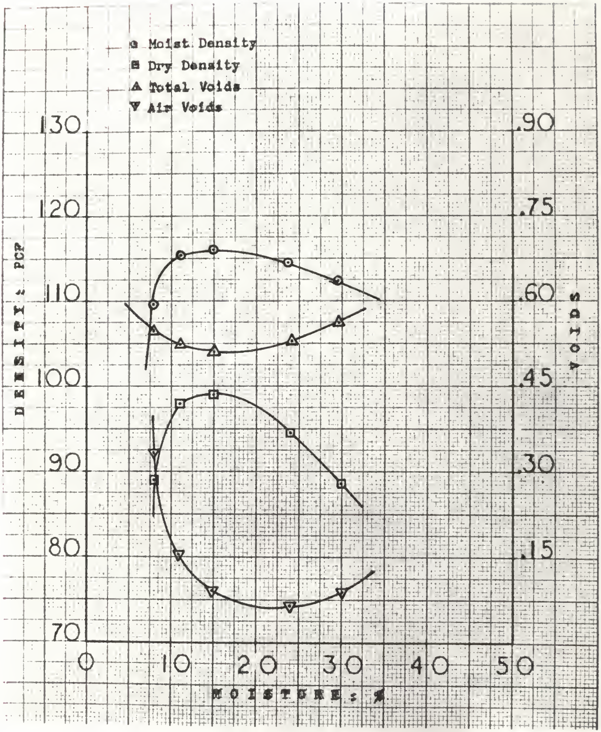

Fig. 3-D. Sample D: 0.25% (by weight) of sodium tripolyphosphate granular 1 added to distilled water.

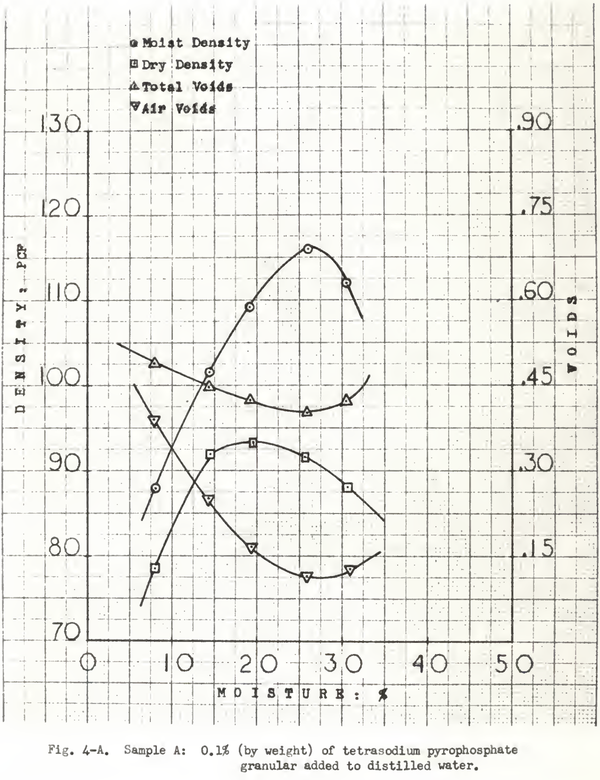

Fig. 4-A. Sample A: 0.1% (by weight) of tetrasodium pyrophosphate granular added to distilled water.

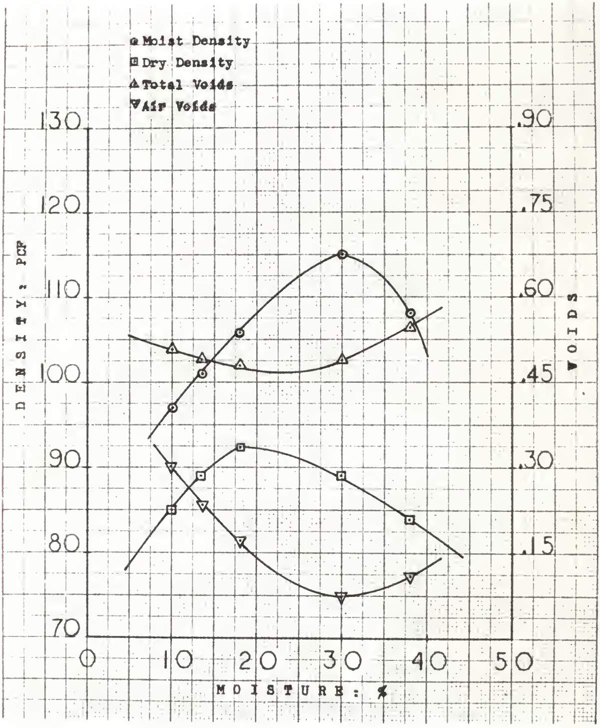

Fig. 4-B. Sample B: 0.1% (by weight) of tetrasodium pyrophosphate granular added to distilled water.

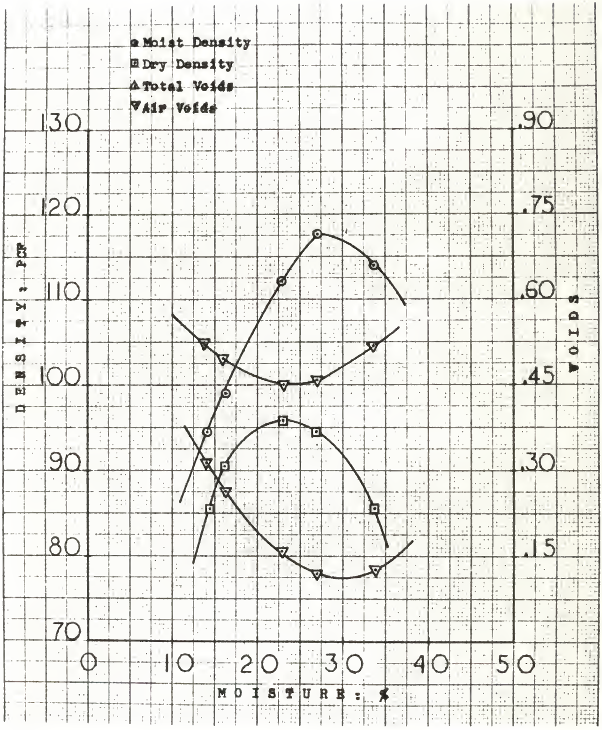

Fig. 4-C. Sample C: 0.1% (by weight) of tetrasodium phrophosphate granular added to distilled water.

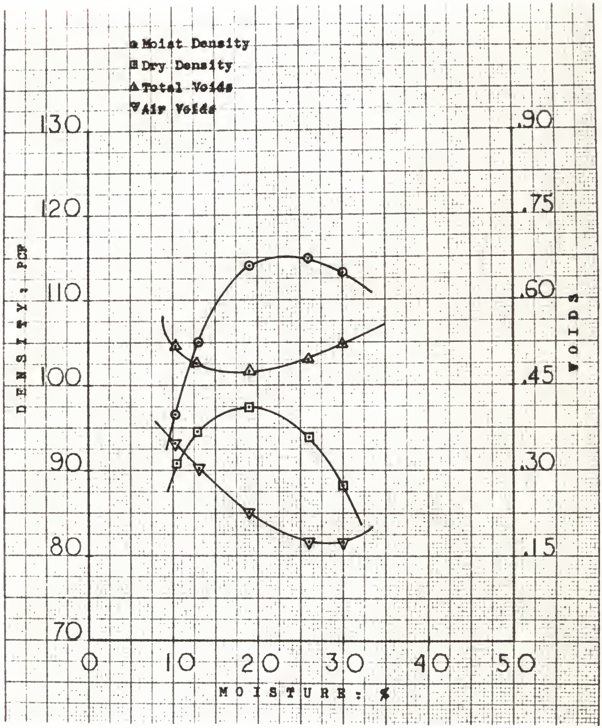

Fig. 4-D. Sample D: 0.1% (by weight) of tetrasodium pyrophosphate granular added to distilled water.

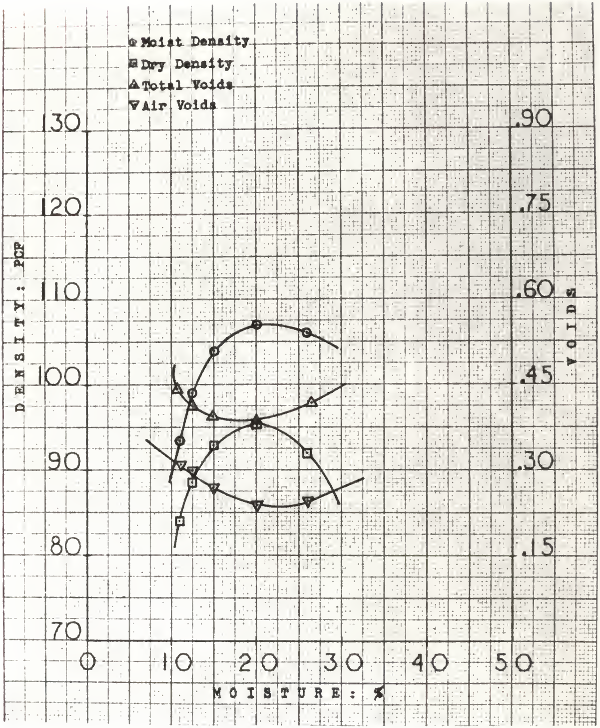

Fig. 5-A. Sample A: 0.25% (by weight) of tetrasodium pyrophosphate granular added to distilled water.

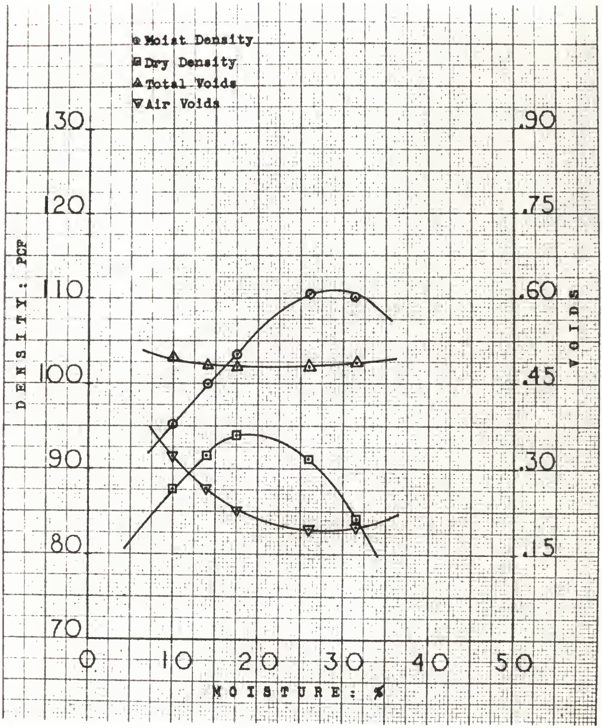

Fig. 5-B. Sample B: 0.25% (by weight) of tetrasodium pyrophosphate granular added to distilled water.

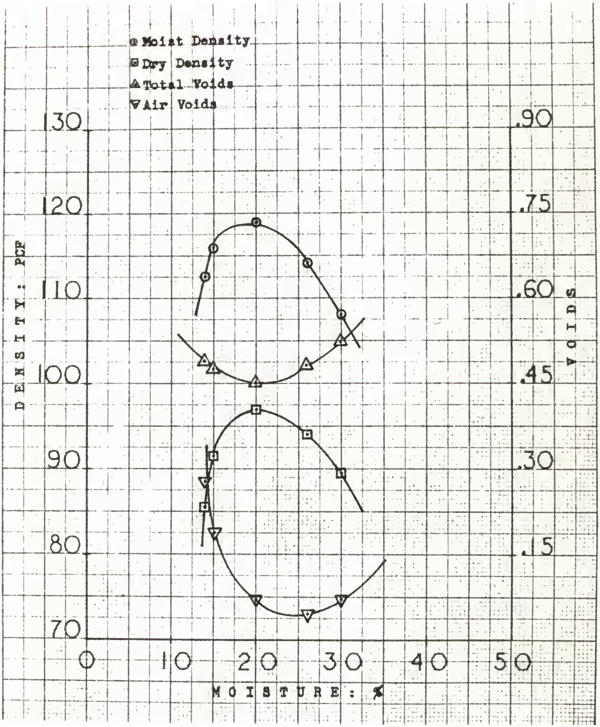

Fig. 5-C. Sample C: 0.25% (by weight) of tetrasodium pyrophosphate granular added to distilled water.

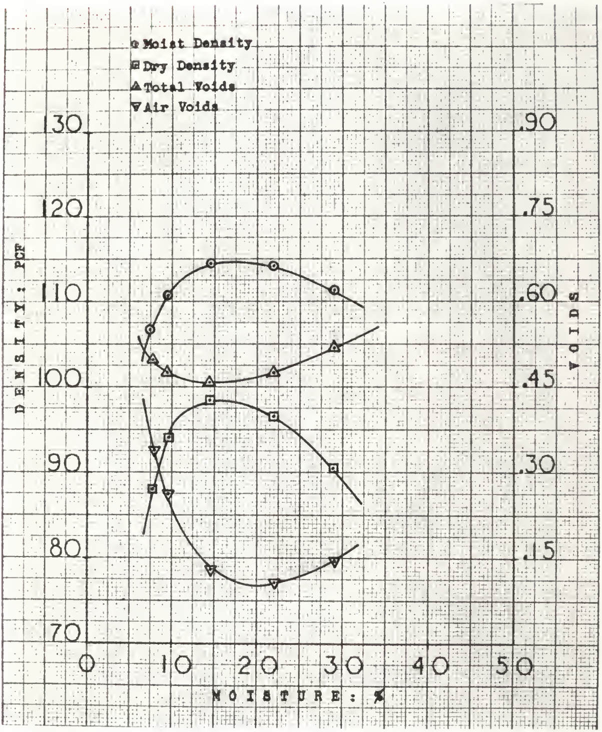

Fig. 5-D. Sample D: 0.25% (by weight) of tetrasodium pyrophosphate granular added to distilled water.

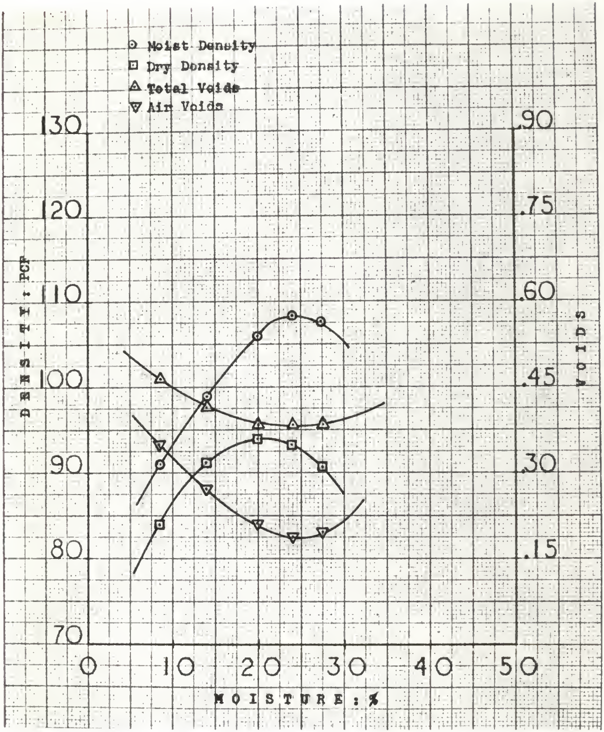

Fig. 6-A. Sample A: 1 gm. calgon + 0.192 gm. salsoda added to 1000 cm3 distilled water.

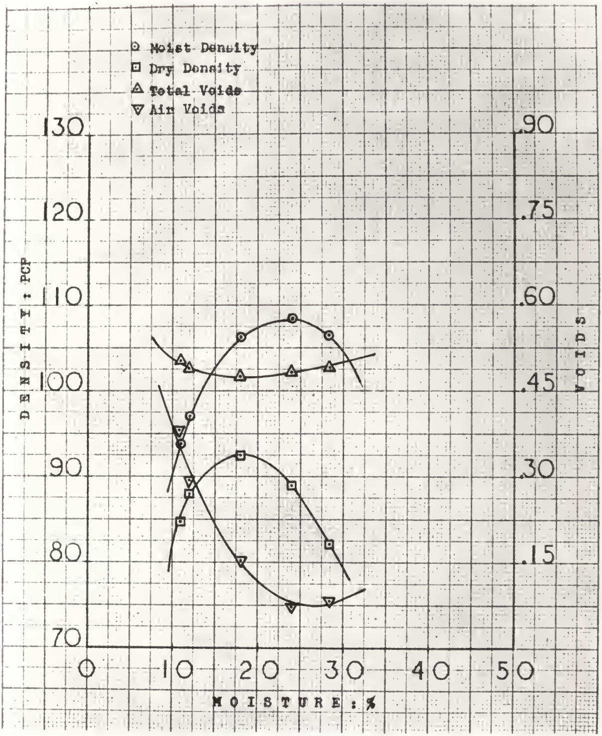

Fig. 6-B. Sample B: 1 gm. calgon + 0.192 gm. salsoda added to 1000 cm3 distilled water.

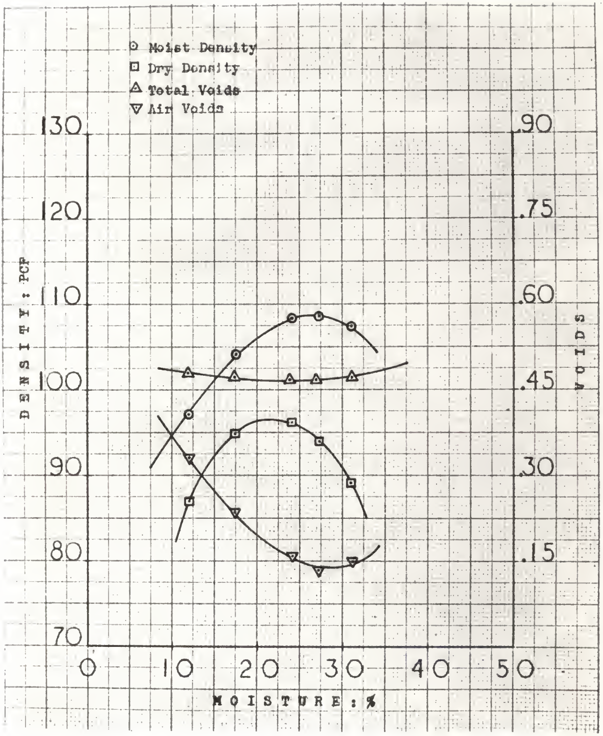

Fig. 6-C. Sample C: 1 gm. calgon + 0.192 gm. salsoda added to 1000 cm3 distilled water.

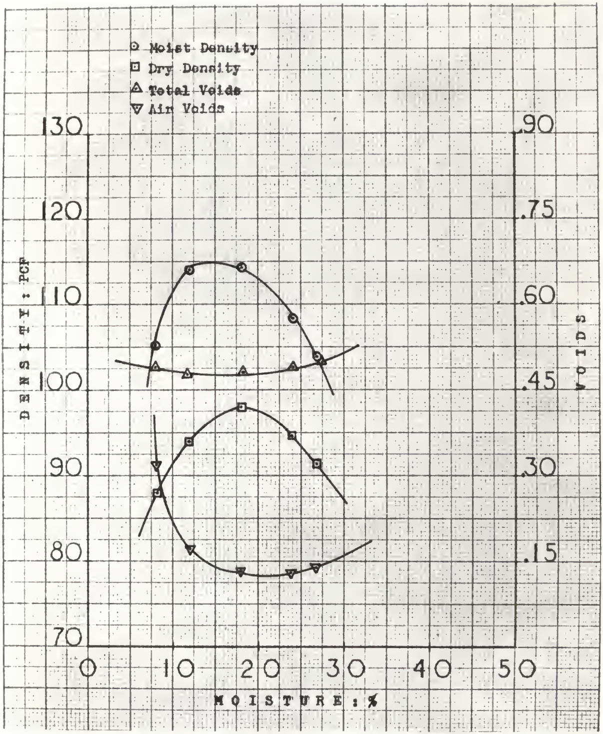

Fig. 6-D. Sample D: 1 gm. calgon + 0.192 gm. salsoda added to 1000 cm3 distilled water.

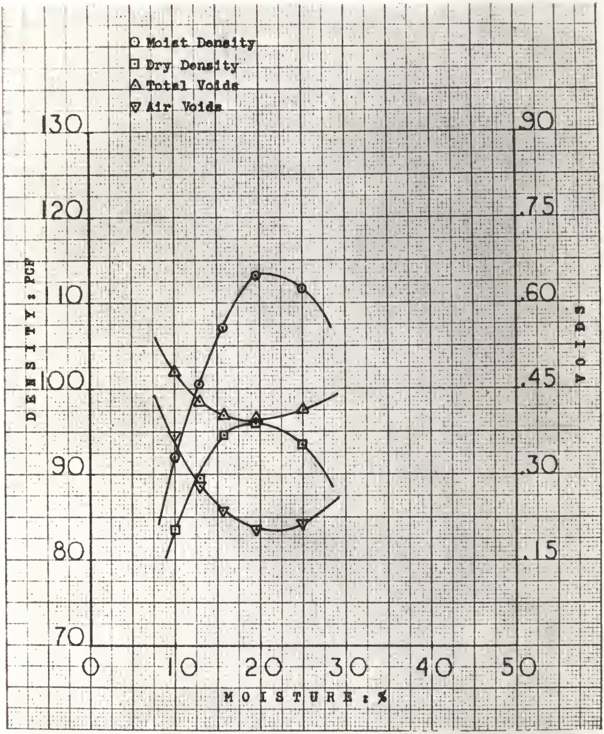

Fig. 7-A. Sample A: 2.5 gm. calgon + 0.476 gm. sal soda added to 1000 cm3 distilled water.

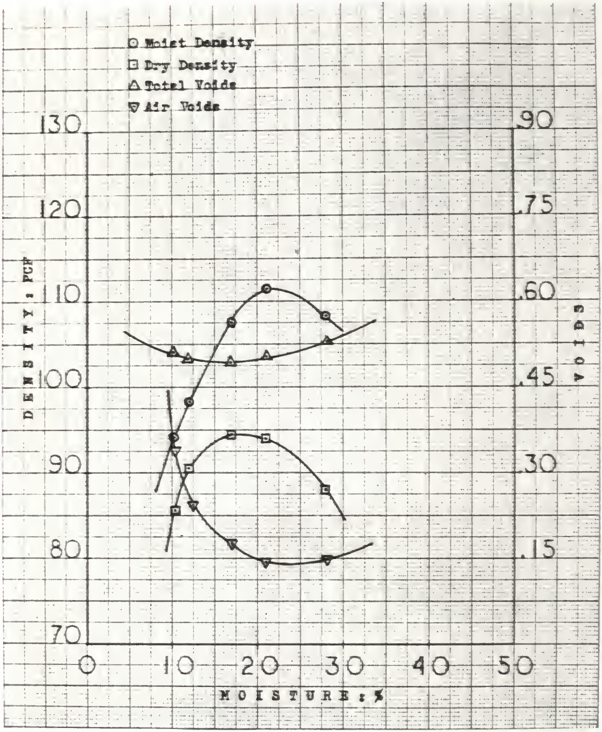

Fig. 7-B. Sample B: 2.5 gm. calgon + 0.476 gm. salsoda added to 1000 cm3 distilled water.

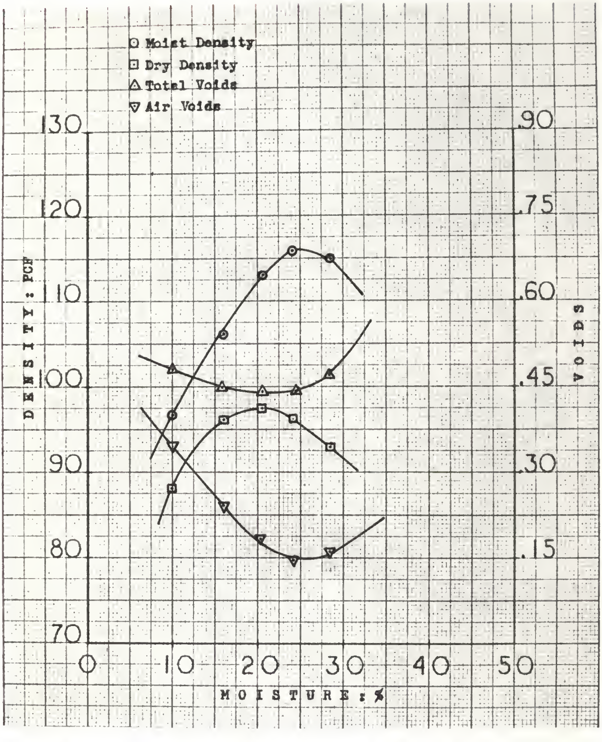

Fig. 7-C. Sample C: 2.5 gm. calgon + 0.476 gm. salsoda added to 1000 cm3 distilled water.

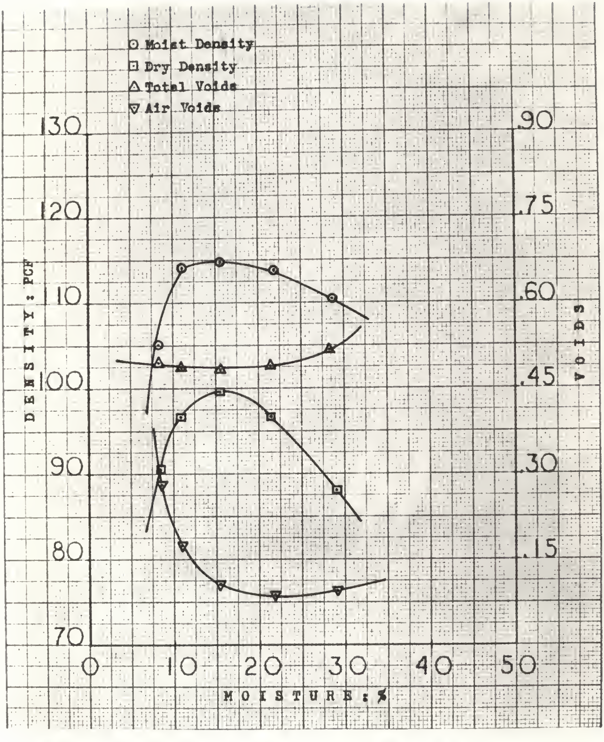

Fig. 7-D. Sample D: 2.5 gm. calgon + 0.476 gm. sal soda added to 1000 cm3 distilled water.

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ABSTRACT

Professor H. H. Munger of the Department of Applied Mechanics of Kansas State College, has been conducting Soil Mechanics research on the effect of dispersion agents on the compaction characteristics of different kinds of soils. The work described in this thesis is a part of this research project.

In this research project, 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. First, all simple and classification tests for all soil samples were completed; then the compaction tests were run with ordinary distilled water, and with the three kinds of commercial dispersion agents. During the compaction tests, two different percents by weight of water from each dispersion agent were used. The dispersion agents and their percents used are as follows:

0.1% Sodium Tripolyphosphate Granular 1
0.25% " " " "

0.1% Tetrasodium Pyrophosphate Granular
0.25% " " "

1 gm. Calgon + 0.192 gm. Sal Soda added
to 1000 cm3 distilled water

2.5 gm. Calgon + 0.192 gm. Sal Soda added
to 1000 cm3 distilled water.

Conclusions of this research are based mostly upon the results of the physical tests. As may be seen from Table 2, the dispersion agents have more effect on the samples which had high colloid content. The last sample was more sandy, and the dispersion agent had less

effect on this sample than it had on the other three samples containing a higher percent of colloids.

One part of the explanation of these facts could be the ion exchange process that takes place in the clay colloids. Before any dispersion agent was added to the distilled water, colloids were holding hydrogen ions; when the dispersion agents were added, some of the ions were released and replaced by the sodium or calcium ions.

Table 1

Sample	U. S. Public Road Classification	Description of Soil
A	Silty Loam	Reclaimed by tile drainage 45 years 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 2. Relation of percent dispersion agent to change in density and optimum moisture.

Sample	% Colloids	% Increase in Density		% Decrease in optimum Moisture	
		% Dispersant		% Dispersant	
		0.1	0.25	0.1	0.25
A	44.0	1.96	4.70	8.70	15.20
B	40.0	1.20	3.20	6.70	14.60
C	28.0	0.52	1.60	5.10	14.00
D	18.0	0.31	1.50	4.50	12.60
Av.	-	1.00	2.25	6.25	14.10

Notes: (1) Changes in density and optimum moisture content are computed in percent of values obtained with ordinary distilled water.

(2) Since there was no significant difference among the changes in density and optimum moisture content obtained with the three dispersion agents used, the data in Table 2 show average values of all three.