AN INVESTIGATION OF THE USE OF EMULSIFIED ASPHALT WITH SAND AND CLAY

THESIS FOR THE DEGREE OF B. S.

G. C. DOWD

1935

An Investigation of the Use of Emulsified Asphalt with Sand and Clay

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

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BACHELOR OF SCIENCE

March 1935

THESIS

CONTENT

FORWARD

"An Investigation of the Use of Emulsified Asphalt with Sand and Clay" was chosen for my thesis because I believe that there is a great deal that can be learned from such an investigation which will be of great value in the constructing of secondary road surfaces both now and in the future. I believe that the experience obtained in performing this thesis has been of great value in that it is doubtless experience which I could not have obtained otherwise.

I wish to thank the Civil Engineering Department for the use of the necessary equipment; to thank Mr. E.A.Finney for his aid, advice and criticism; and to thank the American Bitumuls Company for the emulsion used in the investigation.

Gaylord C. Dowd

INTRODUCTION

In the United States there are more than three million miles of roads of which more than two thirds are earth roads. Until very recently the public demanded better main roads with little thought of improving the secondary or feeder roads. But the time has now come when the average person is beginning to realize the importance of improving the vast milage of unimproved roads.

The people living in rural districts have for many years supported the various state highway programs with the hope that they too might obtain better roads -- which are a necessity of community life.

It is over these roads that commodities consisting principally of foodstuffs vital to the life of the nation are carried. Because of the present-day economic conditions, a large amount of research has been carried on in order to discover a way of building cheaper surfaces which will require little upkeep and yet will be adequate to handle the demands placed upon them.

To build cheaper roads it is necessary to use the material at hand in so far as possible along with some type of bonding material. With this in mind this investigation was carried on, using both fine and coarse sand, and clay as the materials, with emulsified asphalt as the bonding material, making use of the mix-in-place method in order to experiment with the construction of a cheap durable road surface.

This investigation will be limited to the state of Michigan although it is a poor state to use for this study because of its abundant supply of natural material such as sand, clay, and gravel.

Sand and clay are very common and very widely distributed materials. Sand-clay roads have been constructed in many sections of the country under various conditions. In this study I desire to determine the suitability of various sand-clay mixtures when mixed with emulsion, which will prove to be suitable under all weather conditions for light-traffic roads.

Sand consists of small particles of rock. It has very little, if any, power of cementation because it undergoes no further decomposition under weathering. When wet, each particle is surrounded by a film of water which possesses some binding power. Thus a sandy road may, when wet, produces a surface that is comparatively firm and stable. However, when dry, the sand has no way of being bonded together. Each particle separates from its neighbor, thus giving no firm surface and hence making travel difficult if not treacherous.

Clay on the other hand produces a very firm and stable road when dry because clay possesses cementing properties. But, when wet, clay becomes plastic, sticky, or slushy, depending upon the amount of water present. Clay is composed of small particles of stone dust which do not possess mechanical bond as do the sand particles when wet. Thus a wet clay road is as bad, if not worse, than a dry sandy one.

A mixture of sand and clay can overcome many of the disadvantages of either the sand or the clay, when used alone. Such road surfaces, made of sand and clay, will prove satisfactory or unsatisfactory depending upon the proportions of the sand and the clay that they possess. A well proportioned sand-clay surface will prove to be a good surface both in dry and wet weather because it possesses the resisting power of the sand in wet weather and the cementing power of the clay in dry weather.

Sand and clay, as I mentioned above, have often been combined for road surfaces and it is this frequency of their use together that has given them the official title of "sand-clay" roads. The term "sand-clay" road is applied to an earth road which is surfaced with especially selected or prepared earth containing sand and clay combined in such proportions as to increase the resistance of the road to wear.

The theory of a sand-clay mixture is that the sand grains shall be in contact and interlock with an amount of clay just sufficient to fill the voids, hold the sand particles together and prevent disintegration in dry weather. The road receives its stability from the sand and must contain enough of this aggregate to support the traffic and resist grinding and crushing action. The purpose of the clay is to act as a binder for the particles of sand and the use of the proper amount of clay is absolutely essential if this type of road is to be a success. If an excess of clay is used in the mixture the grains of sand, which are forced out of contact with each other, are free to move about in the mass so that they offer no more resistance to pressure than if the entire mass were made of clay. If an insufficient amount of clay is present, the mixture will lack the required binding power and will disintegrate.

Because of the extensive application of surface treatment in the construction of low cost roads and the great need for further information on this subject, representatives of the tar industry and the Bureau of Public Roads have recently made a field and laboratory study in North Carolina of surface treated roads in which tar was used. This particular type of treatment consisted essentially in the application of a light tar to the untreated base followed by an application of hot tar with a cover of mineral aggregate, a third application of tar being applied with a mineral aggregate cover after the surface had been subjected to traffic for a period of time. This method of treatment was designed to provide a wear-resisting surface that would adequately protect the base from deterioration and which would be economically maintained in a satisfactory condition.

Various investigations, with different materials, have been conducted from time to time, some of which have proven very successful while others were not so successful. In all these investigations however, asphaltic emulsions seem to have been left in the background, supposedly because of their newness in the field. Now I believe that a sand and clay roadbed with a binding of asphaltic emulsion has a great many advantages over these other types.

By the term asphaltic emulsion or emulsified asphalt, we

mean pure asphalt dispersed, for economy and convenience in using, into ultra-microscopic sized droplets, dispersed in water as the suspending medium for giving the proper fluidity.

An emulsion saves the cost and inconvenience of heating, eliminates the danger of over-heating which is detrimental to the efficiency of the surface and makes application possible by inexpensive equipment.

Its high penetrating quality permits a high percentage of aggregate without affecting the proper coating with asphalt and enables the asphalt to infiltrate to the very bottom of the coarse layer.

When used cold, it is practically the same temperature as the aggregate to which it is applied; hence, there is no sudden congealing to affect its infiltration.

It may properly be used on moist or wet aggregate eliminating many wet weather delays.

The likelihood of excess asphalt or fat spots is minimized ---thoroughly non-skid surfaces are characteristic of emulsion construction.

It permits the use of a wide variety of aggregate that would not always be suitable for binding by penetration methods.

In light surface-dressing work it sets quickly so that there is no throwing or spattering upon cars using the surface immediately after its application.

With these very apparent advantages in mind, I set out to investigate the feasibility of mixing an asphaltic emulsion with various proportions of sand and clay in order to find a surface that would resist wear and weathering and be suitable for a secondary road.

THE INVESTIGATION

After deciding to continue the investigation carried on by R.C.Monnett and J.L.Scott, I collected the required material to carry on my problem. I decided to study the effects that different sands have in the mixture while at the same time leaving out silt. This problem was carried on with just one asphalt which passes the requirements shown later.

The sands I used were concrete sand which is a course sand and dune sand which is a fine sand. The mechanical alalysis of soil was run on a sample of each sand and clay. This analysis was run by the hydrometer method under the directions of a bulletin by G.J.Bouyoucos of Michigan State College.

Various mixes were then made varying the amounts of sand and clay content, using the method of obtaining percentage of ingredients used in the design of sheet asphalt pavement. The liquid limit test was run on each sample to determine the amount of water it would be necessary to use in the sample. These mixes were then made using 9 percent by weight asphalt in all the mixes. All the samples were mixed by hand. After the samd and clay were thoroughly mixed, the amount of water was added that would give the sample its liquid limit. After the mixture was thoroughly mixed the asphalt was added. This was then mixed thoroughly and allowed to stand for a period of 24 hours. At the conclusion of this time the sample was compressed into a pat 6 inches in diameter and about $1\frac{1}{2}$ in.

in depth. These samples were placed outside where weathering action would take place. While outside, they were subjected to both freezing and thawing action. These samples, shown in Figs. 4 and 7 were left outside for 5 weeks and then dried in the laboratory. The shear test was run on these samples and curves, as shown on plates 3 and 4, were drawn.

After this set of samples was mixed, I made up samples of the same percentages by weight as the above samples. One set was made with samples 4 inches in diameter and about 2¼ in. in depth, which were cured in the laboratory. These samples are shown in Figs. 3 and 6, and are used as comparison samples.

The other set of samples were 2 inches in diameter and approximately 2 inches in depth. These samples were placed in the water bath and their weights were recorded each day for a period of two weeks. The absorption percentage was obtained from this data and curves, as shown in plates 1 and 2 were drawn. Figs. 2 and 5 show these samples.

All samples were compressed into pats by the machine shown in Fig. 1, which is shown below. There was applied to each pat the equivalent of fifteen hundred pounds per square inch of pressure, which is approximately the pressure exerted by an average sized road roller.

A new set of samples was made using a constant percentage of sand and clay, while increasing the percent of asphalt. This was done after the previous samples had been cured. Samples 1A and 1B shown in Figs. 3 and 6 respectively, show a very good color. These samples contain 70 percent sand, 21 percent clay and 9 percent asphalt. From all outward appearances there is just the right amount of asphalt, sand, and clay in these samples. Samples 5A and 5B have 71 percent clay, 20 percent sand, and 9 percent emulsion. The color of these pats was a very light color, making them appear as if they hadn't had a high enough asphalt content. It was with this mix that I varied the content of asphalt, attempting to get a mix whose color approximated that of samples 1A and 1B. It was found that with a mix of such high clay content, it would be economically impossible to mix enough asphalt with the mix and obtain a good dark color. These samples in which I varied the asphalt content, were placed in the water bath and the percentage of absorption was obtained for a 7-day period. These samples are shown in figures 8-11.

Table 2 gives data obtained from samples in which I used varying percents of asphalt, while running the clay down to zero. Table 3 gives data obtained from samples in which a combination of coarse and fine sand was used with a constant percent of asphalt.

The samples for these last two tables were oven cured and allowed to come to room temperature before testing. The shear test was run by placing a sample in a 2 inch cylinder with an inch and one-half knife-edged throat, and then the pressure was noted at which the briquette pushed through the throat.

Particular note should be made of the deterioration of the samples as shown in the pictures. The samples that cracked the worst were the ones that had the higher percents of clay in them. The samples in the water bath cracked badly. Sample 5A of Fig. 4. cracked so badly that it was impossible to cut out briquettes in order to run the shear test on that sample. The samples in which the asphalt content was varied cracked up very considerably, showing that the clay content was too high and not enough sand was present to give the necessary bonding property.

Very strangely the shear increased as the percentage of clay increased. However I believe that smaller shear can be had with safety, when using a mix of less clay and more sand. I believe that the shear increased as it did because the clay became so brittle when dried and thus caused a much tougher sample.

Tests for wear and abrasion were to have been run on the treadometer, using various mixtures. But these tests could not be run because the use of the treadometer was not available, and because of an insufficient amount of time for further investigation on this subject.

I believe that a great deal of valuable information could be obtained by making such tests. I hope that I may some day be able to run these and many more tests and thus carry this investigation on to its true conclusion.

It is certain that a great deal of worth while work can be done in this field, since emulsified asphalt is a comparatively new surfacing material. It is very economiaal and easy to apply, and makes a very good road surface. Therefore I believe that it is one of the best materials we have available today for surfacing low-type roads.

Fig. 1. Compression Machine.

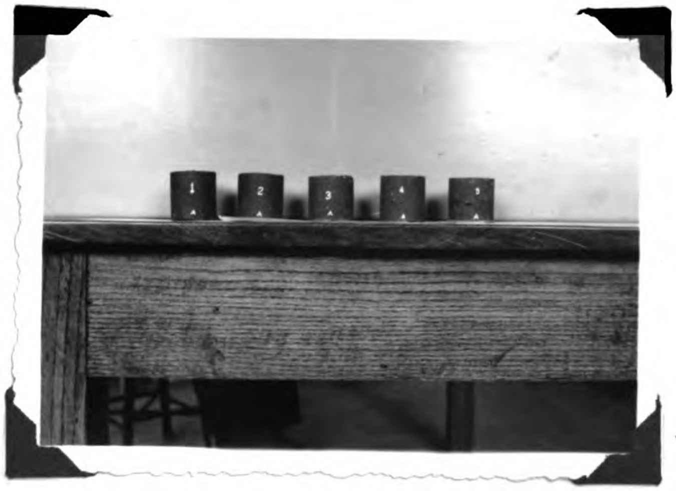


Fig. 2. Coarse Sand Mix--absorption test; 14 days in water.

Fig. 3. Coarse Sand Mix--lab. cured.

Fig. 4. Coarse Sand Mix--alternate freezing & thawing for 5 weeks.

Fig. 5. Fine Sand Mix--absorption test; 14 days in water.

Fig. 6. Fine Sand Mix--lab. cured.

Fig. 7. Fine Sand Mix--alternate freezing & thawing for 5 weeks.

Fig. 8. Coarse Sand & Clay with Varying Asphalt Content--lab. dried.

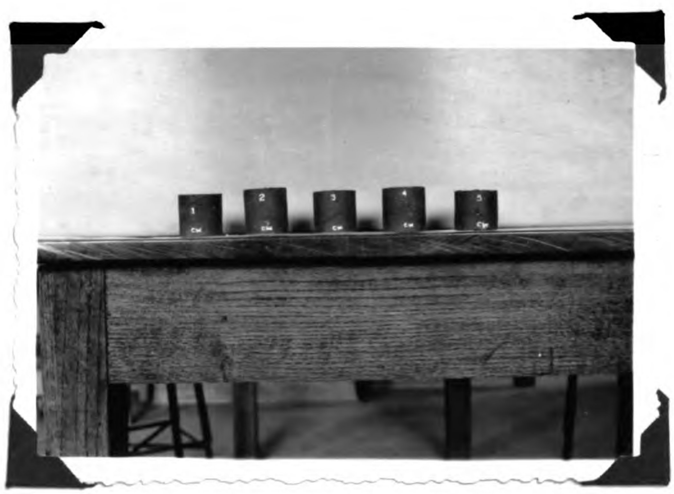


Fig. 9. Same as Above--subjected to 7 days in water.

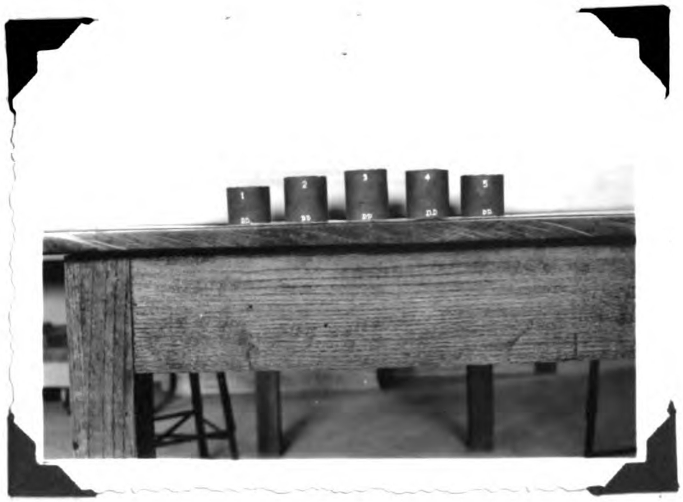


Fig. 10. Fine Sand & Clay with
Varying Asphalt Content-lab dried.

Fig. 11. Same as Above--subjected
to 7 days in water.

omd

Requirements for Emulsified Asphalt XRM Grade

Bitumuls XRM is a homogeneous emulsion of asphalt, water, emulsifying and stabilizing agents. It is miscible with pure water in all proportions and shows no separation of asphalt, after thorough mixing, within thirty days after delivery, provided separation has not been caused by freezing. When tested as hereinafter specified, the emulsions conform to the following requirements:

Viscosity - Saybolt Furol - 60 cc. at 25° C.

Not more than 60 sec.

Miscibility- - - No appreciable separation in 2 hrs.

Mixing - - - - - - - - - -Break, not more than 2 %

Total combined amount of all saponifiable substances,

including petroleum acids - - - -Not more than 1 %

Residue at 163° C. 3 hrs., 50 gms. Not less than 55 %

Settlement, 10 days - - - - - - - - - - Not more than 3 %

Demulsibility - - - - - - - - - - - - - -Not more than 1 %

The residue obtained from the test at 163° C. shall conform to the following requirements:

Penetration at 25° C. - - - - - - - - - - - 200 to 300

Solubility in carbon disulphide- - Not less than 95%

Ductility at 25° C. - - - - - - - - Not less than 10 cm.

Ash - - - - - - - - - - - - - - - - - - -Not more than 3 %

Key for Tables 1, 2, and 3.

V_P = shear in lbs. per sq. in. on absorption samples

V_W = " " " " " " " weathered "

V_N = " " " " " " " lab. cured "

P = percent of absorption

X = " " asphalt by weight

C.S.= " " coarse sand by weight

F.S.= " " fine " " "

C = " " clay " "

TABLE 1.

No.	C.S.	F.S.	C.	X.	V_W	V_N	V_P	P
A								
1	70.0		21.0	9.0	819	552	725.45	3.23
2	57.0		34.0	9.0	955	1141	874.5	4.105
3	44.6		46.4	9.0	1401	1090	1085.5	6.335
4	32.4		58.6	9.0	2005	965	1288	7.845
5	20.0		71.0	9.0	2330	1550	1485.5	10.125
B								
1		70.0	21.0	9.0	1257	756	724.25	2.85
2		57.0	34.0	9.0	1544	1259	1271	4.98
3		44.6	46.4	9.0	1475	1234	1644	5.375
4		32.4	58.6	9.0	1892	1335	1413.5	7.885
5		20.0	71.0	9.0	1397	1710	1586	9.025

No.	C.S.	F.S.	C	X	V_W	V_N	V_P	P
C								
1	20.0		71.0	10.0		1735	1702	6.9
2	20.0		71.0	11.0		1583	1292	6.4
3	20.0		71.0	12.0		1470	1098	5.84
4	20.0		71.0	13.0		1469	1000	5.94
5	20.0		71.0	14.0		1221	998	5.045
D								
1		20.0	71.0	10.0		889.5	1421	7.94
2		20.0	71.0	11.0		1128	860	6.94
3		20.0	71.0	12.0		1085	1062	6.5
4		20.0	71.0	13.0		1178	975	7.08
5		20.0	71.0	14.0		1448	1070	7.92

TABLE 2.

No.	C.S.	F.S.	C	X	V_N
1	75.6		15.4	9	676
2		75.6	15.4	9	686
3	81		10	9	703
4		81	10	9	657
5	86		5	9	516
6		86	5	9	243
7	91		0	9	957
8		91	0	9	198
9	62		30	8	1345
10		62	30	8	1587
11	72		20	8	1156
12		72	20	8	1209
13	82		10	8	1033

No.	C.S.	F.S.	C	X	V_N
14		82	10	8	555
15	73		20	7	1352
16		73	20	7	1299.6
17	83		10	7	1044
18		83	10	7	431
19	93		0	7	253
20		93	0	7	225

TABLE 3.

No.	C.S.	F.S.	C	X	V_N
1	17.75	53.25	20	9	486
2	30.5	30.5	20	9	599
3	53.25	17.75	20	9	636
4	19	57	15	9	736
5	38	38	15	9	938
6	57	19	15	9	955
7	20.25	60.5	10	9	686
8	40.5	40.5	10	9	744
9	60.5	20.25	10	9	822
10	21.5	63.25	5	9	377
11	43	43	5	9	397
12	63.25	21.5	5	9	499

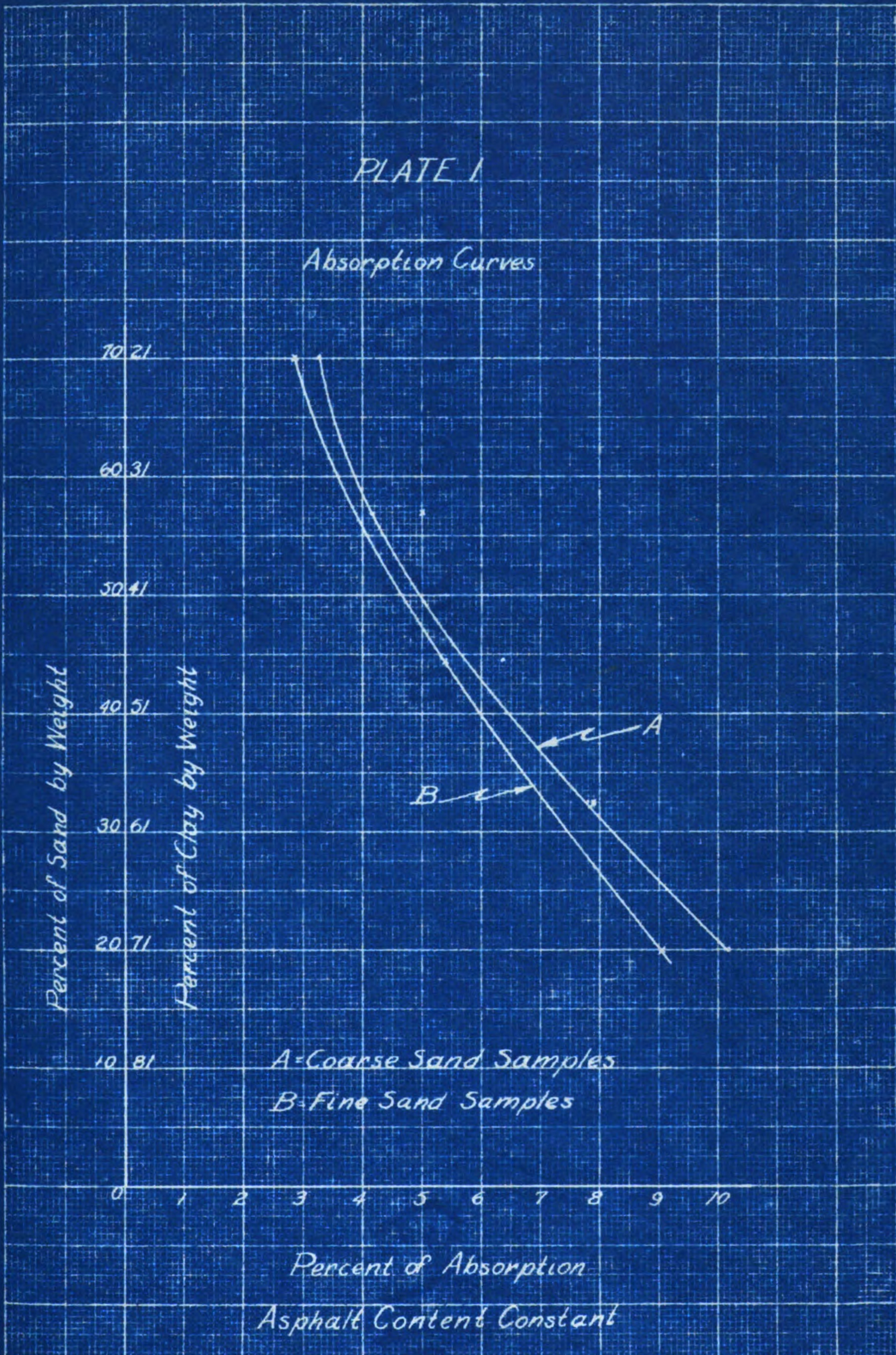


PLATE I
Absorption Curves
70 21
60 31
50 41
40 51
30 61
20 71
10 81
0
1 2 3 4 5 6 7 8 9 10
Percent of Sand by Weight
Percent of Clay by Weight
A
B
A=Coarse Sand Samples
B=Fine Sand Samples
Percent of Absorption
Asphalt Content Constant

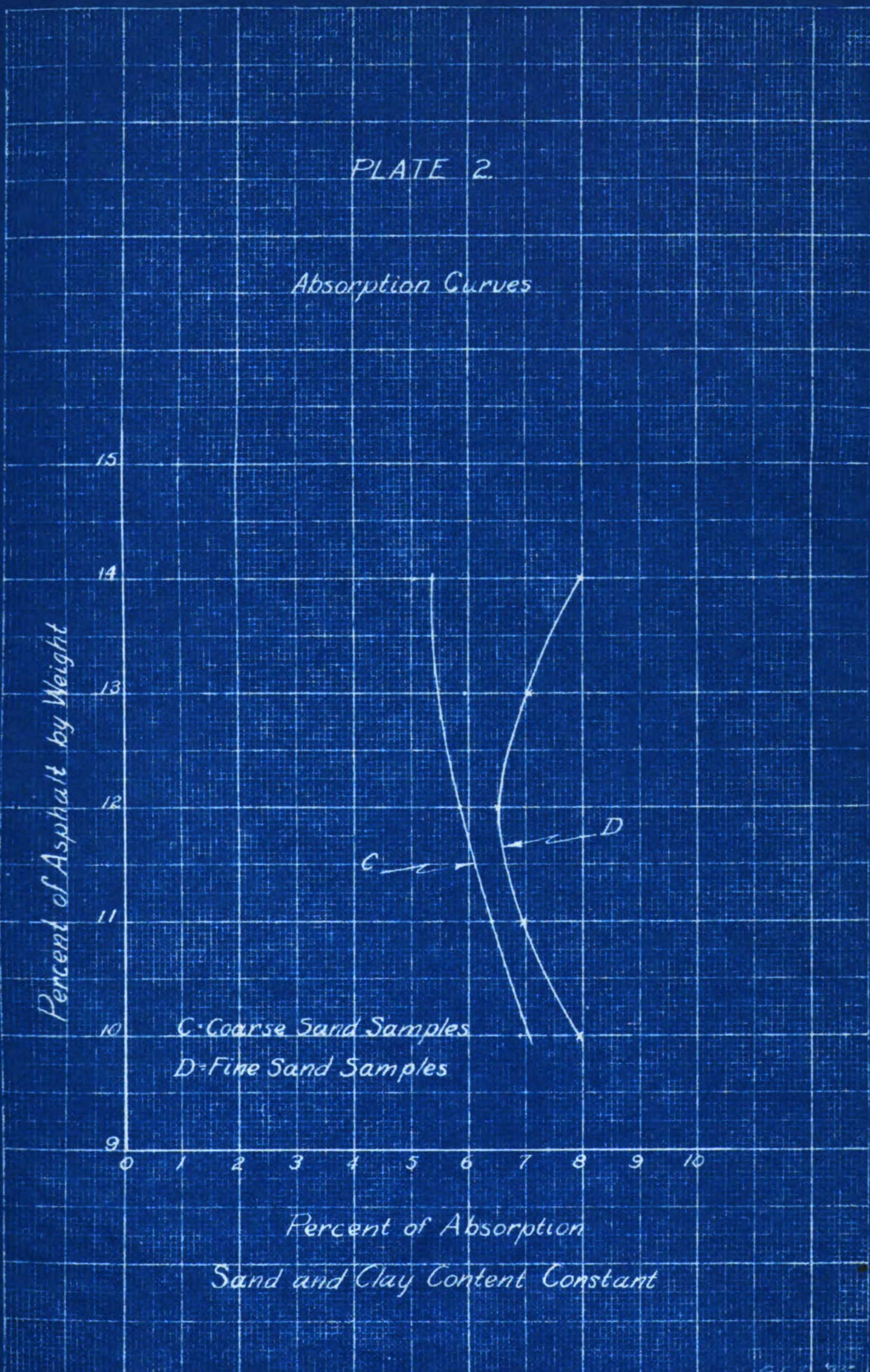


PLATE 2.
Absorption Curves
Percent of Asphalt by Weight
15
14
13
12
11
10
9
0
1
2
3
4
5
6
7
8
9
10
C
D
C-Coarse Sand Samples
D-Fine Sand Samples
Percent of Absorption
Sand and Clay Content Constant

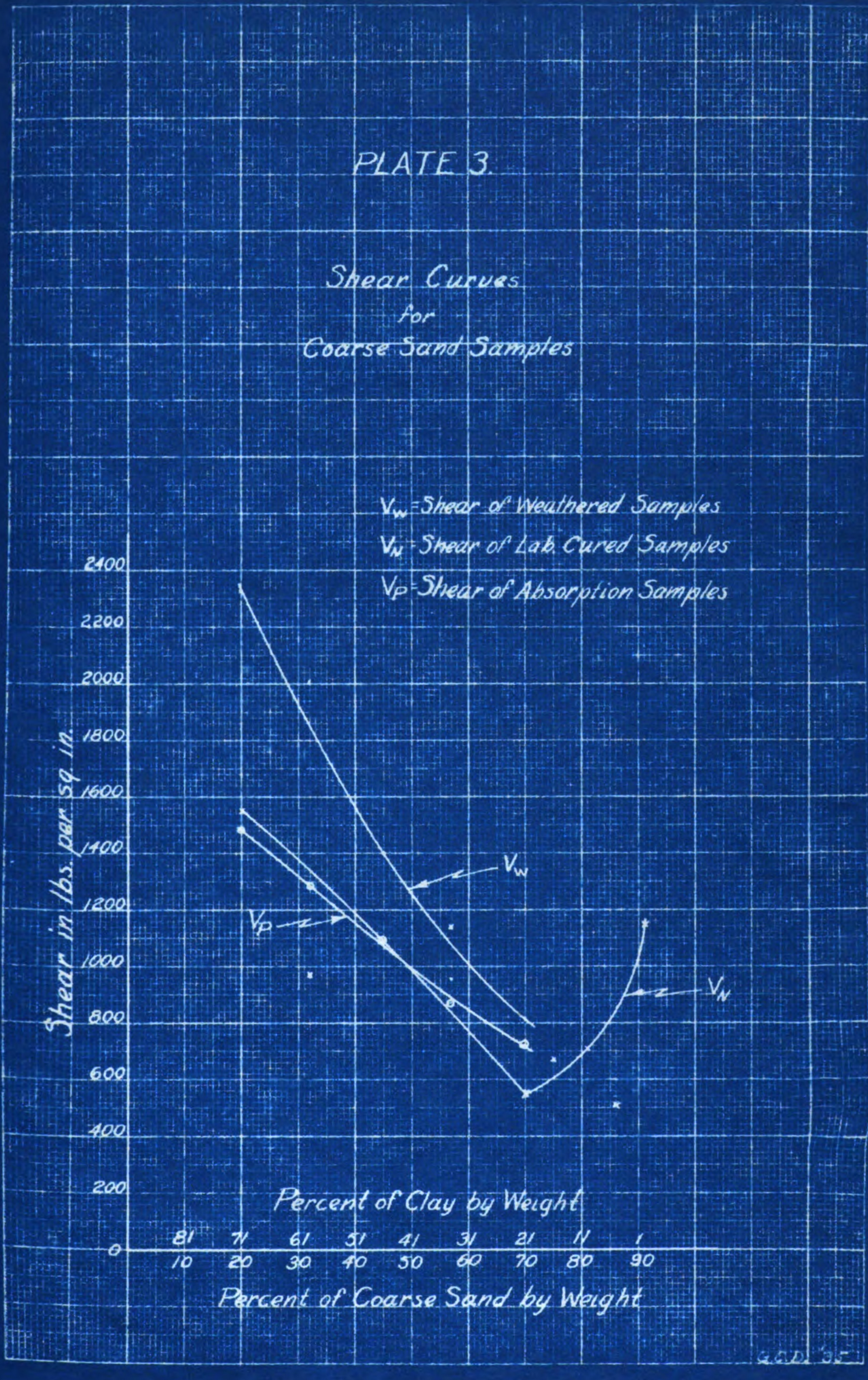


PLATE 3.
Shear Curves
for
Coarse Sand Samples
Vw = Shear of Weathered Samples
VN - Shear of Lab. Cured Samples
VP = Shear of Absorption Samples
Shear in lbs. per sq. in.
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Vw
VP
VN
Percent of Clay by Weight
81
71
61
51
41
31
21
11
1
10
20
30
40
50
60
70
80
90
Percent of Coarse Sand by Weight

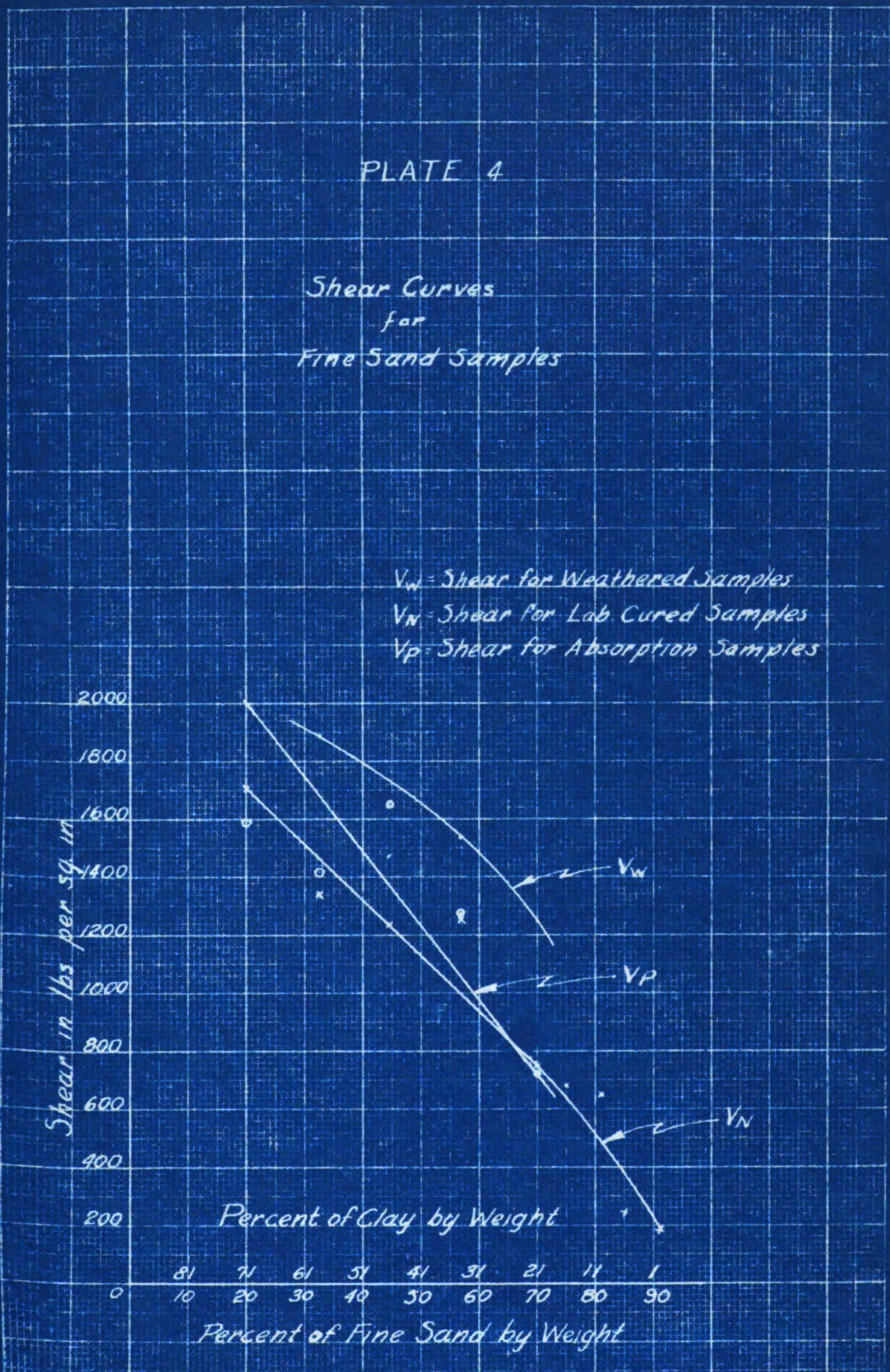
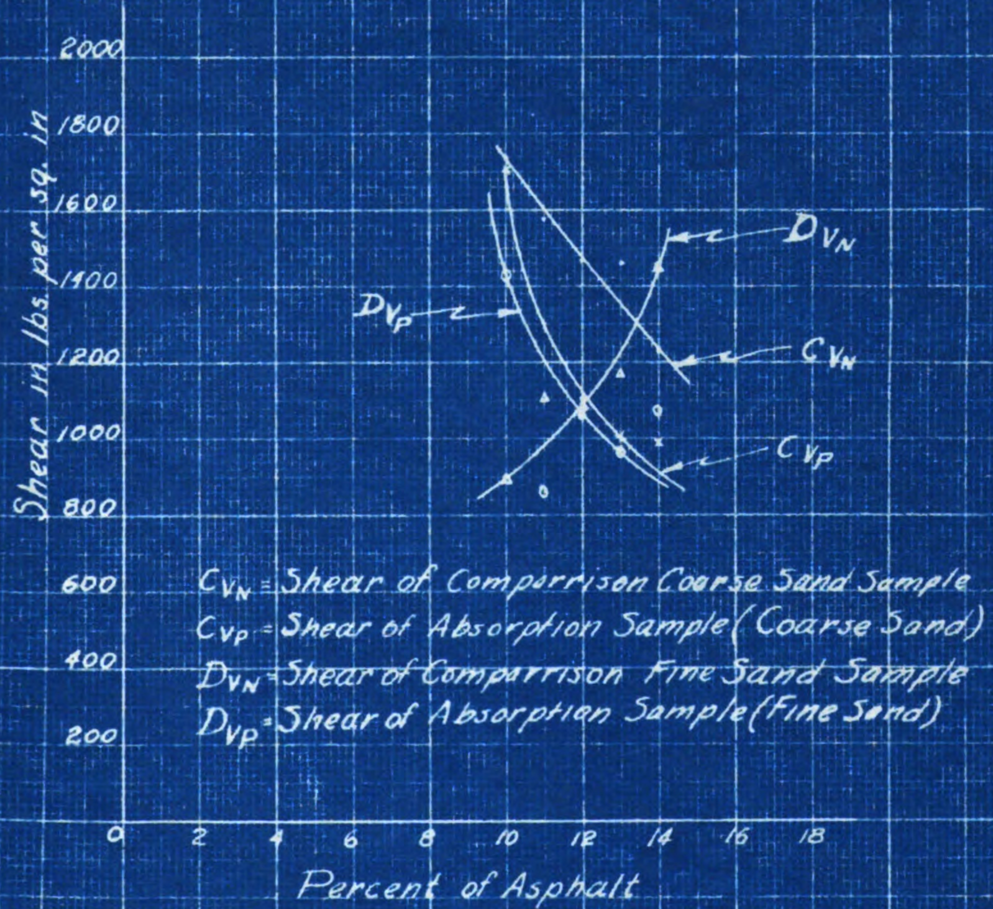


PLATE 4
Shear Curves
for
Fine Sand Samples
V_W = Shear for Weathered Samples
V_N = Shear for Lab. Cured Samples
V_P = Shear for Absorption Samples
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Shear in lbs per sq in
V_W
V_P
V_N
Percent of Clay by Weight
81
71
61
51
41
31
21
11
1
10
20
30
40
50
60
70
80
90
Percent of Fine Sand by Weight

PLATE 5

Shear Curves for

Samples of Varying Asphalt Content



Sand and Clay Content Constant

CONCLUSION

As a result of this investigation I feel that the following conclusions are warrented:-

1. Coarse sand gives a stronger and better mix than fine sand.
2. A combination of coarse and fine sand gives a desirable mix provided that the mixture contains about three quarters of coarse sand and one quarter of fine sand.
3. Water and weathering aid in toughening a mixture.
4. Percentages by weight of asphalt of over 9 are not economical and do not give good results. Those between 7 and 9 are the best for this type of cold-mix road surface.
5. When either fine or coarse sand is used alone with clay and asphalt, a good durable mix demands about 70 % sand, 20 % clay and 8 or 9 % asphalt.
6. A mix of the above proportions will withstand extreme weather conditions without deterioration.
7. Samples with sand content above 81 % and with clay content above 40 % are unstable no matter how much asphalt is added.
8. Cracking will take place on any sample that contains an excess amount of clay. This means mixtures of over 40 % clay.
9. Absorption will be the least in samples with the least amount of clay.
10. Shear increases as the percent of clay increases, but it cannot be used as a guide because in all other respects

an increase in clay decreases the strength and serviceability of the mixture.

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BULLETINS

AMERICAN BITUMULS COMPANY

(a) Asphalt Speciality Products.

(b) Bitumuls for Roads.

(c) Col-Pen Dust Cure.

(d) Cold Asphaltic Binder.

(e) Construction Methods.

(f) Drives and Walks in Country Estates.

(g) Laykold Tennis Courts.

(h) Paving Construction with Bitumuls H.

(i) Modern Way to Use Asphalts.

(j) Maintenance with Bitumuls H.

(k) Usefull Information and Tables for Paving, Engineer's and Contractors.

(l) Retread and Road-Mix with Bitumuls HRM.

BARRETT COMPANY

(a) Maintaining Roads with Tarvia.

(b) Tarvia Retread.

BOUYOUCOS, G.J.

A Comparison of the Hydrometer Method and the Pipette Method for Making Mechanical Analysis of Soils, with New Directions.

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Treatment of Secondary Roads with Calcium Chloride

THE OHIO OIL COMPANY

(a) Lincoln-ite.

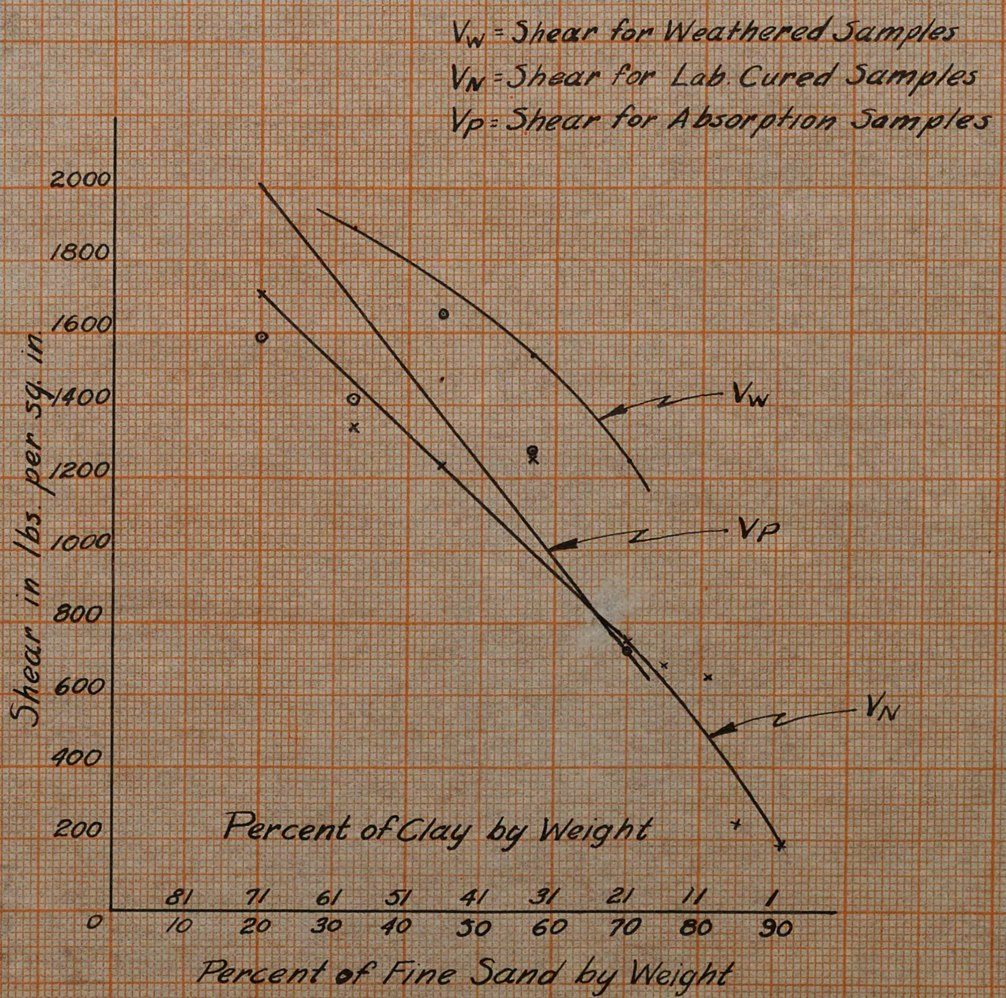
(b) Linco Cut-Back Asphalt.

GRIFFITH, JOHN H.

Physical Properties of Earths

PLATE 4

Shear Curves for Fine Sand Samples

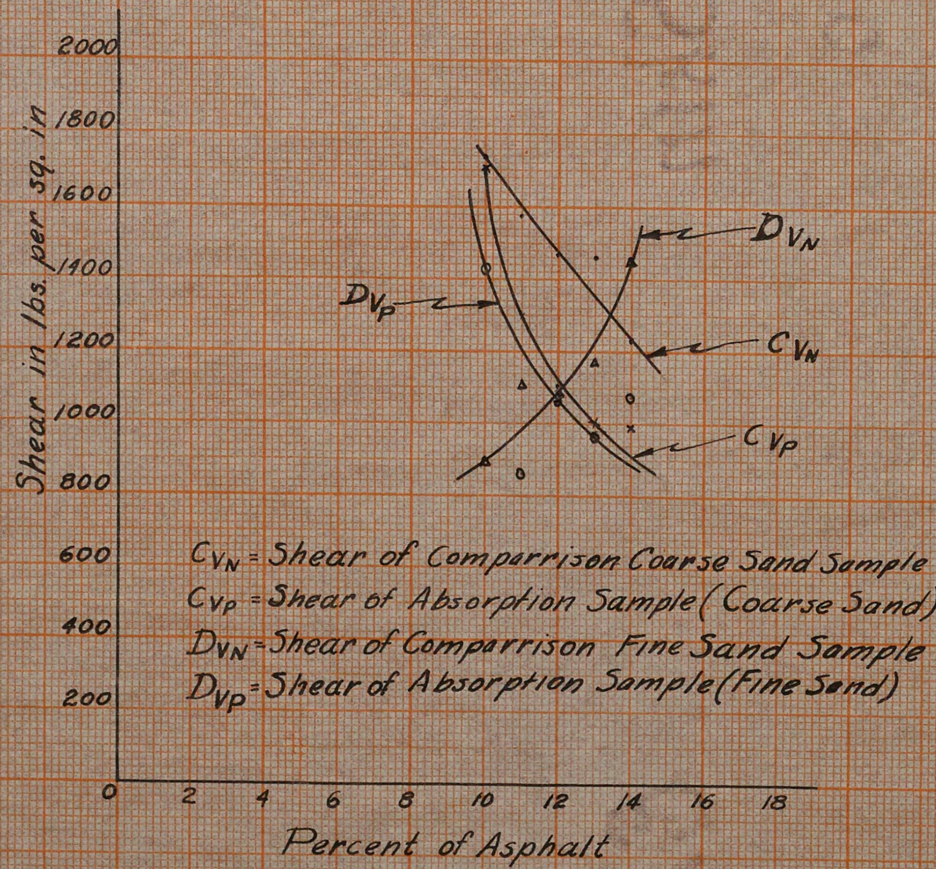


G.C.D. '35

PLATE 5

Shear Curves for

Samples of Varying Asphalt Content

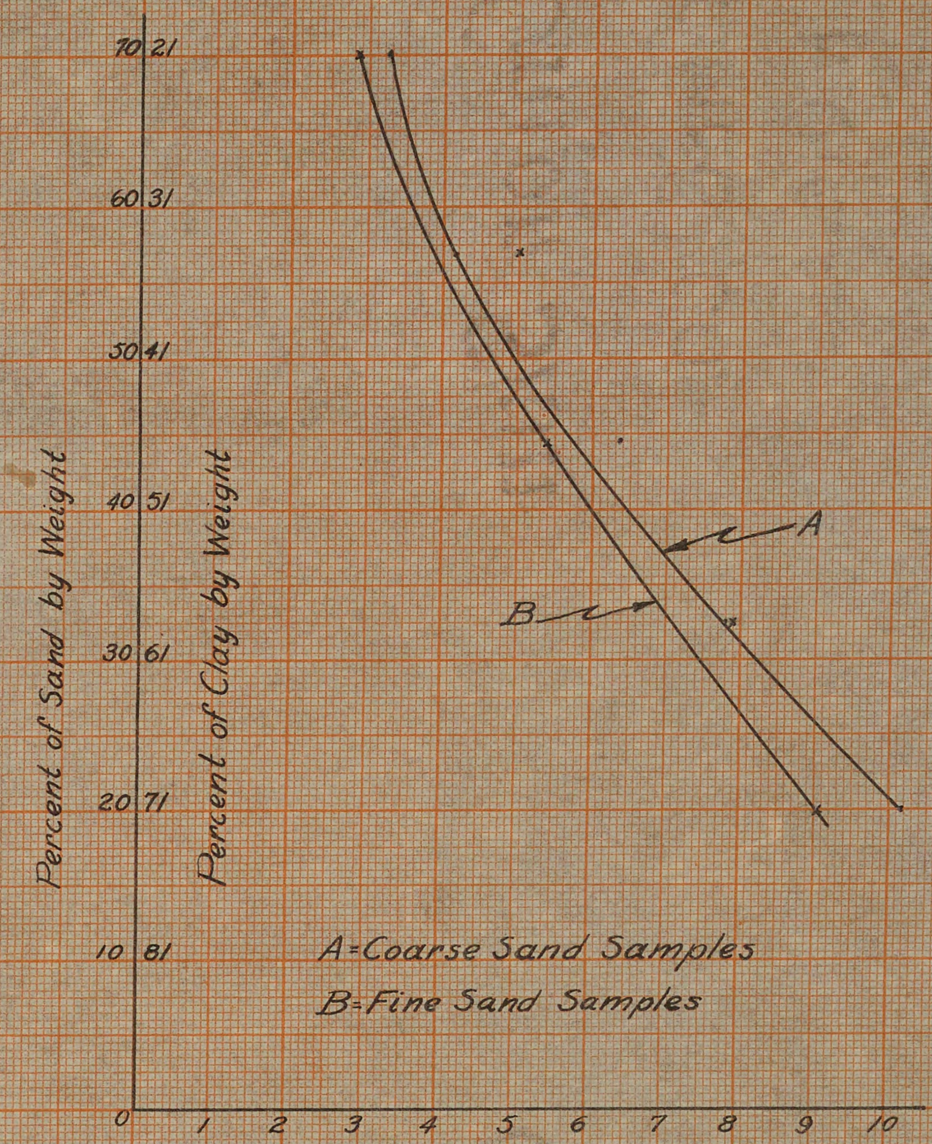


Sand and Clay Content Constant

G.C.D. '35

PLATE I.

Absorption Curves



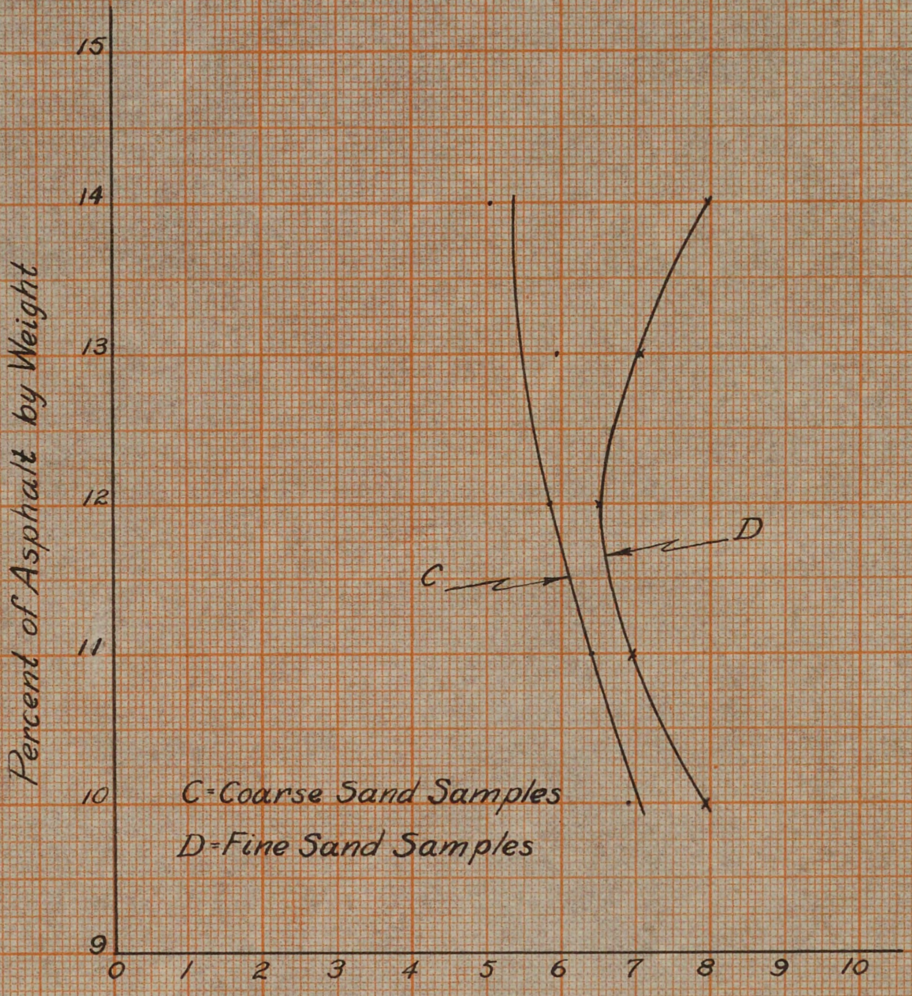
Percent of Absorption

Asphalt Content Constant

G.C.D. '35

PLATE 2.

Absorption Curves



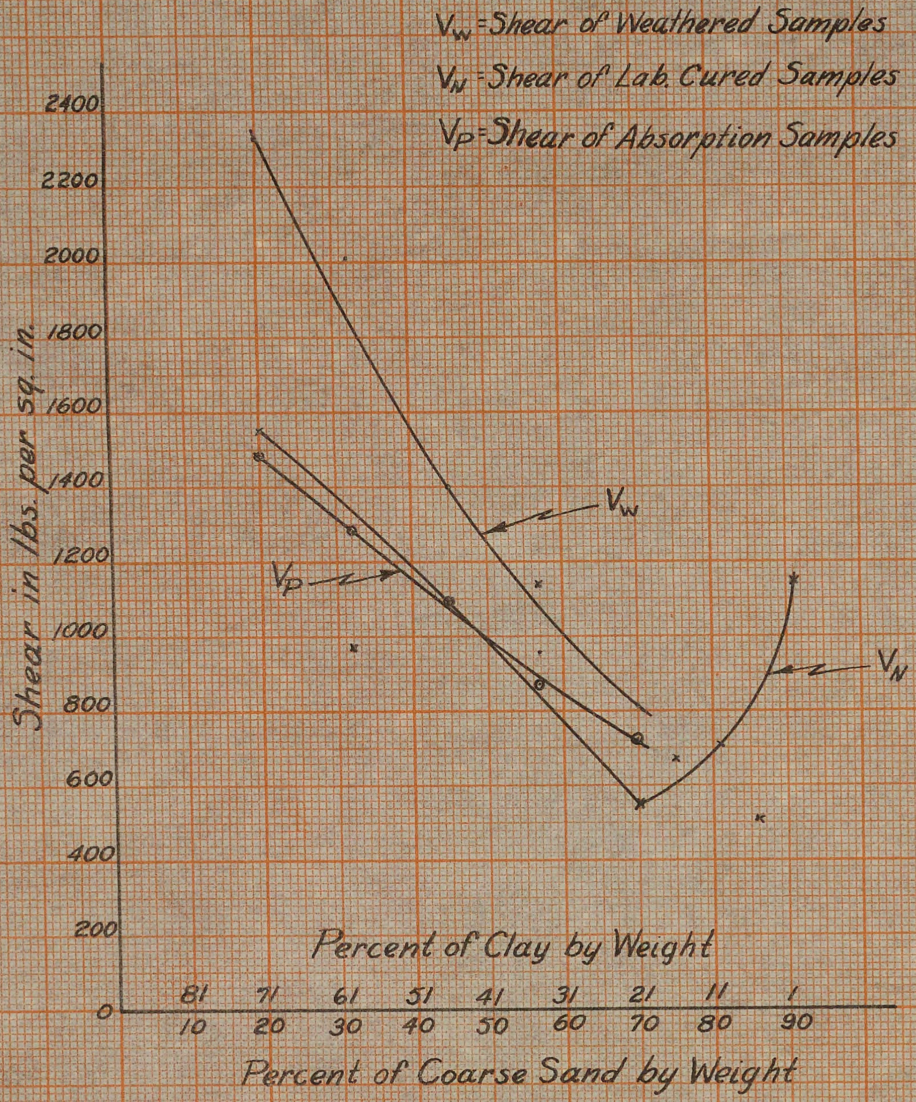
Percent of Absorption

Sand and Clay Content Constant

G.C.D. '35

PLATE 3.

Shear Curves for Coarse Sand Samples



G.C.D. '35