THE EFFECT OF SALT ON THE COMPRESSIVE STRENGTH OF SUPER-CEMENT CONCRETE

THESIS FOR DEGREE OF B. S.

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THE EFFECT OF SALT ON THE COMPRESSIVE STRENGTH OF SUPER-CEMENT CONCRETE.

A THESIS SUBMITTED TO THE FACULTY OF
THE MICHIGAN STATE COLLEGE

BY

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THESIS

In order to keep concrete from freezing when poured in the winter months, it has been the custom to add common salt (NaCl) to the mixing water. The addition of the salt lowered the freezing point to a considerable degree depending on how much salt was added. The effect upon the compressive strength of the resulting concrete has been investigated and found to be detrimental.

The object of this investigation was to find out the effect, if any, when salt was added to a concrete made of "Super Cement" as manufactured by the Peerless Cement Company.

Obviously, a test of this kind consisted of making a number of test specimens containing various proportions of salt and testing them at different ages. The first problem confronting the investigator is at what time to make the tests. As it is generally accepted that tensile strength of concrete bears some relation to the compressive strength, a piolet tension test was made.

The method of making the above test was as follows: A set of briquettes was made of the neat cement with enough water to bring the resulting neat mortar to its normal consistency. The briquettes were molded in the molds specified, and by the methods as laid down by the American Society for Testing Materials. These briquettes were broken at the following intervals of time: 6 hours, 15 hours, 1, 2, 3, 4, 5, 6, 7 days. Using the results of these tests a curve was plotted using tensile strength as an ordinate and age of

specimen as an abscissa. (See Plate II) From an inspection of this curve it was decided to break the compression specimens at the following ages: 15 hours, 1, 2, 3, 4, 5, 6 and 7 days.

The materials used in making the compression specimens were as near as possible what the average user of concrete has available.

The aggregate consisted of land run gravel. Enough was selected to make the entire set of specimens. This gravel was spread on the floor until it was thoroughly dried out when it was stored in containers until used. The silt content of this aggregate was determined by washing on a 200 mesh sieve and found to be 1.0%. A sieve analysis was made according to the method as described in Hool & Johnson's "Concrete Engineer's Hand Book." For the sieve analysis curve (See plate I).

The cement was new Peerless "Super" which was packed in paper bags of 1/4 barrel capacity each.

The water was top water from the college water supply system.

The salt (NaCl) used was table salt made by the Morton Salt Company.

Throughout these tests, the amount of cement, water and aggregate were kept constant, the only variable being the amount of salt used. After many trials to obtain a workable mix which could be used to advantage, the following proportions were adopted:

Parts by weight of	Cement	10
" " "	Water	6
" " "	Aggregate	60

The cylinders were made with the following amounts of salt as expressed as a percentage of the cement by weight used;

0%, 6%, 9%, 12% and 15%. As these cylinders were broken at the eight ages before stated, there would be eight cylinders of each percentage if only one were made. To insure better results, four cylinders containing the same percentage of salt were broken each time. Thus the number of cylinders made containing like amounts of salt were:
4 X 8 = 32.

As it took some time to place the concrete in the molds, it was decided to mix up batches containing enough concrete to cast 16 cylinders at one time. By splitting each batch into two parts, as outlined above, the concrete could be placed in the mold in about fifteen minutes, and any tendency for the concrete to set up was avoided.

The method of mixing used was as follows: The amounts of aggregate and cement were carefully weighed and placed in a pile on a concrete floor. By the use of a shovel, the materials in the pile were thoroughly mixed dry. To accomplish this, the pile was shoveled over six times. Then the water was weighed out and the paper weight of salt dissolved in it. After a hole had been made in the top of the pile of aggregate and cement, the water containing the dissolved salt was poured in the hole. With the aid of a garden hoe the dry mixture was worked into the

hole until all of the free water was absorbed. Then the entire mass was worked thoroughly.

After a search for a suitable mold, quart ice cream cartons were adopted. Molding and puddling were accomplished in the usual manner, the mold retaining its shape, and when full struck off level with a trowel. In order to obtain an even base, the empty cartons were set on loose sand during molding and until set.

After casting, the cylinders were allowed to set for a period of 15 hours, when the mold was removed and the cylinders placed in water to cure at normal temperature (60^{o} - 75^{o}F) until the time of testing.

The dimensions of the finished cylinders were: height, 6.5", diameter 3 1/3". The volume was 57¾ cubic inches and the cross sectional area 8.7 square inches.

The testing of the cylinders was done in a "Riehle" 100,000 # compression machine. Before testing each cylinder was bedded in, and capped with Plaster of Paris to insure an even bearing on both ends.

Each cylinder was compressed until it broke and the breaking stress adopted on the strength of the cylinder. For results of these tests, see data sheets 1, 2, 3, 4, 5 and 6, also Plates III and IV.

CONCLUSIONS:

(1) That the addition of salt to a batch of concrete makes it much more workable. In fact, two batches of grout exactly alike except that one has about 5% salt added has

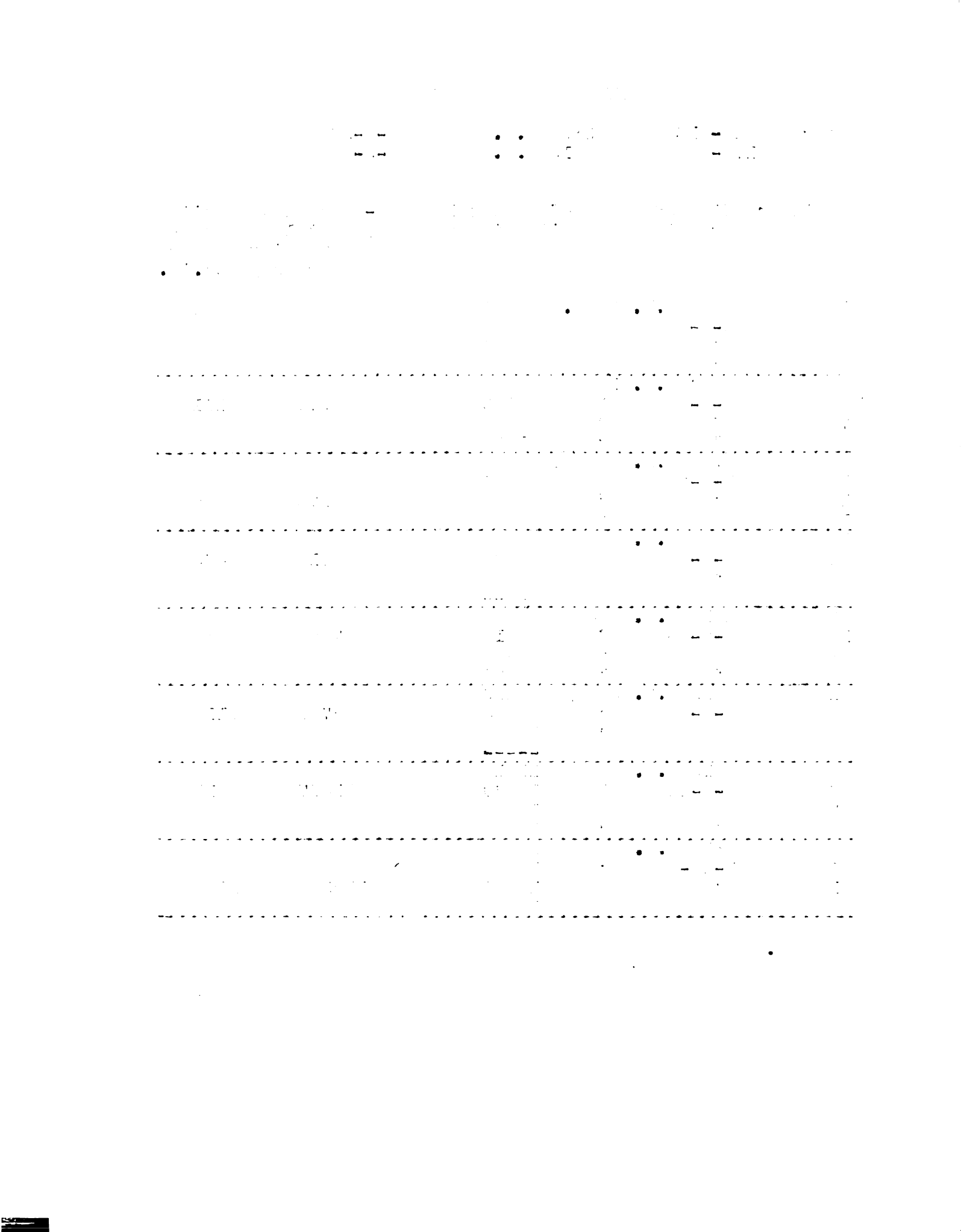
altogether different characteristics. While the amount of water remains the same in both, the salted batch appears to have much more water in than the other. It is not known why this is true; rather it is suggested that it would be a fit subject for further investigation.

(2) The second and last conclusion is of far greater importance. On inspection of the curves (Plate III & IV) will plainly show that salt very materially reduced the compressive strength of concrete in about the same proportion as the amount of salt used. For that reason, the use of salt (NaCl) should be looked on with suspicion. Protection of against frost should be obtained by the use of some other agent which will not lower the compressive strength of the resulting concrete, or better still by the proper and judicious use of salamanders and covering materials.

CYLINDERS 0% SALT

Poured # 1 - 16 3:00 P.M. 5-3-26
17 - 32 2:15 P.M. 5-3-26

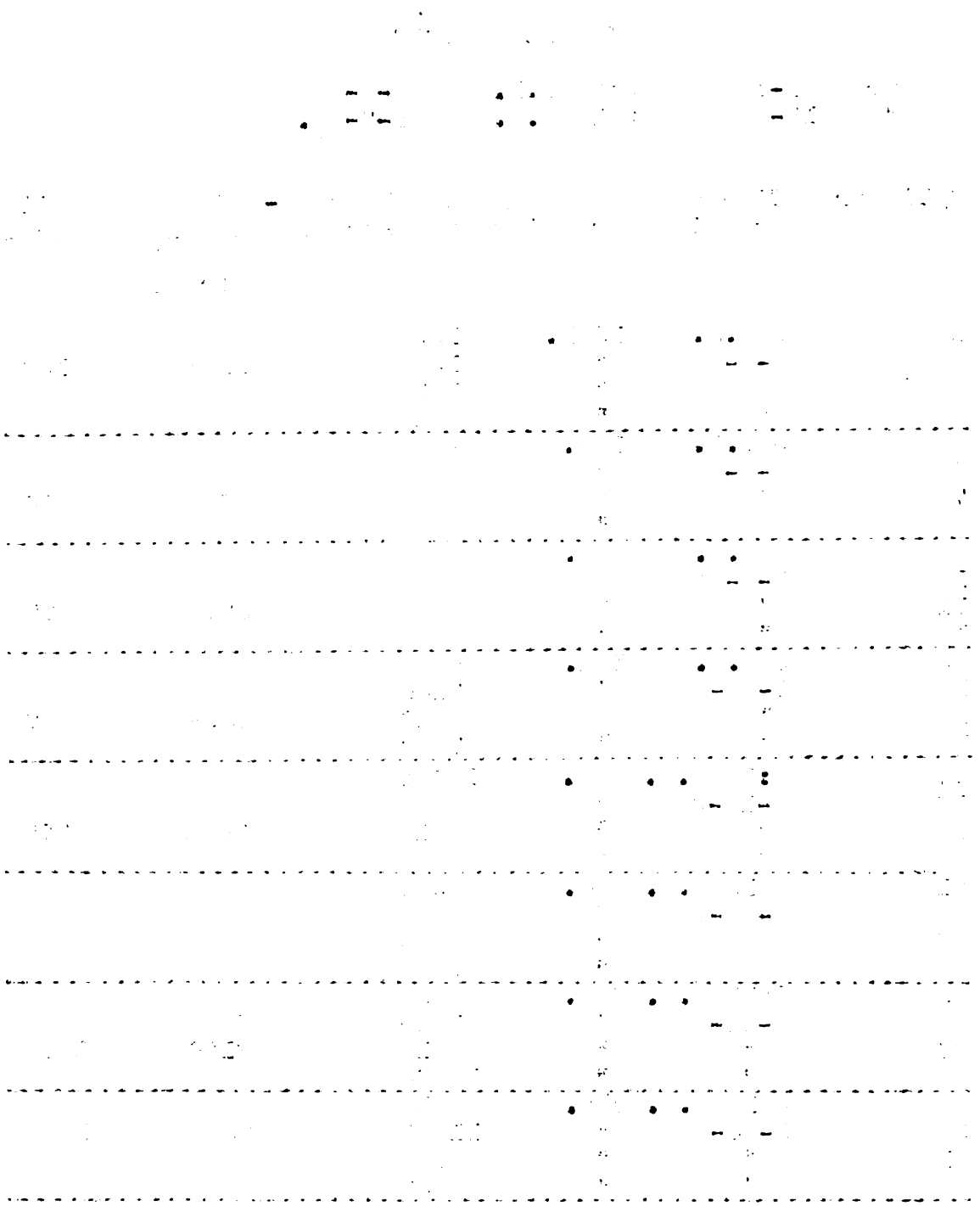
Cylinder	Time of breaking	Age of breaking	Total breaking stress #	Adopted total breaking stress #	Unit stress # per sq.in.
1	6:00 A.M.	15 h.	430	288	33
2	5-4-26	"	230		
3	"	"	270		
4	"	"	220		
5	3:00 P.M.	1 day	920		
6	5-4-26	"	890	970	111
7	"	"	890		
8	"	"	1180		
9	3:00 P.M.	2 days	2240		
10	5-5-26	"	3250		
11	"	"	3540	3172	365
12	"	"	3660		
13	3:00 P.M.	3 days	4430		
14	5-6-26	"	6000	4018	463
15	"	"	5640		
16	"	"	----		
17	2:15 P.M.	4 days	7660		
18	5-7-26	"	8210	7955	916
19	"	"	8480		
20	"	"	7470		
21	2:15 P.M.	5 days	8410		
22	5-8-26	"	8890	9708	1114
23	"	"	12500		
24	"	"	-----		
25	2:15 P.M.	6 days	11210		
26	5-9-26	"	13160	11467	1315
27	"	"	10550		
28	"	"	10950		
29	2:15 P.M.	7 days	14620		
30	5-10-26	"	13050		
31	"	"	12900	13255	1525
32	"	"	12450		



CYLINDERS of SALT

Poured #1-16 3:00 P.M. 5-7-26
" #17-32 2:15 P.M. 5-7-26.

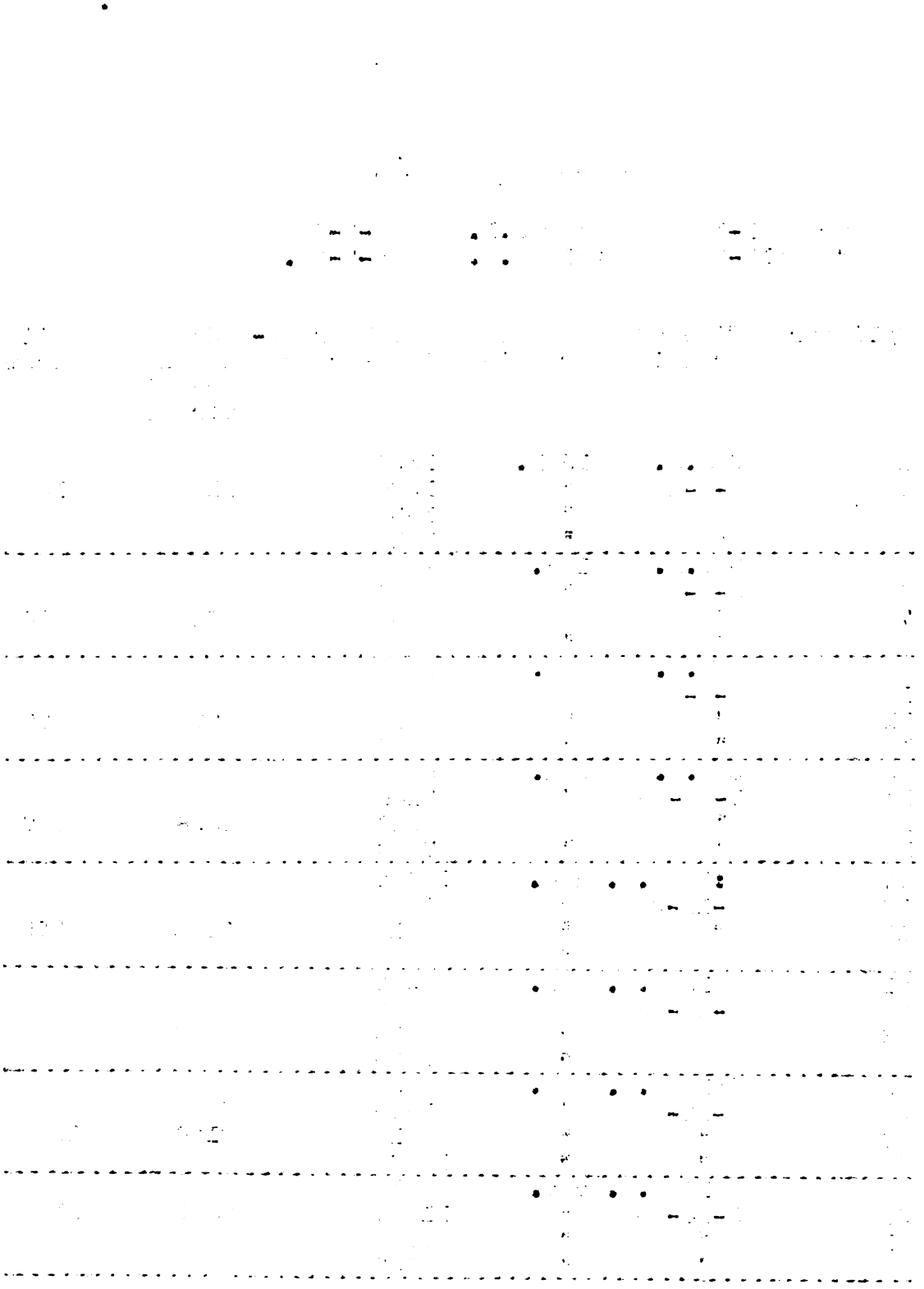
Cylinder	Time of breaking	Age of breaking	Total breaking stress	Adopted total breaking stress	Unit stress
1	6 A.M.	15 h.	1330		
2	5-8-26	"	1320	1198	139
3	"	"	1030		
4	"	"	1110		
5	3 P.M.	1 d.	2620		
6	5-8-26	"	2680		
7	"	"	2740	2642	304
8	"	"	2530		
9	3 P.M.	2 d.	5410		
10	5-9-26	"	4980		
11	"	"	5410	5275	607
12	"	"	5300		
13	3 P.M.	3 d.	5300		
14	5-10-26	"	7140		
15	"	"	6940	6595	757
16	"	"	7000		
17	2:15 P.M.	4 d.	10440		
18	5-11-26	"	8000		
19	"	"	6010	8482	975
20	"	"	8480		
21	2:15 P.M.	5 d.	8520		
22	5-12-26	"	8080		
23	"	"	9280	8840	1020
24	"	"	9480		
25	2:15 P.M.	6 d.	8650		
26	5-13-26	"	7960		
27	"	"	9610	9120	1050
28	"	"	10260		
29	2:15 P.M.	7 d.	9910		
30	5-14-26	"	11900	9590	1106
31	"	"	7620		
32	"	"	8930		



CYLINDERS 9% SALT

Poured #1-#16 3:30 P.M. 4-30-26
" 17-32 2:30 P.M. 4-30-26

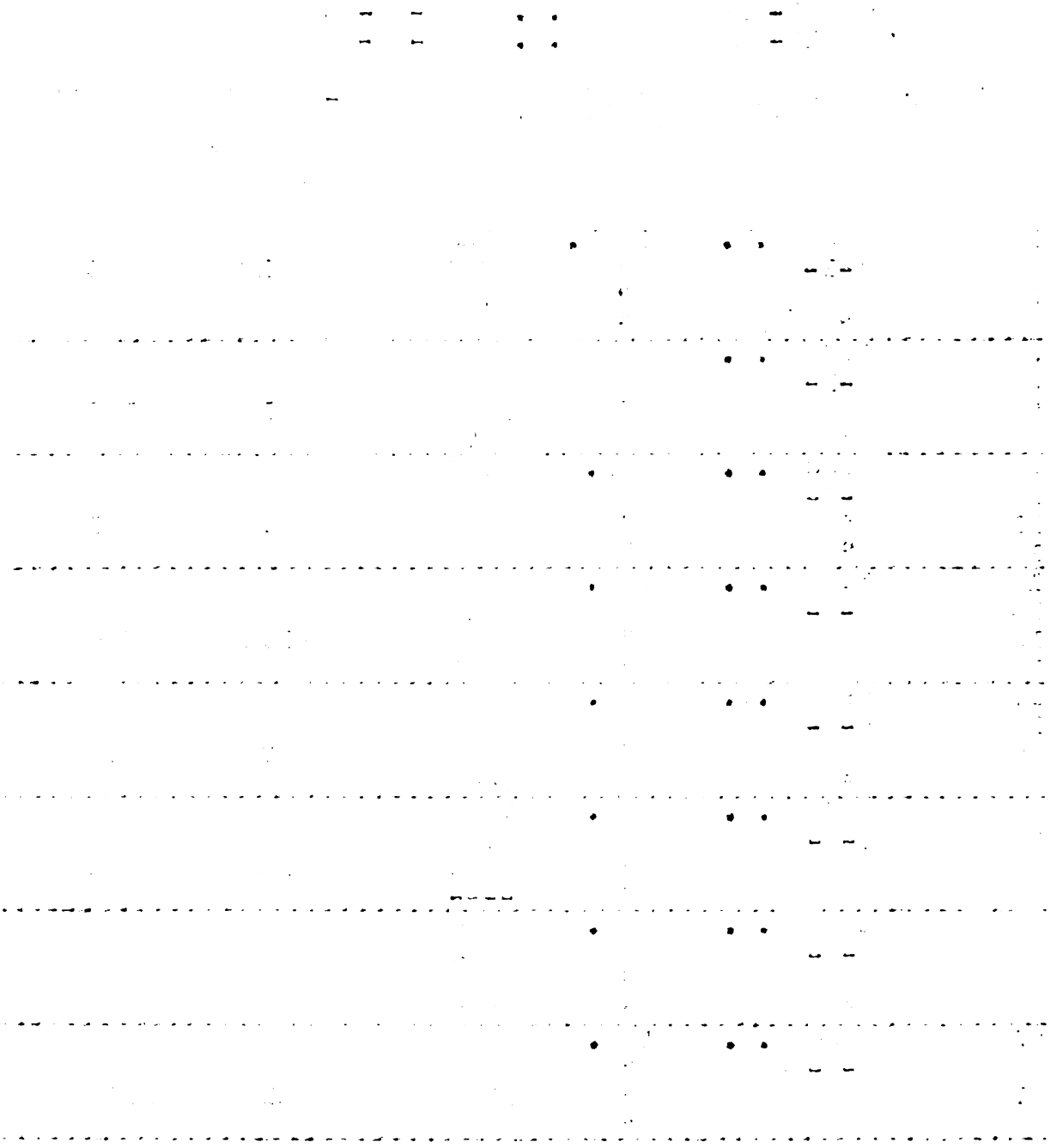
Cylinder	Time of breaking	Age of breaking	Total breaking stress	Adopted total breaking stress	Unit stress
1	6:30 A.M.	15 h.	530		
2	5-1-26	"	660	612	70
3	"	"	700		
4	"	"	560		
5	3:30 P.M.	1 day	1540		
6	5-1-26	"	2440		
7	"	"	1520	1718	198
8	"	"	1370		
9	3:30 P.M.	2 d.	3740		
10	5-2-26	"	4350		
11	"	"	5260	4875	560
12	"	"	6150		
13	3:30 P.M.	3 d.	4300		
14	5-3-26	"	5940		
15	"	"	6950	6142	706
16	"	"	7380		
17	2:30 P.M.	4 d.	5610		
18	5-4-26	"	6500		
19	"	"	6286	6472	743
20	"	"	7500		
21	2:30 P.M.	5 d.	7460		
22	5-5-26	"	8700		
23	"	"	8220	8126	932
24	"	"	----		
25	2:30 P.M.	6 d.	9040		
26	5-6-26	"	6910	8488	975
27	"	"	8300		
28	"	"	9700		
29	2:30 P.M.	7 d.	8930		
30	5-6-26	"	8200		
31	"	"	11180	9318	1070
32	"	"	8960		



CYLINDERS 2% SALT

Poured #1-#16 3:30 P.M. 4-30-26
" 17-32 2:30 P.M. 4-30-26

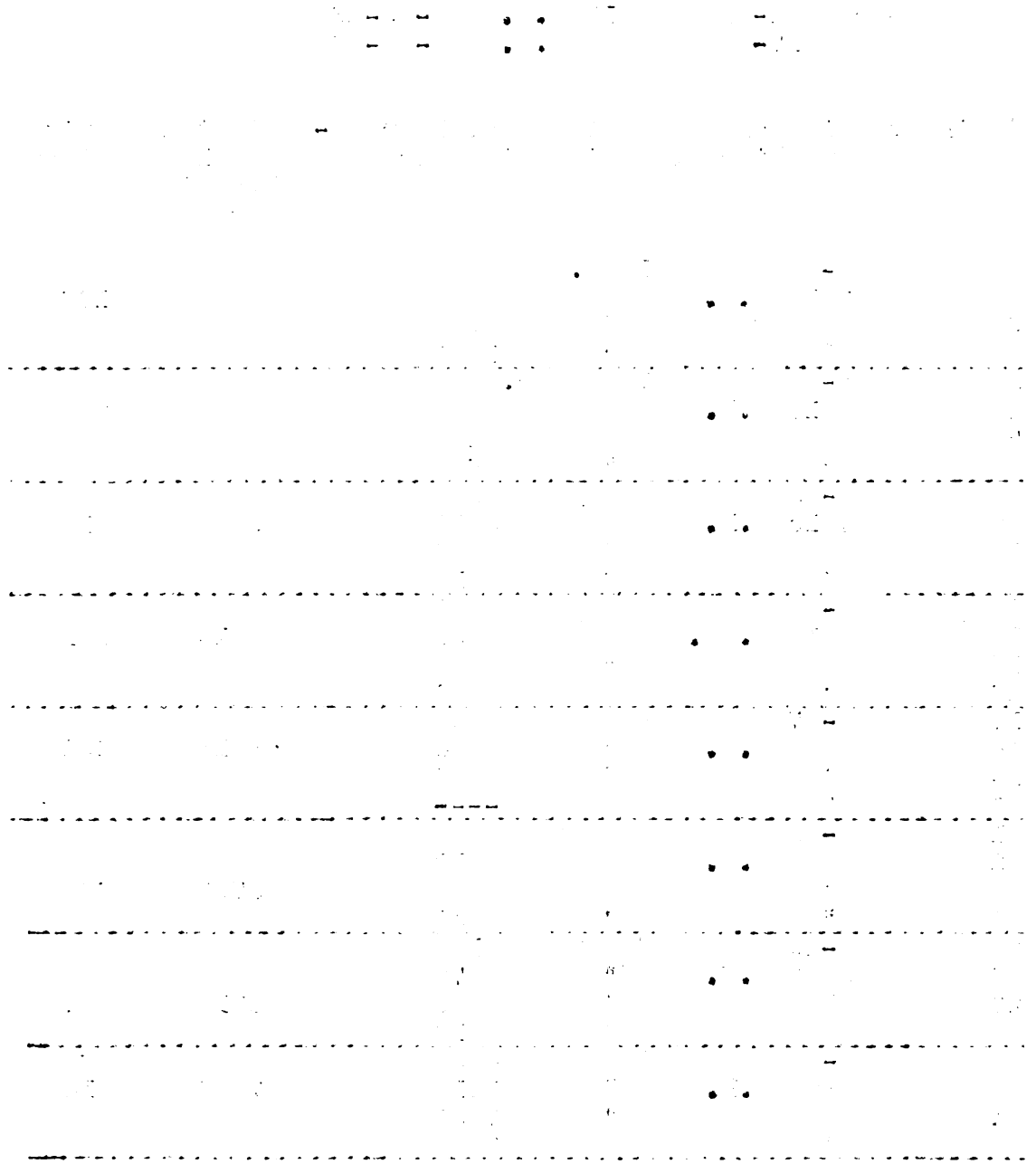
Cylinder	Time of breaking	Age of breaking	Total breaking stress	Adopted total breaking stress	Unit stress
1	6:30 A.M.	15 h.	530		
2	5-1-26	"	660	612	70
3	"	"	700		
4	"	"	560		
5	3:30 P.M.	1 day	1540		
6	5-1-26	"	2440		
7	"	"	1520	1718	198
8	"	"	1370		
9	3:30 P.M.	2 d.	3740		
10	5-2-26	"	4350		
11	"	"	5260	4875	560
12	"	"	6150		
13	3:30 P.M.	3 d.	4300		
14	5-3-26	"	5940		
15	"	"	6950	6142	706
16	"	"	7380		
17	2:30 P.M.	4 d.	5610		
18	5-4-26	"	6500		
19	"	"	6280	6472	743
20	"	"	7506		
21	2:30 P.M.	5 d.	7460		
22	5-5-26	"	8700		
23	"	"	8220	8126	932
24	"	"	----		
25	2:30 P.M.	6 d.	9040		
26	5-6-26	"	6910	8488	975
27	"	"	8300		
28	"	"	9700		
29	2:30 P.M.	7 d.	8930		
30	5-6-26	"	8200		
31	"	"	11180	9318	1070
32	"	"	8960		



CYLINDERS 12% SALT

Poured #1-#16 4:15 P.M. 4-23-26
" 17-32 5:00 P.M. 4-23-26

Cylinder	Time of breaking	Age of breaking	Total breaking stress	Adopted total breaking stress	Unit stress
1	4:24	15 h.	650		
2	7:15 A.M.	"	850	920	106
3	"	"	930		
4	"	"	1250		
5	4:24	1 daylhr.	2070		
6	5:15 P.M.	"	2990	2596	298
7	"	"	2290		
8	"	"	2690		
9	4:25	2 days	4160		
10	4:15 P.M.	"	5250	5350	615
11	"	"	5980		
12	"	"	6010		
13	4-26	3 days	6860		
14	4:15 P. M.	"	6830	6016	691
15	"	"	5520		
16	"	"	4840		
17	4-27	4 days	5750		
18	5:00 P.M.	"	5650	6016	692
19	"	"	6650		
20	"	"	----		
21	4-28	5 days	4320		
22	5:00 P.M.	"	5210		
23	"	"	6880	5790	666
24	"	"	6750		
25	4-29	6 days	6126		
26	5:00 P.M.	"	6470		
27	"	"	7860	6815	784
28	"	"	6810		
29	4-30	7 days	4830		
30	5:00 P.M.	"	7210	7088	814
31	"	"	7330		
32	"	"	7980		



CYLINDERS 15% SALT

Poured 1#-16# 3:45 P.M. } April 29, 1926.
17#-32# 3:00 P.M. }

Cylinder	Time of breaking	Age of breaking	Total breaking stress	Adopted total breaking stress	Unit stress
1	6:45 A.M.	15 h.	170		
2	4-30-26	"	370	280	31
3	"	"	360		
4	"	"	220		
5	3:45 P.M.	1 d.	720		
6	4-30-26	"	750		
7	"	"	640	700	80
8	"	"	690		
9	3:45 P.M.	2 d.	2810		
10	5-1-26	"	2790		
11	"	"	2820	2840	326
12	"	"	2930		
13	3:45 P.M.	3 d.	3590		
14	5-2-26	"	4600		
15	"	"	4420	4465	512
16	"	"	5250		
17	3:00 P.M.	4 d.	4940		
18	5-3-26	"	5900		
19	"	"	6200	5785	665
20	"	"	6040		
21	3:00 P.M.	5 d.	4600		
22	5-4-26	"	8200		
23	"	"	6660	6485	747
24	"	"	6480		
25	3:00 P.M.	6 d.	5650		
26	5-5-26	"	5330		
27	"	"	6880	6302	726
28	"	"	7350		
29	3:00 P.M.	7 d.	8000		
30	5-6-26	"	6400		
31	"	"	7800	7300	839
32	"	"	7000		

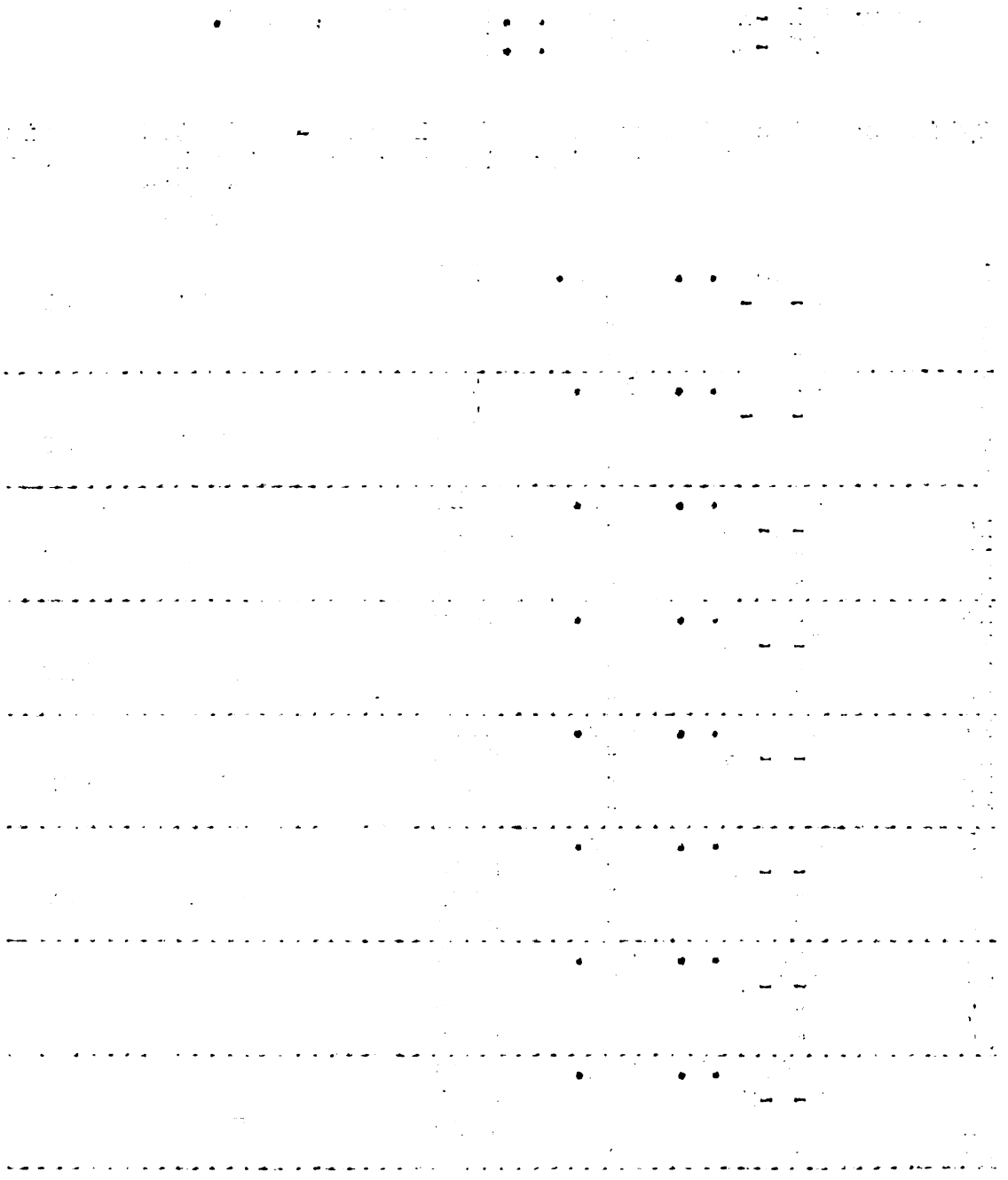


TABLE SHOWING AVERAGE UNIT BREAKING STRESS OF THE DIFFERENT CYLINDERS OF VARIOUS AGES

Cyl. Ages	15 h.	1 d.	2 d.	3 d.	4 d.	5 d.	6 d.	7 d.
0%	33	111	365	463	916	1114	1315	1525
6%	139	304	607	787	975	1020	1050	1100
9%	70	198	560	706	743	932	975	1070
12%	106	298	615	691	692	666	784	814
15%	31	80	326	512	665	747	728	889

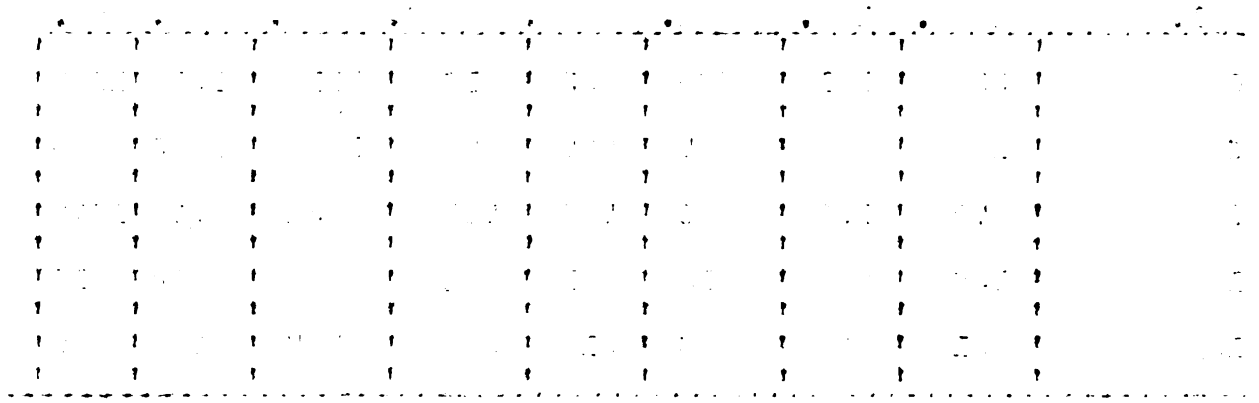
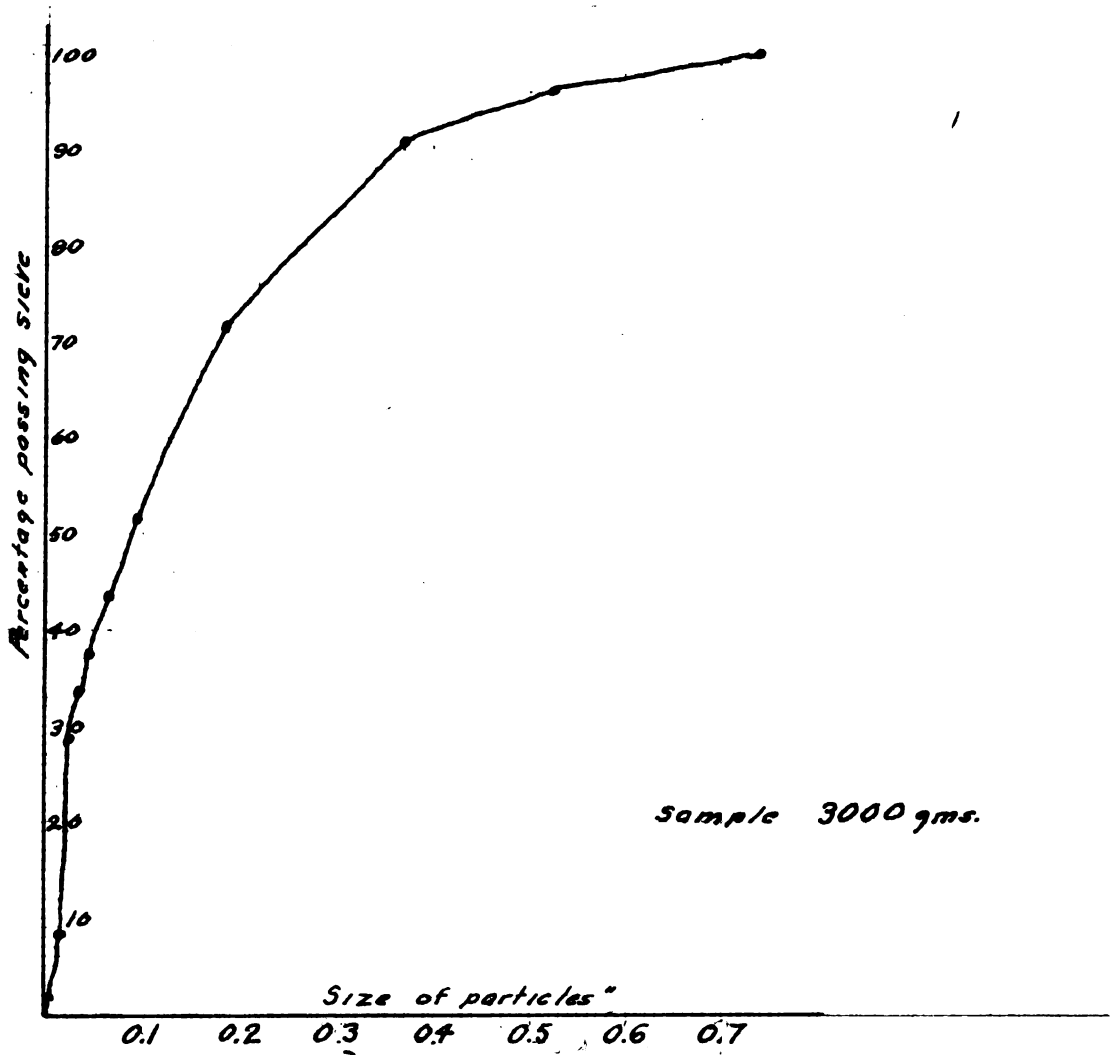


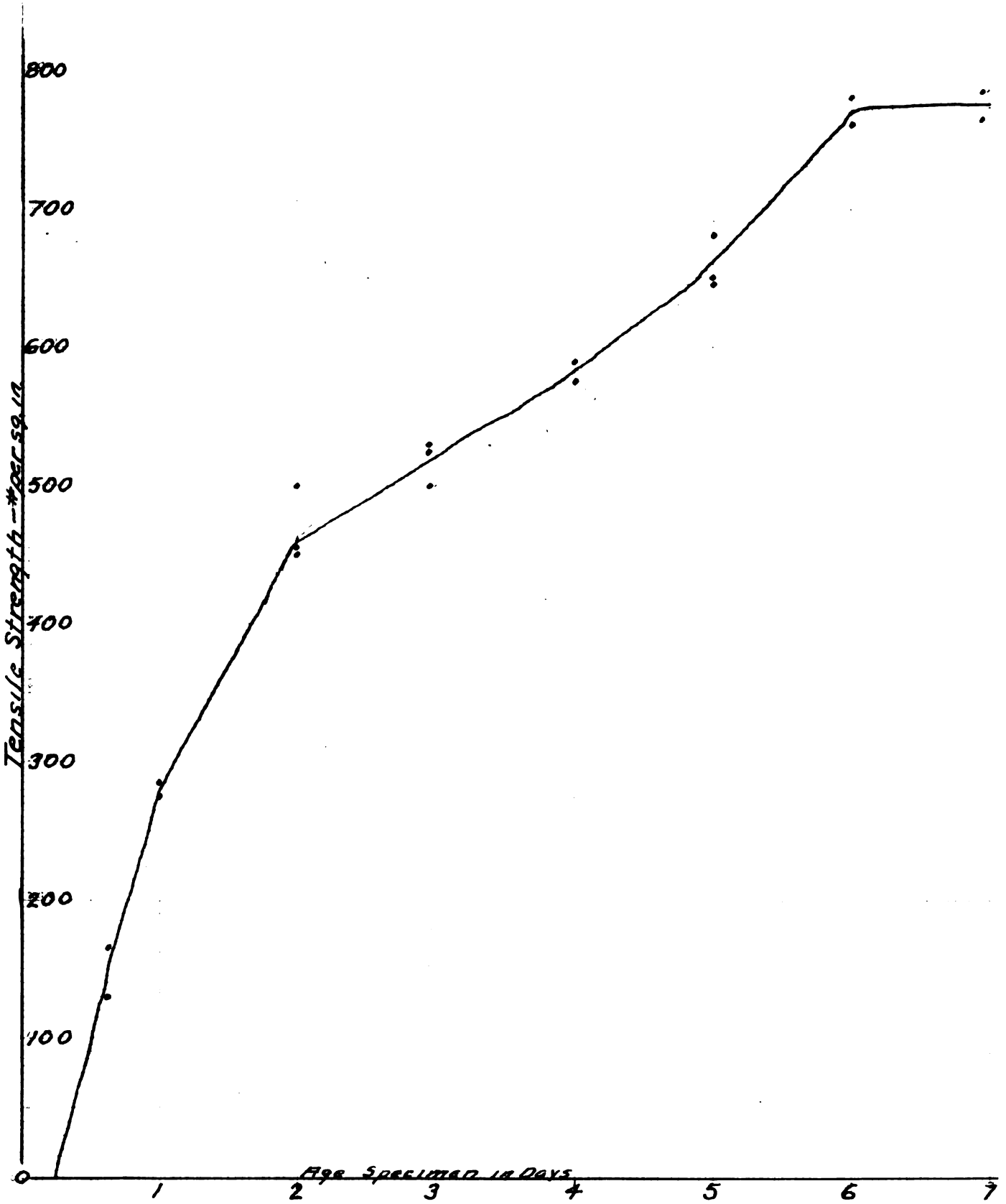
Plate I

MECHANICAL ANALYSIS CURVE OF AGGREGATE

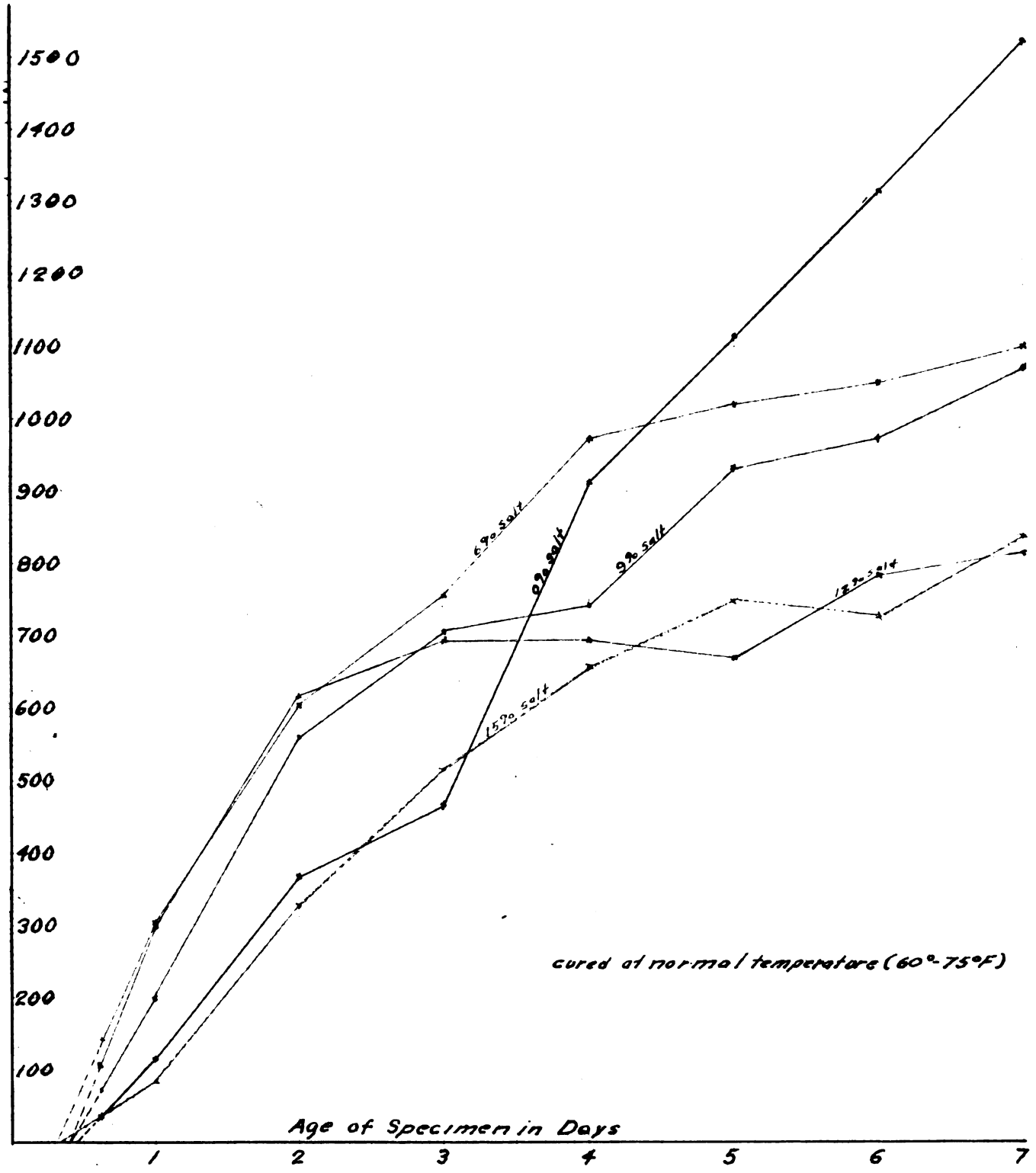


Size of Screen Openings"	Amount retained on Screen (gms.)	Amount passing Screen (gms.)	Percentage of Total passing
.742	0	3000	100.0
.525	109	2891	96.3
.371	170	2721	90.7
.185	566	2155	71.7
.093	604	1551	51.7
.065	244	1307	43.5
.046	187	1120	37.3
.0328	110	1010	33.6
.0232	155	855	28.5
.0116	603	252	8.5
.0058	199	53	1.8
.0028	37	16	0.5

CURVE SHOWING TENSILE STRENGTH OF NEAT MORTAR NORMAL CONSISTANCY: 25



CURVES SHOWING THE EFFECT OF SALT UPON STRENGTH OF SUPER-CEMENT CONCRETE



CURVES SHOWING THE EFFECT OF SALT ON COMPRESSIVE STRENCTH AT VARIOUS AGES

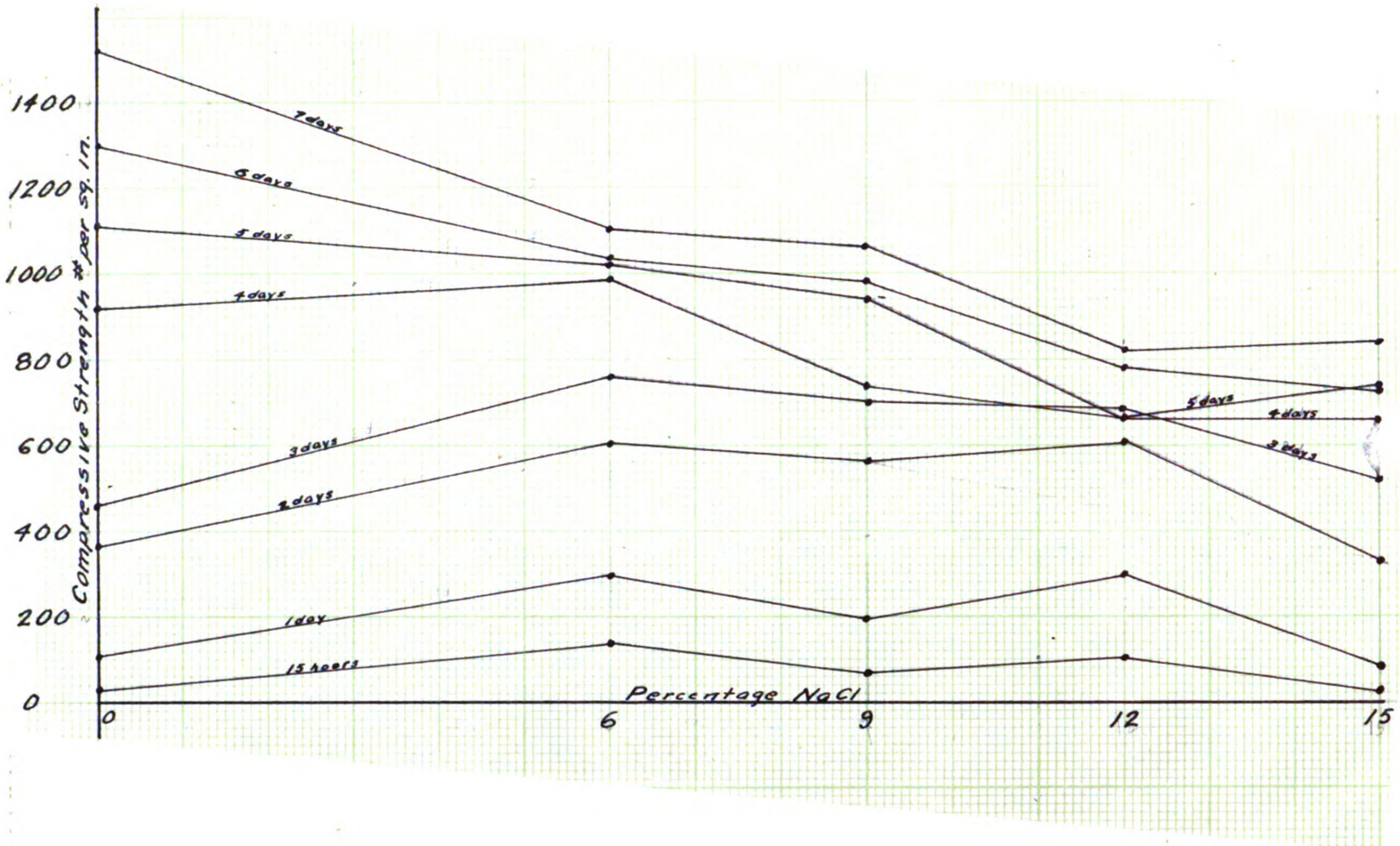


Plate IX

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