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Report on
STUDIES ON EUROPEAN MOLDING SANDS

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ANACOSTIA STATION
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AUTHORIZATION

1. The studies of the foreign molding sands French Chamotte, German Industrial Extra, German Edelschlichte and Cement-bonded sand were authorized by the Bureau of Engineering in its letter EF30(10-18-N) 6/15 of 5 April 1933.

OBJECTS

2. The objects of these studies were (a) to assist the Norfolk Navy Yard in the practical use of the sand, (b) to determine the physical properties of the foreign sands and (c) to compare these physical properties with those of domestic sands.

CONSULTING SERVICE RENDERED TO NORFOLK NAVY YARD

3. Upon the arrival of the shipments of the foreign sands at the Norfolk Navy Yard, the Laboratory was requested to furnish information as to the "optimum water content" of the sands and the methods to be used in mixing the sands. At that time there were no samples of the materials available and an outline of what was considered a good general practice was forwarded rather than specific data. As the "optimum water content" could only be approximated the procedure for an easy method of determining the correct value was included.

4. A representative of the Laboratory was present during the first trials of the foreign sands in production at the Norfolk Navy Yard. At that time it was noted that the sands in the dried condition had very low shear and tensile strengths and that the corners of the molds and cores crumbled badly. In an attempt to remedy this condition a series of experiments were conducted using additional binders. The results of these experiments were forwarded to the Norfolk Navy Yard.

5. The physical properties of the foreign and several domestic sands were determined and the results forwarded to the Norfolk Navy Yard.

6. The chemical analyses of the German Industrial Extra and Edelschlichte were sent to the Norfolk Navy Yard.

MATERIALS STUDIED

7. The materials studied were samples of Chamotte, Industrial Extra and Edelschlichte obtained from the shipments that were received by the Norfolk Navy Yard and a cement bonded sand, similar to that mentioned in the report by Captain Louis Chanc, U.S.N., prepared from washed silica sand and Portland cement. The properties of these materials were compared with those of Downer sand, a nationally semi-bonded sand, and a synthetic green sand composed of washed silica sand, colloidal clay and cereal binders. The latter two sands are used extensively as molding materials in this country.

METHODS USED IN TESTING

8. The standard tests recommended by the American Foundrymen's Association were used to determine the permeability, compression strength, shear strength, tensile strength, fineness, clay content, moisture content and chemical analysis of each sample.

9. The samples were prepared for testing by mulling a weighed sample of sand and a weighed amount of water in a Simpson muller for four minutes. After mulling representative samples were taken and allowed to "temper" for twenty-four hours in sealed Mason jars to insure an even distribution of moisture. Each type of sand was milled and tested with different amounts of water in order that the importance of this variable might be demonstrated.

10. A series of experiments were conducted to increase the tensile and shear strength of chamotte by the additions of other binders in the form of fines (silica sand), raw clay, Mogul and Dextrine. The cereal binders, Mogul and Dextrine, were added in amounts of 1, 2, and 3 percent, the silica sand in amounts of 25 and 33-1/3 percent and the clay in an amount sufficient to bring the total clay content to 20 percent. These mixtures were milled and tested with varying water contents in the same manner as the chamotte and German sands.

11. A series of tests were made on a cement bonded sand mixed in the following proportions by weight: 90 parts of washed silica sand and 10 parts of Portland cement. This mixture was milled for four minutes after adding water in varying amounts.

12. The test specimens of this material must be prepared soon after the sand is mixed, for as this molding medium is really an under-hydrated mortar, the mixture will harden if allowed to "temper" for any considerable period of time.

13. A large number of specimens were prepared and tested at intervals of 0, 24, 48, 72, 120 and 168 hours after preparation.

14. A synthetic green sand was prepared and test in order to furnish data with which to compare the results obtained with the cement bonded sand. This sand was tested in both the green and the dried state in order that the maximum strengths obtainable might be determined.

15. The composition of the green sand mixture was:

500 parts of washed silica sand
19 parts of bentonite (colloidal clay)
1 part of Mogul
1 part of Dextrine
1/2 part of Molasses

16. A study was made of the heat conductivity of the different sands. A 6 inch diameter sphere with a 3 inch central down gate was molded in each type of sand. Thermocouples were inserted in the mold at distances of 1/8, 1/2, 1, 2, and 3 inches from the mold-metal interface. As soon as the molds were poured temperature readings were taken so that the temperature indicated by each thermocouple was recorded once a minute. These molds were all poured at practically the same temperature there being merely the short pouring interval between molds which is accompanied by a slight drop in temperature. Thus, the amount of heat to be released through the sand was practically the same. All of the molds were identical with respect to flasks, gates, method of ramming and the like.

DISCUSSION OF RESULTS

(a) Chamotte

17. The synthetic sand that has the greatest reputation in Europe is Chamotte. This molding medium is composed of a highly aluminous clay that is roasted at high temperatures to make it very refractory. This clay is introduced into roasting ovens in 9 inch cubes and is roasted above 1500 degrees C whence it breaks into pieces about the size egg coal. After cooling it is ground to the required fineness. For molding this calcined clay is mixed with a raw clay binder in the proportions of 85 percent, by weight, of calcined clay, and 15 percent of raw clay. Upon the addition of water it is suitable for immediate use.

18. The analyses show that chamotte varies somewhat. However, the three analyses shown in Table 4 are typical.

19. The point of fusion, cones Seger, is usually about 34-35 (1750-1770 degrees C or 3180-3220 F).

20. Chamotte as ready for use is quite granular (Plate I). This is because the European foundryman prefers a sand the grain of which is 5-2 millimeters in diameter. Calcined clay finer than 2 millimeters in diameter is removed before mixing with the raw clay. The screen analysis given in Table II shows the distribution of the grain size.

21. The most important feature in preparing this sand for molding is the control of the water additions. If too much water is added, the mixture becomes a sticky mass which is extremely difficult to mix and very nearly impossible to mold. Water additions in the neighborhood of 5 to 8 percent, depending upon local conditions, appear to be the best to use. The mulling time can be varied, of course, to suit the foundrymen's likes but four minutes mulling is sufficient.

22. The permeability is very high being 2000 or greater in green state. The dry permeability was unobtainable due to the fact that in using the core permeability tube the mercury ran through the test piece.

23. A study of chamotte using varying water contents was made and the results are listed in Table III. It will be noticed that the green and dry compression strengths are very good. The green compression strength is higher than that found in the average American naturally bonded sand. The green shear strength is fair but the dry shear strength is lower than that which is generally recorded for the naturally bonded sands.

24. These low values for shear and tensile strengths caused considerable difficulty during the first trials of the material at the Norfolk Navy Yard as sharp corners on molds and cores fell off and were difficult to patch.

25. In Table IV are shown the results of several experiments conducted to increase the tensile and shear strengths. The additions of Dextrine and Mogul did increase the shear strength appreciably but had no effect upon the tensile strength. Whether or not this increase in shear strength is sufficient to remedy the difficulty experienced in molding the material has not been determined as there is not sufficient material on hand at the Laboratory to prepare a large mold or core and the Norfolk Navy Yard has not stated whether or not the sand is now satisfactory.

26. In using Mogul as an additional binder a higher moisture content must be used. With too low a water content the moisture has no green strength and is entirely unsuitable for molding purposes.

27. The addition of more raw clay to the prepared chamotte accomplished nothing. The additions of silica sand, added on the theory that the bond would be more uniformly spread through the sand and that the smaller grains would tend to fill the interstices and provide a larger bonded area, also failed to increase the shear or tensile strength.

(b) Industrial Extra.

28. German Industrial Extra has received considerable mention as a molding material especially for large castings and European foundrymen consider it to be an ideal material when large quantities of sand are necessary.

29. German Industrial Extra is composed mostly of quartz and chalcedony grains. The smaller quartz grains appear to be fairly well rounded but the larger quartz grains and the chalcedony grains are very angular. Pieces of carbon can be seen occasionally. (See Plate I).

The product is prepared by crushing quartz and chalcedony to the required size and then adding some clay as a binder and pulverized carbon. These constituents are thoroughly mixed and the material sold ready for the additional of the water. The chemical analysis is given in Table V.

30. The screen analysis, Table VI, shows a product that is not at all uniform. In fact, there does not appear to be any attempt made to grade the sand. Synthetic sands as a rule are graded so that the bulk of the grains are retained on one or possibly two screens and even the naturally bonded sands of this country usually show more graded characteristics than the German material. The high figure of 26.02 percent bond listed for the Industrial Extra includes the clay bond plus the pulverized carbon that could be syphoned off.

31. In preparing Industrial Extra for molding the moisture content must be closely controlled. If the sand becomes too moist it will pack too solidly and, when dried, will be too close to allow gases to escape.

The properties of Industrial Extra were obtained with varying water contents and are reported in Table VII. The results listed in this table indicate that the 7.5 percent water content gives the best results. Tests with higher percentages of water were not conducted as the sand with 7.5 percent water "balled-up" badly and was rather difficult to mold. A water content of about 7.0 percent would be better for molding purposes.

32. In the testing of most sands an increase in moisture content usually brings about a decrease in the permeability. It is interesting to note that as the water content increases the permeability of the Industrial Extra increases. This is due to the "balling" action which, though not perceptibly noticeable until about 7 percent of water is added, is present even with small additions of water. When the sand is screened small balls, approximately the size of the mesh used, are formed. The ramming action exerted by three blows of the standard rammer is not sufficient to force these agglomerates together and as a result large air spaces are present between them and an unusually high permeability reading is obtained. If, however, harder ramming is resorted to, such as would probably be used in a mold to insure a good surface on the casting these interstices are closed and the material is almost impermeable. For this reason, and the fact that with a high water content the material is very sticky and almost impossible to mold, the water content must be closely controlled.

(c) Downer Sand.

33. It was thought advisable to include a good, naturally bonded, American sand in order that a more complete comparison of the physical properties of the German Industrial Extra and the Chamotte might be obtained. The sand selected was a semi-bonded Downer sand which is used for dry sand molds at the Naval Research Laboratory and also at the Naval Gun Factory. This sand can be used in the condition in which it is received but its properties can be improved by small additions of cereal binders and raw clay.

34. The screen analysis of the Downer sand is given in Table VI and its physical properties are listed in Table VIII.

35. It will be noted that the permeability of the Downer sand is considerably less than that of the Chamotte and slightly less than that of the Industrial Extra with 7.5 percent moisture. The green compression strength of both of the foreign sands is also greater than that of the American material. The outstanding feature is that the Downer sand has higher dry shear and dry tensile strengths. It was the lower values of dry shear and tensile strength found in the foreign sands that caused the molding difficulties in the trials at the Norfolk Navy Yard.

(d) Edelschlichte

36. Edelschlichte is a prepared mold wash to be used in conjunction with the Industrial Extra. It is composed of fine silica sand, clay, and pulverized carbon.

The chemical analysis of this material is given in Table IX. It will be noted that the total of the analysis given is considerably greater than 100 percent. This is due to the fact that "total volatile matter" and "carbon" are in a manner duplicate analyses. That is, the "total volatile matter" minus the "carbon" is equal to the volatile inorganic and organic matter plus the water not driven off at 105 degrees C.

37. The screen analysis, Table X, and the photo-micrographs on Plate X indicate how fine the material is as compared to ordinary molding sands.

38. This mold wash is prepared for use by mixing with enough water to bring it to the consistency of porridge. Before using the mixture must be well stirred. It should be painted on the molds soon after the pattern is removed. The molds are then dried at a temperature of from 400-500 degrees C. A second coat of the wash is applied after the molds are dried and while they are still warm so that the moisture will evaporate. The molds should not be too hot as then the wash will crack and may break off. If little cracks appear after drying they should be coated with Edelschlichte and polished.

(e) Cement Bonded Sand

39. A more recent addition to the list of European molding materials is cement bonded sand. This sand is a mixture of washed silica sand, a good grade of cement and water.

40. Care must be exercised in mixing this type of sand as the water content must be closely controlled. All of the physical properties of the sand depend almost entirely upon the amount of water present. The length of time allowed for air drying also affects the physical properties to some extent.

of but 1120 degrees F, and that only after twenty-five minutes have elapsed. The thermocouple at 2 and 3 inches show a maximum of 200 throughout the recorded interval. The heat transference of this sand is exceptionally low and this condition must be due entirely to the type of bond used. A comparison of this data with that obtained with the green sand mold will show that the temperatures indicated by 1/2, 1, and 2 inch curves of the green sand mold are considerably higher than those of the cement mold. The 1/8 inch curve of the green sand mold never attains the maximum recorded on the cement bonded mold. Since the sand used as a base, a washed silica sand, was the same in each case, the difference in thermal conductivity must be due to the bond used.

51. In comparing all of the heat transference curves it is observed that the Chamotte has the highest rate of heat transference and the cement bonded the lowest, of the sands studied. The order of heat transference is as follows:

- (1) Chamotte
- (2) Downer Sand
- (3) Industrial Extra
- (4) Green Sand
- (5) Cement-bonded Sand

52. The importance of the rate of heat transference in sands is not thoroughly known. It has been shown, however, that the slower a casting cools the better physical properties it will have regardless of the following heat treatments. It is also known that casting solidification depends upon the rate with which the sand conducts heat, but how important a part it plays with regard to the rate of skin formation, hot tear formation and other physical metallurgical characteristics of solidifying steel, steel castings has not been definitely determined, as yet.

TABLE I

CHEMICAL ANALYSES OF CHAMOTTE

	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>
Al ₂ O ₃	37.50	31.75	42.69
SiO ₂	56.46	63.50	34.78
FeO ₃	2.5	2.15	1.15
CaO	0.5	Trace	0.15
MgO	0.8	1.0	0.17
TiO ₂	1.8	1.17	
Na ₂ O			0.25
K ₂ O			0.45

TABLE II

SCREEN ANALYSIS OF CHAMOTTE

<u>Screen No.</u>	<u>Percent</u>	<u>Screen No.</u>	<u>Percent</u>
6	0	100	1.09
12	20.2	150	.70
20	54.3	200	.60
28	4.1	270	.46
35	1.56	-270	.70
48	1.01	Clay bond	14.3
65	1.08		

TABLE III

PHYSICAL PROPERTIES OF CHAMOTTE

Test	Water Content		
	5%	6.9%	9%
Permeability			
Green	2450	2000	2000 cc/min
Dry	unobtainable		
Compression			
Green	15.3	16.1	7.6 lbs/ sq.in.
Dry	Beyond	Scale or +93.5	
Shear			
Green	1.0	1.3	0.6 lbs/ sq.in.
Dry	5.6	6.3	8.3 "
Tensile			
Dry	Nil	Nil	Nil "
Sintering Point	1100 degrees Centigrade		

TABLE IV

PHYSICAL PROPERTIES OF CHAMOTTE AND CHAMOTTE PLUS SILICA SAND OR ADDITIONAL BONDING MATERIALS

<u>Composition of Mixture</u>	Percent age <u>Moisture</u>	Permeability cc/min.		Compression lbs/sq. in.		Shear lbs/sq. in.		Tensile
		<u>Green</u>	<u>Dry</u>	<u>Green</u>	<u>Dry</u>	<u>Green</u>	<u>Dry</u>	<u>lbs/sq. in</u> <u>Dry</u>
Chamotte	6.9	2450	*	16.1	Beyond Scale +93.5	1.3	6.3	0.3
Chamotte 75%, silica sand 25%	7	850	492	6.7	Beyond Scale +93.5	0.4	12.5	0.2
Chamotte 66-2/3%, silica sand 33-1/3%	7	710	492	7.4	+93.5	0.3	9.2	N11
Chamotte 99%, Dextrine 1%	6.8	2450	*	8.2	+93.5	0.5	14.9	0.2
Chamotte 98%, Dextrine 2%	7.2	2450	*	9.9	+93.5	0.8	15.4	0.2
Chamotte 97%, Dextrine 3%	6.6	2000	*	10.3	+93.5	0.83	23.2	0.3
Chamotte 99%, Mogul 1%	10.1	2000	*	5.5	+93.5	0.4	12.2	0.6
Chamotte 98%, Mogul 2%	10.4	1200	*	5.9	+93.5	0.6	12.2	0.3
Chamotte 97%, Mogul 3%	9.95	850	*	6.2	+93.5	0.2	11.5	N11
Chamotte plus additional raw clay to make total clay content 20%	6.7	2000	*	15.9	+93.5	1.0	8.3	0.2

* The dry permeability was unobtainable with the core permeability tube as the mercury used as a seal ran through the specimen.

TABLE V

CHEMICAL ANALYSIS OF INDUSTRIAL EXTRA

Total volatile matter	5.61 %
SiO ₂	72.50
Al ₂ O ₃	19.75
Fe ₂ O ₃	1.59
CaO	1.11
MgO	0.00

TABLE VI

SCREEN ANALYSIS OF INDUSTRIAL EXTRA AND DOWNER SANDS

Sieve No.	Industrial Extra Percent	Downer Percent
Retained on 6	5.32	0.0
12	11.24	.10
20	8.24	.71
30	3.22	1.89
40	3.02	6.33
50	3.72	15.54
70	15.20	32.41
100	11.76	32.23
140	2.36	4.66
200	2.12	.65
270	1.40	.40
-270	6.04	.45
Clay bond	26.02	4.63

TABLE VII

PHYSICAL PROPERTIES OF INDUSTRIAL EXTRA

Test	Water Content		
	4%	5.5%	7.5%
Permeability			
Green	36	48	97 cc/min.
Dry	42	61	130 "
Compression			
Green	16.9	18.8	15.4 lbs/ sq. in.
Dry	Beyond scale	or 93.5	"
Shear			
Green	1.4	1.5	1.3 "
Dry	7.5	9.9	21.3 "
Tensile			
Dry	Nil	.18	.30 "

Sintering Point 1000 degrees C.

TABLE VIII

PHYSICAL PROPERTIES OF DOWNER SAND

	Water Content 5.5%
Permeability	
Green	70 cc/min.
Dry	87 "
Compression	
Green	3.1 lbs/sq. in
Dry	29.5 "
Shear	
Green	0.12 "
Dry	29.5 "
Tensile	
Dry	2.87 "

Sintering Point 1100 degrees C.

TABLE IX

CHEMICAL ANALYSIS OF EDELSCHLICHTE

Total volatile matter, percent	13.84
Carbon	11.00
SiO ₂	45.62
Al ₂ O ₃	38.90
Fe ₂ O ₃	1.69
CaO	1.50
MgO	0.00

TABLE X

SCREEN ANALYSIS OF EDELSCHLICHTE

<u>Screen No.</u>	<u>Percent</u>	<u>Screen No.</u>	<u>Percent</u>
20	0.0	140	9.36
30	0.06	200	10.08
40	0.2	270	6.18
50	1.02	-270	23.00
70	4.46	Bond	35.00
100	10.6		

TABLE XI

PHYSICAL PROPERTIES OF CEMENT BONDED SANDS

	Moisture 7.2%					
Hours air dried	0	24	48	72	120	168
Permeability cc/min	87	97	102	102	100	100
Compression-lbs./sq.in.	1.4	Beyond scale +93.5				
Tensile - lbs/sq.in.	Nil	92	1.53	1.93	1.50	1.46
Shear - lbs/sq.in.	Nil	47.75	62.5	63.2	66.4	61.9
	Moisture 9.9%					
Hours air dried	0	24	48	72	120	168
Permeability - cc/min.	52	56	58.3	61	57.9	63.3
Compression-lbs/sq.in.	1.5	Beyond scale +93.5				
Tensile - lbs/sq.in.	Nil	1.45	2.23	2.33	2.06	2.63
Shear - lbs/sq.in.	Nil	55.7	65.9	Beyond scale +73.5		
	Moisture 11.6%					
Hours air dried	0	24	48	72	120	168
Permeability cc/min	28.6	34.6	36.6	34	37.3	41.3
Compression - lbs/sq.in.	1.3	beyond scale +93.5				
Tensile - lbs/sq.in.	Nil	1.3	2.0	2.1	1.76	1.83
Shear - lbs/sq.in.	Nil	34.3	63.1	67.7	70.3	70.9

TABLE XII

PHYSICAL PROPERTIES OF GREEN SAND

Test	Water Content 4%	
	Green State	Dried State
Permeability	173	219 cc/min
Compression	3.5	Beyond scale +93.5 lbs/sq.in.
Shear	Nil	40.7 "
Tensile	Nil	0.8 "



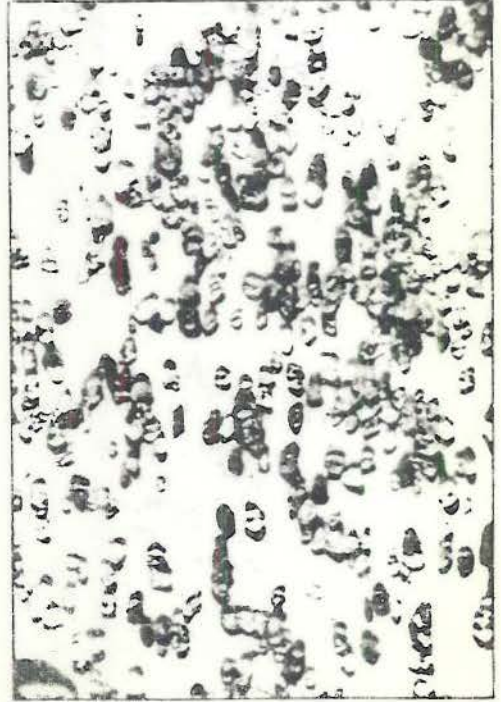
CHAMOTTE



INDUSTRIAL EXTRA

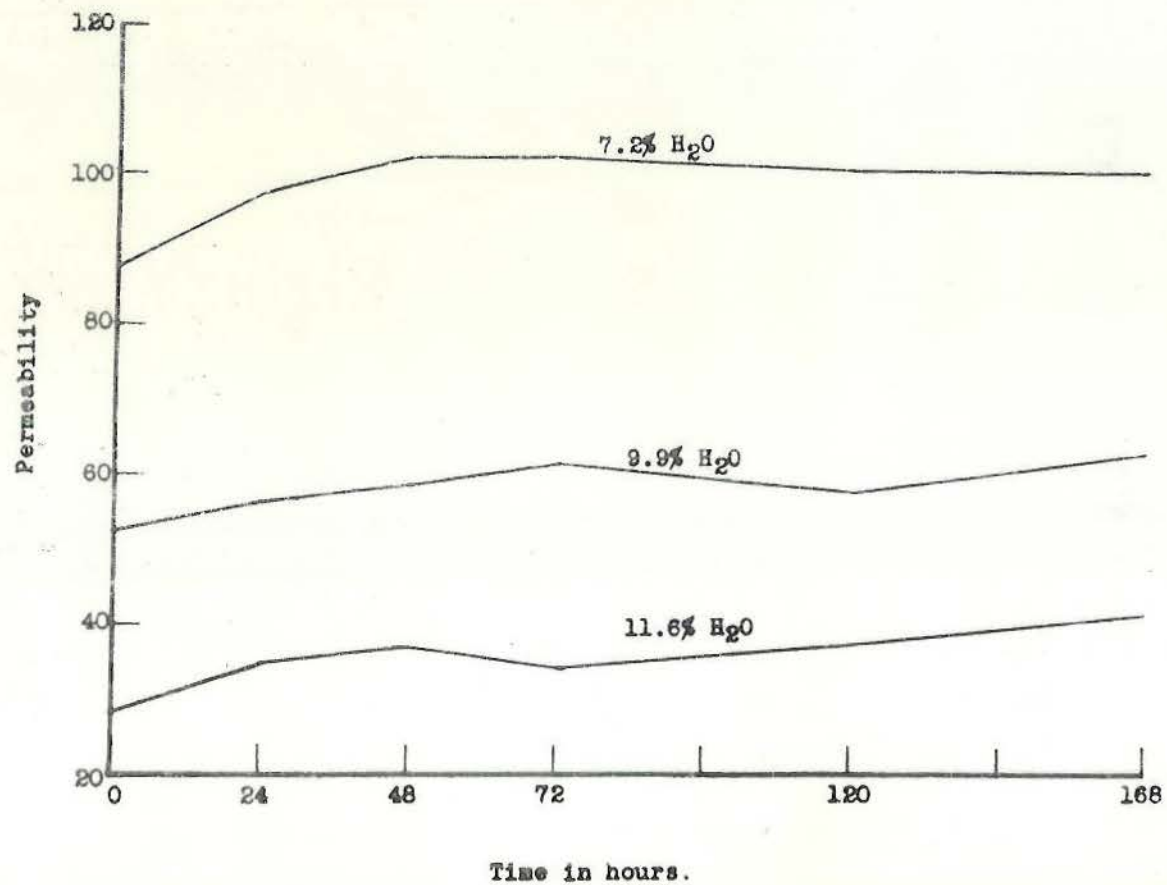


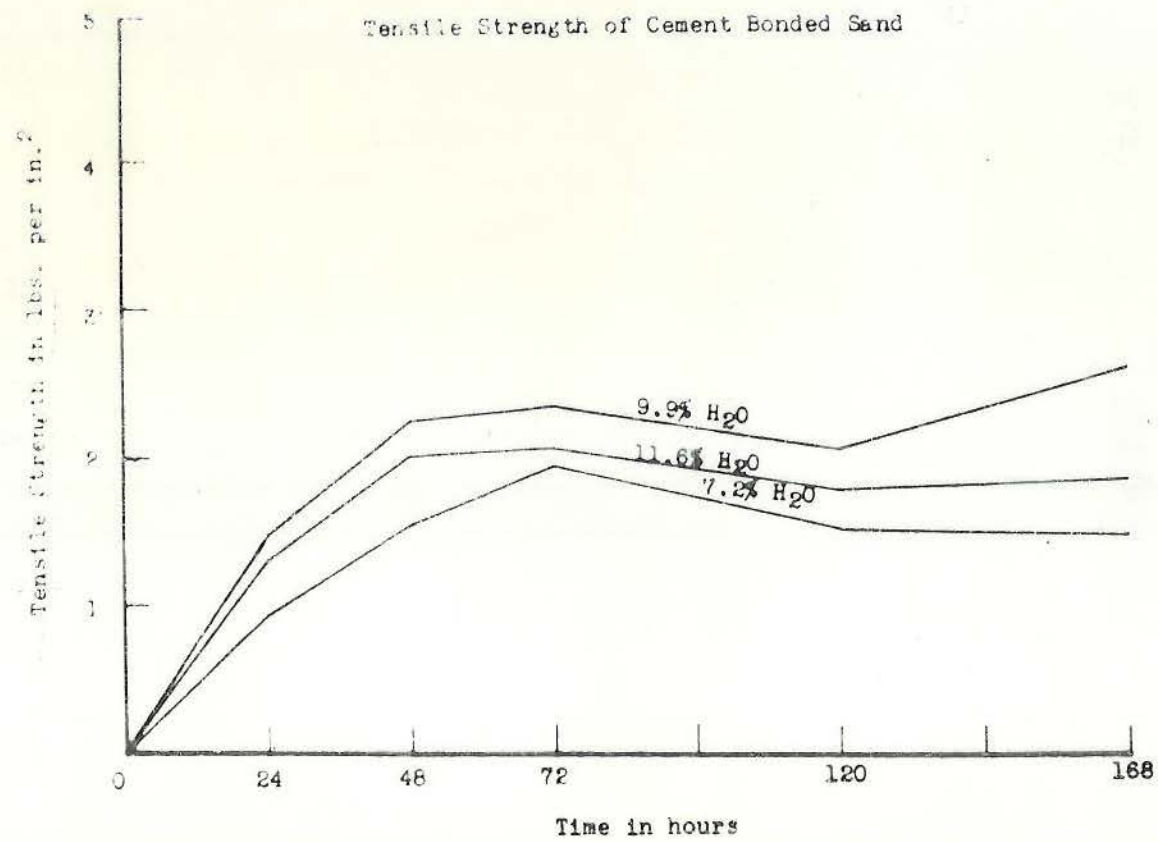
EDELSCHLICHTE



SILICA SAND

Permeability of Cement Bonded Sand





Shear Strength of Cement Bonded Sand.

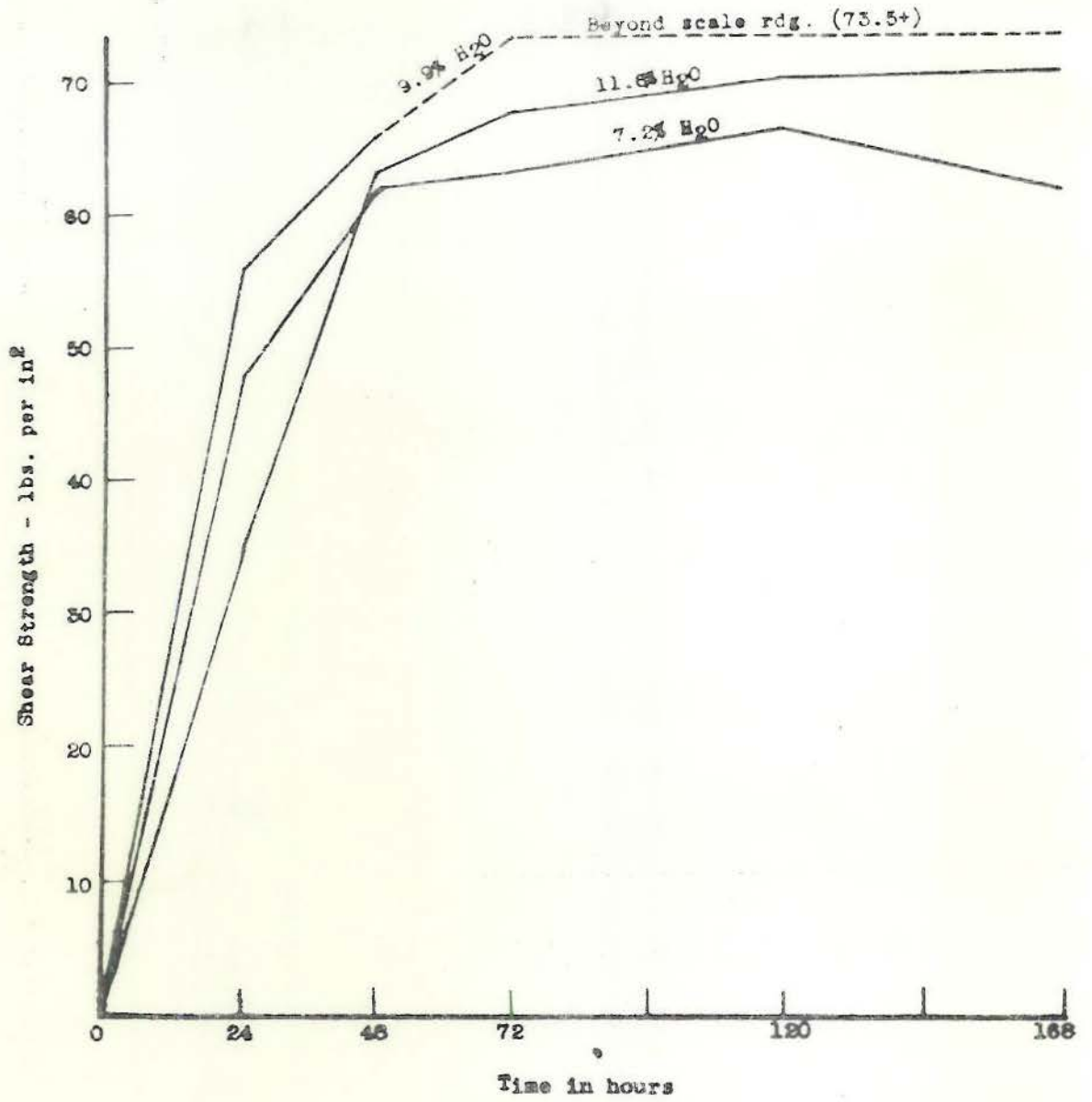


Plate 4

PERCENT RETAINED ON SCREEN

