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Report

on

Synthetic Steel Molding Sands

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ABSTRACT

Several variables producing inaccuracies in sand test results are studied and recommendations are made for avoiding or minimising these variables. A study of a fine synthetic molding sand over a wide moisture range is made with other sands shown for comparison. Other points investigated are the effect of silica flour when used to "close up" a sand, the effect of bentonite and sand grain size on the surface finish of steel castings and the effect of the relative humidity of the atmosphere on dry sand strength.

AUTHORIZATION

1. The studies in steel casting research were originally authorized by Bureau of Engineering letter QP/Castings (6-19-Ds) of 13 July 1928.

STATEMENT OF PROBLEM

2. The present report consists of several more or less unconnected studies which have been carried on in conjunction with the work on synthetic steel foundry sand. An attempt has been made to answer some of the questions concerning testing technique, lack of agreement between various investigators and the causes of variations in sand properties which often occur in the same laboratory.

METHODS USED IN TESTING AND TEST RESULTS

(a) Rammer Support

3. It has often been suggested that variations in the nature of the support used under the A.F.A. sand rammer may be responsible for variations between the results of different workers trying to check results on identical sand samples. Table 1 gives the results of an investigation made to determine the amount of variation which might exist under extreme conditions.

4. Sample A was tested for the usual properties with the A.F.A. sand rammer securely bolted to a substantial, rigid steel support, weighing about 150 pounds. Sample B was taken from the same batch of sand and is identical to A except that during the ramming the sand rammer rested on, but was not fastened to, a wooden plank 1-3/8 inches thick by 17 inches wide which in turn rested on supports 20 inches between centers.

5. The loss in strength is 0.38 lb/sq.in. or 7.3 per cent for the extreme cases. The weights of the specimens indicate that A is slightly more dense than B. It is, therefore, recommended that a rigid support of steel or concrete be used and that the base of the rammer be securely bolted down. If these precautions are observed, the variations due to rammer support should be negligible.

(b) The Effect of Ramming

6. The number of rams used in making a test specimen has been the subject of much discussion. The present A.F.A. standard method calls for three rams. The late George Batty, however, advocated ten rams and his recommendations are still being followed in some foundries. Since the modern trend in molding with synthetic sand is toward harder ramming, the use of ten rams may be more representative of actual mold conditions.

7. A large test batch was made containing 5 per cent bentonite and 95 per cent washed silica sand with a fineness of 60.9. This was mulled dry for 1 minute, 3.4 per cent water added and mulling continued

for 5 more minutes. Specimens were made by ramming 3, 5, 7, 10, 15 and 25 times. The test results are shown in Table 2 and Plate 1.

8. As the number of rams is increased, the green strength increases and the green permeability decreases. This is the normal effect of improving the grain contacts and reducing the voids, the latter being clearly shown by the increase in weight. These properties appear to approach asymptotic values as the ramming is increased.

9. The flowability, measured between the fourth and fifth rams as established by definition, was 80.9.

10. The deformation fluctuated between values of 0.0227 and 0.0264 inch per inch of specimen length. Since 0.0037 is within the experimental error for this property, the variations are inconclusive. The average deformation was about 0.022 inch per inch. The resilience curve adds nothing to the information already contained in the green strength curve.

11. Regarding the choice between three and ten rams, there seems to be no reason for recommending one above the other. The use of five or more rams would have the advantage that flowability could be read on the permeability specimen and would not require extra specimens to be made. This is not sufficient reason for changing the standard procedure, however, since there is some doubt that the flowability device actually measures flowability.

(c) Aeration of Sand

12. Most of the synthetic sand used in steel foundries is mixed in muller type units. This leaves a large part of the sand in heavy lumps which will often produce defects if the lump is against the casting face. It is generally thought desirable to aerate or fluff the sand in some way to break up the lumps, and possibly make the sand easier to mold. The following tests were made to determine the effect of aerating on the measurable sand properties, one batch being taken directly from the muller and the other passed through a 1/4-inch power screen. Table 3 includes the results of this investigation.

13. It will be noted that 0.16 per cent water has been lost during the aerating operation. Reference to Naval Research Laboratory Report No. M-1478 indicates that loss of moisture in this range would tend to increase green strength and decrease dry strength. The dry strength has decreased as expected (163.6 lb/sq.in. to 155.7 lb/sq.in.) but the green strength also has decreased, contrary to expectations. This is explained by the change in weight of the specimen from 153.5 grams to 151.5 grams, showing that the aerated sand does not ram as compactly and the less dense specimen naturally tends to be weaker. This effect has more than counteracted the increase to be expected from the change in water content. Green and dry permeability are both definitely improved by aeration while other properties remain practically unchanged.

14. On the basis of the improvement in texture and permeability, it is concluded that aeration is justified. It will reduce defects and improve the surface finish of castings.

(d) Comparison of Binders

15. In order to show the variations in physical properties produced in sand by different binders, several kinds were tested under similar conditions with the result shown in Table 4.

16. All mixes contained 99 per cent silica sand with an A.F.A. grain fineness number of 63, 1 per cent by weight of the binder and sufficient water to produce a moisture content of approximately 5 per cent. The first ten mixes contain proprietary core and facing binders while bentonite, foundry molasses, and rosin are included for comparison. The last five mixes are from various samples of linseed oil.

17. The proprietary binders ranged from 0.74 to 1.27 lb/sq.in. green compressive strength and 84.2 to 575 lb/sq.in. dry compressive strength. Green permeabilities were between 13 and 129 while dry permeabilities varied from 111 to 167. It must be realized that the physical properties listed are for a single binding material since the use of two binders may produce very peculiar effects. For instance, bentonite or other clay is often added to a core sand containing linseed oil or other core binder for the purpose of raising the green strength. While it may serve this purpose, it may at the same time almost completely destroy the dry strength of an excellent core binder. In the same manner, core binders are often added to green facing sand to raise the dry strength, and while this may be accomplished the green strength may be considerably reduced. The reason that clay and some of the other binders do not work well together is due to the fact that the clay has a very large surface area and when used, a large part of the core binder is required to wet the clay, leaving very little to form a useful dry bond between the grains. The binders, in turn, form a film over the clay crystals preventing them from bonding the adjacent grains in the green state.

18. Tests 15 to 19 contain various samples of linseed oil. Test No. 15, sample A, was made from a supply which had been in use in the foundry for some time. Since the supply was nearly exhausted, a new stock was obtained which was much darker in color than the other and cloudy. After several weeks the oil became clear and a yellow sediment was noted in the bottom. Part of the clear oil was decanted off and the remainder mixed with the sediment to form samples B and C respectively. Sample A tested 619 lb/sq.in. while sample B produced 342 lb/sq.in., showing a tremendous difference in the quality of the oil. The sample containing the sediment produced 411 lb/sq.in. compared with 342 lb/sq.in. in the clear sample of the same oil. The wide variation in dry strength indicates that linseed oil should be investigated to determine the factors producing good physical properties in cores.

19. A reliable manufacturer of linseed oil was asked to supply a grade suitable for cores. The sample submitted was "Pure Raw Linseed" (sample D), which produced 318 lb/sq.in. as received. A small amount of

this oil was actually boiled (sample E) and produced 376 lb/sq.in. dry strength. A more complete investigation of linseed oils is planned as future research to include information on the effect of metal oxides and other drying agents as well as a study of the baking times and temperatures.

(e) Loam Sands

20. Since the synthetic sand-bentonite-water mix (Report No. M-1478) was found suitable for green, dry and air dried sand molds, it was suggested for use in loam molds. "Loam" as used in the foundry is a very wet mix of clay, sand, and usually other materials, often including manure. Its use was very common years ago, but at present is rarely used. The reasons for this are not apparent because on some jobs loam molding can be used to advantage. The method is particularly applicable to castings which are circular in shape such as pipes, bells, etc., as they can be made with sweeps, patterns not being required.

21. A batch of sand was mixed dry with 95 per cent of a No. 53 fineness sand and 5 per cent bentonite. Water was added until the water content, based on total weight, was 26 per cent. The mix was stirred to the consistency of a thick mud and applied to the face of a revolving drum. The mass was sufficiently sticky to adhere to the drum and could be formed into shape by holding a tool or pattern against the rotating material. The test core was brought to a cylindrical shape by rotating against a straight sweep, finished with a wet brush, and dried. The surface was found to be smooth, hard, and very strong. A silica wash was then brushed on (rotating the core) and dried. Two coats produced an excellent surface.

22. The results of this test indicate that the synthetic sand-bentonite-water mix will make satisfactory loam cores and molds.

(f) The Effect of Humidity

23. The dry compressive strength test of molding sand is, next to green strength and permeability, one of the most important tests made. In spite of its importance it sometimes appears to be very unreliable, since values obtained may fluctuate between wide limits. In an effort to locate some of the causes for this variation samples were made and treated in several ways. All samples came from the same batch of sand and were baked at the same time. They were then separated into several groups. Group A was tested when the specimens had cooled just enough to be handled, and taken as the point of zero humidity. Group B was placed in a desiccator over calcium chloride, thereby maintaining an atmosphere of about 1 per cent relative humidity. The dry strength was 250.6 lb/sq.in., however, as compared with 193.7 lb/sq.in. for sample A. Group C was allowed to cool and remain in the atmosphere of the laboratory for several days. When this group was tested, the relative humidity of the atmosphere was 25 per cent and the dry strength of the specimens was found to be 147.7 lb/sq.in., a decrease of 41 per cent below Group B. Group D was placed in a desiccator, containing a saturated water solution of magnesium

chloride with an excess of the salt. This produces a relative humidity of 33 per cent and a weighed, dry sample was found to pick up 0.267 per cent of its weight in water. The dry strength of this group was 138.5 lb/sq.in. Group E was placed in a desiccator over water which produces an atmosphere with 100 per cent relative humidity. The dried and weighed sample picked up 1.75 per cent of its weight in moisture and the dry strength decreased to 67.6 lb/sq.in. The results of these tests are plotted on Plate 2. From this it appears that maximum strength occurs somewhere between 0 and 5 per cent relative humidity. The number of points in this range is insufficient to establish the curve accurately and further work is necessary to cover this range more thoroughly. It should include two or three strong desiccants such as phosphorous pentoxide and sulphuric acid and some solutions producing atmospheres of less than 10 per cent relative humidity. From the present work, the following laboratory practice has been established.

(1) Specimens should be baked until thoroughly dry. One hour at 105° to 110° C. is recommended by the American Foundrymen's Association but this is usually insufficient. Two hours is always allowed and this is increased to three or four if the sand is very wet or dense.

(2) Specimens should be placed in a desiccator over fresh calcium chloride as soon as possible. This is usually done just as soon as they are cool enough to be handled.

(3) Keep the $CaCl_2$ fresh by replacing it frequently and replacing the cover quickly when specimens are put in or removed.

(4) Allow the specimens to remain in the desiccator at least 24 hours before testing.

(5) Remove one specimen at a time and complete the tests on it as quickly as possible to avoid moisture absorption from the air.

(6) Some specimens show a variation in strength when broken in a vertical testing machine being weaker in the position in which they were baked than in the inverted position. This applies particularly to binders which migrate during drying out and baking. Linseed oil and some of the lignin and soluble binders tend to concentrate at the outer surface and in the lower half. In the compression machine the stress appears to concentrate in the upper half. For this reason some specimens appear to be stronger in the inverted position than in the "as baked" position. Until further work is done, specimens will be stripped, baked and broken in the same positions even though this may not produce maximum strength.

(g) Tests on Fine Synthetic Sand

24. Since the trend in many foundries is toward the use of finer sand, it was thought that a fine synthetic molding sand of the silica sand-bentonite-water type should be investigated. A washed silica sand with an A.F.A. grain fineness number of 123 was selected (see Table 5). 96 per cent of the sand was mixed with 4 per cent bentonite and mulled dry for 1 minute. Water was then added and mulling continued for 5 more minutes. Several batches were produced with water contents from 1 to 14 per cent. The results are shown on Plate 3.

25. The curves produced are characteristic of this type of sand. The strength is low for very low moisture contents. As the water is increased the strength increases rapidly up to 1.65 per cent, the point of maximum strength. This is called the optimum moisture content with respect to strength. As the water is increased above 1.65 per cent, the strength decreases rapidly to 4 per cent water and from 4 to 14 per cent water it is nearly constant. As the sand becomes saturated with water (18 to 24 per cent) loam mixtures will be produced and the strength will be reduced to zero.

26. The green permeability increases with increase in water content up to 2.5 per cent water and then decreases steadily until the sand is saturated. If metal match plate patterns are used and the molds can be closed quickly without much finishing, the sand can be worked at 2.5 per cent water. Where wooden patterns are used and much hand finishing is necessary, the moisture content must be raised. Water contents as high as 7 or 8 per cent have been used with good results.

27. The flowability remains almost constant at 84 per cent from 2 to 14 per cent water increasing, however, for the drier mixes. The minimum weight occurs at 2.0 per cent water, and as moisture is increased, the weight of the specimen increases almost in a straight line relation. Deformation and resilience are not very informative. The values show the usual changes with change in water content and from what is known about them, they appear to be satisfactory. Experimental castings have been made in this sand using steel as well as cast iron, brass and aluminum, with excellent results.

28. A series of tests were made on an Albany sand of A.F.A. fineness number 191 to compare with the fine synthetic sand described above. The various properties are plotted as functions of the water content on Plate 4. Important points to note are the green strength maximum of 6.95 lb/sq.in. at 3.25 per cent water, and the shape of the permeability curve. The latter is nearly flat instead of showing the usual well defined maximum, characteristic of synthetic sands. The lowest water content which could be conveniently tested was 2.72 per cent, as specimens of lower water content were too dry to hold their shape. The synthetic sand could be worked at a water content as low as 1.20 per cent. Plate 5 shows the strength curves of the fine synthetic sand, Albany sand and a medium synthetic sand.

range covered is from 185 at 0 per cent silica flour to 43 at 30 per cent. Since the use of silica flour is usually confined to dry sand, this curve indicates the amount of "closing up" which can be expected at various silica flour contents.

37. The curve for dry compressive strength resembles that for green compressive strength. It increases gradually to a maximum of 404 lb/sq.in. at 25 per cent silica flour and then decreases.

38. The decrease in green and dry permeability and increase in weight may be attributed to a filling up of the voids with silica flour.

39. In the strength curves two opposing influences are at work. One is the addition of silica flour which acts as a weak clay and increases dry and green strength. The other is an absorption of water by the silica flour which decreases the amount of water available to produce plasticity in the bentonite. As the silica flour is increased, it therefore has the effect of reducing the water content to an amount necessary to produce an optimum moisture content with respect to strength for the amount of bentonite present. A further increase in clay reduces the available moisture below the optimum point and green strength is decreased. This accounts for the maximum green strength of 12.8 lb/sq.in. at 28 per cent silica flour.

(i) Test Block

40. For purposes of correlating laboratory sand test data with actual results in terms of steel castings, a standard form of test piece was designed, the details of which are shown in Plate 9. The flat external faces serve to show the surface finish to be expected on top, side or bottom, while the central channel will show whether or not the sand is deficient in permeability or refractoriness. The castings are sectioned on the plane A B C in order to examine the re-entrant angles for blow holes and pin holes.

(j) The Effect of Sand Grain Size on Surface Finish

41. The test block described above was used to find the effect of the grain size of a silica sand on the surface finish of steel castings. The dry mix contained 5 per cent bentonite, 3/4 per cent Mogul and the remainder washed silica sand. Water was added to 6 per cent of the total weight and the molds were oven dried. The resulting surfaces are shown on Plate 7. The numbers are the A.F.A. grain fineness numbers and the photographs are magnified two diameters, the section photographed being from the bottom face of the casting. The 22 sand allows considerable penetration which is gradually reduced as the sand becomes finer. The 63 sand produces a fairly smooth surface while the last two in 78 and 123 sands are very smooth.

(k) The Effect of Bentonite on Surface Finish

42. Plate 8 shows a similar series in which the bentonite was varied from 1 to 11 per cent. The water content was 6 per cent and no

cereal binder was used. The mix with 1 per cent bentonite was so weak that considerable difficulty was experienced in molding it. When the mold was closed after being oven dried a crush occurred along one side. The defects shown are probably the effect of the water used in attempting to repair the crush. All the mixes from 3 to 11 per cent bentonite produced surfaces which were excellent and almost identical. The mixes with 9 and 11 per cent bentonite were not rammed quite as hard as the others due to the stiffness of these mixes and they, therefore, show a little penetration. This test indicates that, in spite of its non-refractory nature, high percentages of bentonite may be safely used.

CONCLUSIONS AND RECOMMENDATIONS

43. When preparing specimens using the A.F.A. sand rammer the base should be bolted to a rigid steel or concrete support.

44. The use of three rams in accordance with the A.F.A. standard method is adequate for testing synthetic steel molding sands. However, the use of five rams gives as good results without the necessity of preparing extra specimens for flowability tests.

45. Aeration of molding sand is recommended since it eliminates lumps which might otherwise cause defects, and improves permeability and texture.

46. A great variation was found in the physical properties produced in sand by proprietary core and facing binders as well as by various linseed oils.

47. Considerable variation was also found in a single linseed oil due to treatment or conditions of storage.

48. Synthetic sand-bentonite-water mixes can be used satisfactorily for loam molds.

49. To eliminate variations due to humidity, test specimens should be baked until thoroughly dry and stored in a desiccator over fresh calcium chloride for at least 24 hours prior to testing.

50. A fine synthetic sand containing 4 per cent bentonite produced physical properties superior to those of a comparable Albany sand throughout the entire range of water contents.

51. The physical properties of synthetic molding sands varies quite uniformly with increasing additions of silica flour.

52. Amounts of silica flour as high as 20 per cent may be used in an A.F.A. 60.9 synthetic sand without excessive lowering of the permeability.

53. Test blocks were made in sands with bentonite contents from 1 to 11 per cent. Results indicate that amounts from 3 to 11 per cent

can be successfully used while 1 per cent or less produces a sand too weak for general use.

54. Photographs of test blocks indicate clearly the effect of grain size on the surface finish of steel castings.

TABLE 1

Effect of Rammer Support

Property	Sample A	Sample B
Weight	153 grams	152 grams
Green Permeability	132	140
Green Compressive Strength	5.20 lb/sq.in.	4.82 lb/sq.in.
Deformation	22.2	22.3
Resilience	115.4	107.5

TABLE 2

The Effect of Ramming

No. of Rams	Weight	G. Per.	G. Comp.	Def.	Res.	Flo.	D. Per.	D. Comp.
3	151.5	148	4.74	26.4	125	80.9	198	163.9
5	~~159~~ 154	126	5.63	23.4	131.8		179	184.9
7	156.5	113	6.28	24.4	153.2		161	196.4
10	158.7	99	7.11	25.3	179.9		146	213.6
15	161	88	8.16	22.8	186.0		130	223.6
25	164.5	77	9.56	22.7	217		112	248.1

TABLE 3

Effect of Aerating Sand

Property	Mulled	Mulled and Aerated
Moisture	4.00%	3.84%
Weight	153.5 grams	151.5 grams
Green Permeability	122	138
Green Comp.	6.64	6.59
Deformation	25.8	25.1
Resilience	171.2	165.3
Flowability	81.2	80.1
Dry Permeability	176	193
Dry Comp.	163.6	155.7

TABLE 5

Fineness Analysis of Sands

Mesh	Fine Synthetic	Medium Synthetic	Albany
6	0.00	0.00	0.00
12	0.00	0.00	0.24
20	0.02	0.16	1.06
30	0.03	0.50	0.76
40	0.04	1.78	2.00
50	0.02	8.32	3.74
70	0.26	41.36	7.98
100	12.48	37.60	8.08
140	42.77	8.48	4.84
200	34.48	1.78	6.60
270	7.37	0.14	6.14
Silt	2.73	0.18	37.44
Clay	0.00	0.00	21.12
A.F.A. Fineness No.	122.6	62.6	191.0

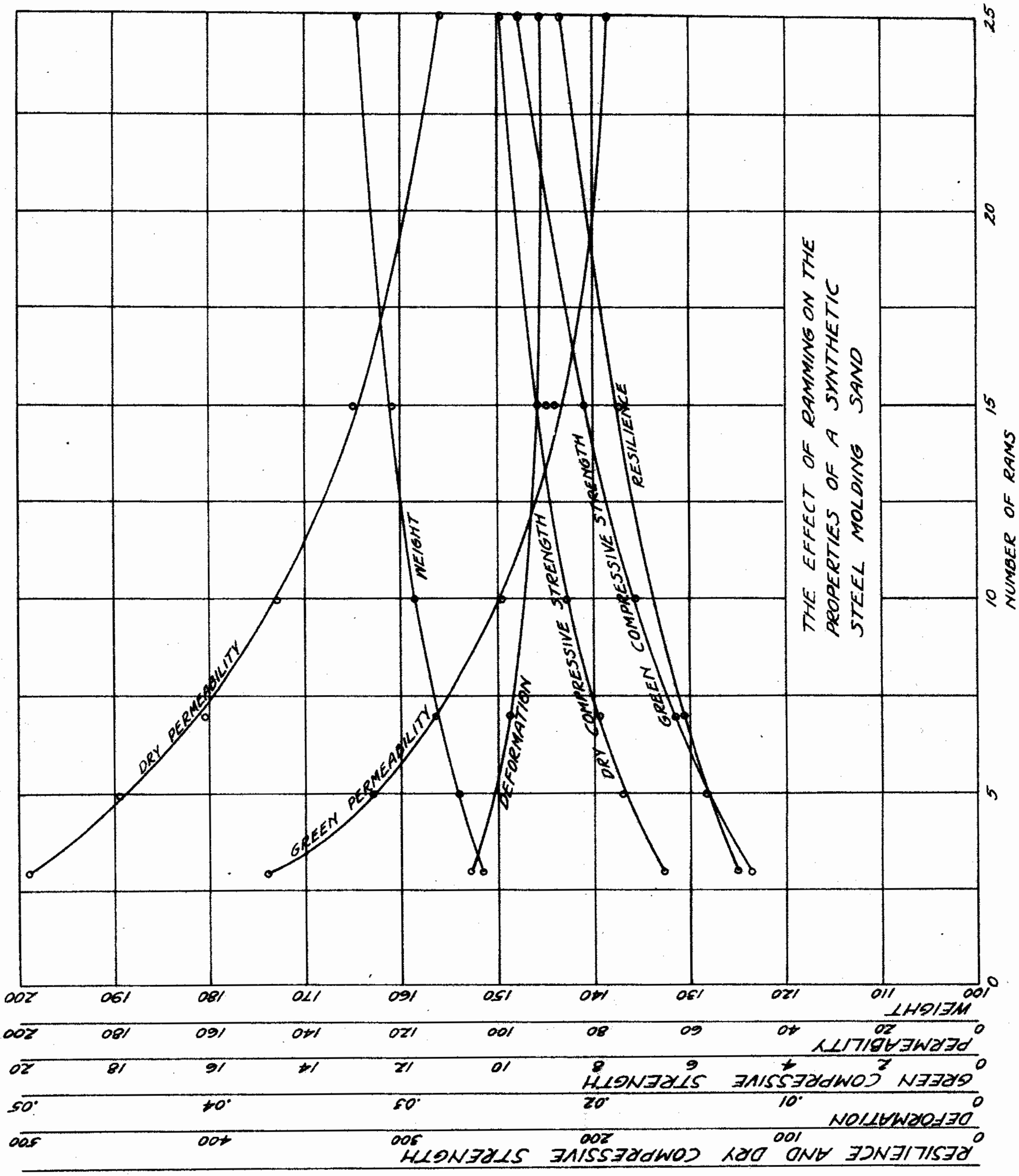
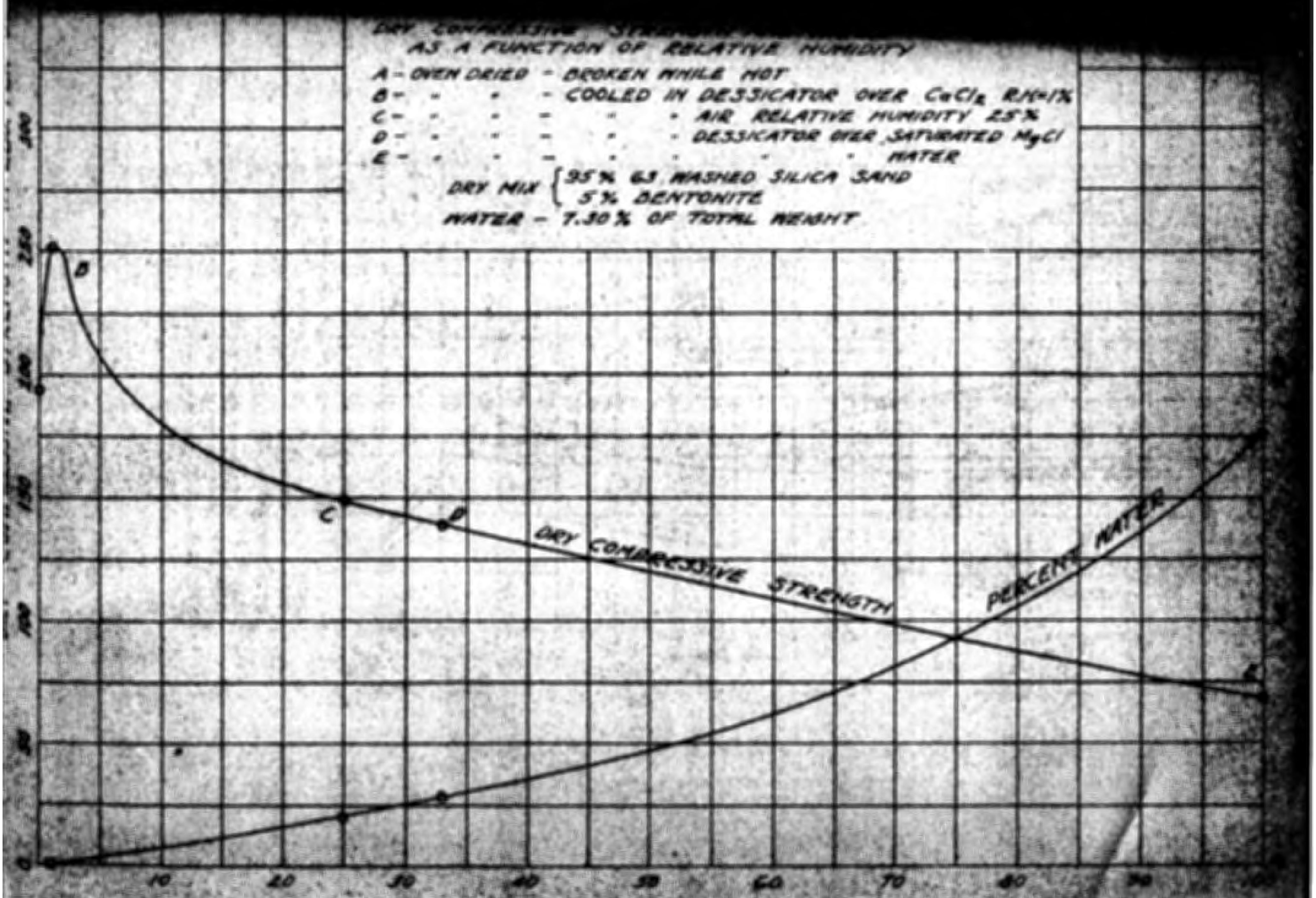

THE EFFECT OF RAMMING ON THE PROPERTIES OF A SYNTHETIC STEEL MOLDING SAND
NUMBER OF RAMS
0
5
10
15
20
25
DRY PERMEABILITY
GREEN PERMEABILITY
WEIGHT
DEFORMATION
GREEN COMPRESSIVE STRENGTH
DRY COMPRESSIVE STRENGTH
RESILIENCE
WEIGHT
100
110
120
130
140
150
160
170
180
190
200
PERMEABILITY
0
20
40
60
80
100
120
140
160
180
200
GREEN COMPRESSIVE STRENGTH
0
2
4
6
8
10
12
14
16
18
20
DEFORMATION
0
.01
.02
.03
.04
.05
RESILIENCE AND DRY COMPRESSIVE STRENGTH
0
100
200
300
400
500

PLATE I


DRY COMPRESSIVE STRENGTH
AS A FUNCTION OF RELATIVE HUMIDITY
A - OVEN DRIED - BROKEN WHILE HOT
B - " " - COOLED IN DESSICATOR OVER CaCl2 RH=1%
C - " " " " AIR RELATIVE HUMIDITY 25%
D - " " " " DESSICATOR OVER SATURATED MgCl
E - " " " " " " WATER
DRY MIX { 95% 63 WASHED SILICA SAND
5% BENTONITE
WATER - 7.30% OF TOTAL WEIGHT
DRY COMPRESSIVE STRENGTH
PERCENT WATER
B
C
D
E
0
50
100
150
200
250
300
10
20
30
40
50
60
70
80
90
100

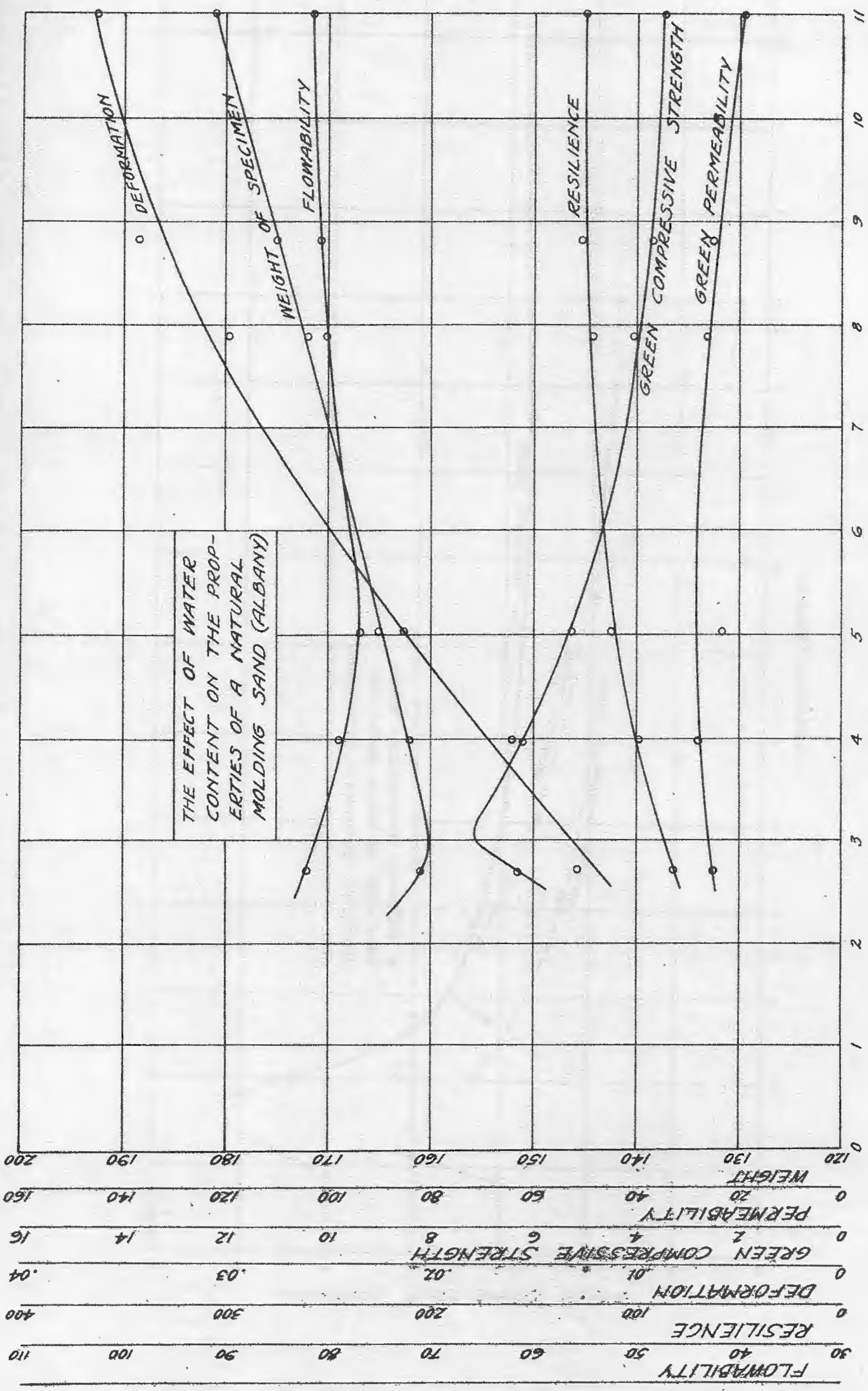

THE EFFECT OF WATER CONTENT ON THE PROPERTIES OF A NATURAL MOLDING SAND (ALBANY)
DEFORMATION
WEIGHT OF SPECIMEN
FLOWABILITY
RESILIENCE
GREEN COMPRESSIVE STRENGTH
GREEN PERMEABILITY
PERCENT WATER
WEIGHT
PERMEABILITY
GREEN COMPRESSIVE STRENGTH
DEFORMATION
RESILIENCE
FLOWABILITY

PLATE 4

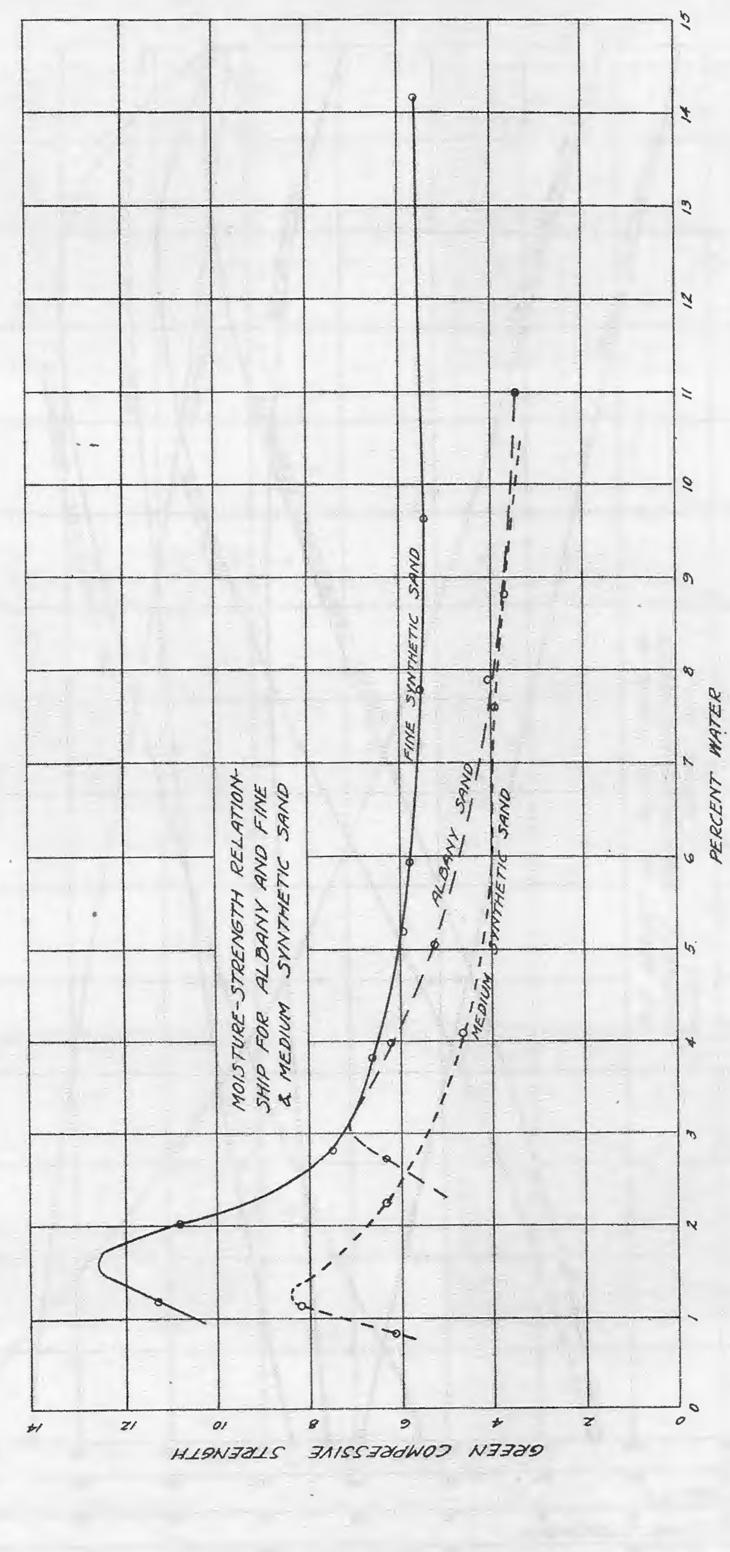

MOISTURE-STRENGTH RELATION-
SHIP FOR ALBANY AND FINE
& MEDIUM SYNTHETIC SAND
FINE SYNTHETIC SAND
ALBANY SAND
MEDIUM SYNTHETIC SAND
PERCENT WATER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
GREEN COMPRESSIVE STRENGTH
0 2 4 6 8 10 12 14

PLATE 5

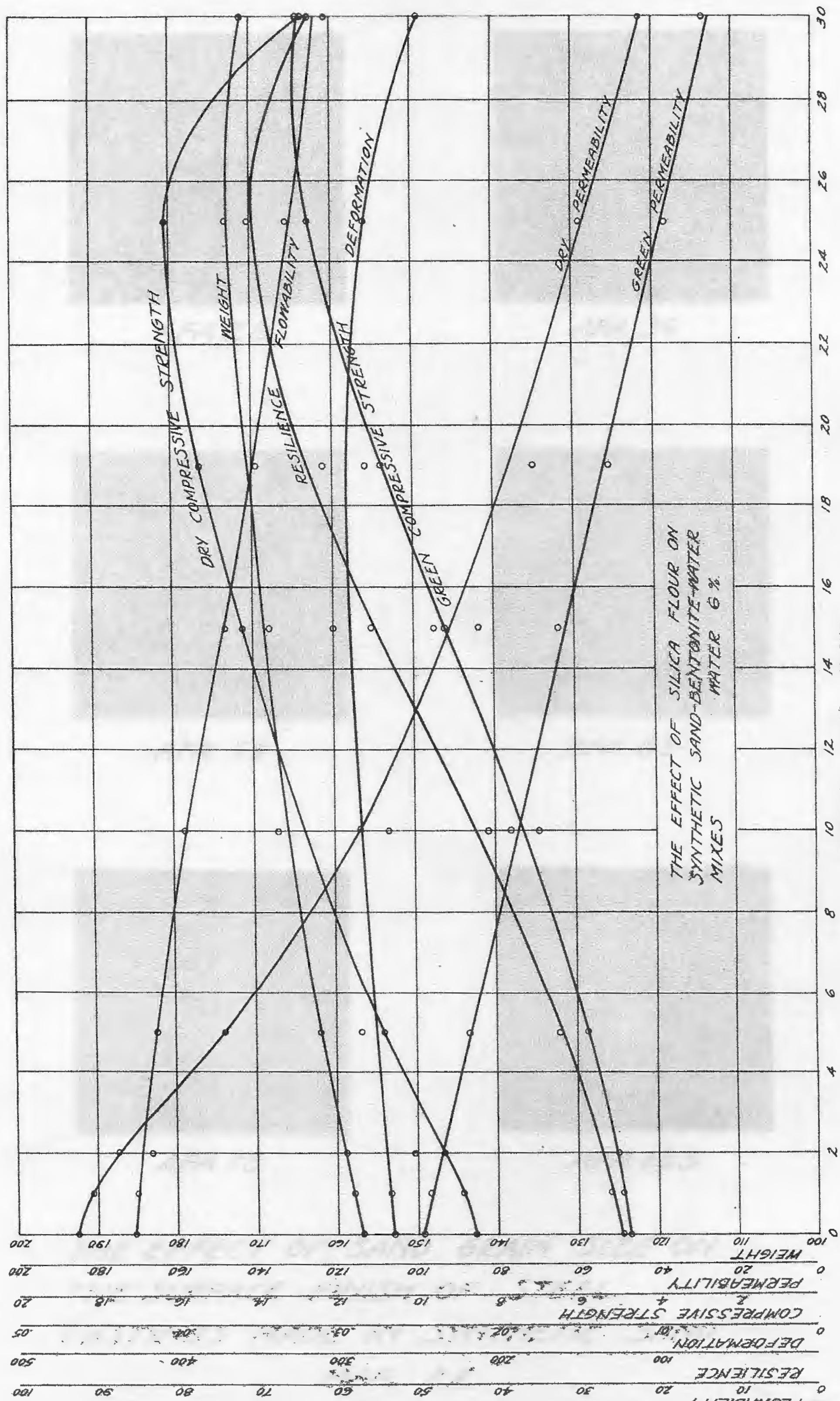
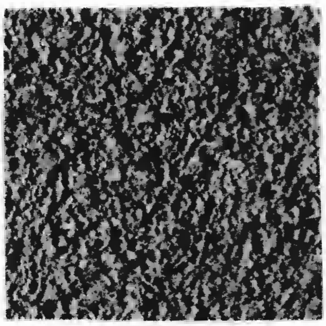

THE EFFECT OF SILICA FLOUR ON SYNTHETIC SAND-BENTONITE-WATER MIXES
WATER 6 %
PERCENT SILICA FLOUR
DRY COMPRESSIVE STRENGTH
WEIGHT
FLOWABILITY
RESILIENCE
DEFORMATION
GREEN COMPRESSIVE STRENGTH
DRY PERMEABILITY
GREEN PERMEABILITY
WEIGHT
PERMEABILITY
COMPRESSIVE STRENGTH
DEFORMATION
RESILIENCE
FLOWABILITY

PLATE 6



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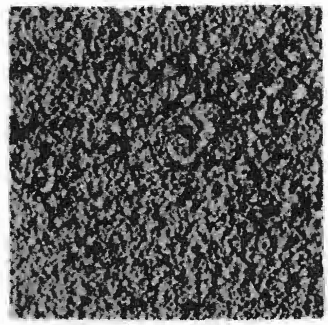
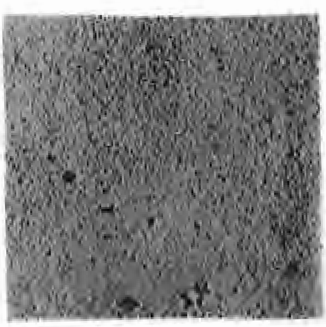


AFA 36

AFA 53

AFA 63



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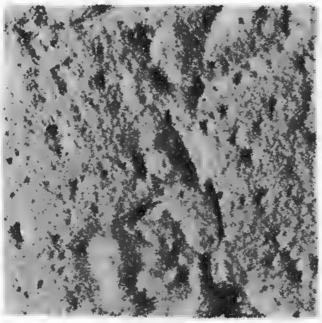
AFA 123

THE EFFECT OF SAND GRAIN SIZE ON THE SURFACE FINISH OF STEEL CASTINGS MADE IN SYNTHETIC SAND

MAG. 2X

PLATE 7



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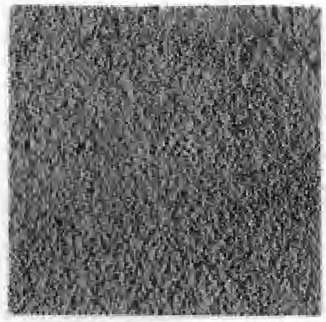

3%

5%

7%

9%

11%

THE EFFECT OF BENTONITE CONTENT ON THE SURFACE FINISH OF STEEL CASTINGS MADE IN SYNTHETIC SAND

MAG. 2X

PLATE 8

TEST BLOCK

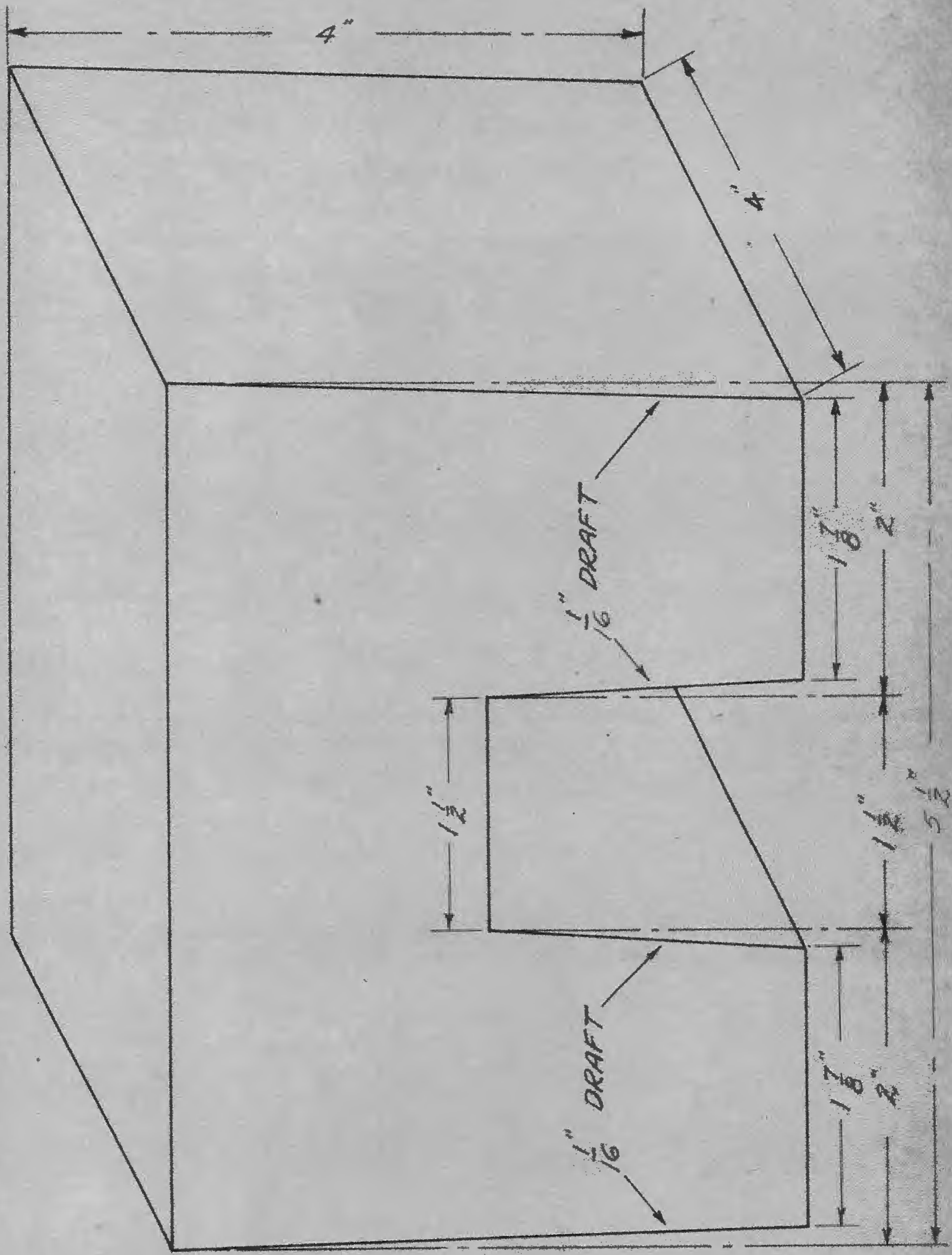

PLATE 9

29. The synthetic sands contained 4 per cent bentonite while the Albany contained 21.12 per cent of a natural clay. This high clay content is the reason for the maximum strength occurring so far to the right. The clay must be wet before the mix reaches the right condition of stiffness to produce strength. For sands with high clay and silt contents and therefore high surface areas, the amount of water required for this condition is naturally greater.

(h) <u>The Effect of Silica Flour</u>

30. Many foundries use silica flour particularly in dry sand molds as an addition to the regular sand to "close up" the sand and prevent metal penetration. In order to determine the effect of this practice on the synthetic silica sand-bentonite-water mixture, several batches were made containing 5 per cent bentonite and silica flour from 0 to 30 per cent, the balance consisting of washed silica sand with an A.F.A. fineness of 60.9. The dry mix was mulled for 1 minute, after which water was added to produce 6 per cent moisture based on total weight, and mulling continued for 5 more minutes. These mixes were tested for the usual green and dry properties and produced the curves shown on Plate 6.

31. The green compressive strength increases gradually from 0 to 26 per cent silica flour reaching a maximum of 12.86 lb/sq.in. From Naval Research Laboratory Report No. M-1478, a similar sand without silica flour, containing 5 per cent bentonite, would produce a maximum strength of 10.0 lb/sq.in. at 1.3 per cent water. This shows that the 26 per cent silica flour may be actually responsible for only about 2.86 lb/sq.in. of the strength, the rest being produced by the bentonite. The silica flour, however, makes it possible for the bentonite to develop its full strength by absorbing the surplus water and leaving just enough to produce the optimum moisture content with respect to strength for the amount of bentonite present.

32. The green permeability decreases approximately as a straight line function of the amount of silica flour added. The addition of 30 per cent silica flour only reduced the permeability from 99 to 25.

33. The deformation curve, as usual, is not very informative, being subject to quite a large experimental error and the resilience curve is practically parallel to the strength curve. It contains no information that the strength curve has not already shown. The limits of the resilience values are 123 and 350.

34. The weight or density curve is similar in shape to the strength curve. It increases slowly to a maximum at 26 per cent silica flour and then decreases.

35. Flowability decreases steadily with increase in silica flour.

36. The curve for dry permeability is very similar to that for green permeability except that it is from 60 to 90 per cent higher. The

TABLE 4

Physical Properties of Core and Facing Binders

Test	Binder	Weight of Specimen	Green Permeability	Green Compressive Strength	Dry Permeability	Dry Compressive Strength
1	Ajax	158	119	1.16	156	575
2	Bindex	172	13	1.27	111	213.6
3	Dextrine	157	129	0.99	165	268.7
4	Glutrin	158	115	0.92	163	197.9
5	Goulac	158	126	0.78	151	299.2
6	Kordek	157	127	0.74	163	428.5
7	Liquid Bindex	160	68	0.95	131	164.8
8	Mogul	158	123	1.08	156	558
9	Quandt	157.5	123	0.79	161	250.8
10	Truline	156	125	1.08	167	84.2
11	Bentonite	153	146	1.63	193	89.7
12	Molasses	157	134	0.62	161	171.0
13	Rosin	165	129	0.98	175	96.6
14	Final Molasses	155	146	0.67	179	64
15	Linseed A	163	88	0.55	122	619
16	Linseed B	161	101	0.61	142	342
17	Linseed C	161	100	0.66	142	411
18	Linseed D	160	119	0.70	159	318
19	Linseed E	158	127	0.74	171	376

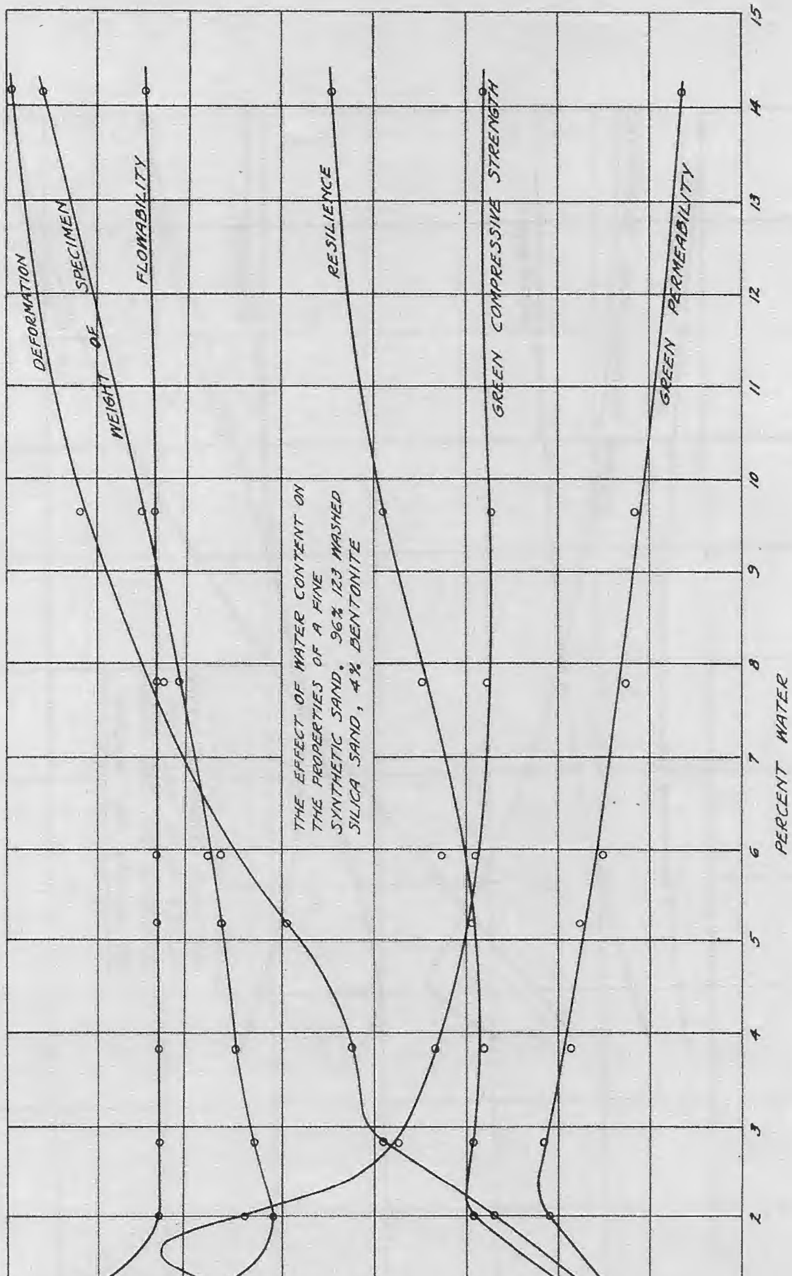
THE EFFECT OF WATER CONTENT ON THE PROPERTIES OF A FINE SYNTHETIC SAND. 96% 123 WASHED SILICA SAND, 4% BENTONITE
DEFORMATION
WEIGHT OF SPECIMEN
FLOWABILITY
RESILIENCE
GREEN COMPRESSIVE STRENGTH
GREEN PERMEABILITY
PERCENT WATER
WEIGHT
GREEN PERMEABILITY
GREEN COMPRESSIVE STRENGTH
DEFORMATION
RESILIENCE
FLOWABILITY

PLATE 3