A STUDY OF THE EFFECT OF MOISTURE

on the

CURING OF CEMENT

By

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For

Massachusetts Institute of Technology

May 15, 1935

Cambridge, Mass.

May 15, 1935

Mr. George W. Swett, S. B.
Secretary of the Faculty
Mass. Institute of Technology
Cambridge, Massachusetts

Dear Sir:

In partial fulfilment of the requirements for a degree of Batchelor of Science in Civil Engineering we submit this thesis entitled, "A Study of the Effect of Moisture on the Curing of Cement" for your approval.

Yours very truly,

Signature redacted

Lorin A. Presby

Signature redacted

Francis W. Muldowney, Jr.

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A STUDY OF THE EFFECT OF MOISTURE
on the
CURING OF CEMENT

Purpose of Thesis

The purpose of this thesis is to investigate the effect of moisture on the curing of cement. The investigation was made by comparing the age-strength relation of cement for several water-cement ratios cured under varying moisture conditions.

Scope of Investigation

The investigation was divided into three parts. First, the age-strength relation was determined for a number of water-cement ratios, ranging from the driest neat mix that could be molded to a mortar which contained so little cement that its strength was too low for consideration. These specimens were sealed in cans so that no change in moisture could take place, for the purpose of providing some data as to the amount of water required for the hydration of portland cement when no additional water can be obtained after the mixing.

It is well known that higher strength is obtained with lower water-cement ratios because of the lesser dilution, but at the same time, appreciable water is required for complete hydration of the cement. Therefore, in order to determine the amount of water necessary for hydration, cylinders of the lower water-cement ratios were opened

after twenty-four hours and additional water was added. Compressive tests of these specimens were made for comparison with tests on specimens not given extra water.

Hydrated cement consists largely of gel which is similar to glue. The hardness of this gel varies with the amount of water absorbed or held by it. In order to demonstrate this variation and to attempt to determine its extent, the cans were stripped from a number of specimens of each water-cement ratio at the age of twenty-eight days and some were immersed in water while others were waterproofed on the sides and placed in the fifty per cent relative humidity room to dry slowly. Compression tests were also made on these specimens to compare with those left sealed. In addition, the amount of change in moisture content was determined by weighing the specimens at frequent intervals.

Methods of Test

In part one, compressive tests were made at four ages--three, seven, twenty-eight and ninety days--four specimens being tested at each age and for each water-cement ratio. The specimens were cast in cylindrical cans three inches in diameter and three inches deep, and were sealed with paraffin so that no moisture might be taken from the air. The cans were left intact until just before testing. The cylinders were then stripped, the ends capped with plaster of Paris, and compression tests made on a hydraulic testing machine.

Neat cement specimens were made for water-cement ratios of 25%, 30%, and 40% by weight, a 25% mix being the driest which could be molded and packed. In order to extend the range of water-cement ratios mortar specimens, containing standard Ottawa sand, were also made. The first set was made by mixing a slurry of neat cement having a water-cement ratio of 40% and adding so much standard Ottawa sand as possible without making the mix too dry to place in cans. This mix contained three and one half parts of sand to one part of cement by weight. The next mix contained the same amount of sand and cement but the water-cement ratio was increased to 50%. The final mix was made by adding standard sand to a slurry of neat cement with a water-cement ratio of 50% until the mix was as dry as it was possible to mold.

Thus, specimens were tested ranging in water-cement ratio from 25% to 50% by weight, and, since the specimens were sealed, they cured without acquiring additional moisture.

In order to study the amount of water required for complete hydration, neat specimens were cast having water-cement ratios of 25% and 30%. After twenty-four hours, the cylinders were opened and enough water added to bring the ratio up to 40%. The covers were then replaced and sealed and the specimens allowed to cure for tests at twenty-eight and ninety days to compare with the tests on specimens not given extra water.

For the purpose of investigating the variation of the hardness of the gel of the hydrated cement with the amount of moisture absorbed by it, specimens were made for each of the water-cement ratios of part one, and, at the end of twenty-eight days, these cylinders were stripped, some being immersed in water and others being coated on the sides with waterproof paint and placed in the 50% relative humidity room for the remainder of the curing period. Four specimens from each group and each water-cement ratio were tested at the age of ninety days for comparison with the specimens left sealed. These specimens were weighed at three and seven days after they had been stripped, weekly thereafter for four weeks and finally at ninety days, so that a record of the change in moisture content could be obtained for the two conditions of curing.

TABULATION OF RESULTS

AGE-STRENGTH RELATION

NEBRASKA NORMAL CEMENT

Mix	3 Days	7 Days	28 Days	3 Months
W/C=25% neat				
Sealed	5640	7070	5100	6580
Water added			4580	4110
Dry room				5100
Under Water				4020
W/C=30% neat				
Sealed	4740	5860	6270	7060
Water added			5780	5510
Dry room				7070
Under water				7550
W/C=40% neat				
Sealed	3870	5390	4830*	8850
Dry room				8850
Under Water				7720
W/C=40% sand 3½:1				
Sealed	1390	1720	2220	2220
Dry room				2740
Under water				1680
W/C=50% sand 3½:1				
Sealed	1080	1480	2020	2380
Dry room				2300
Under water				2770
W/C=50% sand 5½:1				
Sealed	410	685	851	950
Dry room				840
Under Water				1080

*See Discussion of Results

AGE-STRENGTH RELATION

P. C. A. CEMENT

Mix	3 Days	7 Days	28 Days	3 Months
W/C=40% neat				
Sealed	3560	4860	6650	8980
Dry room				8550
Under water				7660
W/C=40% sand $3\frac{1}{2}$:1				
Sealed	800	954	1200	1750
Dry room				1950
Under water				1420

NEBRASKA PLAIN CEMENT

Special Tests

Mix	7 Days	28 Days
W/C=25% neat		
Capped in open air	7400	4960
Capped under burlap	5450	6270
W/C=40% neat		
Capped in open air	5700	5490
Capped under burlap	4910	8750

FREE WATER IN CYLINDERS

40% neat

NEBRASKA PLAIN CEMENT

Time	Total Weight	Weight of Spec.	Free H_2O	Original H_2O	% Free H_2O
3 Days	901	884	17	257	6.6
7 Days	903	888	15	258	5.8
28 Days	924	919	5	264	1.9
3 Months	924	907	17	264	6.4

40% neat

P. C. A. CEMENT

Time	Total Weight	Weight of Spec.	Free H_2O	Original H_2O	% Free H_2O
3 Days	930	910	20	266	7.5
7 Days	933	914	19	266	7.1
28 Days	937	916	21	268	7.8
3 Months	920	900	19	263	7.4

CHANGE IN MOISTURE CONTENT OF SPECIMENS
IN PERCENTAGE OF ORIGINAL WATER

CURED IN DRY ROOM AFTER 28 DAYS

W/C	Loss at 31 days	Loss at 35 days	Loss at 42 days	Loss at 49 days	Loss at 56 days	Loss at 90 days
25% neat	1.35	1.93	2.88	3.60	4.18	16.55
30% neat	0.97	1.67	2.78	3.66	4.44	15.70
40% neat	2.58	3.71	5.27	6.40	7.50	18.20
40% sand 3½:1		9.68	13.5	16.3	18.0	22.1
50% sand 3½:1		10.8	15.6	19.4	21.4	28.1
50% sand 5½:1		21.0	26.0	29.2	29.8	30.8

CURED UNDER WATER AFTER 28 DAYS

W/C	Gain at 31 days	Gain at 35 days	Gain at 42 days	Gain at 49 days	Gain at 56 days	Gain at 90 days
25% neat	9.74	10.5	10.9	11.1	11.5	1.48
30% neat	3.21	3.44	4.08	4.27	4.68	-3.72
40% neat	0.76	0.64	0.84	0.88	1.16	-6.28
40% sand 3½:1		54.5	55.9	53.2	50.3	45.9
50% sand 3½:1		13.6	14.1	14.1	15.9	18.9
50% sand 5½:1		100.5	101.8	104.7	105.0	110.0

Discussion of Results

The accompanying tables include the results of the laboratory investigations made for the purpose of studying the effect of moisture on neat cement and mortars. These results fall into two general classifications: (1) age-strength relation and (2) change in moisture content. The age-strength relation has been used as a basis for comparison of the six mixes studied.

The wide variation in the strengths of the four specimens used in computing the averages for each age shows the need for a greater number of samples if a more detailed investigation were to be made. One possible source of error lies in the use of plaster caps. The high strength and rough surfaces of the specimens combined with the plasticity and lower strength of the plaster of Paris is liable to cause uneven bearing and hence distort the compressive strengths. It was not feasible to use cement caps due to the length of time required for hardening. However, sulphur-cement or plaster of Paris-cement caps might have been used more satisfactorily. It was also found that a careful control of temperature and moisture conditions should be kept during the period of capping and breaking the cylinders as well as during the mixing. This fact can be shown from the results of special tests made for that purpose.

Because of questionable results obtained from the 28 day compressive tests on the neat mixes of 25% and 40% water-cement ratios, it seemed advisable to make a study of the effect of the atmospheric conditions during the capping and breaking period. As it was impossible to regulate the room conditions conveniently, some specimens were capped under wet burlap which tended to maintain high relative humidity and a slightly lower temperature, while others were exposed to the extremely low humidity and high temperature of the laboratory. The capping period for those cylinders which were left in the open air was made about twice as long as was normally used in order to exaggerate the results. It was found that changes in the conditions of temperature and humidity caused wide variations in the compressive strength. The strengths obtained from these extra tests indicate that a value of 7000 to 8000 pounds per square inch for the 28 day compressive strength of the neat mix of 40% water-cement ratio is more nearly correct than the 4830 pounds per square inch found in the regular tests. It should be understood for all of these tests that while the figures may not represent the absolute strengths of the cement, it is believed that they are relatively correct.

In accordance with general belief, the tests indicate that the highest early strengths (3 and 7 day) are obtained with the lower water-cement ratios. However, up to

a water-cement ratio of 40%, the strength at 28 and 90 days increases with water-cement ratio. These specimens were cast and sealed in the cans with no attempt to prevent segregation.

This maximum water-cement ratio was actually something less than 40% as evidenced by the free water in the sealed cans caused by segregation of material. It was noticed that this free water, although greatly reduced at 28 days, increased to practically the original amount at 90 days. This phenomenon was again observed, but to a lesser extent, in the cylinders of low water-cement ratio to which water was added after 24 hours.

The effect of this added water on the strength of the specimens of 25% water-cement ratio was the same as that of curing the specimens under water after 28 days tending to reduce substantially the strength in both instances. In the case of the neat mix of 30% water-cement ratio, the specimens to which water was added were slightly weaker than those cured under water, but neither value was greatly different from that obtained for the sealed specimens. The strength of the mortars cured under water, with the exception of the 3½ to 1 mix of 40% water-cement ratio, was increased over that of the sealed specimens. The strength of these 40% mortar specimens was greatly reduced. It was

noticed that these cylinders were losing weight under water which was attributed to the dissolving of the calcium compounds in the cement, although no chemical analysis was made. Curing under water also tends to soften the gel. This, of course, would tend to weaken the sample.

The placing of the cylinders in the 50% relative humidity room after 28 days had little effect on the strength of the specimens, except for the neat mix of 25% water-cement ratio and the 5½ to 1 mix of 50% water-cement ratio. In these mixes it caused a decrease in strength due to the fact that the drying prevented complete hydration. The low porosity of the mixes investigated made it impossible for sufficient drying to take place to hinder the hydration of the other specimens.

Conclusions

With the foregoing discussion in mind, it is believed that the following conclusions can be drawn from this investigation.

1. The highest early strengths can be obtained from neat mixes of low water-cement ratio.

2. The strength at 28 and 90 days increases with water-cement ratio up to a water-cement ratio of 40% when segregation is not prevented.

3. The addition of water to the cylinders of low water-cement ratio after 24 hours tends to weaken the specimen.

4. The curing of these mixes under water after 28 days allows the soluble compounds in the cement to be dissolved and the gel to be softened, thereby lowering the strength.

5. The dense nature of the mixes used in this investigation was such that drying had little effect on the strength at 90 days.

APPENDIX A

(Data)

COMPRESSIVE STRENGTHS
of
NEBRASKA NORMAL CEMENT

W/C-25% neat lb/sq.in.	W/C-30% neat lb/sq.in.	W/C-40% neat lb/sq.in.	W/C-40% sand-3½:1 lb/sq.in.	W/C-50% sand-3½:1 lb/sq.in.	W/C-50% sand-5½:1 lb/sq.in.
		Three day tests"			
6890	5060	3880	1435	1110	434
5100	4340	4820*	1300	1085	398
5400	3920	3780	1410	1192	366
5150 5640	5490 4740	3960 3870	1387 1390	916 1080	436 410
		Seven day tests"			
6550	7170	5950	1760	1482	860
7290	5780	5450	1508	1845	796
7470	5780	5300	1677	1190	556
6990 7070	4700 5860	4860 5390	1965 1720	1470 1480	535 685
		Twenty-eight day tests"			
6700	6390	5040	2150	2060	916
5140	6390	3980	1828	1940	825
4280	5950	4470	2290	2200	812
4310 5100	6390 6270	5850 4830	2620 2220	1870 2020	1045* 851
Specimens to which water was added up to W/C=40%					
6670	6700				
4700	4950				
2650	4660				
4290 4580	6770 5780				
		Three month tests"			
7650	6250	8500	2020	2130	1110
7650	7090	4820*	2080	2340	1000
4820	6150	8750	2390	2560	816
6200 6580	8750 7060	9310 8850	2380 2220	2470 2380	890 950
Specimens cured in dry room after 28 days (R.H.=50%)					
5060	6900	9060	2800	2140	927
6080	6580	9430	2370	2890	686
4410	7230	8070	2760	1760	964
4820 5100	7760 7070	7230*8850	3030 2740	2410 2300	783 840
Specimens cured under water after 28 days					
3700	7500	6990	1120*	2590	1445
3780	7140	8310	1585	2880	1460
1690*	5930*	5950*	1785	2830	699
4600 4020	8010 7550	7850 7720	1670 1680	2770 2770	711 1080
Specimens to which water was added up to W/C=40%					
8080*	5040				
3730	8200*				
4380	6500				
4210 4110	5000 5510				

"Specimens were sealed in cans until time of testing unless otherwise noted.
*Specimen omitted in computing average.

COMPRESSIVE STRENGTHS

of

P. C. A. CEMENT

Three day	Seven day	28 day	Ninety days		
sealed	sealed	sealed	sealed	dry room	in water
		W/C-40% neat			
3760	4510	6600	9340	7900	6390
3920	5460	7090	8740	9100	8850
3540	4960	5770	8850	8670	7410
3130 3560	4470 4860	7140 6650	----*8980	8550 8550	8010 7660
		W/C-40% - sand, $3\frac{1}{2}$:1			
659	1025	1930*	1680	2360	1510
948	880	1210	1950	2230	1360
871	1065	1190	1760	1690	1385
723 800	843 954	1130*1200	1590 1750	1530 1950	1095*1420

*Specimen omitted in computing average.

COMPRESSIVE STRENGTHS
of
NEBRASKA NORMAL CEMENT

W/C-25% neat		W/C-40% neat	
capped in air lb/sq. in.	capped under burlap lb/sq. in.	capped in air lb/sq. in.	capped under burlap lb/sq. in.
	Seven day tests		
7350	5840	5300	5600
7230	5120	5540	6150*
7650	5360	6080	4700
6080* 7400	7100* 5450	5840 5700	4460 4910
	Twenty-eight day tests		
4820	5600	4880	8800
7700*	6930	4460	8900
4760	6450	6560	5540*
5300 4960	5960 6270	6030 5490	8530 8750

*Specimen omitted in computing average.

FREE WATER IN CYLINDERS AT TIME OF TESTS

W/C-40% neat

Nebraska Normal Cement						P. C. A. Cement					
Total weight grams		Wgt. of specimen grams		Free water grams		Total weight grams		Wgt. of specimen grams		Free water grams	
Three days						Three days					
934		916		18		955		940		15	
912		890		22		935		915		20	
934		920		14		915		895		20	
823	901	810	884	13	17	915	930	890	910	25	20
Seven days						Seven days					
925		905		20		945		925		20	
905		885		20		930		915		15	
900		890		10		945		930		15	
880	903	870	888	10	15	910	933	885	914	25	19
Twenty-eight days						Twenty-eight days					
893*		877*		16*		965		948		17	
915		907		8		948		935		13	
933		929		4		925		895		30	
924	924	920	919	4	5	910	937	885	916	25	21
Three months						Three months					
955*		922*		33*		958		940		18	
913		900		13		937		916		21	
895		892		3		897		881		16	
933	914	915	902	18	12	888	920	865	900	23	20

*Specimen omitted in computing average.

SPECIMENS TO WHICH WATER WAS ADDED UP TO W/C OF 40% AFTER 24 HOURS

NEBRASKA NORMAL CEMENT

Twenty-four Hours			Twenty-eight days			Ninety Days		
Wgt. of sample	Water added	Total weight	Total weight	Wgt. of sample	Free water	Total weight	Wgt. of sample	Free water
			W/C-25% neat					
1065	128	1193	1201	1085	116			
1060	127	1187	1194	1082	114			
960	115	1075	1088	991	97			
945	113	1058	1067	968	99			
1008*	121*	1129*	1139*	1032*	107*			
1065	128	1193				1192	1073	119
1010	121	1131				1122	1019	103
1050	126	1176				1181	1061	120
1010	121	1131				1148	1019	129
1034*	124*	1158*				1161*	1043*	118*
			W/C-30% neat					
950	73	1023	1031	974	57			
975	75	1050	1055	991	64			
910	70	980	991	932	59			
1050	81	1131	1143	1078	65			
971*	75*	1046*	1055*	994*	61*			
995	77	1072				1067	1007	60
1125	87	1212				1209	1146	63
1000	77	1077				1077	1010	67
1020	78	1098				1097	1032	65
1035*	80*	1115*				1110*	1049*	64*

*Average of four specimens.

CHANGE IN MOISTURE CONTENT

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
			W/C-25% neat				
			Twenty-eight days				
985.3				937.5			
944.5				900.8			
932.5				941.6			
966.0				858.0			
957.1				909.5			
			Thirty-one days				
982.7	2.6			951.1	13.6*		
943.0	1.5*			917.9	17.1		
930.0	2.5			959.1	17.5		
963.4	2.6			876.5	18.5		
	2.6	2.6	1.36		17.7	17.7	9.74
			Thirty-five days				
980.4	2.3			952.8	1.7		
941.9	1.1			919.2	1.3		
928.9	1.1			960.3	1.2		
963.3	0.1			876.5	0.0*		
	1.1	3.7	1.93		1.4	19.1	10.5
			Forty-two days				
979.4	1.0			953.4	0.6		
940.2	1.7			919.9	0.7		
926.6	2.3			961.1	0.8		
961.2	2.1			878.2	1.7*		
	1.8	5.5	2.88		0.7	19.8	10.9

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
			W/C-25% neat (cont.)				
			Forty-nine days				
977.7	1.7			954.3	0.9		
938.9	1.3			919.5	0.4		
925.1	1.5			961.2	0.1		
960.2	1.0			878.2	0.0		
	1.4	6.9	3.60		0.3	20.1	11.1
			Fifty-six days				
977.2	0.5			954.9	0.6		
938.0	0.9			920.5	1.0		
923.5	1.6			961.8	0.6		
958.6	1.6			879.1	0.9		
	1.1	8.0	4.18		0.8	20.9	11.5
			Ninety days				
953.3	23.9			936.4	-18.5		
914.3	23.7			902.6	-17.9		
899.8	23.7			944.0	-17.8		
935.4	23.2			860.7	-18.4		
	23.6	31.6	16.55		-18.2	2.7	1.48

*Specimen omitted in computing average.

CHANGE IN MOISTURE CONTENT

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
			W/C-30% neat				
			Twenty-eight days				
949.1				896.2			
940.4				877.9			
941.6				926.8			
900.7				1007.2			
933.0				927.0			
			Thirty-one days				
947.2	1.9			907.3	11.1		
938.3	2.1			881.5	3.6		
939.1	2.5			936.3	9.5		
898.7	2.0			1011.1	3.9		
	2.1	2.1	0.97		7.0	7.0	3.21
			Thirty-five days				
944.9	2.3			908.8	1.5		
936.8	1.5			881.3	-0.2		
938.0	1.1			937.2	0.9		
897.4	1.3			1010.7	-0.4		
	1.5	3.6	1.67		0.5	7.5	3.44
			Forty-two days				
943.1	1.8			909.9	1.1		
934.5	2.3			883.2	1.9		
935.4	2.6			938.9	1.7		
895.0	2.7			1011.7	1.0		
	2.4	6.0	2.78		1.4	8.9	4.08

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
			W/C-30% neat (cont.)				
			Forty-nine days				
941.2	1.9			909.9	0.0		
932.8	1.7			883.5	0.3		
933.3	2.1			939.3	0.4		
892.9	2.1			1012.8	1.1		
	1.9	7.9	3.66		0.4	9.3	4.27
			Fifty-six days				
939.6	1.6			910.9	1.0		
931.2	1.6			884.3	0.8		
931.5	1.8			940.0	0.7		
890.9	2.0			1014.0	1.2		
	1.7	9.6	4.44		0.9	10.2	4.68
			Ninety days				
915.2	24.4			891.8	19.1		
907.4	23.8			866.7	17.6		
906.5	25.0			921.8	18.2		
866.9	24.0			995.7	18.3		
	24.3	33.9	15.70		18.3	-8.1	-3.72

CHANGE IN MOISTURE CONTENT

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
			W/C-40% neat				
			Twenty-eight days				
866.0				868.6			
926.5				851.0			
967.1				915.4			
930.0				860.0			
897.4				873.8			
			Thirty-one days				
860.5	5.5			870.0	1.4		
920.0	6.5			851.8	0.8		
860.2	6.9			918.8	3.4		
922.5	7.5			861.9	1.9		
	6.6	6.6	2.58		1.9	1.9	0.76
			Thirty-five days				
857.7	2.8			869.5	-0.5		
917.6	2.4			851.4	-0.4		
856.4	3.8			919.2	0.4		
919.8	2.7			861.7	-0.2		
	2.9	9.5	3.71		-0.3	1.6	0.64
			Forty-two days				
854.2	3.5			870.0	0.5		
913.2	4.2			851.8	0.4		
852.4	4.0			919.7	0.5		
915.5	4.3			862.2	0.5		
	4.0	13.5	5.27		0.5	2.1	0.84

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
			W/C-40% neat (cont.)				
			Forty-nine days				
851.4	2.8			870.0	0.0		
910.2	3.0			851.9	0.1		
849.6	2.8			920.0	0.3		
912.4	3.1			862.3	0.1		
	2.9	16.4	6.40		0.1	2.2	0.88
			Fifty-six Days				
848.8	2.6			870.7	0.7		
907.3	2.9			852.4	0.5		
846.4	3.2			920.6	0.6		
909.7	2.7			863.4	1.1		
	2.8	19.2	7.50		0.7	2.9	1.16
			Ninety days				
822.0	26.8			852.0	-18.7		
880.7	26.6			833.8	-18.6		
818.6	27.8			902.1	-18.5		
881.5	28.2			843.9	-19.5		
	27.4	46.6	18.20		-18.6	-15.7	-6.28

CHANGE IN MOISTURE CONTENT

cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
		W/C-40% - sand 3½:1					
		Twenty-eight days					
935.7				905.5			
947.8				950.0			
902.6				932.6			
913.2				902.0			
924.8				922.5			
		Thirty-five days					
928.3	7.4			948.3	42.8		
940.2	7.6			991.2	41.2		
895.1	7.5			973.0	40.4		
906.7	6.5			942.0	40.0		
	7.3	7.3	9.68		41.1	41.1	54.5
		Forty-two days					
925.3	3.0			949.2	0.9		
937.6	2.6			991.9	0.7		
892.2	2.9			974.2	1.2		
903.7	3.0			943.6	1.6		
	2.9	10.2	13.5		1.1	42.2	55.9
		Forty-nine days					
923.1	2.2			946.4	-2.8		
935.0	2.6			988.7	-3.2		
890.2	2.0			973.1	-1.1		
902.1	1.6			942.2	-1.4		
	2.1	12.3	16.3		-2.1	40.1	53.2

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total loss	% loss
		W/C-40% - sand 3½:1 (cont.)					
			Fifty-six days				
921.8	1.3			944.4	-2.0		
933.9	1.1			986.5	-2.2		
889.3	0.9			971.4	-1.7		
900.0	2.1			939.1	-3.1		
	1.3	13.6	18.0		-2.2	37.9	50.3
			Ninety days				
918.7	3.1			947.6	-3.2		
930.5	3.4			989.3	-2.8		
886.5	2.8			974.2	-2.8		
897.0	3.0			943.5	-4.4		
..	3.1	16.7	22.1		-3.3	34.6	45.9

CHANGE IN MOISTURE CONTENT

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
		W/C-40% - sand 3½:1					
		Twenty-eight days					
855.9				884.5			
900.7				868.9			
872.8				849.2			
943.6				906.6			
893.2				877.3			
Thirty-one days					Thirty days		
853.0	2.9			935.3	50.8		
898.1	2.6			936.8	67.9		
869.9	2.9			924.1	74.9		
941.3	2.3			962.0	55.4		
	2.7	2.7	4.23		62.2	62.2	86.9
		Thirty-three days					
851.4	1.6			929.9	-5.4		
897.3	0.8			929.5	-7.3		
868.8	1.1			914.5	-9.6		
940.3	1.0			953.4	-8.6		
	1.1	3.8	5.95		-7.7	54.5	76.1
		Thirty-five days					
851.1	0.3			929.6	-0.3		
896.3	1.0			927.3	-2.2		
868.0	0.8			908.6	-5.9		
940.0	0.3			950.6	-2.8		
	0.6	4.4	6.90		-2.8	51.7	72.2

CHANGE IN MOISTURE CONTENT

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
		W/C-50% - sand $3\frac{1}{2}$:1					
		Twenty-eight days					
985.0				973.6			
998.4				935.2			
977.5				980.0			
1002.4				951.8			
990.8				960.2			
		Thirty-five days					
971.1	13.9			990.3	16.7		
988.7	9.7			951.7	16.5		
966.7	10.8			989.2	9.2		
994.0	8.4			961.7	9.9		
	10.7	10.7	10.8		13.1	13.1	13.6
		Forty-two days					
965.7	5.4			990.7	0.4		
984.2	4.5			951.5	-0.2		
962.2	4.5			989.3	0.1		
989.7	4.3			962.7	1.0		
	4.7	15.4	15.6		0.4	13.5	14.1
		Forty-nine days					
961.6	4.1			990.4	-0.3		
980.5	3.7			951.5	0.0		
958.1	4.1			989.3	0.0		
986.4	3.3			963.0	0.3		
	3.8	19.2	19.4		0.0	13.5	14.1

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
		W/C-50% - sand 3½:1 (cont.)					
			Fifty-six days				
959.4	2.2			992.0	2.0		
979.0	1.5			954.0	2.5		
956.0	2.1			990.5	1.2		
984.1	2.3			964.6	1.6		
	2.0	21.2	21.4		1.8	15.3	15.9
			Ninety days				
953.2	6.2			994.7	2.7		
972.0	7.0			956.1	2.1		
949.5	6.5			994.1	3.6		
977.5	6.6			967.8	3.2		
	6.6	27.8	28.1		2.9	18.2	18.9

CHANGE IN MOISTURE CONTENT

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
		W/C-50% - sand 5½:1					
		Twenty-eight days					
829.7				834.5			
822.6				812.0			
821.8				818.6			
822.4				841.8			
824.1				826.7			
		Thirty-five days					
816.8	12.9			898.2	63.7		
810.3	12.3			867.7	55.7		
809.5	12.3			881.8	63.2		
810.3	12.1			896.6	54.8		
	12.4	12.4	21.0		59.4	59.4	100.5
		Forty-two days					
813.7	3.1			893.4	-4.8*		
807.5	2.8			868.7	1.0		
806.6	2.9			882.5	0.7		
807.4	2.9			897.0	0.4		
	2.9	15.3	26.0		0.7	60.1	101.8
		Forty-nine days					
812.0	1.7			894.0	0.6		
805.5	2.0			871.2	2.5		
804.8	1.8			884.2	1.7		
805.2	2.2			899.4	2.4		
	1.9	17.2	29.2		1.8	61.9	104.7

Cured in dry room				Cured under water			
Weight grams	Loss grams	Total loss	% loss	Weight grams	Gain grams	Total gain	% gain
		W/C-50% - sand 5½:1 (cont.)					
			Fifty-six days				
811.7	0.3			894.6	0.6		
805.6	-0.1*			872.3	1.1		
804.6	0.2			883.3	-0.9		
804.7	0.5			899.2	-0.2		
	0.3	17.5	29.8		0.2	62.1	105.0
			Ninety days				
811.2	0.5			897.4	2.8		
804.6	1.0			875.1	2.8		
804.4	0.2			886.2	2.9		
803.9	0.8			902.6	3.4		
	0.6	18.1	30.8		3.0	65.1	110.0

*Specimen omitted in computing average.