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ANALYSIS OF ACCELERATED CONCRETE STRENGTH TESTS FROM FIELD DATA SUPPLIED BY THE OTTAWA PRE-MIXED CONCRETE LIMITED, ONTARIO

by

V. M. MALHOTRA & N. G. ZOLDNERS

MINERAL PROCESSING DIVISION

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ANALYSIS OF ACCELERATED CONCRETE STRENGTH TESTS FROM FIELD DATA SUPPLIED BY THE OTTAWA PRE-MIXED CONCRETE LIMITED, ONTARIO

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SUMMARY OF RESULTS

Following the publication of the Mines Branch Research Report R 134 entitled, "Accelerated Test for Determining the 28-Day Compressive Strength of Concrete", Ottawa Pre-Mixed Concrete Limited installed the accelerated curing equipment at its laboratory and is carrying out the test on a routine basis. This report analyses the data obtained by the Company using the accelerated curing method. The analysis indicates that the accelerated curing method can be used satisfactorily in the field, and confirms the conclusion drawn in the research report, that the 28-day compressive strength can be predicted within an accuracy of ± 12 per cent.

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INTRODUCTION

Since 1963 the Construction Materials Section of the Mineral Processing Division has been engaged in the development of an accelerated test for determining the 28-day compressive strength of concrete. The findings of this research work have been reported in Mines Branch Research Report R 134* and published elsewhere (1-7).

Briefly, the method consists of standard moist-curing of test specimens for 24 hours, followed by boiling for 3 1/2 hours and testing for compression one hour later.

Since the introduction of the above method, Ottawa Pre-Mixed Concrete Limited has installed the accelerated test equipment at its plant No. 8 laboratory in Ottawa, and has carried out the test on a routine basis.

The test results analysed in this report were obtained on concrete samples secured from different construction sites in Ottawa, using the standard and the accelerated testing methods.

TEST PROCEDURE AND RESULTS

From September 1964 through to January 1965 a total of 38 concrete batches were sampled from truck mixers on various construction sites in Ottawa. In each case slump, air content and temperature of the concrete** were measured on the job. A representative two-pail sample of concrete was taken to the plant laboratory, dumped onto a mixing pan and remixed. Three 6 x 12 in. test cylinders were prepared in steel moulds using standard rodding procedure. One mould was fitted with a watertight steel cover and was used for the boiling test. The other two cylinders were standard moist-cured until tested at the age of 28 days.

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*V. M. Malhotra, N. G. Zoldners and R. Lapinas, "Accelerated Test for Determining the 28-Day Compressive Strength of Concrete", Mines Branch Research Report R 134, October, 1964.

**Coarse aggregate - crushed gravel, max. size 5/8 and 1 in.
Fine aggregate - natural sand.

The concrete mix characteristics and the results of compression tests, both the accelerated-cured 28 1/2 hr and the standard-cured 28-day tests, are compiled in Table 1.

It must be emphasized that these tests were carried out and data collected by the plant technician without any engineering supervision.

ANALYSIS OF TEST RESULTS

The analysis of the test results is given in Table 2. Columns 2 and 3 give the accelerated and companion 28-day standard cured strength. Column 4 gives the predicted 28-day strength using the equation:

$$Y = \frac{X}{0.000075x + 0.27} \qquad (1)$$

This equation was derived during the original research programme for the test results obtained using concrete supplied by Ottawa Pre-Mixed Concrete Limited. The results of both plain concrete and concrete made with admixtures were pooled to obtain this equation.

Column 5 lists the difference between the predicted and the actual 28-day standard-cured strengths expressed as a percentage of the actual 28-day standard-cured strengths.

Column 6 gives the predicted 28-day strengths using the equation:

$$Y = \frac{X}{0.000096 + 0.23} \qquad (2)$$

This equation has been derived using the new data (Table 1). Column 7 gives the difference between predicted strengths (using equation 2) and the actual 28-day strengths expressed as a percentage of the actual 28-day standard-cured strengths.

The test data (Table 1) are plotted in Figure 1. The line of best fit, $Y = \frac{X}{0.000096 + 0.23}$ together with $\pm$ 12 per cent limits, is also shown in the figure.

TABLE 1

Summary of Test Results

Test No.	Nominal W/C Ratio (by wt.)	Max. Aggr. Size, in.	Admixtures used+	Properties of Fresh Concrete				Compressive Strength, psi	
				Slump, in.	Temperature, °F	Air Content, %	Unit Weight, lb/cu ft	28 1/2-hr Accelerated Cured*	28-day Standard Cured**
1	0.61	5/8	Nil	3 1/2	62	-	-	1080	3590
2	0.61	5/8	Accel.	3 1/2	70	-	-	1110	3470
3	0.61	5/8	Accel.	3	65	-	-	1110	3550
4	0.61	5/8	Accel.	3 1/2	66	-	148.8	1240	3770
5	0.65	1	WR	3 1/2	-	-	-	1250	3100
6	0.61	5/8	WP	4 1/2	69	-	-	1310	3540
7	0.61	5/8	Nil	3 1/2	70	-	-	1320	3340
8	0.65	1	WR	3	66	-	149.2	1340	3400
9	0.53	5/8	WR+AEA	3	72	4.5	-	1340	3550
10	0.56	5/8	Accel.	3	78	-	-	1380	4110
11	0.61	5/8	Accel.	3 1/2	-	-	-	1430	4160
12	0.61	5/8	Nil	3 1/2	67	-	-	1430	3870
13	0.61	5/8	Accel.	4	65	-	-	1490	3640
14	0.56	5/8	Nil	3 1/2	-	-	-	1520	4620
15	0.53	5/8	WR+AEA	3	68	5.2	-	1520	3930
16	0.56	5/8	Accel.	3 1/2	66	-	-	1570	4070
17	0.43	5/8	WR+AEA	3	66	6.8	139.6	1590	3930
18	0.56	5/8	Accel.	3 1/2	70	-	-	1610	4030
19	0.50	5/8	WR+Acc.	5	65	-	-	1650	4240
20	0.50	5/8	WR+Acc.	5	70	-	147.6	1680	4330
21	0.50	1	WR+Acc.	4	-	-	-	1720	4810
22	0.50	5/8	WR	4	-	-	-	1750	4370
23	0.55	1	WR	4 1/2	-	-	-	1790	4250
24	0.55	1	WR	4	-	-	-	1800	4210
25	0.50	5/8	WR	3 1/2	-	-	-	1800	4550
26	0.61	5/8	Nil	2	-	-	-	1860	4360
27	0.43	5/8	WR+AEA	2	65	7.8	138.8	1870	4160
28	0.50	1	WR	3 1/2	70	-	-	1890	4460
29	0.50	1	WR+Acc.	4	66	-	-	2000	4880
30	0.50	1	WR	4	75	-	-	2020	4740
31	0.5	5/8	WR	4	-	-	-	2280	5570
32	0.50	1	WR+Acc.	3 1/2	70	-	-	2380	4880
33	0.47++	1	WR	3	-	-	-	2370	5980
34	0.48	1	WR+AEA	2 1/2	-	5.1	-	2450	5410
35	0.47	1	WR+AEA	2	-	-	-	2810	5785
36	0.47	1	WR+AEA	2	-	-	-	2870	5800
37	0.40	5/8	WR+Acc.	4	66	-	-	2940	5710
38	0.47	5/8	WR+AEA	2	-	3.6	-	3080	5910

*Only one cylinder was accelerated cured and tested

**Each test result is a mean of two 6 x 12 in. cylinder strength tests

+Abbreviations used: Accel. - accelerating admixture; WR - water-reducer and dispersing agent; WP - waterproofer; AEA - air entraining agent;

++Type II portland cement was used. For all other mixes Normal Type I cement was used.

TABLE 2

Analysis of Test Results

1	2	3	4	5	6	7
Test No.	28 1/2-Hr Accelerated-Cured Strength, psi	28-day Standard-Cured Strength, psi	28-day Predicted Strength Using Equation No. 1, psi	Difference $\frac{\text{Col. (4)-Col. (3)}}{\text{Col. (3)}} \times 100$ per cent	28-day Predicted Strength Using Equation No. 2, psi	Difference $\frac{\text{Col. (6)-Col. (3)}}{\text{Col. (3)}} \times 100$ per cent
1	1080	3590	3080	-14.3	3235	- 9.9
2	1110	3470	3140	- 9.5	3300	- 5.0
3	1110	3550	3140	-11.5	3300	- 7.1
4	1240	3770	3415	- 9.4	3555	- 5.8
5	1250	3100	3435	+10.8	3570	+15.2
6	1310	3540	3555	+ 0.5	3680	+ 4.0
7	1320	3340	3575	+ 7.1	3700	+10.8
8	1340	3400	3620	+ 6.4	3735	+ 9.9
9	1340	3550	3620	+ 1.9	3735	+ 5.3
10	1380	4110	3695	-10.1	3810	- 7.4
11	1430	4160	3790	- 8.9	3895	- 6.5
12	1430	3870	3790	- 2.0	3895	+ 0.6
13	1490	3640	3905	+ 7.2	3995	+ 9.7
14	1520	4620*	3960	-14.3	4045	-12.5
15	1520	3930	3960	+ 0.7	4045	+ 2.9
16	1570	4070	4050	- 0.5	4125	+ 1.3
17	1590	3930	4085	+ 3.9	4155	+ 5.7
18	1610	4030	4120	+ 2.2	4185	+ 3.9
19	1650	4240	4190	- 1.2	4250	+ 0.2
20	1680	4330	4240	- 2.0	4295	- 0.8
21	1720	4810	4310	-10.4	4355	- 9.5
22	1750	4370	4360	- 0.2	4395	+ 0.6
23	1790	4250	4430	+ 4.2	4455	+ 4.8
24	1800	4210	4445	+ 5.5	4470	+ 6.1
25	1800	4550	4445	- 2.3	4470	- 1.8
26	1860	4360	4540	+ 4.2	4550	+ 4.4
27	1870	4160	4560	+ 9.6	4565	+ 9.8
28	1890	4460	4590	+ 2.9	4595	+ 3.0
29	2000	4880	4760	- 2.4	4740	- 2.9
30	2020	4740	4790	+ 1.1	4720	- 0.4
31	2280	5570	5170	- 7.2	5080	- 8.8
32	2350	4880	5270	+ 7.9	5160	+ 5.7
33	2370	5980	5290	-11.5**	5180	-13.4
34	2450	5410	5400	- 0.2	5265	- 2.6
35	2810	5785	5845	+ 6.7	5620	- 2.8
36	2870	5800	5915	+ 2.0	5680	- 2.1
37	2940	5710	5995	+ 5.0	5740	+ 0.5
38	3080	5910	6145	+ 4.0	5860	- 0.9

*28-day Standard-Cured Strength unusually high
**Type II Portland Cement used

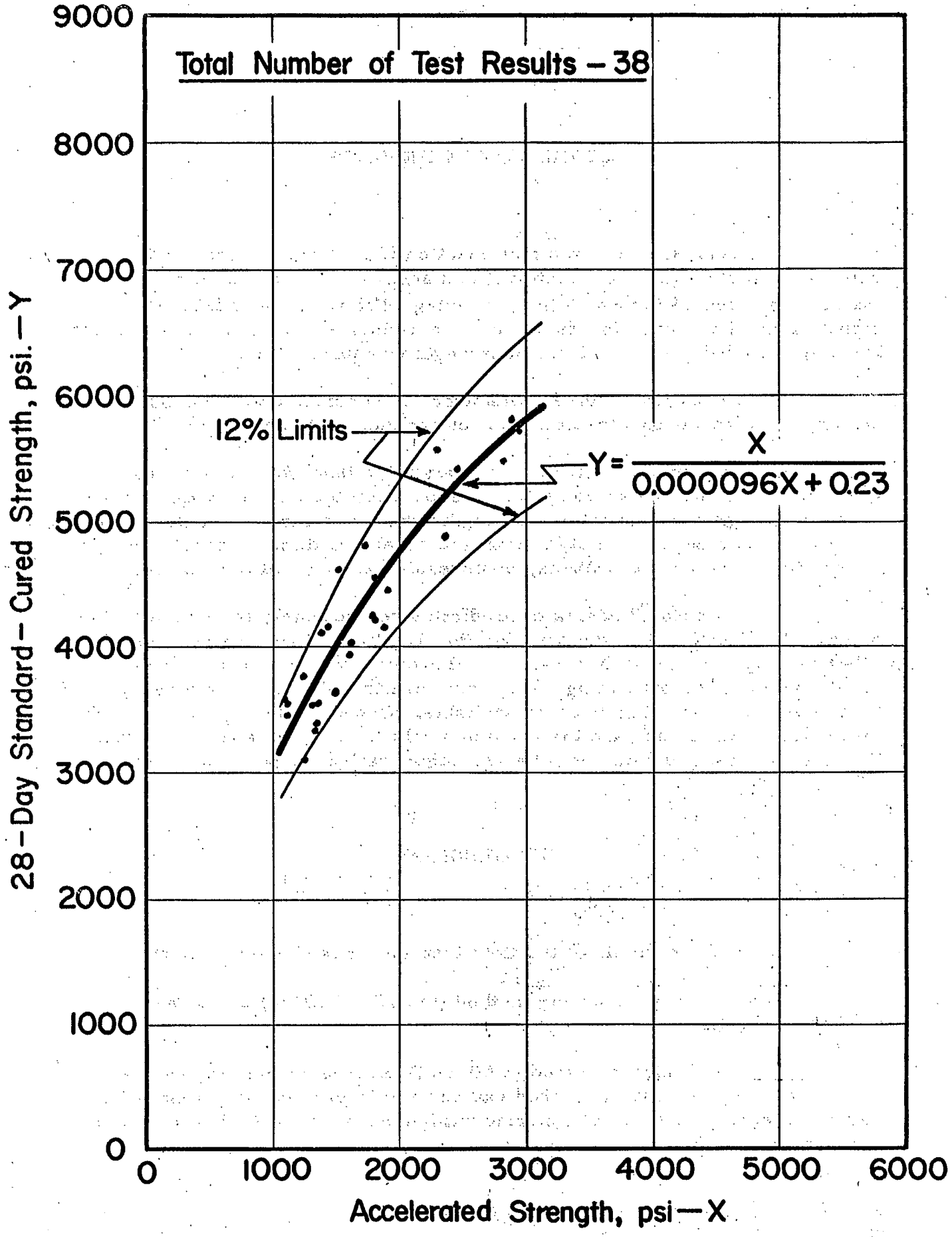

FIGURE RELATIONSHIP OF ACCELERATED TO 28-DAY STRENGTH

DISCUSSION OF RESULTS

The analysis indicates that equation No. 1 predicts the 28-day compressive strength of concrete with an accuracy of ± 12 per cent, except for results 1 and 14 for which the percentage difference is -14.3. No explanation can be offered for these large variations except that for the result No. 14, the 28-day standard-cured strength was unduly high.

Type II portland cement was used for concrete batch No. 33 and, strictly, this result should not have been included in the analysis.

One important feature of the analysis is that, for the test results for which the predicted values differ greatly from the actual 28-day compressive strengths, the predicted strengths are lower than the actual strengths. This provides a built-in safety factor; the accelerated test generally do not overestimate the potential 28-day compressive strength of the concrete.

Equation No. 2 seems to predict more accurately the compressive strength of concrete than the equation No. 1. This is because equation No. 2 is based upon actual field data. It is therefore recommended that this equation be used in predicting future test results and be reviewed every three months as new data become available. However, in the statistical "t" test carried out to compare the predicted values using the above two equations, the calculated value of "t" was insignificant at 95 per cent level.

CONCLUSIONS

From the analysis of the field test data it is concluded that:

1. The accelerated-curing method (modified boiling) can be satisfactorily used in the field.

2. The conclusion reported in Mines Branch Research Report R 134, that the accelerated curing method can be used to predict the potential 28-day compressive strength of concrete with an accuracy of ± 12 per cent, is confirmed.

ACKNOWLEDGEMENT

The field work and the collection of the test results were carried out by Mr. R. Laframbois, senior technician of Ottawa Pre-Mixed Concrete Limited, Ottawa, Ont.

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