H. R. PRICE

AN EXPERIMENTAL STUDY OF THE EFFECT ON CONCRETE OF HEATING AGGREGATES TO HIGH TEMPERATURES

THESIS FOR THE DEGREE OF B. S.

H. R. Price

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Concrete

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An Experimental Study of the Effect on Concrete of Heating Aggregates to High Temperatures

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H. R. Price

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Introduction

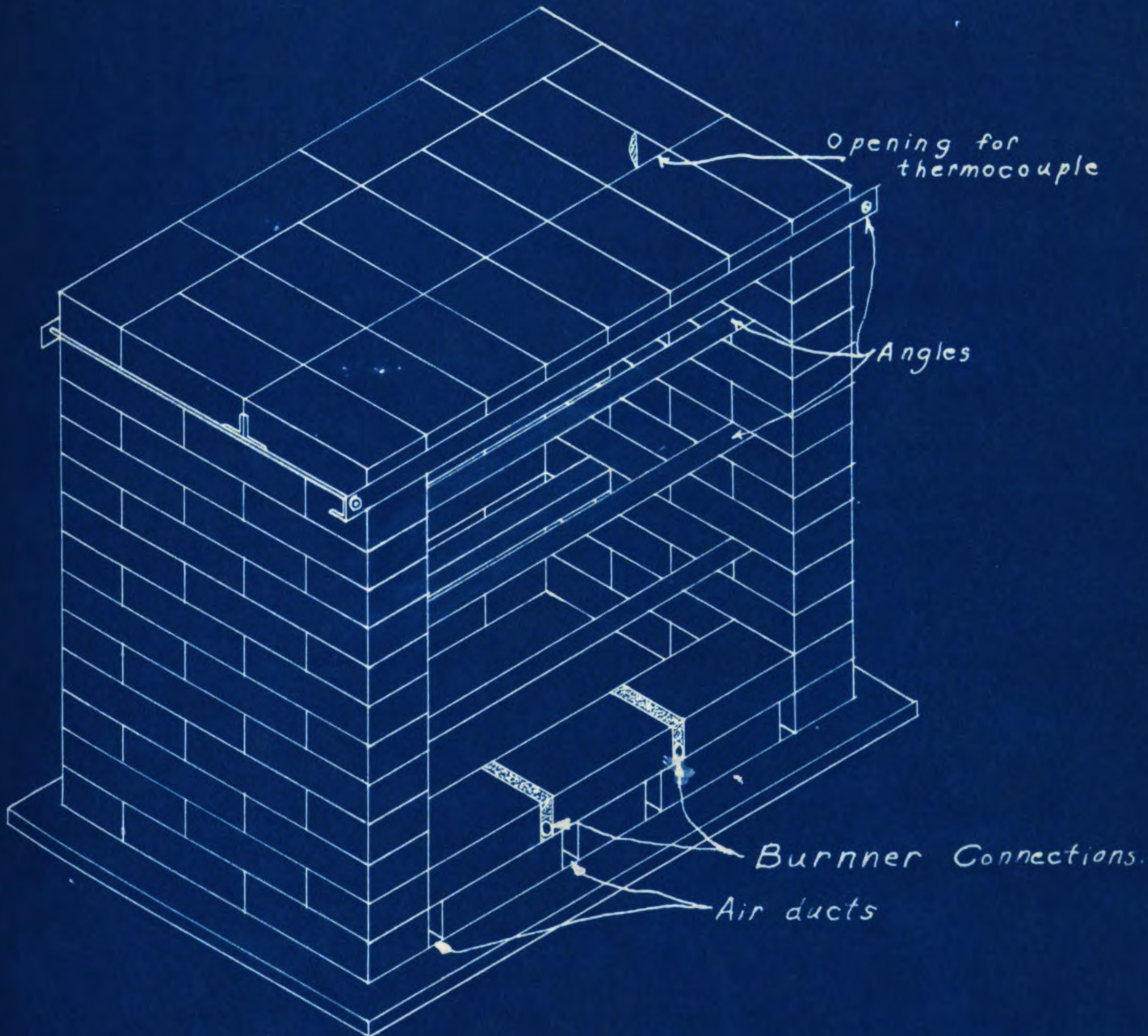
During the last few years there has been more and more winter construction taking place. There have been various methods of heating aggregates for this winter construction, some of which heat the aggregate in the near vicinity of the heating elements to a very high temperature. There have been no extensive experiments to determine the effect of this heating to a high temperature on the strength of the finished concrete. The purpose of these experiments was to determine the effect, if any, of this heating on the strength of the finished concrete.

Test Specimens

The concrete used in the specimens was designed for a strength of fifteen pounds per square inch according to the water cement ratio theory. The sand used was a graded clean sand with a grading between 0" and 1/4" and with a fineness modulus of 1.99. The course aggregate used was made up by mixing 3/4" and 1/2" stone in equal parts, which gave a fineness modulus of 7.54. The mixing for the cylinders was done in a mixing pan by hand. The mixing for the beams was done in a 2 1/2 cubic foot Smith mixer. Curve "A" was used in the design of the mix. Each batch was tested for slump, and a consistancy of 5" to 6" slump was maintained.

The molds for the beams were made from 8" channel sections to give a beam 6" x 8" x 36" beam. This was long enough to give two breaks on each beam. The beams were broken with the 8" side vertical. One break was made with the top as poured and the other with the top down. This method of breaking would tend to eliminate any irregularity that might be due to segregation or variation in the concrete in the beam. The cylinders were the standard cylinders, 6" in diameter and 12" high.

All of the beams and cylinders were cured in the moist curing room. All of the beams were cured for seven days only, and part of the cylinders were cured for seven days, the rest of them being cured for twenty eight days. Before breaking the test pieces were allowed to dry for a few hours and then brushed clean. The cylinders were capped on both ends in a capping machine with leadite to insure an even bearing over the whole surface. An Olson Universal Testing Machine of 150,000 pounds capacity was used. The beams were fastened in place between the steel plates of the testing machine that was built as part of a thesis in 1930.



Oven with door removed

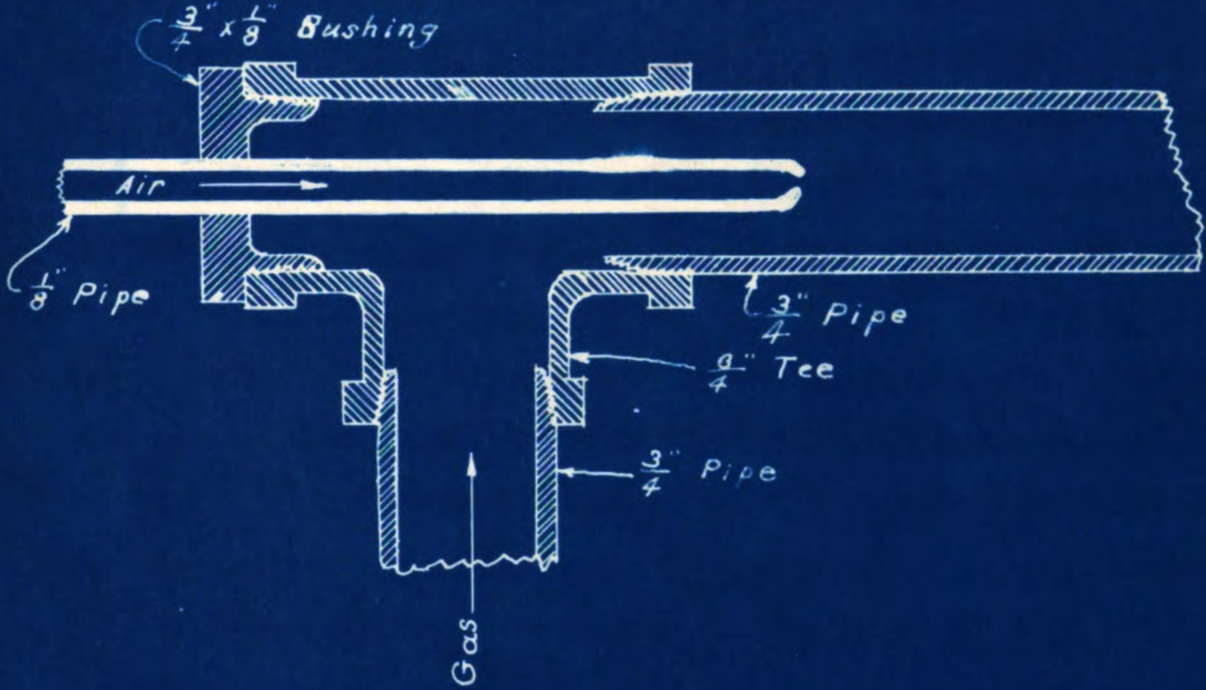
The Oven

The oven that was used for heating the aggregates was built according to the enclosed drawing. It is composed of fire brick laid up with small angles imbedded in the brick at intervals to support the pans in which the aggregates were placed for heating. The inside dimensions of the oven were 18" x 27" x 30" with the angles imbedded in every third layer of brick. The top of the oven was composed of brick held up by more small angles, the cracks between the bricks being grouted full of morter. The cement used to lay up the oven was a special heat resisting cement that would stand a temperature of about twenty-five hundred degrees fahrenheit. The door of the oven was hung with hinges from the top of the oven. It was made up of a heat insulating board and a pan of sheet iron with the two inch space between them filled with Magnesia.

The pans in which the aggregate was heated were made up of eighteen gauge sheet iron. They were made 3" x 10" x 14" so that all of the material placed in them would heat through uniformly.

The oven was heated with gas, the burners being made of pipe fittings. The gas was drawn into the burner and burned with air. The air was blown into the burner mixing chamber through a small jet in such a way that the pressure in the gas line was reduced and thus more gas was fed into the burner than would otherwise have entered it. The details of this mixing chamber are shown on the enclosed sketch.

The temperature in the oven was read with the aid of a thermocouple and a millivolt meter along with a calibration curve for the couple used. The thermocouple was inserted into the oven through a hole left for that purpose in the top of the oven.



Mixing Chamber for Gas Burner.

Method of treating aggregates

The aggregates to be used in a batch of concrete to be made into test specimens was weighed out approximately and placed in the pans for heating. Each type of aggregate was kept in a pan by itself during heating. The pans were then placed in the oven, the pans with the sand being placed on the bottom angles and the coarse stone was put on the angles next to the top of the oven. The burners were then lit and turned up until a long flame with a light blue inner cone was produced. The temperature was checked from time to time as the oven would not rise at too fast a rate. When the oven and contents had reached nearly the desired heat the burners were turned down so that the temperature would come up to the desired value very slowly. When the oven and contents had reached the desired temperature, the burners were turned down very low and the temperature in the oven was held constant for a period of twenty minutes. The object of doing this was to make sure that all of the aggregate in the oven had reached the desired temperature.

After the oven had been heated to the desired temperature it was then allowed to cool off with all of the contents still inside. The heating of a batch was done one day and the cooling off was allowed to go on over night and the batch was mixed up the next day.

When the treated aggregates were ready to be mixed they were again weighed out very accurately and then dumped in the mixing pan and mixed into concrete. In the concrete for the twenty eight day cylinders all of the batches were made with the same amount of mixing water. In the case of the seven day cylinders and the test beams, the batches were all made with a slump of five inches and the amount of water used to do this was recorded. It was found that the samples that had been heated to the higher temperature required more mixing water to give the same slump than did the samples that were heated to the lower temperatures. This would mean that when materials are heated to high temperatures they will require more water to give that same workability as when heated to low temperatures or when they are not heated at all. The results of the strength tests show that there is no definite relation between the temperatures that the aggregates are heated to, and the strength of the finished concrete.

Twenty eight day cylinders

Temperature		Total comp. force	Lbs. per sq. in.	Percent variation from average
1200°	#1	55,910	1,980	19.2
	#2	59,140	2,100	29.0
1100°	#1	47,610	1,690	3.9
	#2	44,100	1,565	3.8
950°	#1	49,700	1,760	8.2
	#2	47,720	1,695	4.2
800°	#1	39,030	1,385	14.8
	#2	43,190	1,530	6.1
650°	#1	39,690	1,405	13.6
	#2	47,530	1,685	3.5
500°	#1	43,750	1,550	4.7
	#2	43,570	1,545	5.0
Control	#1	38,610	1,370	15.8
	#2	42,610	1,510	7.2

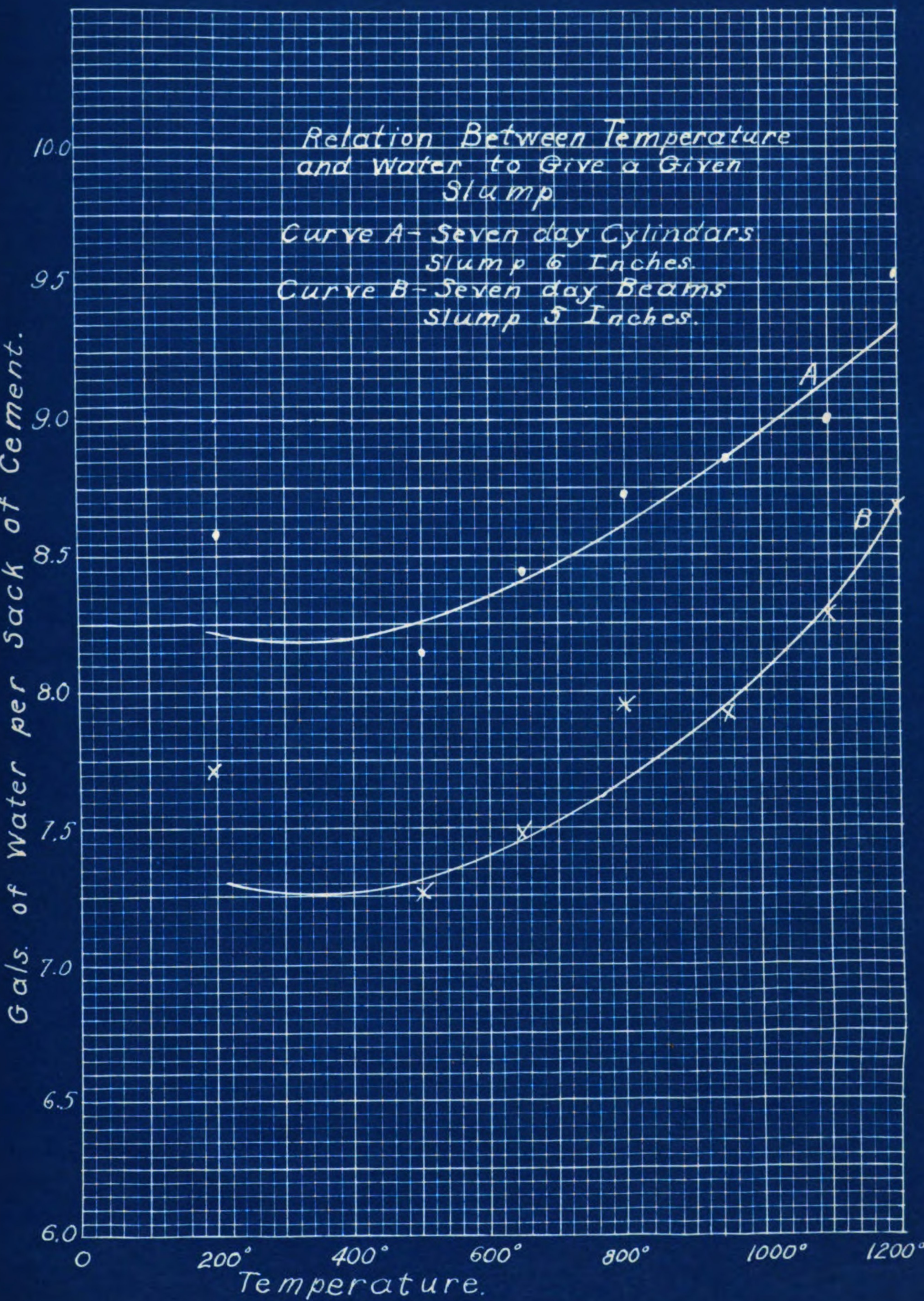
Average 1,627

Seven day cylinders

Cylinder		Total load	Lbs. per sq. in.	Percent variation from average	Water gals. per sack
1200°	#1	46,150	1,635	11.7	9.54
	#2	53,050	1,875	28.1	
1100°	#1	28,550	1,010	30.9	9.00
	#2	30,100	1,065	27.2	
950°	#1	45,110	1,600	9.4	8.86
	#2	40,650	1,440	1.6	
800°	#1	25,500	905	38.1	8.73
	#2	25,310	897	38.7	
650°	#1	44,780	1,590	8.8	8.44
	#2	45,830	1,625	11.1	
500°	#1	49,820	1,710	23.7	8.15
	#2	52,150	1,850	26.4	
Control	#1	40,850	1,450	.9	8.58
	#2	45,830	1,625	11.0	
		Average	1,463		

Beams

Beam	Break	Modulus of rupture lbs. per sq. in.	Percentage variation from average	Water gals. per sack
1200	#1	291	13.4	8.68
	#2	313	5.4	
1100	#1	319	5.1	8.29
	#2	378	12.5	
950	#1	342	1.8	7.92
	#2	300	10.1	
800	#1	368	9.5	7.97
	#2	360	7.1	
650	#1	355	5.6	7.49
	#2	320	4.8	
500	#1	366	9.0	7.27
	#2	320	4.8	
Control	#1	342	1.8	7.72
	#2	331	.3	
Average		336		


Relation Between Temperature
and Water to Give a Given
Slump
Curve A - Seven day Cylindars
Slump 6 Inches.
Curve B - Seven day Beams
Slump 5 Inches.
A
B
Gals. of Water per Sack of Cement.
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
0
200°
400°
600°
800°
1000°
1200°
Temperature.

Conclusion

The time that was available for these experiments was not long enough for a very comprehensive study of the problem envolved. It was found that at some temperatures there was a very marked effect on the strength of the concrete. At some temperatures there was a marked increase in the strength of the concrete but on other strengths there was a very marked decrease in the strength of the concrete. The variations in the strength at different temperatures did not seem to follow any definite order or system. From the above it will be seen that any definite conclusions as to the strength of concrete, with the conditions encountered would be superficial and probably erroneous.

It was found that the heating of the aggregates to the higher temperatures had the effect of increasing the amount of mixing water required to give a definite slump. This increase in the amount of mixing water might decrease the strength of the concrete but the experiments did not show positively any such decrease in the strength.

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