Diatomaceous Silica as an Admixture
in
Mortars and Concrete

A Thesis
Submitted for the Degree
Master of Science

by
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Approved by:

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The Nature and Occurence of Diatomaceous Silica.

Diatomaceous Silica, occuring in great deposits in certain localities, consists of the remains of a flowerless aequatic plant; Algae. The plant is surrounded by a silica shell consisting essentially of two parts fitting together as the top and bottom of a box. Reproduction takes place by the division of each individual Diatom into two separate parts, thus forming two new Diatoms which in turn split up within forty eight hours. The Diatoms are microscopic in size and the figures on the shells, appearing almost as carvings, vary to such an extent that an expert may after close examination of the contours be able to give the location of their origin; the flow of ocean currents has in some cases been determined by Diatoms carried to distant parts.

Diatoms are found in most pools of stagnant water and probably all persons have noticed, at one time or another, this slime-like substance attached to weeds or grass in a pool.

The large deposits of Diatomaceous Silica, formed on the bed of the ocean in the Tartiary period, vary up to two thousand feet in thickness and some are now far above sea level.

Diatomaceous Silica when dry is a whitish substance, very porous and light in weight. It is capable of absorbing a considerable amount of water but when wet is not plastic like clay. As found in nature the substance may vary in color from pure white to dark brown, depending upon the impurities present, however, it will in any case be white or have only a grayish tinge when dry.

Numerous names are applied to the material and a number of them follow; diatomaceous earth, kieselguhr, infusorial earth, tripoli, tripolite, desmid earth, bergmehl, radiolarium earth, polirscheifer, white peat, molera, randanite, tellurine, ceyssatite, and the trade names, Filter-cel, Celite, Calatom, Pacatome, etc. The terms infusorial earth and tripoli are erroneously applied as these materials are of distinctly different origin, containing no Diatoms.

V.L. Eardley-Wilmot in a report, "Diatomite", issued by the Canadian Bureau of Mines gives the analyses of Diatomaceous Silica from different localities in the United States and Canada, those from the United States being given in the following table:

		1	2	3	4	5
Silica	(SiO_2)	80.53	80.66	81.53	88.68	86.89
Alumina	(Al_2O_3)	5.80	3.84	3.43	2.68	2.32
Iron Oxide	(Fe_2O_3)	1.03	-	3.34	trace	1.28
Lime	(CaO)	0.35	0.58	2.61	1.61	0.43
Magnesia	(MgO)	-	-	-	1.30	trace
Potash	(K_2O)	-	-	1.16	-	3.58
Soda	(Na_2O)	-	-	1.43	-	-
Water and Organic Matter		12.03	14.01	6.04	5.54	4.89
Total		99.74	99.09	99.54	99.81	99.39

1 Lake Umbagog, N.H.
2 Morris County N.J.
3 Popes Creek, Md.
4 Lampoc, Santa Barbara County, Calif.
5 Monterey County, Calif.

Diatomaceous Silica is used as a filterer in Chemical Processes, as an unsulator against heat and cold and as a constituent of metal polishes. It has long been used as a building material, bricks containing the material being very light in weight, Within recent years its use as an admixture in concrete has found wide favor.

The Purpose of The Investigation.

As an admixture for concrete a number of reasons for the use of Diatomaceous Silica have been advanced during the past few years; first, the workability of the mix will be increased; second, the concrete will be more impervious to water; third, the strength of the concrete will be increased; fourth, the yield will be increased; fifth, segregation and the formation of laitance will be prevented.

While no attempt will be made to check all of the above mentioned claims for Diatomaceous Silica as an admixture, its effect upon the yield and strength with reference to sands containing varying amounts of fine particles will be investigated.

Although many experiments have been made on concrete containing Diatomaceous Silica the writer has been unable through search, aided by searchers at the Engineering Societies Library, to locate any data pertaining to its effect on mixes having as fine aggregate sands containing varying percentages of fine particles; i.e. particles passing a 48 mesh sieve.

The material to be used is practically pure silica crushed to such fineness that nearly all of it will pass a two hundred mesh seive and about seventy five per cent would pass a screen with six hundred meshes per inch. It is thought that the use of Diatomaceous Silica as an admix in concretes containing sands relatively low and high in fine particles will give materially different compressive strengths. The admix, from a physical standpoint, can, when added in certain quantitise, be expected to fill the minute voids thus increasing the density of the mix. The quantity of admix generally used varies from 2# to 6# per sack of cement and it is planned to run tests on all mixes with 2#, 4# and 6# per sack.

The effect of the admix on mortars, using water cement ratios varying from 0.5 to 1.0 will first be investigated and afterward concrete cylinders will be tested; the tests on mortars being expected to give some indication of the effect of the admix on concrete.

Diatomaceous Silica is said to be capable of absorbing twice its own weight of water; therefore, on the water cement theory it must be expected that the strength of mix will be affected by its addition. It is planned to determine the absorptive power of the admix and check the strength and yield on the effective water cement ratio, allowing for this absorption, as well checking the same mixes without making the allowance for water absorbed.

It is expected from results obtained that it may be possible to predict whether or not it will be wise from the standpoint of yield and strength, to add Diatomaceous Silica to concrete mixes; having at hand the sieve analysis of the fine aggregate to be used.

Screen Analysis of Sand.

200 gram Samples.

Run #1.

Meshes per inch	Grams Caught	Passing 100	% Caught
4	0		0
8	3.12		1.56
14	19.98		11.55
28	67.14		45.12
48	86.54		88.39
100	21.34		99.06
		1.88	
	Total 200.00 g.		245.68

Run #2.

Meshes per inch	Grams Caught	Passing 100	% Caught
4	0.83		0.42
8	2.53		1.68
14	17.88		10.62
28	64.09		42.67
48	87.82		86.57
100	24.69		98.92
		2.16	
	Total 200 g.		240.88

Run #3.

Meshes per inch	Grams Caught	Passing 100	% Caught
4	0.0		0.0
8	3.04		1.52
14	19.23		11.13
28	66.18		44.22
48	85.75		87.10
100	23.30		98.75
		2.50	
	Total 200 g.		242.72

Fineness Modulus (Average) 2.4309

Screen Analysis (Coarse Aggregate)

Sample #1 - 27#

Sieve	#	Amount caught on sieve (oz.)	(#)	%caught	Fineness Modulus.
1½	0	11.26	0.705#	2.76	
¾	8	13.52	8.847	35.30	
3/8	13	0.28	13.018	83.50	
4	4	3.00	4.188	99.20	
8	0	2.77	0.173	99.80	
14	0	0.03	0.002	100.00	
28				100.00	
48				100.00	
100				100.00	
	26	14.86	26.931	720.66	7.2066

Sample #2 - 23#

Sieve	#	oz.	#	%caught	Fineness Modulus
1½	0	0.0	0.00	0.00	
¾	5	8.46	5.528	24.00	
3/8	12	1.70	12.106	76.80	
4	4	14.34	4.897	97.00	
8	0	7.07	0.442	99.70	
14	0	0.80	0.05	100.00	
28	0	0.30	0.019	100.00	
48	0	0.15	0.009	100.00	
100				100.00	
	23	0.82	23.051	697.50	6.975

Sample #3 - 25#

Sieve	#	oz.	#	%caught	Fineness Modulus
1½	0	0.0	0.00	0.00	
¾	6	5.95	6.372	25.50	
3/8	12	8.87	12.550	75.80	
4	5	5.60	5.35	97.30	
8	0	9.40	0.588	99.50	
14	0	1.27	0.080	99.80	
28	0	0.40	0.025	99.90	
48	0	0.40	0.025	100.00	
100				100.00	
	24	15.89	24.990	697.80	6.978

Average 7.0532

Unit Weights of Sands.

$\frac{1}{10}$ cu.ft. Measure (Wt = 1# 7.82oz

Calibration of Measure -.09982 cu.ft.

% Sand Past 48	Weight Sand and Measure #	Oz.	Average Net.
	11	6.0	
0	11	6.0	9# 14,15oz
	11	5.92	98.89#cu.ft.
	11	7.56	
10	11	7.63	9# 15.77oz
	11	7.57	
			100.00#/cu.ft
	11	8.53	
12.65	11	8.85	10# 1.07oz.
	11	9.30	
			100.86#/cu.ft.
	11	10.00	
20	11	9.85	10# 2.0oz.
	11	9.60	
			101.43#/cu.ft.
	11	10.75	
25	11	10.20	10# 2.85oz.
	11	11.06	
			101.98#/cu.ft

Ultimate Compressive Load 7 and 28 Day.

2" by 4" Cylinders (1-3 Mortar)

Diatomaceous Silica -#/Sack Cement.

W/c - 0.435

12.65% Sand Past 48

	0		2		4		6	
	5,480	#1	5,190	#2	6,240	#3	5,100	#4
7 Day	8,500		7,140		5,000		5,200	
	8,130	7,370	6,870	6,400	4,000	5,080	5,240	5,180
	8,780		7,170		4,390		4,340	
28 Day	8,970		7,360		8,840		5,590	
	8,900	8,883	8,250	7,593	6,430	6,543	6,720	5,550

$\frac{W}{c} = 0.505$

12.65% Sand Past 48

	0		2		4		6	
	7,630	#5	6,030	#6	4,820	#7	6,090	#8
7 Day	7,510		6,000		7,600		4,740	
	9,500	8,213	6,510	6,180	5,130	5,850	5,910	5,580

$\frac{W}{c} = 0.6$

% Sand Past 48

	0		2		4		6	
	6,070	#9	6,400	#10	9,760	#11	8,900	#12
7 Day	6,310		6,460		10,160		7,560	
	7,450	6,610	9,200	7,353		9,960	7,990	8,150
	8,560		11,490		11,480		9,470	
28 Day	10,270		9,000		10,140		12,970	
	11,500	10,110	9,640	10,043	11,240	10,958	12,180	11,540

12.65% Sand Past 48

	0		2		4		6	
	11,070	#13	10,910	#14	12,480	#15	8,630	#16
7 Day	11,130		13,540		12,170		9,470	
		11,100	10,370	11,606	10,360	11,670	8,000	8,700
	16,570		17,010		12,370		13,200	
28 Day	11,170		14,650		12,940		16,740	
	13,850	13,863	15,620	15,760	13,700	13,003	10,290	13,410

1-3 Mortar

2" by 4" Cylinders

Sample No	%Sand Past 48	Cement #	Water c.c.	Sand #	Diatomaceous Silica (Grams)	Aver. Strength #/Sq. in. 7 Day	Aver. Strength #/Sq. in. 28 Day
			W/c - 0.435				
1	12.65	1.414	205	4.55	0	2290	2760
2	12.65	"	"	"	13.62	1990	2360
3	12.65	"	"	"	27.24	1580	2030
4	12.65	"	"	"	40.86	1610	1720
			W/c - 0.505				
5	12.65	1.414#	235	4.55	0	2550	
6	12.65	"	"	"	13.62	1920	
7	12.65	"	"	"	27.24	1820	
8	12.65	"	"	"	40.86	1740	
			W/c - 0.6				
9	0	1.414	276	4.46	0	2050	3140
10	0	"	"		13.62	2290	3130
11	0	"	"		27.24	3100	3410
12	0	"	"		40.86	2530	3590
13	12.65	1.414	276	4.55	0	3450	4310
14	12.65	"	"		13.62	3610	4890
15	12.65	"	"		27.24	3620	4040
16	12.65	"	"		40.86	2700	4170
			W/c - 1.0				
70	0	1.414	446	4.46	0	2150	3250
71	0	"	"	"	13.62	2180	3630
72	0	"	"	"	27.24	2300	3640
73	0	"	"	"	40.86	2480	3600
74	12.65	1.414	446	4.55	0	1740	2930
75	12.65	"	"	"	13.62	2120	3210
76	12.65	"	"	"	27.24	2480	3190
77	12.65	"	"	"	40.86	2820	3990

Ultimate Compressive Load - 7 and 28 Day.

2" by 4" Cylinders. (1-3 Mortar)

W/c - 0.542

Diatomaceous Silica - #/sack Cement.

0		2		4		6	

% Sand Past 48

0		2		4		6	
7,850	#17	7,760	#18	7,470	#19	7,200	#20
8,430		7,170		6,880		5,630	
8,130	8,136	7,300	7,410	8,750	7,700		6,415
10,840		10,590		9,430		8,640	
9,900		9,420		11,030		9,020	
10,320	10,383	10,320	10,110	8,100	9,520	6,860	8,173

10% Sand Past 48

0		2		4		6	
8,510	#21	8,480	#22	7,270	#23	6,080	#24
9,080		9,370		6,450		7,300	
9,210	8,933		8,925	6,770	6,830		6,690
12,350		11,400		9,620		8,310	
12,460		12,600		10,930		7,880	
11,620	12,143	12,080	12,027	10,880	10,476	8,600	8,263

20% Sand Past 48

0		2		4		6	
9,610	#25	8,500	#26	7,580	#27	5,510	#28
10,340		8,010		7,490		4,630	
9,970	9,973	9,770	8,760		7,535	5,380	5,173
12,240		10,310		9,700		6,560	
11,000		11,010		7,600		5,800	
11,020	11,420		10,660	10,750	9,350	7,710	6,690

25% Sand Past 48

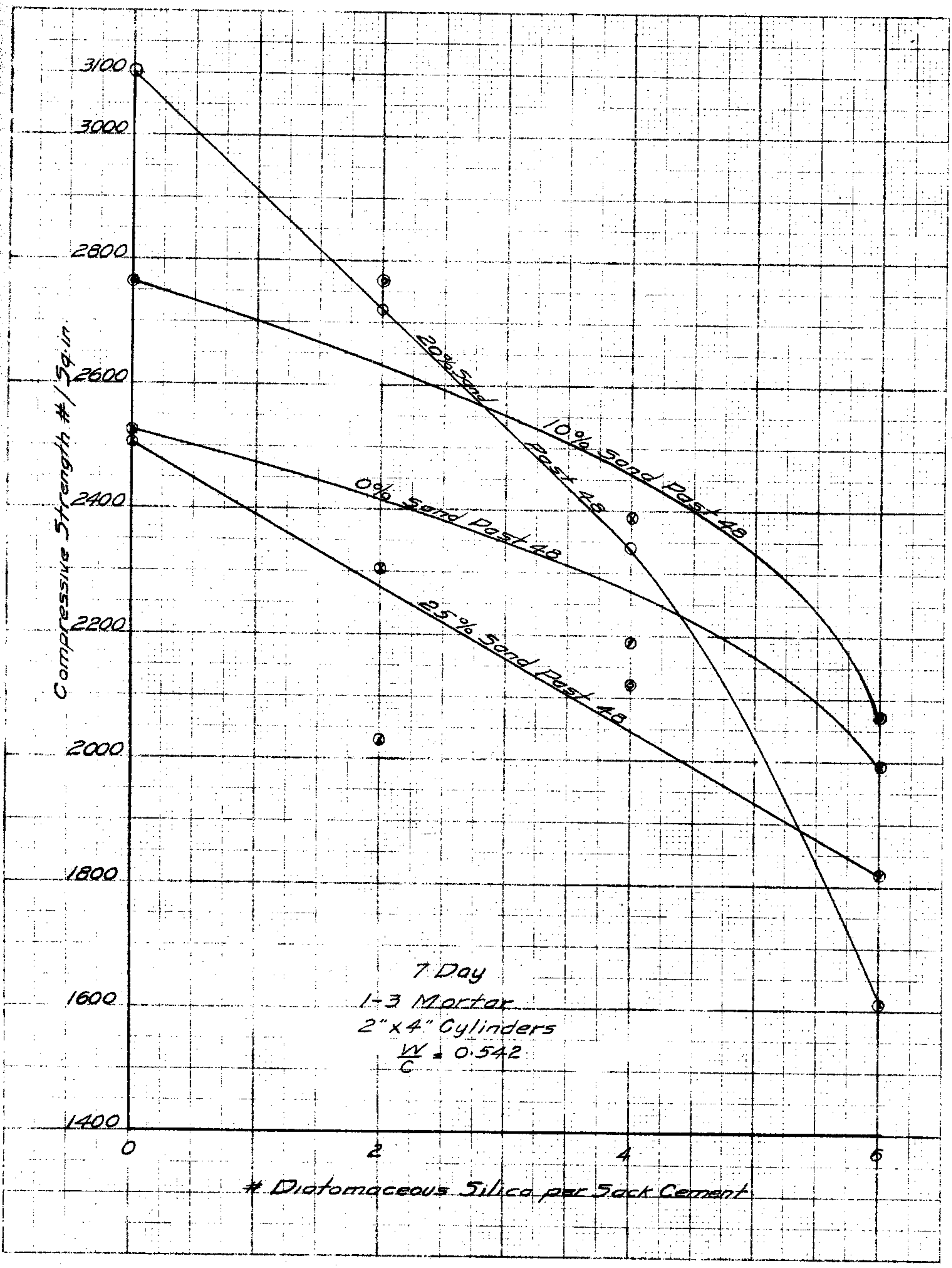
0		2		4		6	
7,630	#29	6,250	#31	7,160	#31	5,720	#32
8,500		6,630		7,040		5,960	
	8,065	6,740	6,540	6,990	7,063	5,870	5,850
10,490		8,930		8,950		7,150	
10,140		10,480		8,170		9,120	
9,800	10,143	11,360	10,250	7,900	8,340	7,480	7,916

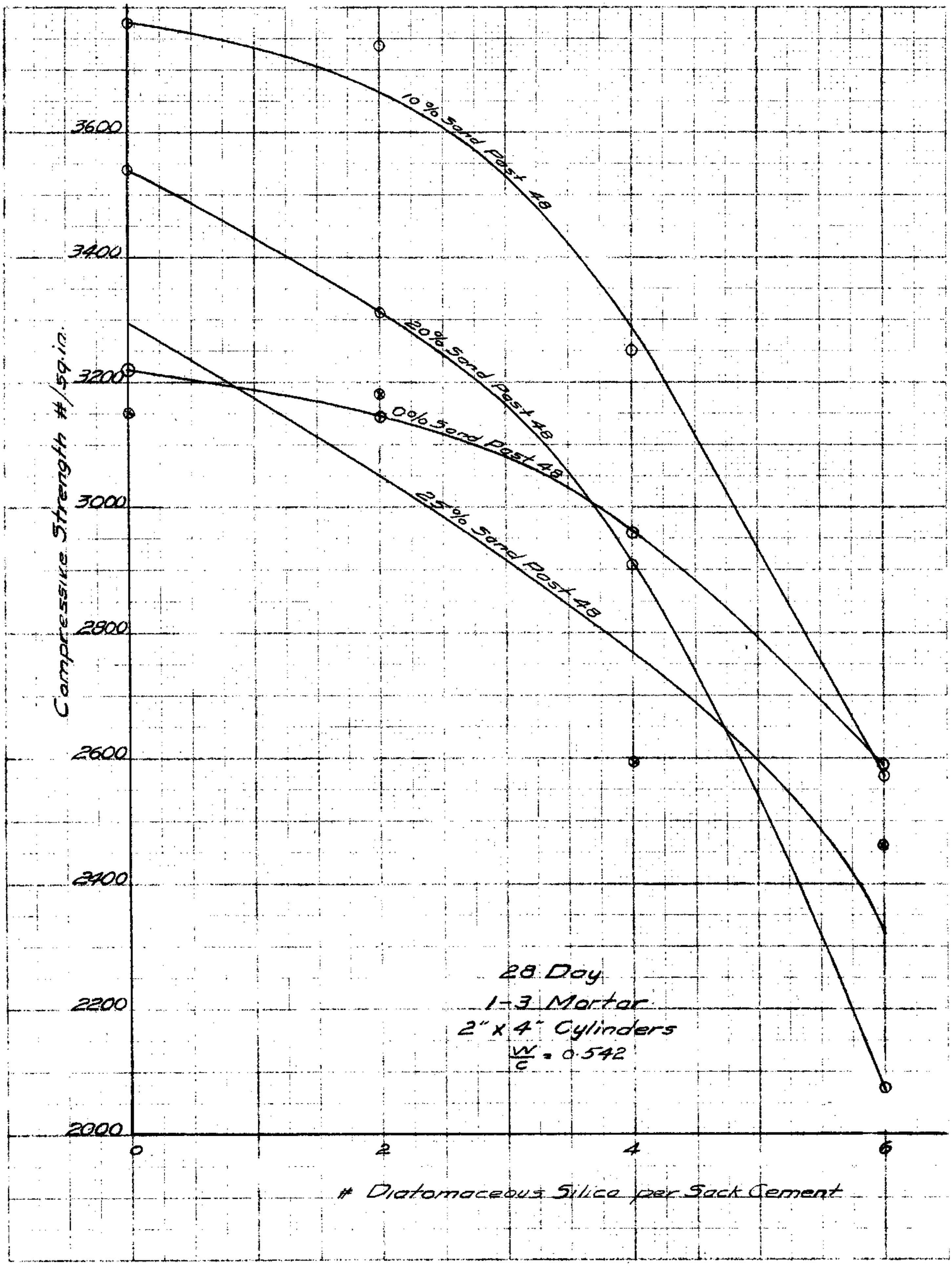
1 - 3 Mortor

2" by 4" Cylinders

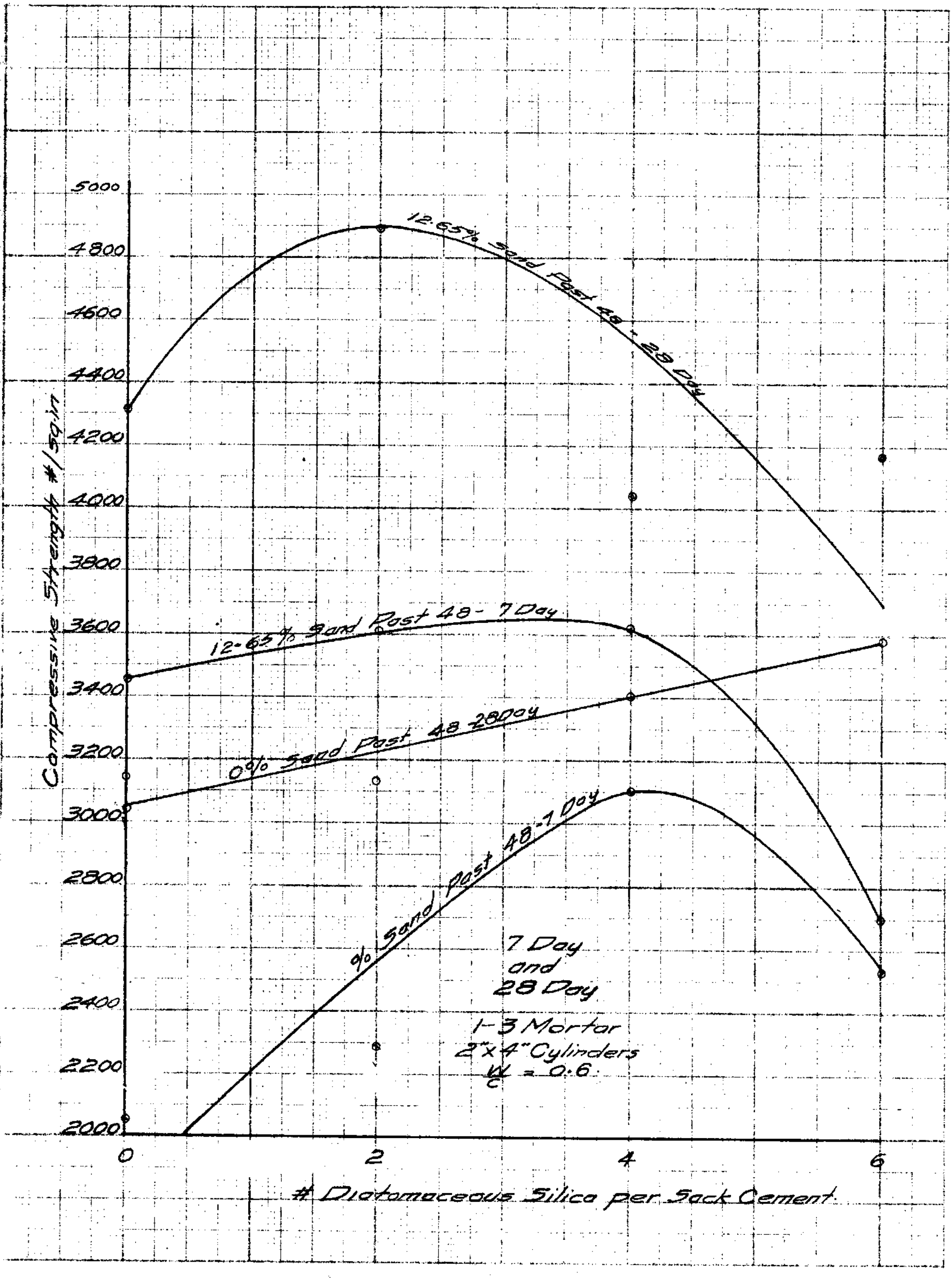
W/c - 0.542

Sample No.	%Sand Past 48	Cement #	Water c.c	Sand #	Diatomaceous Silica (Grams)	Average Strength #/Sq.in. 7 Day	Average Strength #/Sq.in. 7 Day
17	0	1.414	250	4.46	0	2525	3220
18	0	"	"	"	13.62	2300	3145
19	0	"	"	"	27.24	2390	2960
20	0	"	"	"	40.86	1995	2540
21	10	1.414	250	4.51	0	2770	3775
22	10	"	"	"	13.62	2770	3740
23	10	"	"	"	2724	2120	3250
24	10	"	"	"	40.86	2075	2570
25	20	1.414	250	4.58	0	3100	3540
26	20	"	"	"	13.62	2720	3310
27	20	"	"	"	27.24	2340	2905
28	20	"	"	"	40.86	1610	2075
29	25	1.414	250	4.60	0	2510	3150
30	25	"	"	"	13.62	2030	3180
31	25	"	"	"	27.24	2195	2590
32	25	"	"	"	40.86	1820	2460


3100
3000
2800
2600
2400
2200
2000
1800
1600
1400
Compressive Strength #/Sq.in
0
2
4
6
Diatomaceous Silica per Sack Cement
20% Sand Past 48
10% Sand Past 48
0% Sand Past 48
25% Sand Past 48
7 Day
1-3 Mortar
2"x4" Cylinders
W/C = 0.542



10% Sand Post 48
20% Sand Post 48
0% Sand Post 48
25% Sand Post 48
3600
3400
3200
3000
2800
2600
2400
2200
2000
Compressive Strength #/sq.in.
0
2
4
6
Diatomaceous Silica per Sack Cement
28 Day
1-3 Mortar
2" x 4" Cylinders
W/C = 0.542


5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
Compressive Strength #/sq.in
0
2
4
6
Diatomaceous Silica per Sack Cement
12.65% Sand Past 48 - 28 Day
12.65% Sand Past 48 - 7 Day
0% Sand Past 48 28 Day
0% Sand Past 48-7 Day
7 Day
and
28 Day
1-3 Mortar
2"x4" Cylinders
W/C = 0.6

Ultimate Compressive Load 7 and 28 Day.

2" by 4" Cylinders (1-3 Mortar)

W/c - 0.8.

Diatomaceous Silica - #/sack cement.

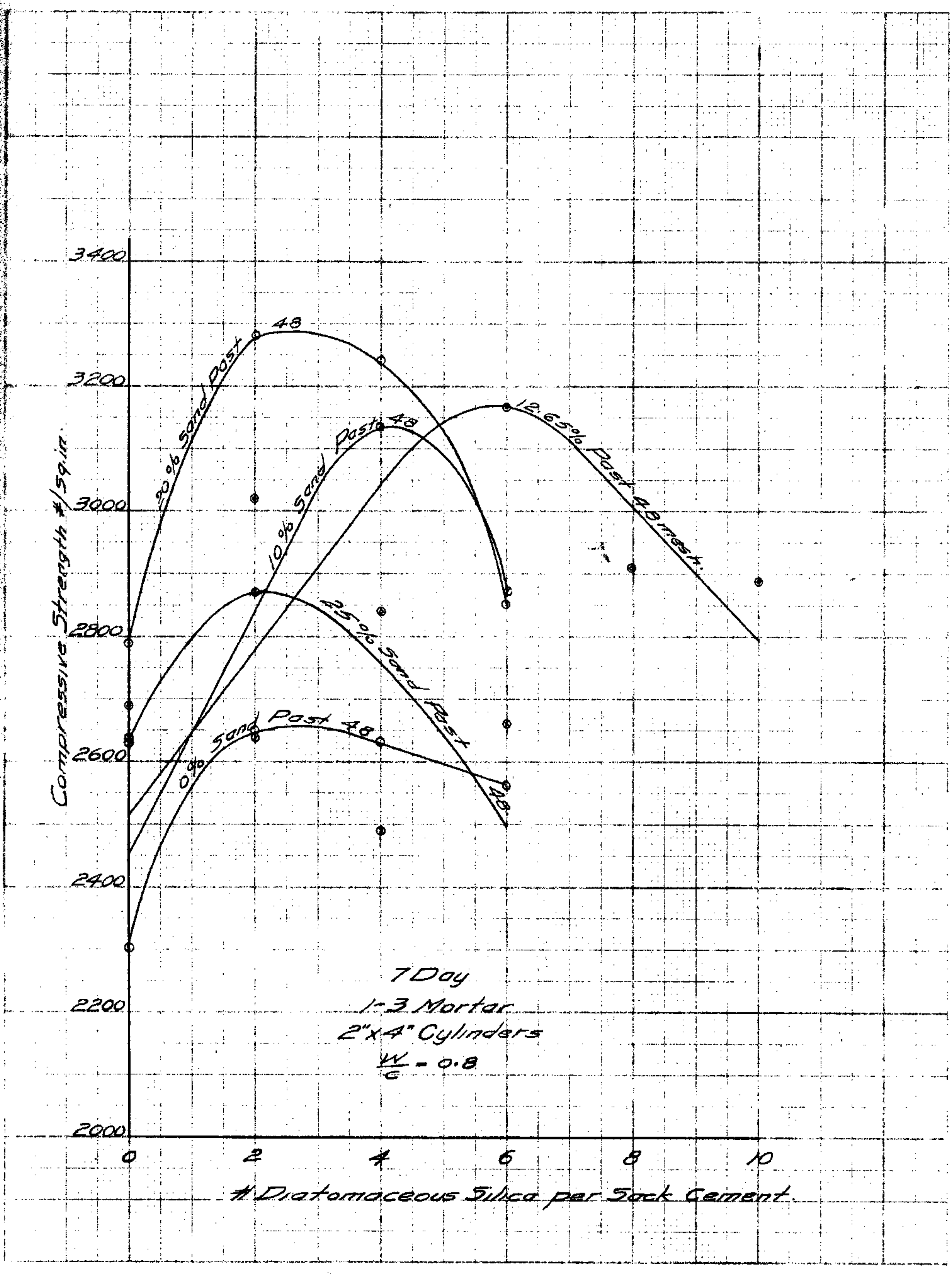
0		2		4		6	
% Sand Past 48							
8,040	#33	8,190	#34	8,430	#35	8,450	#36
7,670		8,620		8,410		8,040	
6,500	7,403	8,820	8,543	8,520	8,453	8,210	8,233
10,880		12,890		13,440		12,850	
11,660		10,660		12,210		12,170	
10,500	11,013	13,360	12,303	12,680	12,776	11,070	12,030
% Sand Past 48							
8,590	#37	9,520	#38	9,120	#39	8,330	#40
8,300		8,100		10,960		9,230	
8,490	8,460	7,910	8,510	10,220	10,100	10,060	9,207
10,480		11,690		12,165		12,720	
12,700		12,650		13,080		12,120	
10,430	11,203		12,170	12,980	12,742	13,680	12,840
12.65 % Sand Past 48							
8,510	#41	10,010	#42	9,060	#43	10,050	#44
8,690		9,830		9,550		10,220	
8,710	8,636	9,330	9,723	8,850	9,153	9,790	10,020
11,600		13,250		13,560		15,160	
12,940		13,770		13,420		15,200	
12,400	12,313	13,440	13,486	15,500	14,160	16,950	15,770
20% Sand Past 48							
10,000	#47	10,800	#48	10,550	#49	9,120	#50
7,510		10,900		9,800		9,250	
9,430	8,980	9,910	10,536	10,890	10,413		9,185
14,070		12,630		13,390		10,020	
10,450		14,490		12,000		12,230	
12,290	12,470	13,150	13,423	12,230	12,540	11,360	11,203
25% Sand Past 48							
10,990	#51	9,530	#52	7,640	#53	9,090	#54
8,410		8,730		7,390		8,210	
6,140	8,513	9,470	9,243	8,970	8,000	8,370	8,556
12,570		12,580		13,420		13,920	
11,600		12,060		12,180		12,300	
11,070	11,747	11,060	11,900	12,010	12,536	11,010	12,410

1 - 3 Mortor

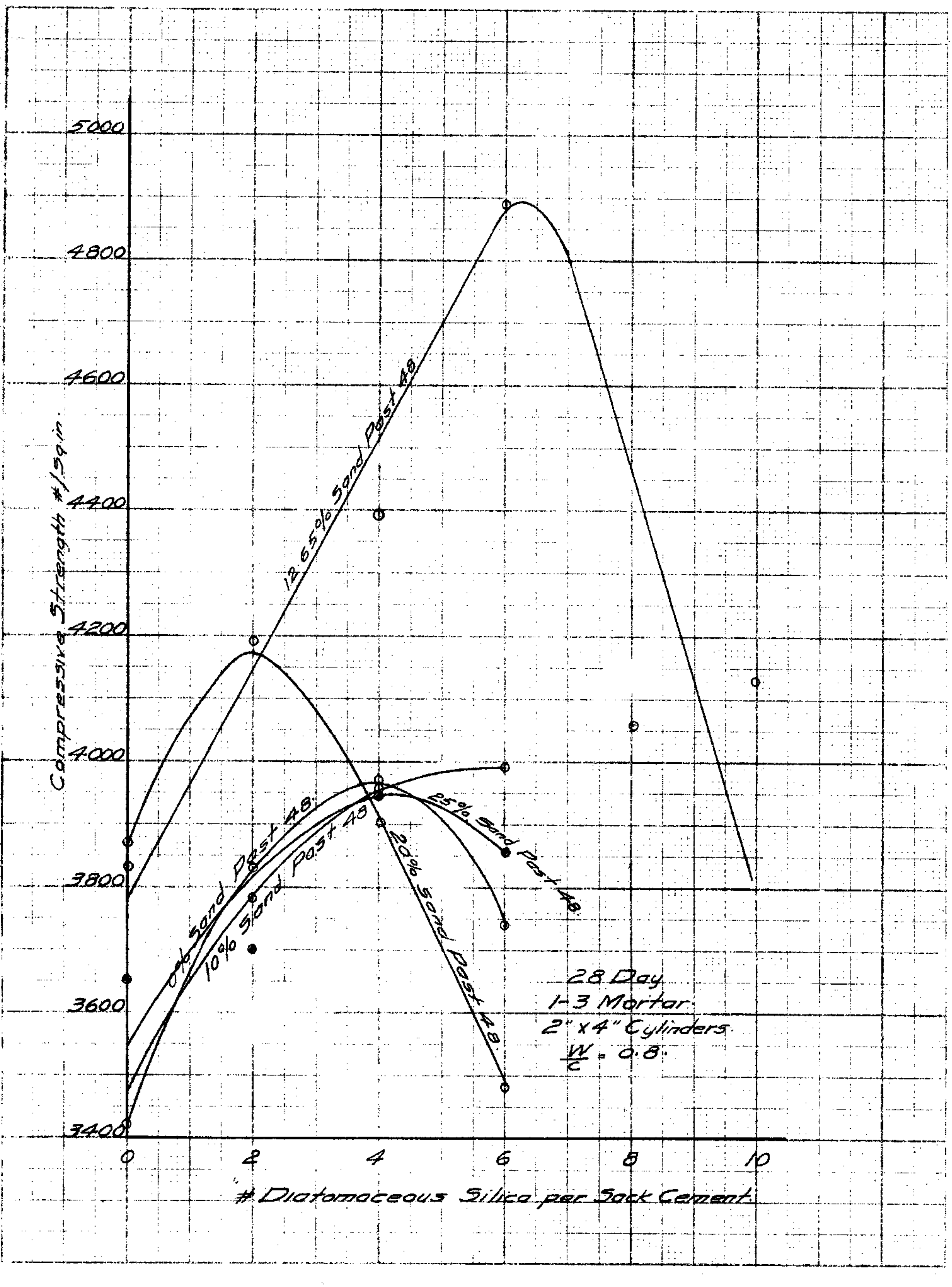
2" by 4" Cylinders

W/c-0.8.

Sample No.	%Sand Past 48	Cement #	Water c.c.	Diatomoosous Silica(Grams)	Sand #	Aver. Strength #/Sq. in 7 Day	28 Day
33	0	1.414	361cc	0	4.46	2300	3420
34	0	"	"	13.62	"	2650	3830
35	0	"	"	27.24	"	2630	3970
36	0	"	"	40.86	"	2560	3740
37	10	1.414	361cc	0	4.51	2630	3480
38	10	"	"	13.62	"	2640	3780
39	10	"	"	27.24	"	3140	3960
40	10	"	"	40.86	"	2870	3990
41	12.65	1.414	361cc	0.	4.55	2690	3830
42	12.65	"	"	13.62	"	3020	4190
43	12.65	"	"	27.24	"	2840	4390
44	12.65	"	"	40.86	"	3170	4890
45	12.65	"	"	54.48	"	2910	4056
46	12.65	"	"	68.03	"	2890	4130
47	20	1.414	361	0	4.58	2790	3870
48	20	"	"	13.62	"	3280	4170
49	20	"	"	27.24	"	3240	3900
50	20	"	"	40.86	"	2850	3480
51	25	1.414	361	0	4.60	2650	3650
52	25	"	"	13.62	"	2870	3700
53	25	"	"	27.24	"	2490	3900
54	25	"	"	40.86	"	2660	3860



3400
3200
3000
2800
2600
2400
2200
2000
Compressive Strength #/sq.in.
0
2
4
6
8
10
Diatomaceous Silica per Sack Cement.
20% Sand Past 48
10% Sand Past 48
12.65% Past 48 mesh.
25% Sand Past 48
0% Sand Past 48
7 Day
1-3 Mortar
2"x4" Cylinders
W/C = 0.8


5000
4800
4600
4400
4200
4000
3800
3600
3400
Compressive Strength #/sq.in.
0
2
4
6
8
10
Diatomaceous Silica per Sack Cement.
12.65% Sand Past 48
0% Sand Past 48.
10% Sand Past 48
20% Sand Past 48.
25% Sand Past 48.
28 Day
1-3 Mortar.
2"x4" Cylinders.
W/C = 0.8.

Ultimate Compressive Load 7 and 28 Day.

2" by 4" Cylinders (1-3 Mortar).

Effective W/c – 0.8
Diatomaceous Silica –#/sack Cement.

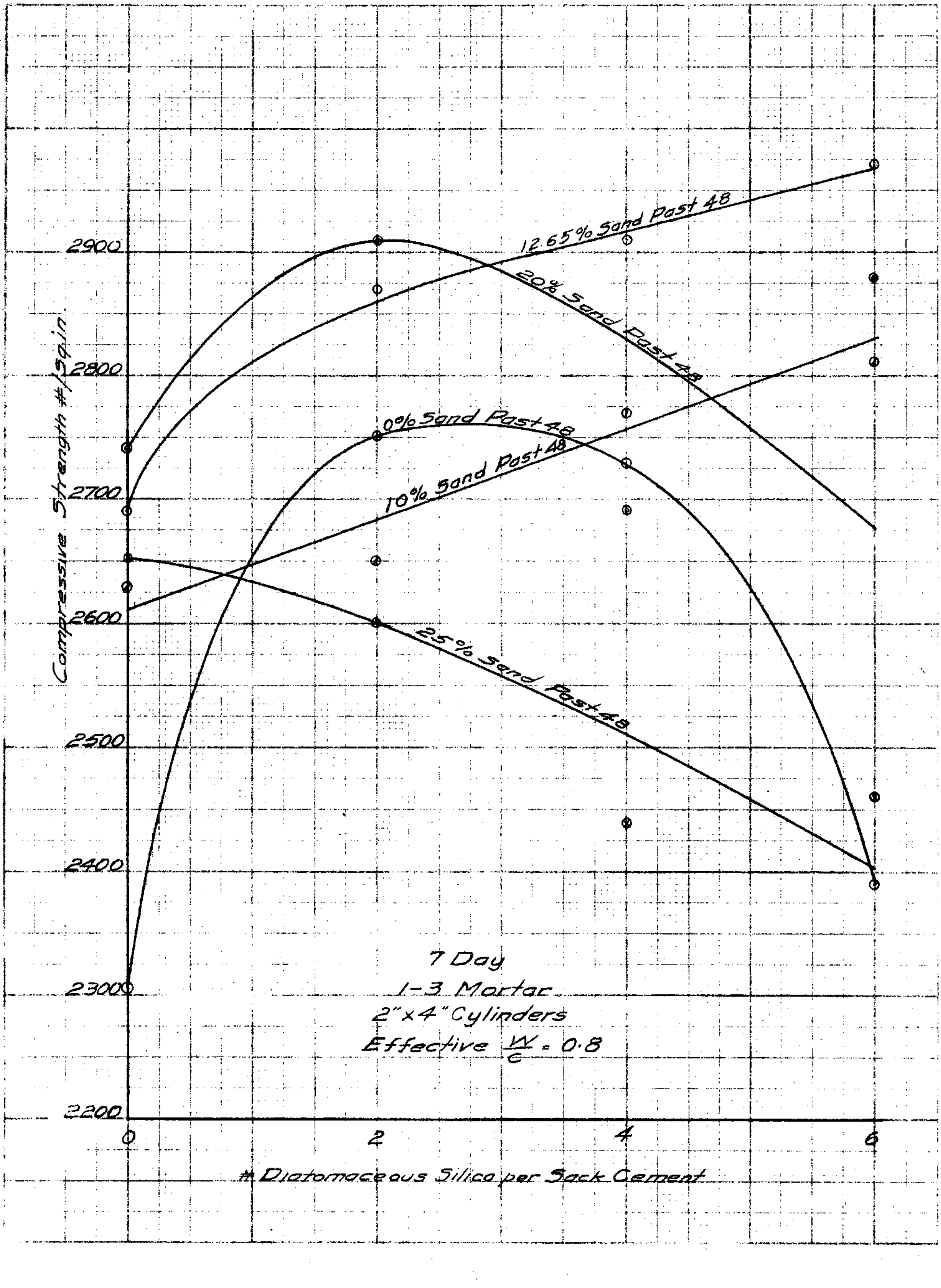
0		2		4		6	
0% Sand Past 48							
8,040	#33	9,500	#55	8,540	#56	7,350	#57
7,670		9,080		8,940		7,990	
6,500	7,403	8,000	8,860	8,860	8,780	7,770	7,703
10,880		12,050		11,480		11,490	
11,660		12,700		11,980		11,450	
10,500	11,013		12,375	12,930	12,130	11,260	11,400
10% Sand Past 48							
8,590	#37	8,590	#58	9,640	#59	9,470	#60
8,300		8,490		8,660		8,860	
8,490	8,460		8,540	8,480	8,926	8,840	9,056
10,400		11,680		13,650		13,320	
12,700		11,010		12,970		10,460	
10,430	11,203	11,520	11,403	13,530	13,386	12,740	12,173
1265% Sand Past 48							
8,510	#41	8,920	#61	10,060	#62	9,610	#63
8,690		9,430		9,060		9,780	
8,710	8,636	9,400	9,250	9,020	9,380	9,240	9,543
11,600		12,870		14,740		12,150	
12,940		10,610		14,060		13,810	
12,400	12,313	11,380	11,620	13,940	14,246	11,990	12,650
20% Sand Past 48							
10,000	#47	9,600	#64	8,250	#65	9,000	#66
7,510		8,200		9,030		9,700	
9,430	8,980	10,260	9,353	8,640	8,640	9,150	9,283
14,070		13,260		14,320		14,410	
10,450		14,920		12,660		11,160	
12,290	12,470	12,340	13,506	11,890	12,956	11,440	12,336
25% Sand Past 48							
6,140	#51	9,230	#67	8,310	#68	7,620	#69
10,990		7,320		7,600		7,850	
8,410	8,513	8,580	8,376	7,640	7,850	8,330	7,933
12,570		13,740		12,320		14,240	
11,600		14,830		14,710		12,640	
11,070	11,747	12,270	13,613		13,515		13,440

1 - 3 Mortar

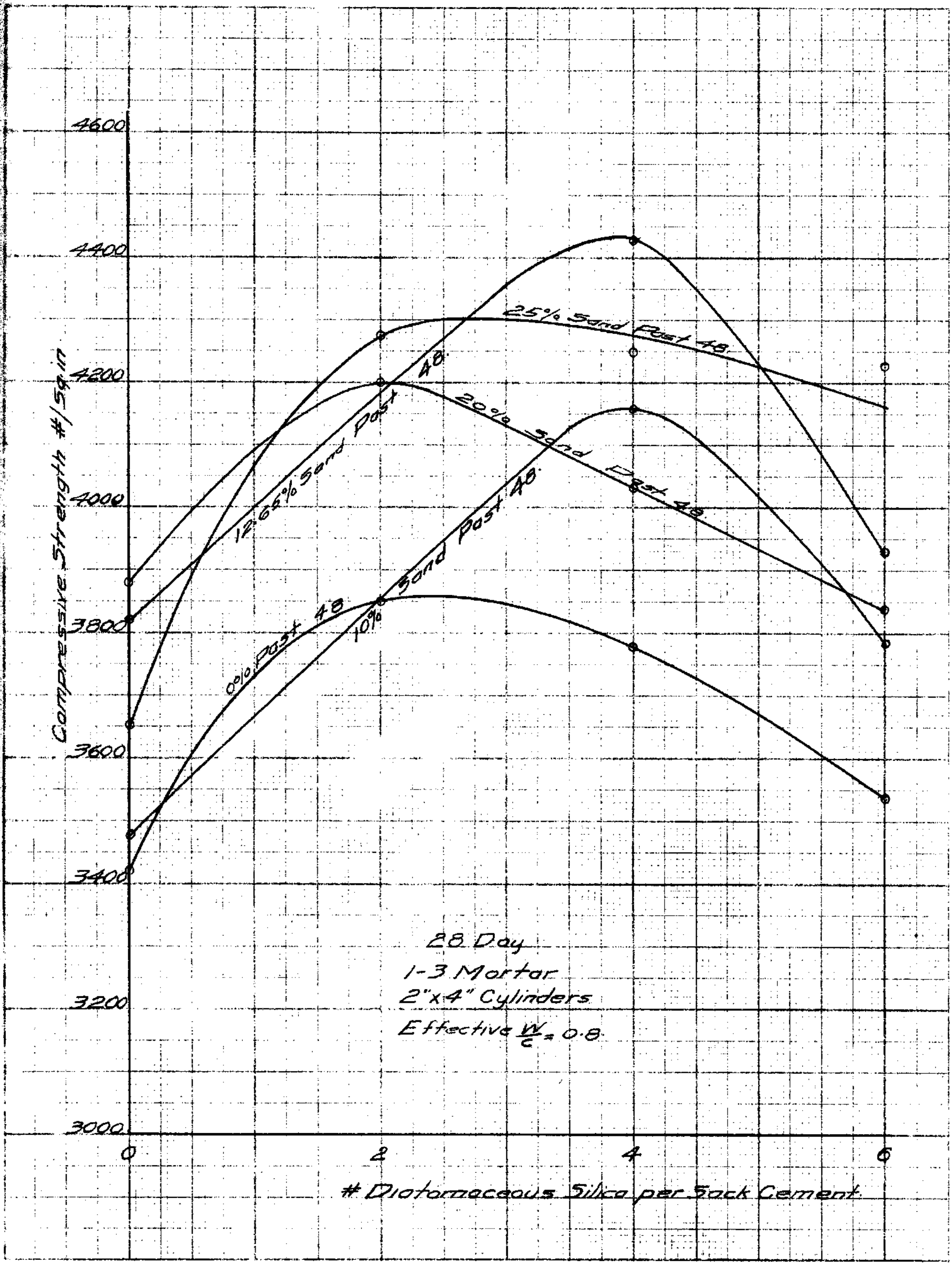
2" by 4" Cylinders

Effective W/c - 0.8.

Sample No.	%Sand Past 48	Cement #	Water c.c	Diatomaceous Silica(Grams)	Sand #	Average Strength #/Sq.in 7 Day	28 Day
33	0	1.414	361	0	4.46	2310	3420
55	0	"	383.5	13.62	"	2750	3850
56	0	"	406	27.24	"	2730	3780
57	0	"	428.5	40.80	"	2390	3540
37	10	1.414	361	0	4.51	2630	3480
58	10	"	383.5	13.62	"	2650	3550
59	10	"	406	27.24	"	2770	4160
60	10	"	428.5	40.86	"	2810	3780
41	12.65	1.414	361	0	4.55	2690	3820
61	12.65	"	383.5	13.62	"	2870	3610
62	12.65	"	406	27.24	"	2910	4430
63	12.65	"	428.5	40.86	"	2970	3930
47	20	1.414	361	0	4.58	2790	3880
64	20	"	383.5	13.62	"	2910	4200
65	20	"	406	27.24	"	2690	4030
66	20	"	428	40.86	"	2880	3840
51	25	1.414	361	0	4.60	2650	3650
67	25	"	383.5	13.62	"	2600	4280
68	25	"	406	27.24	"	2440	4250
69	25	"	428	40.86	"	2460	4230



Compressive Strength #/sq.in
2900
2800
2700
2600
2500
2400
2300
2200
0
2
4
6
Diatomaceous Silica per Sack Cement
12.65% Sand Past 48
20% Sand Past 48
0% Sand Past 48
10% Sand Past 48
25% Sand Past 48
7 Day
1-3 Mortar
2"x4" Cylinders
Effective W/C = 0.8



Compressive Strength #/sq.in
4600
4400
4200
4000
3800
3600
3400
3200
3000
0
2
4
6
Diatomaceous Silica per Sack Cement
25% Sand Past 48
12.66% Sand Past 48
20% Sand Past 48
10% Sand Past 48
0% Past 48
28 Day
1-3 Mortar
2"x4" Cylinders
Effective W/C = 0.8

Ultimate Compressive Load 7 and 28 Day

2" by 4" Cylinders (1-3 Mortar).

W/c - 1.0.

Diatomaceous Silica -#/ Sack Cement

0		2		4		6	

0% Sand Past 48

6,910	#70	7,020	#71	7,210	#72	8,270	#73
				7,530		8,480	
	6,910		7,020	7,520	7,420	7,150	7,966
10,700		11,470		11,800		10,430	
10,230		11,210		11,680		12,670	
10,460	10,463	12,400	11,693	11,620	11,700	11,640	11,576

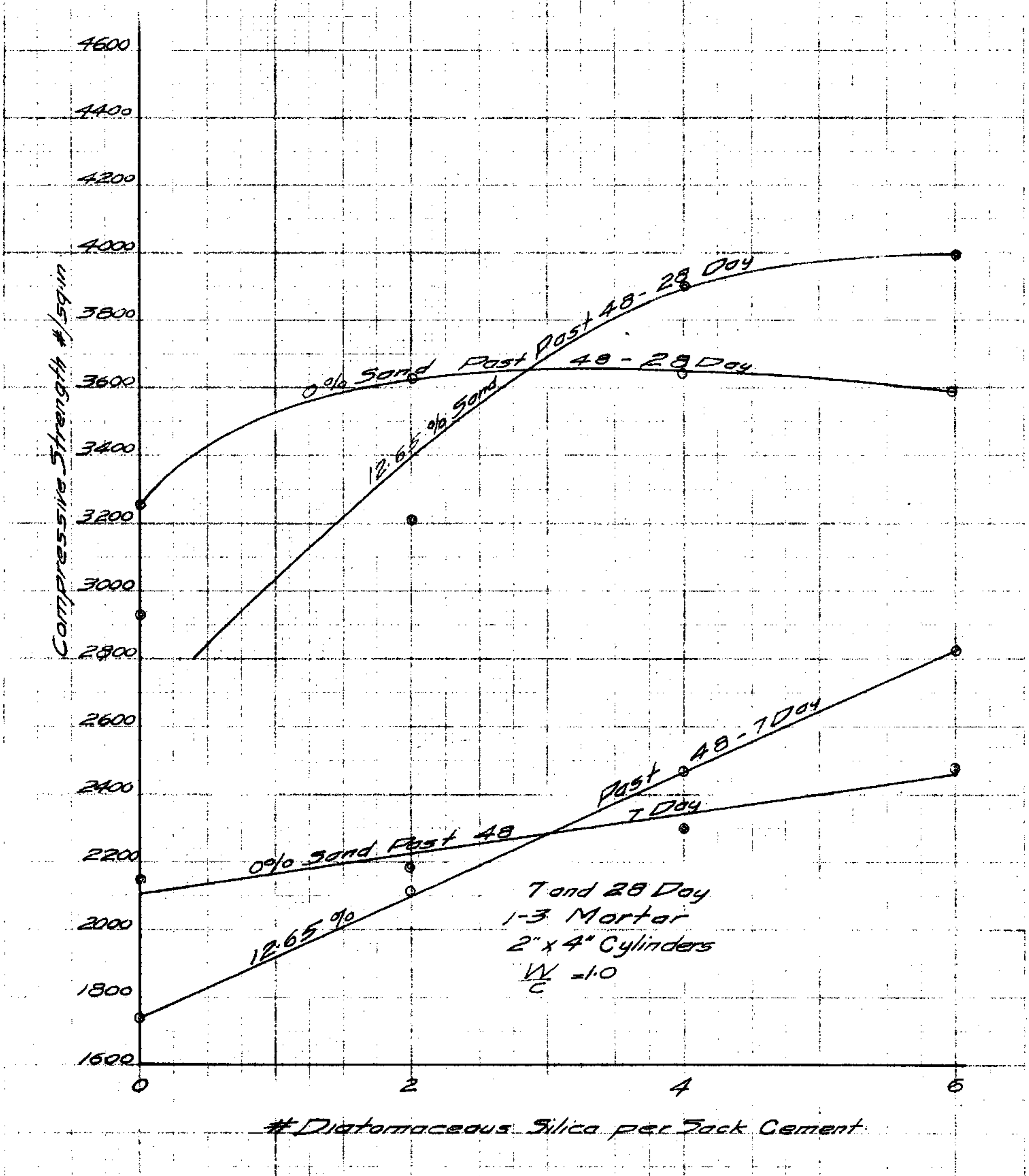
12.65% Sand Past 48

5,840	#74	7,250	#71	7,900	#76	9,590	#77
5,330		6,220		7,360		8,550	
5,670	5,613	7,020	6,830	8,690	7,983		9,070
10,310		10,920		10,900		11,550	
9,450		8,530		13,130		13,730	
8,500	9,420	11,480	10,310	13,700	12,576	13,300	12,860

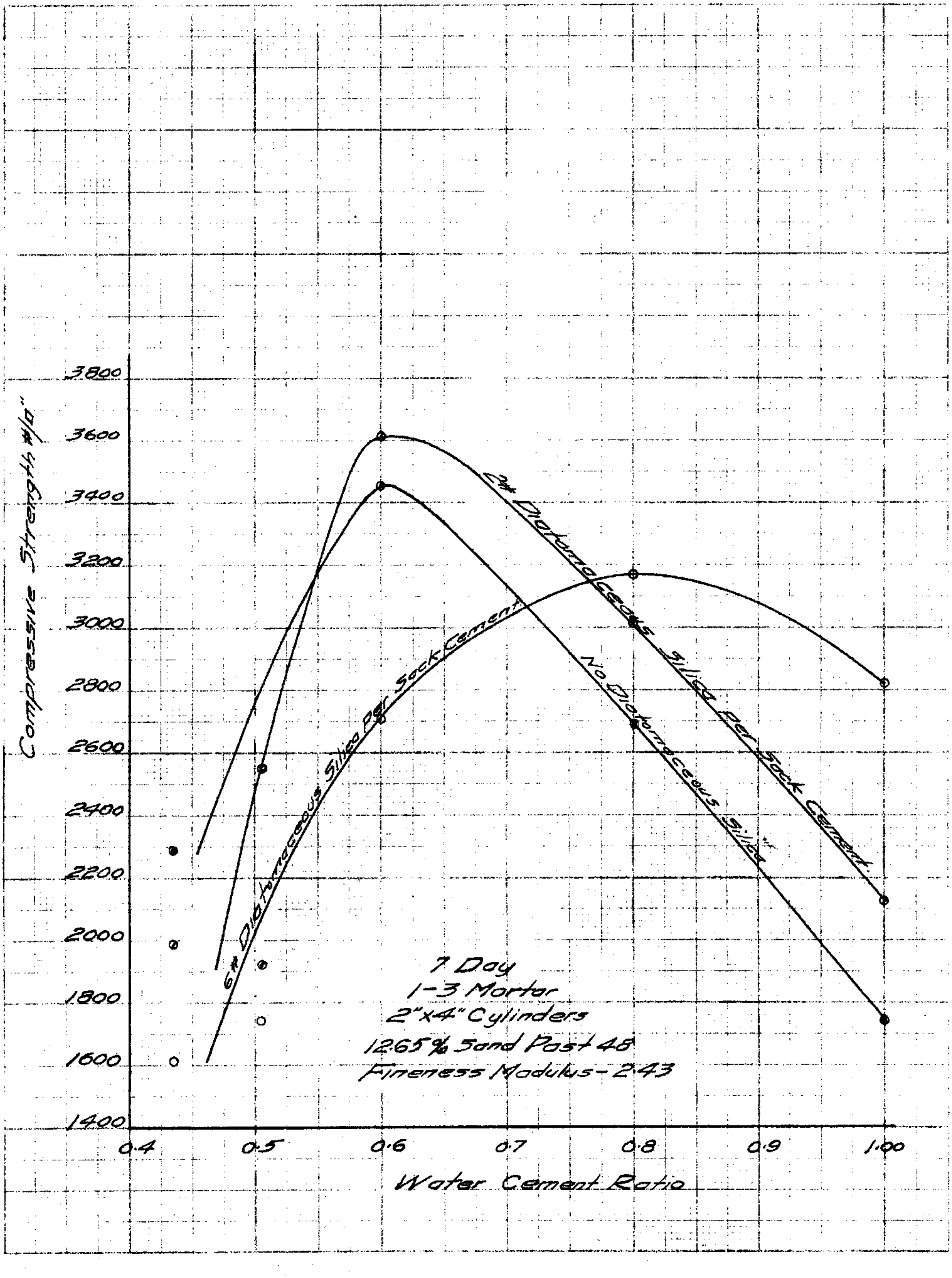
12.65% Past 48

W/c - 0.8.

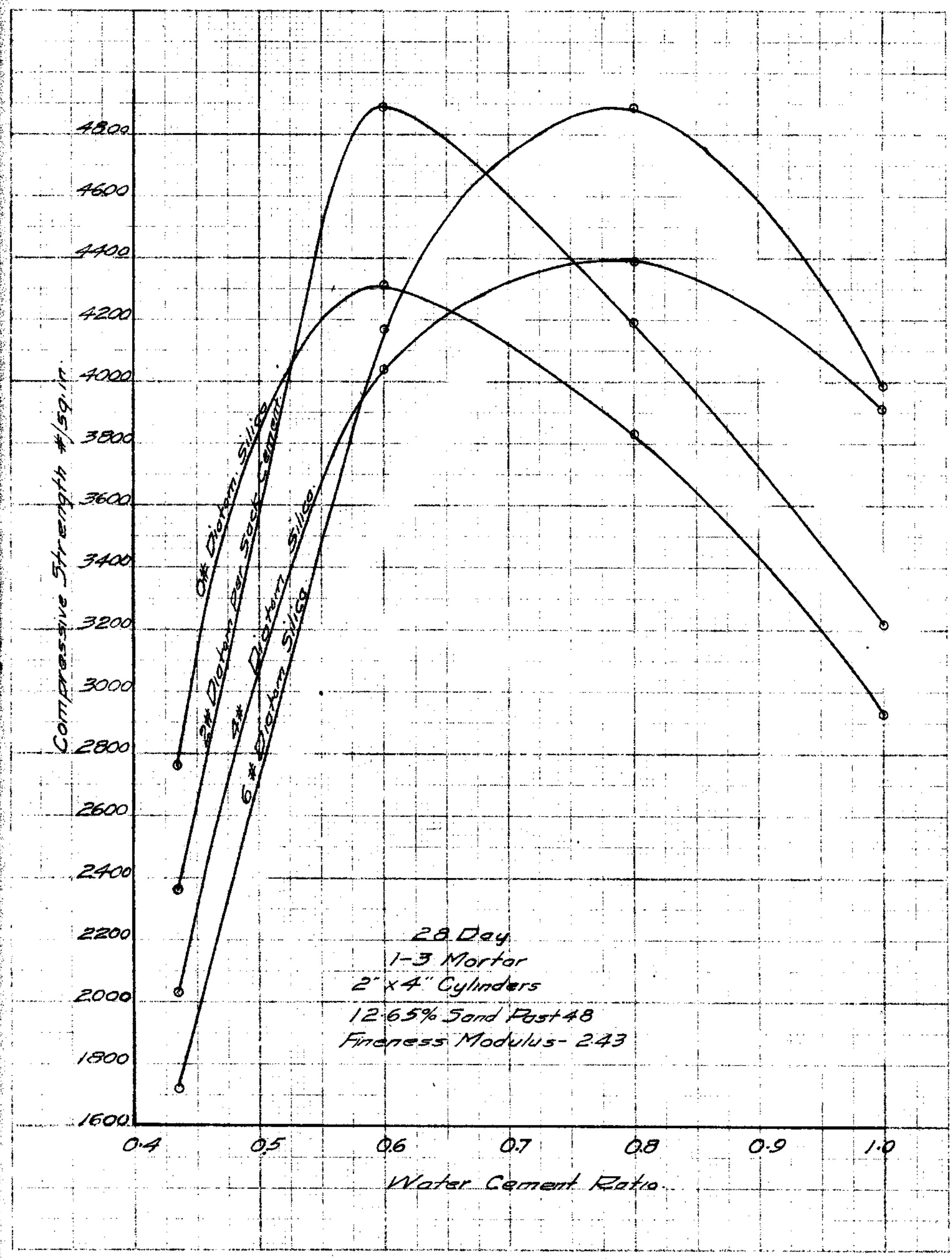
8#		10#	
10,000	#45	10,640	#46
7,960		8,630	
10,210	9,390	8,630	9,317
14,350		11,620	
12,660		13,510	
15,080	13,030	14,730	13,286



Compressive Strength #/sq.in
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
0
2
4
6
Diatomaceous Silica per Sack Cement
0% Sand Past 48 - 28 Day
12.65 % Sand Past 48 - 28 Day
0% Sand Past 48 7 Day
12.65 % Past 48 - 7 Day
7 and 28 Day
1-3 Mortar
2" x 4" Cylinders
W/C = 1.0



Compressive Strength #/□"
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
0.4
0.5
0.6
0.7
0.8
0.9
1.00
Water Cement Ratio
2# Diatomaceous Silica Per Sack Cement.
No Diatomaceous Silica
6# Diatomaceous Silica Per Sack Cement
7 Day
1-3 Mortar
2"x4" Cylinders
12.65% Sand Past 48
Fineness Modulus - 2.43


Compressive Strength #/sq.in.
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Water Cement Ratio
0# Diatom. Silica
2# Diatom Per Sack Cement
4# Diatom. Silica
6# Diatom Silica
28 Day
1-3 Mortar
2" x 4" Cylinders
12.65% Sand Past 48
Fineness Modulus - 2.43

1-2-4 Concrete

$\frac{W}{C} = 0.8$

Diatomaceous Silica (# per sack Cement)

0		2		4		6	

% Sand Past 48

14,240	#12	21,860	#13	20,110	#14	21,000	#15
16,870		14,500		20,440		12,570	
21,390	17,500	20,750	19,036	17,710	19,420	15,210	16,780
23,420		19,190		25,700		31,000	
22,990		30,890		26,840		27,220	
24,510	23,640	28,250	26,110		26,270	27,670	28,630

12.65% Sand Past 48

16,900	#1	19,510	#2	22,110	#3	20,200	#4
17,930		24,610		15,610		25,860	
	17,415	22,010	22,043	25,120	20,946	21,200	22,430
29,350		35,700		32,560		26,500	
25,440		28,710		33,370		25,850	
23,000	25,930	27,110	30,506	25,190	30,373	22,720	25,023

20% Sand Past 48

15,540	#19	16,700	#20	21,710	#21	16,930	#22
19,730		14,570		18,680		12,740	
	17,635	17,750	16,373	17,850	19,413	13,120	13,263
22,310		24,390		28,770		27,620	
23,800		26,980		23,910		20,600	
24,040	23,383	28,110	26,493		26,340	20,820	23,013

12.65% Sand Past 48

8#/sack		10#/sack	
14,850	#5	14,170	#6
19,390		12,450	
15,250	16,496	8,810	11,810
22,880		12,300	
23,400		18,070	
19,730	22,003	19,190	16,520

Ultimate Compressive Load. 7 and 28 Day.

1-2-4 Concrete.

Effective $\frac{W}{C} = 0.8$

Diatomaceous Silica # per sack Cement

% Sand Past 48.

0		2		4		6	
16,870	#12	15,890	#16	17,080	#17	16,630	#18
14,240		16,030		15,360		17,500	
21,390	17,500	23,510	18,476	16,570	16,337	17,860	17,330
23,420		27,000		26,540		26,880	
22,990		26,920		27,020		25,250	
24,510	23,640	21,000	24,973		26,770	25,670	25,933

12.65% Sand Past 48

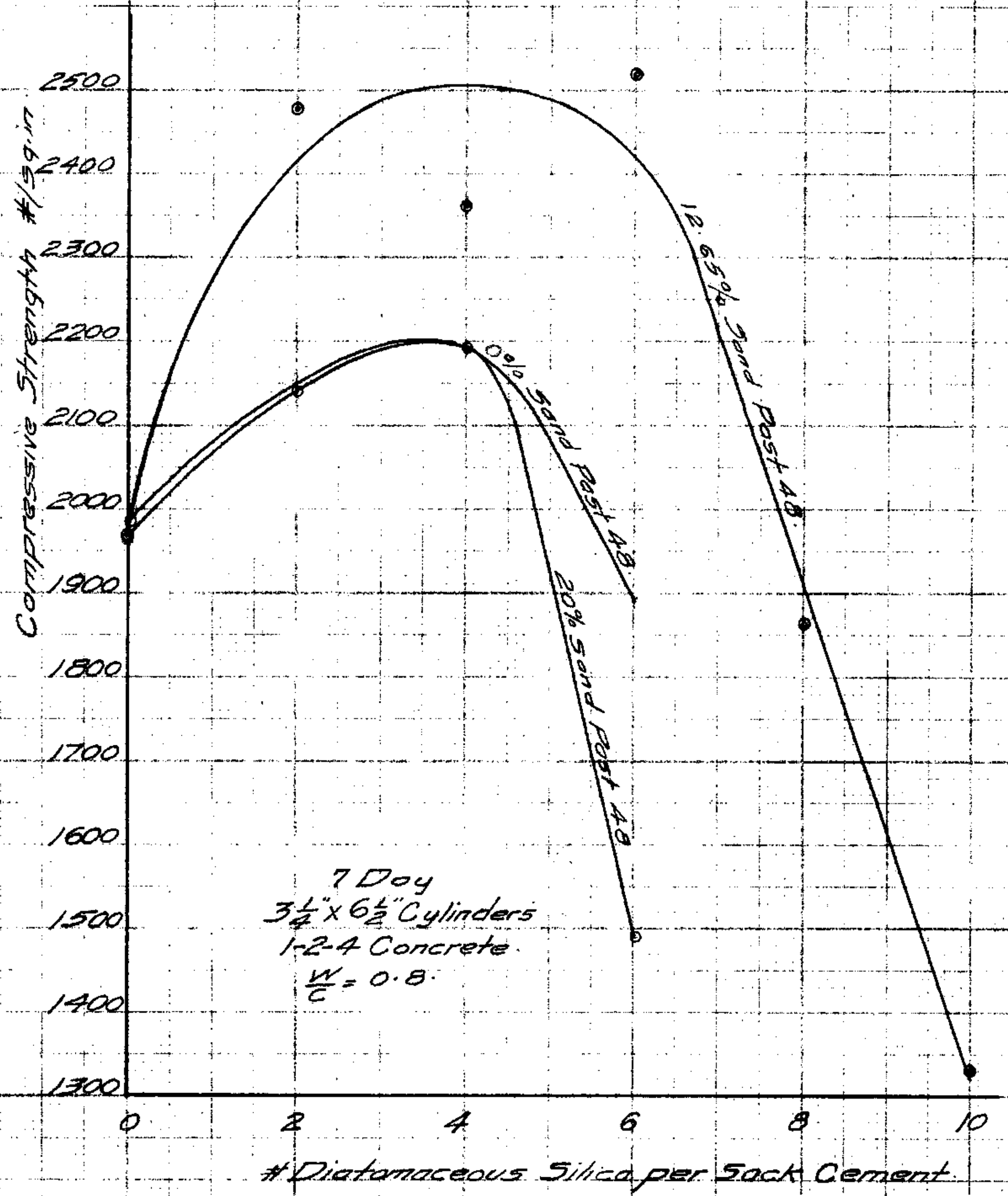
0		2		4		6	
16,900	#1	17,080	#7	17,300	#8	13,200	#9
17,930		18,890		14,800		15,120	
	17,415	20,240	18,736	17,180	16,426	11,490	13,274
29,350		30,830		27,840		24,050	
25,440		25,700		33,370		21,010	
23,000	25,930		23,365	25,050	25,420	22,550	22,355

20% Sand Past 48

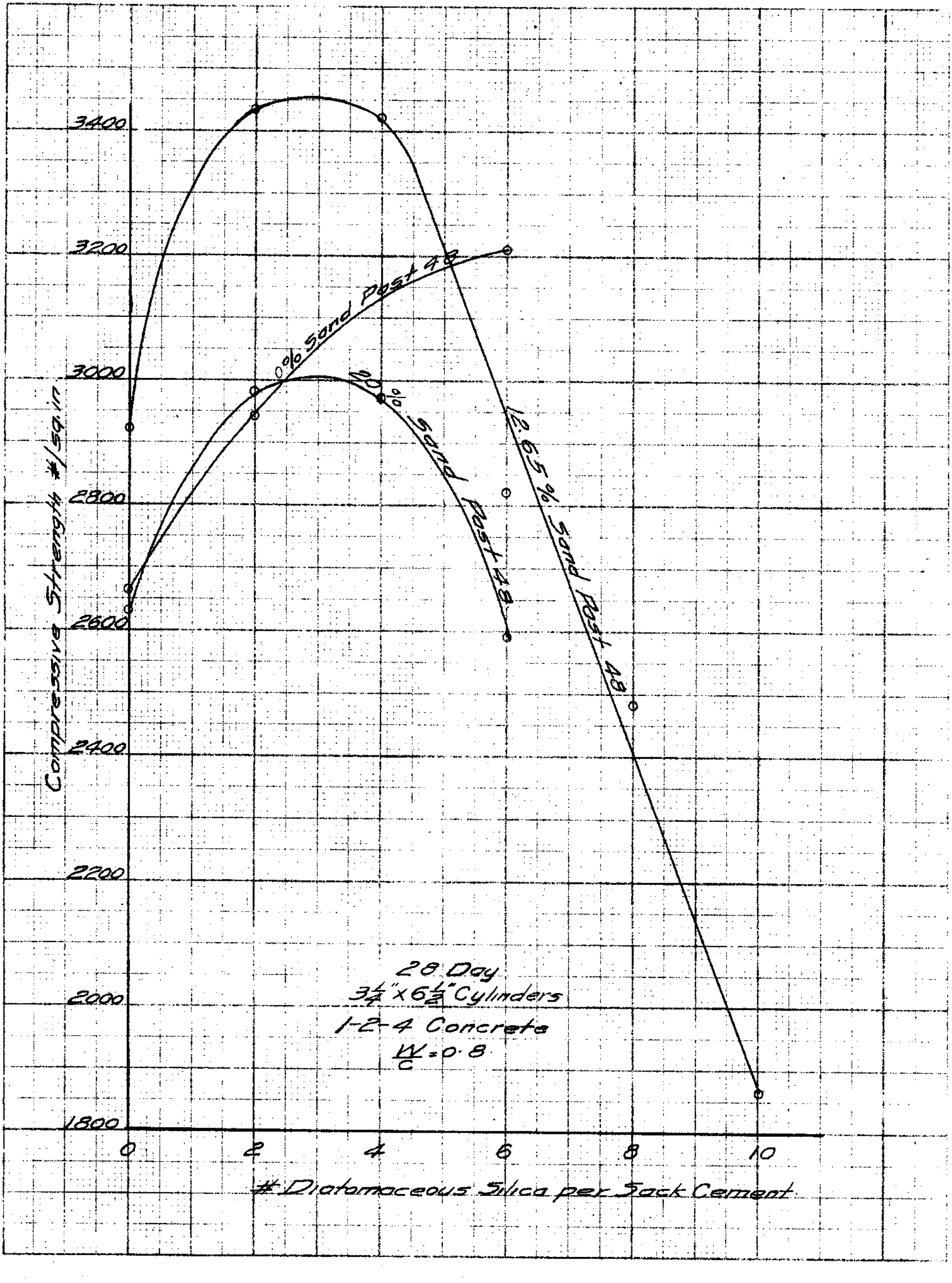
0		2		4		6	
15,540	#19	14,370	#23	12,670	#24	13,330	#25
19,730		19,130		14,470		12,930	
	17,635	13,710	15,736	18,950	15,363	13,950	13,403
22,310		24,600		30,800		28,620	
23,800		21,560				25,540	
24,040	23,383	25,000	23,720	22,970	26,885	23,670	25,926

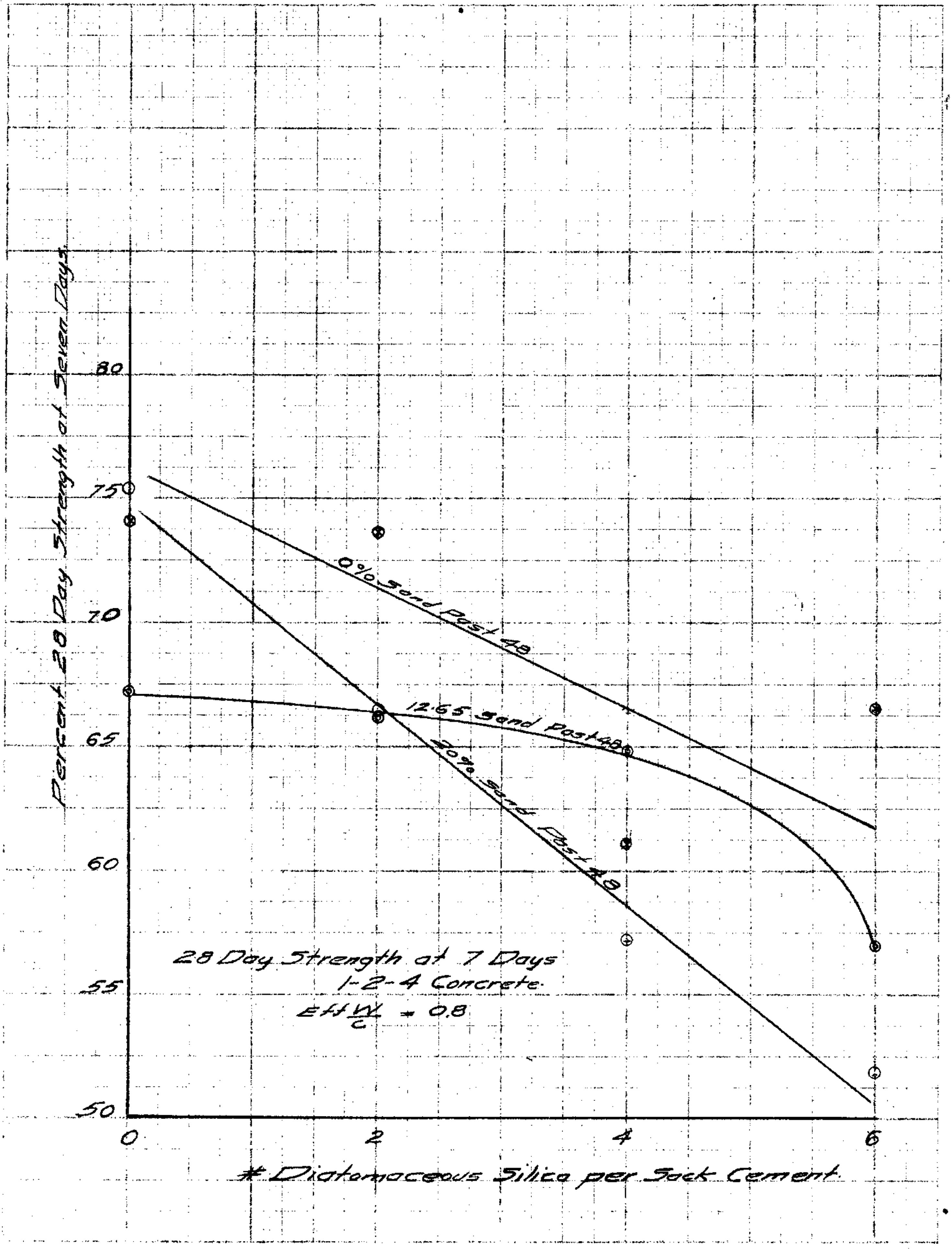
1-2-4 Concrete
3¼" by 6½" Cylinders.

Mix No	Quantities for Mixes: % Sand Past 48	Cement #	Water cc	Sand #	Gravel #	Diatomaceous Silica (Grams)	Aver. Strength #/Sq.in. 7 Day	28 Day
12	0	3.86	1005	8.14	17.8	0	1,970	2660
13	0	"	"	"	"	37.2	2140	2940
14	0	"	"	"	"	74.4	2190	2960
15	0	"	"	"	"	111.6	1890	3210
1	12.65	3.86	1005	8.27	17.8	0	1960	2,920
2	"	"	"	"	"	37.2	2,480	3435
3	"	"	"	"	"	74.4	2,360	3420
4	"	"	"	"	"	111.6	2,520	2820
5	"	"	"	"	"	148.8	1860	2480
6	"	"	"	"	"	186.0	1330	1860
19	20	3.86	1005	8.35	17.8	0	1985	2630
20	"	"	"	"	"	37.2	1840	2980
21	"	"	"	"	"	74.4	2190	2970
22	"	"	"	"	"	111.6	1490	2590
12	0	3.86	1005	8.14	17.8	0	1970	2660
16	0	"	1066	"	"	37.2	2080	2820
17	0	"	1127	"	"	74.4	1840	3010
18	0	"	1188	"	"	111.6	1950	2910
1	12.65	3.86	1005	8.27	17.8	0	1960	2920
7	"	"	1066	"	"	37.2	2110	3190
8	"	"	1127	"	"	74.4	1850	2860
9	"	"	1188	"	"	111.6	1495	2630
19	20	3.86	1005	8.35	17.8	0	1985	2630
23	"	"	1066	"	"	37.2	1770	2670
24	"	"	1127	"	"	74.4	1730	3030
25	"	"	1188	"	"	111.6	1510	2920

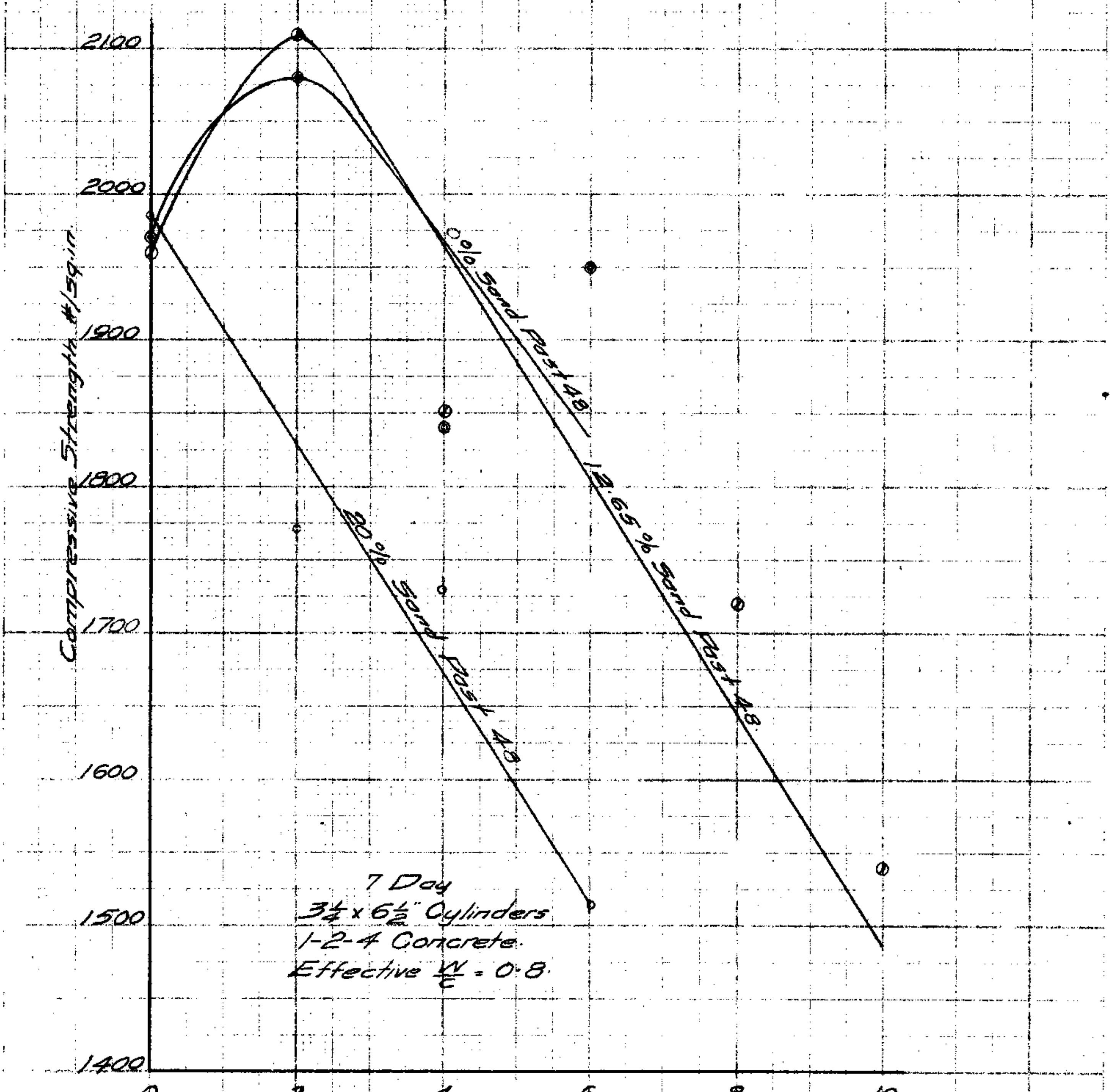


Compressive Strength #/sq.in
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
0
2
4
6
8
10
Diatomaceous Silica per Sack Cement
12.65% Sand Past 48
0% Sand Past 48
20% Sand Past 48
7 Day
3¼" x 6½" Cylinders
1-2-4 Concrete
W/C = 0.8

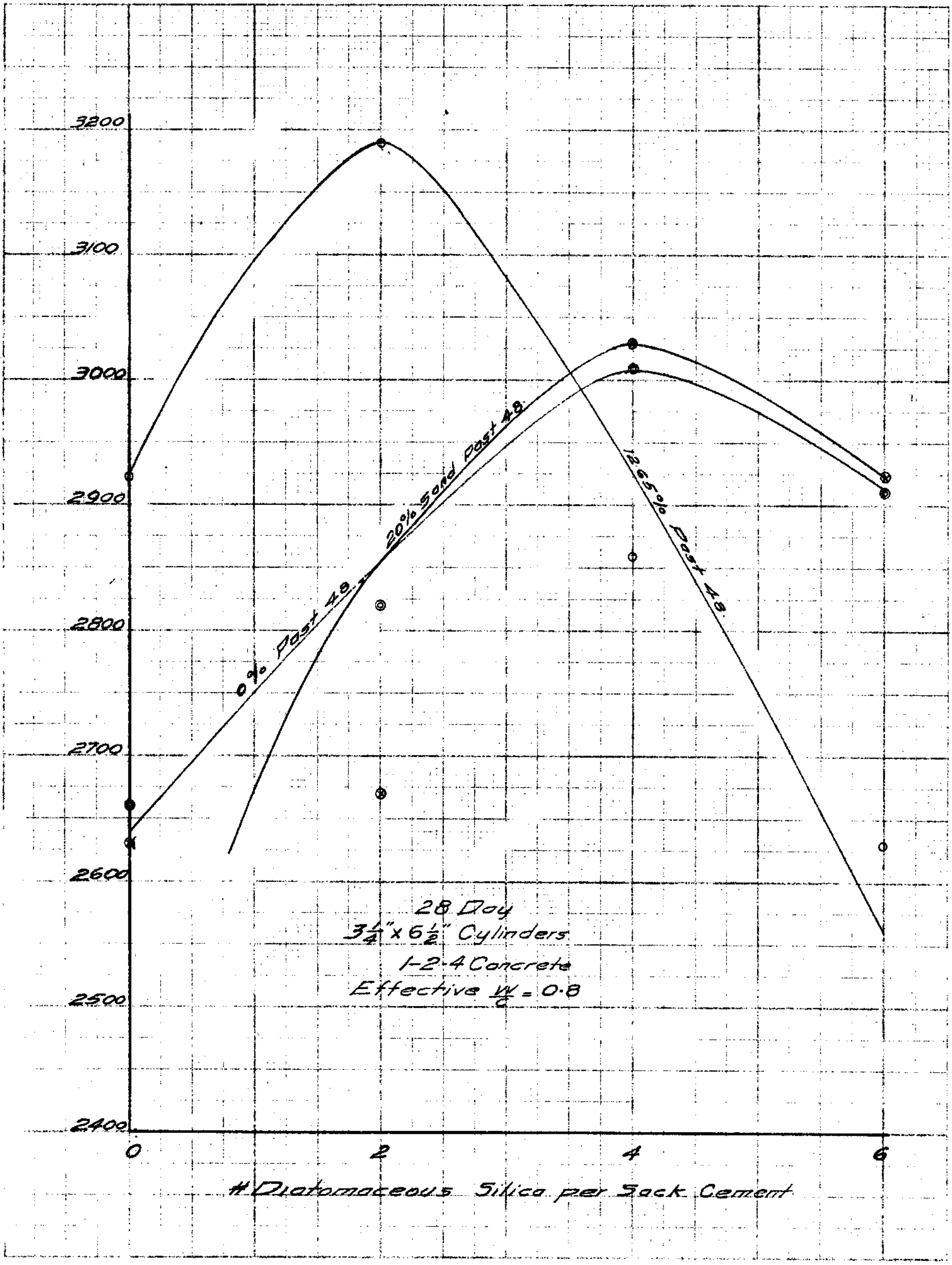

3400
3200
3000
2800
2600
2400
2200
2000
1800
0
2
4
6
8
10
Compressive Strength #/sq.in
Diatomaceous Silica per Sack Cement
0% Sand Post 48
20% Sand Post 48
12.65% Sand Post 48
28 Day
3¼" x 6½" Cylinders
1-2-4 Concrete
W/C = 0.8



Percent 28 Day Strength at Seven Days
80
75
70
65
60
55
50
0
2
4
6
Diatomaceous Silica per Sack Cement
0% Sand Past 48
12.65 Sand Past 48
20% Sand Past 48
28 Day Strength at 7 Days
1-2-4 Concrete
Eff W/C = 0.8



Compressive Strength #/sq.in.
2100
2000
1900
1800
1700
1600
1500
1400
0
2
4
6
8
10
Diatomaceous Silica per Sack Cement
0% Sand Past 48
12.65 % Sand Past 48
20 % Sand Past 48
7 Day
3¼ x 6½" Cylinders
1-2-4 Concrete
Effective W/C = 0.8



3200
3100
3000
2900
2800
2700
2600
2500
2400
0
2
4
6
0% Past 48
20% Sand Past 48
12.65% Past 48
28 Day
$3\frac{1}{4}$" x $6\frac{1}{2}$" Cylinders
1-2-4 Concrete
Effective $\frac{W}{C}$ = 0.8
Diatomaceous Silica per Sack Cement

Percent 28 Day Strength at 7 Days.

– Mortars –

# Admix	Water	Cement Ratio					
Per sack	0.435	0.505	0.542	0.60	0.80	Eff 0.8	1.0
0 % Sand Past 48.							
0			78.5		67.3	67.1	66.6
2			73.0		69.2	71.5	60.0
4			80.7		66.2	72.2	63.2
6			78.6		68.3	67.5	69.0
10% Sand Past 48							
0			73.4		75.5	75.5	
2			74.0		69.8	74.7	
4			65.3		79.2	66.6	
6			80.7		72.0	74.3	
12.65% Sand Past 48							
0	83				70.2	70.3	59.5.
2	84				71.7	79.5	66.0.
4	78				64.7	65.7	63.5.
6	94				64.8	75.5	70.6.
8					71.7		
10					69.8		
20% Sand Past 48							
0			87.6		72.0	72.0	
2			82.1		78.7	69.4	
4			80.5		83.0	66.7	
6			77.5		82.0	75.0	
25% Sand Past 48							
0			79.7		72.6	72.6	
2			63.9		77.5	60.7	
4			84.7		63.9	57.4	
6			74.0		68.9.	58.2	

Mortars

Percent Strength 28 Day.

#Admix Per Sack	Water Cement Ratio 0.435	0.542	0.6	0.8	Eff 0.8	1.0
0% Sand Past 48						
0		100	100	100	100	100
2		98	100	112	113	112
4		92	109	116	110	112
6		79	114	109	103	111
10% Sand Past 48						
0		100		100	100	
2		99		109	102	
4		86		114	120	
6		68		115	109	
12.65% Sand Past 48						
0	100		100	100	100	100
2	86		113	109	95	110
4	74		94	115	116	133
6	62		97	128	103	136
8				106		
10				108		
20% Sand Past 48						
0		100		100	100	
2		94		108	108	
4		82		101	104	
6		59		90	99	
25% Sand Past 48						
0		100		100	100	
2		101		101	117	
4		82		107	117	
6		78		106	116	

Concrete
1-2-4.

# Admix	Percent 28 Day Strength at 7 Days		Percent Strength 28 Day	
	Water Cement Ratio.			
Per Sack	0.8	Eff. 0.8	0.8	Eff. 0.8
	0% Sand Past 48			
0	74.0	74.0	100	100
2	72.3	73.7	111	106
4	74.0	61.2	111	113
6	59.0	66.4	121	110
	12.65% Sand Past 48			
0	67.2	67.2	100	100
2	72.3	66.2	117	109
4	69.0	64.8	117	98
6	89.3	57.0	97	90
8	75.0		85	
10	71.5		64	
	20% Sand Past 48			
0	75.5	75.4	100	100
2	61.7	66.4	113	102
4	73.8	57.2	113	115
6	57.7	51.8	99	111

Procedure.

As shown in sample calculations all materials used in the various mixes were carefully weighed to hundredths of an ounce with the exception of the admix which was weighed to hundredths of a gram. One cubic cm. of water was taken as equivalent to one gram without temperature corrections.

The sand and admix were first mixed, after which the cement was added and the whole again carefully mixed; in the case of concrete the course aggregate was added and mixed well with the other materials. The water was added in a crater formed in the thoroughly mixed dry materials and the edge materials worked toward the center, after which the mixing was continued for about two minutes. For mortars all mixing was done by thorough kneading by hand and the concrete was turned with a blunt end trowel.

The mixing was done in a galvanized iron pan and before adding the water to the materials the pan was wet to take care of the water which this process would ordinarily take from the mix.

The mortar mixes were carefully rodded into the 2" by 4" moulds, consisting of split pipe having an average internal diameter as used of 2.0245 inches and an average cross section area of 3.22 sq.in. Rodding was done in four layers at twenty five strokes per layer with the exception of the wetter mixes which were rammed enough to insure against entrained air and other possible voids.

The concrete mixes were rodded in four layers of twenty five strokes per layer into $3\frac{1}{4}$" by $6\frac{1}{2}$" carton moulds, the resulting cylinders having an average diameter of 3.36 inches and an average cross section of 8.88 sq.in.

The cylinders were placed in water approximately twenty four hours after moulding and allowed to remain until within an hour of breaking at seven and twenty eight days.

Before breaking all cylinders were capped with plaster of paris to insure flat ends. A Riehle testing machine of 100,000# capacity was used for breaking and the load applied thru a ball and socket joint consisting of a 1 inch steel ball resting in two spherical seats. The rate of travel of the machine head was 0.165 inches per minute, unloaded.

Sand used in tests commonly known as "Rollo", comes from the Fort Valley section of Georgia; in a test for organic matter the resulting solution is colorless.

Determination of Quantities.

Mortars 1 - 3

Assume for all mixes of 6-2x4 cylinders
78 cu. in. Sand and 26 cu. in. cement.

% Sand Past 48	Wt. Sand	Wt. cement.
0	$\frac{78}{1728}(98.89) = 4.46\#$ = 4# 7.36 oz.	$\frac{26}{1728}(94) = 1.414\#$ = 1#6.62 oz.
10	$\frac{78}{1728}(100.00) = 4.51\#$ = 4# 8.16 oz.	1#6.62 oz.
12.65	$\frac{78}{1728}(100.86) = 4.55\#$ = 4# 8.8 oz	1#6.62 oz.
20	$\frac{78}{1728}(101.43) = 4.58\#$ = 4#9.28 oz.	1#6.62 oz.
25	$\frac{78}{1728}(101.98) = 4.60\#$ = 4 #9.60 oz.	1#6.62 oz.

Weight of Admixture (Diatomaceous Silica).
Assume for calculation 2#/ Sack Cement.

$\frac{2}{94}$ (1.414 = 0.0030085# = 0.048136 oz = 13.62 grams.

Wt. Admix per Sack cement.	Wt. Admix for each 6 cylinder mix (grams)
2	13.62
4	27.24
6	40.86
8	54.48
10	68.10

Sample Calculations for Mixes.

– Mortars –

10% Sand Past 48 mesh.
Wt Required for 6 cylinders – 4.51#
" " " 24 cylinders – 18.04#
18.04 (0.1) = 1.804# Amount past 48 mesh.
18.04 – 1.804 = 16.236#
To 16.236# 0% Past 48 mesh add 1.804#, 100%
Passing 48 mesh.

20% Past 48 mesh.
Wt required for 6 cylinders – 4.58#
" " " 24 " – 18.32#
Take 17.5# unseived sand – 12.65% passing 48 mesh.
17.5 (0.1265) = 2.215# passing 48 mesh.
17.5 – 2.215 = 15.285#, 0% Past 48 mesh.
15.285 + 0.20X = X. Where X = Total wt. containing 20% past 48

$$X = \frac{15.285}{.80} = 19.1\#$$

19.1 – 17.5 = 1.6#, 100% passing 48 mesh.
Therefore: To 17.5# unseived add 1.6# passing 48 mesh.
Note: Only 18.32# of the total 19.1# to be used.

25% Past 48 mesh.
Wt Required for 6 cylinders – 4.6#
" " " 24 cylinders – 18.4#
Take 16# unseived sand. 12.65% passing 48 mesh.
16 (0.1265) = 2.024#, passing 48 mesh.
16 – 2.024 = 13.976# ~~25%~~ Past 48 mesh.
13.976 + 0.25X = X. Where X = Total wt. containing

$$\frac{13.976}{0.75} = X = 18.63\# \quad 25\% \text{ Past 48 mesh.}$$

18.63 – 16 = 2.63# Past 48 mesh.
Therefore: To 16# unseived add 2.63# passing 48 mesh.

Note: Only 18.4# of total 18.63# to be used.

Sample Calculations

- Mortars -

Water.

For water cement Ratio - 1.00
For 6 cylinders 4.46# Sand 10% sand past 48

$$\frac{26}{1728}(1.0) = 0.01504 \text{ cu.ft water.}$$

$$62.355\ (0.01504) = 0.9378\#.$$

Allowing for 1% Absorption by sand
4.46 (0.01) = 0.0 446 #

0.9378 (28.35) (16) plus 0.0446 (28.35) (16) =
425.3 grams plus 20.2 grams = 446 grams

Water cement Ratio 0.8

$$425.3\ \frac{(8)}{10} \text{ plus } 20.2 = 340.3 \text{ plus } 20.2 = 361 \text{ grams.}$$

Water cement Ratio 0.6

$$425.3\ \frac{(6)}{10} \text{ plus } 20.2 = 255.2 \text{ plus } 20.2 = 276 \text{ grams.}$$

Note: Variation in weights of sands will affect water in any case less than 1 gram. therefore the above quantities will be used for all mixes.

205g water

$$\frac{W}{C} = \frac{205 - 20.2}{425.3} = 435.$$

235g water

$$\frac{W}{C} = \frac{235.20.2}{425.3} = 0.505.$$

$$\frac{W}{C}\quad \frac{250 - 20.2}{425.3} = 0.542.$$

Sample Calculations

$3\frac{1}{4}$ X $6\frac{1}{2}$ Cylinders

1-2-4 Mix

Assume 497 cu.in. materials measured separately (6 cylinders)

71 cu.in. cement
142 cu.in. sand
284 cu.in. gravel

$\frac{71}{1728}$ (94) = 3.86# = 3# 13.8 oz. Cement

$\frac{142}{1728}$ (98.89) = 8.14# = 8# 2.24 oz (% sand past 48)

$\frac{142}{1728}$ (100.86) = 8.27# = 8#4.32 oz. (12.65% sand past 48)

$\frac{142}{1728}$ (101.43) = 8.35# = 8#5.6 oz (20% sand past 48)

$\frac{284}{1728}$ (108.30) = 17.8# = 17# 12.8 oz gravel

Water

$$\frac{W}{c} = 0.8$$

Allowing 1%, by weight, absorption for sand and one half of 1%, by weight, absorption for gravel.

8.27 (.01) = .0827#
17.8 (.005) = .0890#

$\frac{71}{1728}$ (62.35) (0.8) = 2.048#

Total water 2.22#.

2.22 (16) 28.35 = 1005. grams

Diatomaceous Silica

2# / sack cement $\frac{3.86}{94}$ x 2 - 0.082# = 37.2 grams

4# /	"	"	-	74.4 g.
6# /	"	"	-	111.6 g.
8# /	"	"	-	148.8 g.
10# /	"	"	-	186.0 g.

Absorption of Diatomaceous Silica.

From experiments made with 20 gram samples of diatomaceous silica it is thought that the material in its room dry condition will absorb water to 165% at its weight. This quantity was arrived at by determining the minimum amount of water required to form the 20 gram sample into a ball which might be handled without crumbling. For a 20 gram sample the water added, to produce the condition mentioned, was 33 grams.

- Mortars -

Water for Effective W/c - 0.8

Original water W/c - 0.8	Diatomaceous Silica	Water for Eff. W/c - 0.8
361 g	0	361.0 g
361	13.62 g	383.5
361	27.24	406.0
361	40.86	428.5

- Concrete -

1005 g	0	1005 g
1005	37.2 g	1066
1005	74.4	1127
1005	111.6	1188
1005	148.8	1249
1005	186.0	1310

Unit Weight - Coarse Aggregate.

Wt. aggregate and Measure	Wt. Measure	Net Wt.
114.5 #	6.53 #	107.97 #
115.0	6.53	108.47
115.0	6.53	108.47

Average 108.30# - 108# 4.8 oz.

Yield - Mortars and Concrete

In investigating the yield for various mixes containing varying amounts of diatomaceous silica the absolute volume of all materials entering into the mix will be computed and the total compared with the actual yield.

Many of the mortar mixes, especially with diatomaceous silica and water-cement ratio less than 0.8 were rather dry and voids might be expected to exist; the concrete mixes on a water-cement ratio of 0.8 containing more than 4% admix per sack of cement contained voids noticeable on the surface. Only those mixes will be used in computing yields in which there was sufficient water to give a workable mix, with or without diatomaceous silica.

The specific gravity of the sand and gravel used was found to average on three tests on each of these aggregates 2.65 and 2.64 respectively. The average specific gravity of diatomaceous silica as given by Eardley-Wilmot is 2.15. The specific gravity of the cement used, Lone Star, will be taken as 3.14.

Yield - Concrete Mixes.

Mix No.1

Cement $\frac{3.86}{3.14}\frac{(1728)}{(62.35)} = 34.10$ cu.in.

Sand $\frac{8.27}{2.65}\frac{(1728)}{(62.35)} = 86.50$ cu.in.

Gravel $\frac{17.8}{2.64}\frac{(1728)}{(62.35)} = 186.50$ cu.in.

Water 100.5 $(0.06102) = 61.3$ cu.in.

Total 368.4 cu.in.

No.1 mix filled 6 moulds 6½" high with 2", measured in a similar mould, remaining.

Cross section area of moulds (Average) 8.88 sq.in.
Actual volume - $41(8.88) = 364.00$ cu.in.
$368.4 - 364.0 = 4.4$ cu.in. unaccounted for.

Absolute Volumes - (cu.in)

Mix#	Cement	Sand	Gravel	Water	Diatom Silica	Total	Actual	Total minus Actual
1	34.1	86.5	186.5	61.3	0	368.40	364.0	4.40
7	"	"	"	65.0	1.06	373.16	368.5	4.66
8	"	"	"	68.6	2.12	377.82	375.0	2.82
9	"	"	"	72.5	3.18	382.78	379.0	3.50
10	"	"	"	76.0	4.24	387.34	385.0	2.34
11	"	"	"	80.0	5.30	392.40	388.0	3.4

The above yields were obtained from cylinders in which the concrete was rodded the same number of times in four layers. While there is a discrepancy between the actual and theoretical yields it amounts to a maximum of only 1.25%. If the diatomaceous silica increased the yield by only the absolute volume added it would seem that all values in the last column should be the same, the maximum difference is 2.06 cu.in. and on that basis the maximum increase in yield from the admix is only 0.53%, therefore taking into consideration experimental errors the above values seem to lead to the conclusion that the admix does increase the yield by only the absolute volume of the added material.

Yield - Mortars
Mix No.67

Diatomaceous Silica $\frac{13.62\ (1728)}{28.35 (16) 62.35\ (2.15)} = 0.4$ cu.in.

Sand $\frac{4.60\ (1728)}{2.65\ (62.35)} = 48.1$ cu.in.

Cement $\frac{1.414\ (1728)}{3.14\ (62.35)} = 12.5$ cu.in.

Water 361 (0.06102) = 22.00 cu.in.

Total 83.0 cu.in.

No.67 mix filled 6 moulds 4" high with 1.5" measured in a similar mould remaining.

Cross section area of moulds (Average) 3.22 sq.in.

Actual volume - 25.5 (3.22) = 82.1 cu.in.

82.6 - 82.1 = 0.5 cu.in. unaccounted for.

Mix No.	Cement	Sand	Water	Diatom Silica	Total	Actual	Total minus Actual
	Absolute Volumes. (cu. in)						
51	12.5	4.81	22.00	0	82.6	82.1	0.5
67	"	"	"	0.4	83.0	82.5	0.5
68	"	"	"	0.8	83.4	84.0	-0.6
69	"	"	"	1.2	83.8	84.4	-0.6
70	12.5	46.8	27.2	0	86.5	84.5	2.0
71	"	"	"	0.4	86.9	86.0	0.9
72	"	"	"	0.8	87.3	86.5	0.8
73	"	"	"	1.2	87.7	86.5	1.2
41	12.5	47.4	22.00	0	81.9	82.5	-0.6
61	"	"	"	0.4	82.3	82.8	- .5
62	"	"	"	0.8	82.7	82.5	0.2
63	"	"	"	1.2	82.1	83.0	0.1

From the above comparisons of theoretical yield based on absolute volumes of the materials entering the mix and the actual volumes the same conclusions must be reached as those set forth on the analysis of concrete yields. The diatomaceous silica as an admix appears to affect the yield only by the amount of the absolute volume of the added material if the mix is sufficiently wet to be easily worked into the moulds.

Discussion of Results

From curves on the water cement ratio equal 0.542 and from tabulation of data on percent strength at 28 days, taking in each case the strength of the mix containing no diatomaceous silica as 100%, it is seen that at both 7 and 28 days the strength varies almost inversely as the added admix, however, this is not strictly true, for as shown by the curves on seven day strength the rate of decrease becomes greater in the case of 0%, 10% and 20% fine particles where a larger amount than 4# per sack was used. At 28 days the rate of decrease of the mixes containing 0%, 10% and 20% fine particles becomes greater where a larger amount than 2# admix per sack was used. While it was not expected that the addition of diatomaceous silica to mixes already too low in water to produce maximum obtainable strength would benefit, it was desired to see just what effect the addition of the material would give. While the results on breaking the cylinders varied more than a reasonable amount in some instances it was found that even on a careful recheck the same variations were liable to occur and these variations appeared to occur more frequently in the mixes notably deficient in water.

At a water cement ratio of 0.6 the strength at 7 days for both 0% percent and 12.65%, the natural sand containing 12.65% fine particles, varied directly in proportion to the weight of the added admix up to 4# per sack and then decreased. The admix apparently adds more to the strength of the sand containing no fine particles at the seven day age. At 28 days the mix with sand containing no fine particles increases in direct proportion to the added admix and is perhaps at its max. at 6# per sack. The mix with 12.65% fine particles of sand is increased in strength at 2# per sack but decreases for a greater amount.

At this low water cement ratio (0.6), which however for the mixes with 0 and 2# admix per sack is very near the correct ratio for maximum obtainable strength, it appears that the sand containing no fine particles should have a maximum at 6# diatomaceous silica per sack and for 12.65% fine particles the maximum should be 2# per sack. The maximum increase in strength found for 0% fine particles was 14% and for 12.65% fine particles 13%.

For mortars with a water cement ratio of 0.8 the mixes with 12.65% fine particles were also tested with 8# and 10# admix as the strength increased up to 6# per sack and it was wished to determine the effect of a greater amount.

At 7 days the admix increases the strength for 0%, 20% and 25% fine particles when added up to 2# per sack and at 10% fine particles, up to 4# per sack. The mix with 12.65% appears to have the greatest strength when mixed with 6# per sack admix. At 28 days the mixes containing 0% and 25% fine particles appear at the maximum strength with 4# per sack, the 10% and 12.65% fine particle mixes at 6# per sack and 20% at 2# per sack. At 28 days the maximum increase in strength for 0% was 16%; for 10%, 15%; for 12.65%, 28%; for 20%, 8% and for 25%, 7%; it appears to be most advantageous from the standpoint of added strength to add diatomaceous silica up to 12.65% fine particles and possibly say up to 15%, the percent added strength to be expected would then range from around 10 to 28.

The effective water cement ratio is, as stated elsewhere in this discussion, based on absorption by the diatomaceous silica of 165% its own weight of water and this has been taken into consideration and allowed for. At seven days the addition of admix appears of greatest advantage with the 0% fine particles sand and then when added at 2# per sack; when added to other mixes it gives as shown in the graph an increase in the strength in all cases except the 25% fine particles, in which case when added in any amount there is a decrease. At 28 Days the admix to be added appears to be 2# per sack to mixes containing 0%, 20% and 25% fine particles and 6# at 10% and 12.65% fine particles. When added in the above amounts the increase in strength is for 0%, 13%; for 10%, 20%; for 12.65%, 16%; for 20%, 8%; and for 25%, 17%. It would seem advantageous from the standpoint of strength to add admix to all mixes and the maximum increase would be about 17%.

At a water cement ratio of 1.0 the admix appears at 7 days to increase the strength directly in proportion to amount added up to 6# per sack and possibly beyond as greater amounts were not used; the increase for the 12.65% fine particle sand appears to be at a greater rate than it does in the case of 0% fine particles. At 28 days the maximum admix to be added would appear in general to be 6# to either mix and the maximum increase in strength is 36% for the 12.65% fine particle mix. This large increase is of course partly due to the absorption of water by the admix and the lowering of the actual or effective water cement ratio.

At 7 days the addition of diatomaceous silica to concretes with water cement ratio of 0.8 appears to the best advantage with 12.65% fine particles at 4# per sack. When the admix is added to 0% and 20% fine particle sand it gives practically the same effect up to a maximum of 4# per sack, the 0% sand past 4# then shows a smaller rate at decrease in strength.

At 28 days the max increase in strength is obtained with 12.65% sand past 48 at 3# per sack and at 6# per sack for 0% past 48, the mixes with 20% fine particles also show an increase up to 3# per sack. The maximum increase, by use of the admix, in strength at 28 days for 0% past 48 is 21%; for 12.65%, 17% and for 20%, 13%; therefore it would seem to be used to the best advantage in mixes with the sand containing no particles past a 48 mesh.

At 7 days, with an effective water cement ratio of 0.8, the addition of the admix to sands containing 0% and 12.65% fine particles appear to give about the same results in strength with a maximum of 2# per sack. The mixes containing 20% sand past 48 are decreased in strength by any addition of the admix and in proportion to the amount added. At 28 days a 0% and 20% sands past 48 give very nearly the same results with a maximum strength at 4# per sack; the mixes containing 12.65% past 48 mesh give a maximum strength at 2# per sack. The increase in strength by the addition of the admix is for 0% sand past 48, 13%; for 12.65%, 9% and for 20%, 15%; therefore it would seem to be advantageous to use the admix in all mixes for added strength but would be of greatest benefit when used with 20% past 48.

From the tabulated data for mortars on percent 28 day strength at 7 days it appears that the addition of the admix has no particularly consistent effect, however it is readily seen that the low water cement ratios give a considerably greater ratio of strength at 7 days, than when the ratio is as high as 1.0. The greatest variation appears at an effective water cement ratio of 0.8 where the average with 10% fine particles is 72.8% and with 25% sand past 48 mesh it is 60.9%. The highest 28 day strength at 7 days was obtained with a water cement ratio of 0.435, a very dry mix, it averaging 85%.

For concretes there appears at the water cement ratio of 0.8 to be no consistent variation in 28 day strength at 7 days but at the effective ratio of 0.8 the variation as shown by a graph can without great error be said to be in inverse proportion to the amount of added admix.

From careful comparisons of the results on mortars and concrete at the water cement ratio of 0.8 and the effective ratio of 0.8 there appear to be no predictions possible from compressive tests on mortars as to what amount of admix should be used in the concrete mixes nor as to the added strength which the admix might be expected to produce.

While it was thought that diatomaceous silica would have a greater effect on the strength of mixes containing a small percent of fine particles than it would on mixes containing a relatively large percent sand passing a 48 mesh, the results as obtained on the compressive tests on mortars where the entire practical range of water cement ratios were used and with sands varying from 0% to 25% past a 48 mesh; it appears that when there is enough water to insure workability that practically the same increase in strength may be expected with sands either low or high in fine particles. Maximum increased strength for mortars was 35% but as this was in a very wet mix with 6# admix per sack it was in part accounted for by the absorption of water by the admix and the consequent lowering of the real water cement ratio. It is thought that the most logical comparison is on the effective water cement ratio of 0.8 and the maximum increase was found to be 20%.

On the concrete tests with a water cement ratio of 0.8 it also appears, as in mortars that about the same increase in strength obtains with a relatively low or high percent of fine particles in the mix, the same can be said with an effective ratio of 0.8, the maximum increase of this ratio being 15%. With the ratio of 0.8 the maximum was 21%. Although it is probably not correct, due to the admix absorbing water, in the following discussion of costs the admix will be favored and taken as giving a maximum increase in strength of 21% rather than 15%.

The cost of diatomaceous silica in this locality being about 15¢ per pound and cement in quantities 0.6¢ per pound, it is seen that for the same outlay 25# of cement could be added in the place of each pound of diatomaceous silica. The maximum increase of 20% in mortars and 21% in concrete occurred with 4# diatomaceous silica per sack of cement and at this amount leaving out the admix and adding cement the mix could have been in the case of concrete 1-1-2 instead of 1-2-4 at practically the same cost, for mortars 1-1.5 instead of 1-3. When combined in the proportions 2-4 the weight of the mixed aggregate was found to be 126.5# per cu.ft., and the fineness modulus of the combined aggregate is by calculation 5.53. The 1-2-4 mix with aggregates used is equivalent to a real mix of 1-5.05. The real mix for the 1-1-2 mix is 1-2.52. From Bulletin No.1, by Prof. Abrams, issued by the Structual Materials Research Laboratory; Fig 6, page 17, the graph shows an expected 28 day strength for the 1-2-4 mix of 3200# per sq.in. and for the 1-1-2 mix a strength of 4700# per sq.in; by doubling the cement an increase of 68% might be expected. Suppose that an increase of only 50% be made in the cement, the mix is 1-1.33-2.66 with an equivalent real mix of 1-3.36; the expected strength would be 4000#

per sq.in. at 28 days which is an increase of 20% over the original 1-2-4 mix.

It would seem that half the cost of diatomaceous silica when expended for cement would give the same additional strength considering the admix to produce a maximum of around 20% increase at 28 days.

Conclusion

The analysis of results obtained leads to the conclusion that the yield is increased by the addition of a diatomaceous silica admix by only the absolute volume of the added material when the mix is readily workable.

The variations of strength as obtained for both mortars and concrete appear to be independent of the variation of the percent of fine particles in the sand; thus disproving the original idea that the increase would show greater for the mixes containing sands relatively low in fine particles.

Considering the cost for obtaining additional strength in concrete by the use of diatomaceous silica; it is shown that half of the cost if expended for cement would produce approximately the same results, considering the admix to give a maximum increase of 20% at 28 days. This must not be interpreted as meaning that for half the additional cost the same results could be obtained with added cement as workability, imperviousness to water and prevention of segregation have their place and were not checked in these experiments.

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Respectfully submitted,

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