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Iowa State Highway Commission
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Chemical Tests Section

Final Report of R-248

An Investigation of the Chemical Method of Determining the Cement Content of Hardened Concrete

March, 1971

IOWA STATE HIGHWAY COMMISSION

MATERIALS DEPARTMENT

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Chemical Tests Section

Research Project R-248

Final Report

AN INVESTIGATION OF THE CHEMICAL METHOD OF DETERMINING THE CEMENT CONTENT OF HARDENED CONCRETE

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by

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AN INVESTIGATION OF THE CHEMICAL METHOD OF DETERMINING THE CEMENT CONTENT OF HARDENED CONCRETE

1.0 Introduction

The Iowa State Highway Commission Laboratory is called upon to determine the cement content of hardened concrete when field problems relating to batch weights are encountered.

The standard test for determining the cement content is ASTM C-85. An investigation of this method by the New Jersey State Highway Department involving duplicate samples and four cooperating laboratories produced very erratic results, however, the results obtained by this method have not been directly compared to known cement contents of concrete made with various cements and various aggregates used in Iowa.

2.0 Purpose

The purpose of this study was to establish the accuracy of ASTM C-85, and establish a correlation between chemical determinations and actual cement contents.

3.0 Materials

Three different ASTM C150, Type I, cements were used in making the concrete mixes for this investigation. They were obtained from Penn Dixie Cement Company of Des Moines, Iowa, Ash Grove Cement Company of Louisville, Nebraska, and Universal Atlas Cement Company of Hannibal, Missouri.

Only one fine aggregate was used. This was obtained from Hallett's Pit located north of Ames, Iowa, and it complied with Section 4110 of the 1964 Iowa Standard Specifications.

The five coarse aggregates used were of 3/4 inch maximum size, meeting the AASHO-57 grading limits. They were selected to represent the various types commonly in use. The types and sources were as follows:

1. Gravel from Bellevue Sand and Gravel, Bellevue, Iowa
2. Gravel from Hallett's, Ames, Iowa
3. Limestone from Weaver, Alden, Iowa
4. Dolomitic Limestone, Concrete Materials, South Cedar Rapids, Iowa
5. Variable Limestone and Dolomitic, Concrete Materials, Ferguson, Iowa

The concrete mixes were made with a slump of 2 inches ± 1/2 inch, an air content of 6 percent ± 1 percent and with cement contents of 4.5, 5.5, and 6.5 bags per cubic yard.

4.0 Procedure

Using the 3 cements, 5 coarse aggregates, and 3 cement contents, a 6" by 6" by 33" concrete beam was cast for each possible combination, making a total of 45 beams. After the concrete had attained an age of at least 7 days, five 4 inch cores were cut from each beam. Each core then served as a separate sample for chemical analysis and the average result of the five analyses was used to determine the cement content of each beam.

In lieu of the procedure given in ASTM C85 for obtaining aggregate samples, the aggregates were sampled prior to mixing the concrete. All aggregates and cements were analyzed in triplicate for the amount of soluble constituent to be determined in the concrete in which they were used. These materials were dried at 550 degrees C. prior to analysis.

To prepare the cores for analysis, they were first broken down into about 2 inch size pieces employing a core breaker and these pieces were then crushed into granular form using a small jaw crusher. The granular material was then quartered three times and the remaining sample was pulverized in a Mikromill. The pulverized material was further quartered to about 10 grams which was placed in a platinum crucible and dehydrated at 550 degrees C. for three hours. The sample for chemical analysis was taken from this dehydrated material.

The chemical analysis of all materials were conducted in accordance with the procedures given in ASTM C85. The cement content of cores involving coarse aggregate from Bellevue Sand and Gravel was determined on the basis of soluble calcium and magnesium oxides using the alternate procedure suggested in ASTM C85. All other determinations were made on the basis of soluble silica.

The calculations of the cement contents were made in accordance with ASTM C85 using equation No. 8.

5.0 Test Results

The data used in calculating the cement contents is given in the appendix. This data includes the decimal fraction of coarse aggregate in the concrete and the percentage of soluble constituent found in the ingredients and in each core.

The following table of results shows the source of materials, the known percent cement, the determined percent cement, the deviation from the known values, and the percent error for each beam.

TABLE OF RESULTS

Beam No.	MATERIAL SOURCES: Cement	MATERIAL SOURCES: Coarse Aggregate	Known % Cement, Dry Basis	ANALYSIS RESULTS: % Cement	ANALYSIS RESULTS: Deviation	ANALYSIS RESULTS: % Error
1	Penn Dixie	Bellevue Sand and Gravel	17.1	13.9	3.2	18.7
2	" "	" "	14.4	12.3	2.1	14.6
3	" "	" "	11.8	9.5	2.3	19.5
4	Ash Grove	" "	17.1	15.2	1.9	11.1
5	" "	" "	14.4	11.6	2.8	19.4
6	" "	" "	11.8	7.6	4.2	35.6
7	Universal Atlas	" "	17.1	13.3	3.8	22.2
8	" "	" "	14.4	10.4	4.0	27.8
9	" "	" "	11.8	8.9	2.9	24.6
10	Penn-Dixie	Weaver, Alden	17.2	12.7	4.5	26.2
11	" "	" "	14.5	10.8	3.7	25.5
12	" "	" "	11.8	10.2	1.6	13.6
13	Ash Grove	" "	17.2	13.9	3.3	19.2
14	" "	" "	14.5	10.3	4.2	28.9
15	" "	" "	11.8	8.3	3.5	29.6
16	Universal Atlas	" "	17.2	13.6	3.6	20.9
17	" "	" "	14.5	12.2	2.3	15.9
18	" "	" "	11.8	7.8	4.0	33.9
19	Penn-Dixie	Concrete Materials So.Cedar Rapids	17.3	14.4	2.9	16.9
20	" "	" "	14.6	12.8	1.8	12.3
21	" "	" "	11.9	10.3	1.6	13.5
22	Ash Grove	" "	17.3	14.5	2.8	16.2
23	" "	" "	14.6	10.8	3.8	26.0
24	" "		11.9	9.1	2.8	23.5
25	Universal Atlas	" "	17.3	15.2	2.1	12.1
26	" "	" "	14.6	11.8	2.8	19.2
27	" "	" "	11.9	10.2	1.7	14.3
28	Penn-Dixie	Concrete Materials Ferguson	17.2	14.8	2.4	14.0
29	" "	" "	14.5	13.4	1.1	7.6
30	" "	" "	11.8	8.8	3.0	25.4

TABLE OF RESULTS

(Continued)

Beam No.	MATERIAL SOURCES Cement	Coarse Aggregate	Known % Cement Dry Basis	ANALYSIS RESULTS % Cement	Deviation	% Error
31	Ash Grove	Concrete Materials Ferguson	17.2	13.5	3.7	21.4
32	" "	" "	14.5	12.5	2.0	13.8
33	" "	" "	11.8	9.1	2.7	22.9
34	Universal Atlas	" "	17.2	15.1	2.1	12.2
35	" "	" "	14.5	12.4	2.1	14.5
36	" "	" "	11.8	6.9	4.9	41.5
37	Penn Dixie	Hallett's, Ames	17.2	12.3	4.9	28.5
38	" "	" "	14.5	12.5	2.0	13.8
39	" "	" "	11.8	8.5	3.3	28.0
40	Ash Grove	" "	17.2	11.9	5.3	30.8
41	" "	" "	14.8	11.1	3.4	23.4
42	" "	" "	11.8	8.8	3.0	25.4
43	Universal Atlas		17.2	14.4	2.8	16.3
44	" "	" "	14.5	11.7	2.8	19.3
45	" "	" "	11.8	9.2	2.6	22.0

6.0 Discussion of Results

The cement contents determined by chemical analysis were in all cases lower than the known values. The deviations ranged from about 5 percent cement to 1 percent cement and did not follow any consistent pattern relative to the amount of cement, coarse aggregate, or brand of cement used in the mixes. An attempt was made to correlate the chemical determinations with the actual cement contents but the results were so inconsistent that any meaningful correlation was impossible.

There are two major sources of error involved in this test. The first is the loss of sample dust during any or all of the five steps used for sample preparation. This error would always lead to low results. The second source of error lies within the chemical analysis which on the other hand could give either high or low results. With careful work these analytical errors should be small, however, they are magnified when the determined amount of soluble constituent is converted to percent cement in the concrete. This magnification of error is dependent on the relative amounts of soluble constituents in the cement and aggregates. For the concrete mixes involved in this work, an error in silica determination is multiplied approximately 5 times in calculating the cement content. Errors in calcium and magnesium oxide determinations are almost doubled. Since dust was lost during the sample preparation low cement content results were anticipated. This inconsistent error, together with analytical errors which either compensate for it or add to it, is the most probable explanation for the consistently low but erratic results.

7.0 Conclusions

This investigation was an attempt to establish the accuracy of determining the cement content of hardened concrete using the procedure given in ASTM C85 and to establish a correlation between these chemical determinations and known cement contents.

It was shown that the ASTM C85 procedure yields consistently low and erratic results which cannot be correlated with known cement contents. In order to produce results of reasonable accuracy it would be necessary to devise a method of breaking down the concrete that would prevent the loss of dust, which is rich in cement.

8.0 APPENDIX

SOLUBLE CONSTITUENTS IN CONCRETE INGREDIENTS

MATERIAL	Soluble Silica % SiO_2	Soluble Magnesium & Calcium % CaO
CEMENTS:		
Penn Dixie, Type I	20.46	70.68
Ash Grove, Type I	21.43	71.45
Universal Atlas, Type I	21.53	70.44
FINE AGGREGATE:		
Hallett's Sand	1.63	14.98
COARSE AGGREGATES:		
Bellevue Sand & Gravel	-	5.40
Weaver, Alden	0.50	-
Concrete Materials, So. Cedar Rapids	0.25	-
Concrete Materials, Ferguson	0.34	-
Hallett's, Ames	1.16	-

TEST DATA

Beam No.	Decimal Fraction of Coarse Aggregate	% Soluble Constituent in Cores					% Soluble Constituent Average For Beam
		A	B	C	D	E	
1	0.453	18.70	18.05	19.03	18.66	17.57	18.40
2	.467	17.63	17.06	16.58	17.09	18.33	17.34
3	.482	15.83	15.71	15.59	15.46	15.54	15.63
4	.453	18.14	18.66	20.61	19.03	19.72	19.23
5	.467	17.61	16.54	17.81	17.21	16.21	17.08
6	.482	13.96	15.50	14.71	15.56	13.68	14.68
7	.453	17.84	17.61	17.67	19.38	17.50	18.00
8	.467	15.62	16.87	15.90	16.42	16.42	16.25
9	.482	15.96	15.60	16.19	14.48	14.39	15.32
10	.451	3.61	3.55	3.49	3.45	3.47	3.51
11	.465	3.10	3.11	3.21	3.23	3.00	3.13
12	.479	2.78	3.10	3.01	3.05	3.07	3.00
13	.451	3.87	3.96	3.70	4.14	3.70	3.87
14	.465	3.47	3.14	3.07	3.06	3.01	3.15
15	.479	3.21	2.73	2.75	2.61	2.41	2.74
16	.451	3.88	3.82	3.77	3.85	3.81	3.83
17	.465	3.26	3.56	3.50	3.69	3.63	3.53
18	.479	2.68	2.90	2.56	2.46	2.58	2.64
19	.447	3.85	3.64	3.67	3.81	3.67	3.73
20	.461	3.48	3.46	3.39	3.30	3.39	3.40
21	.476	2.99	2.84	2.87	2.93	2.92	2.91
22	.447	3.81	3.90	3.80	3.97	3.94	3.88
23	.461	2.90	3.27	3.30	3.13	3.09	3.14
24	.476	2.85	2.61	2.70	2.98	2.73	2.77
25	.447	4.10	4.03	4.00	4.06	3.98	4.03
26	.461	3.11	3.45	3.27	3.34	3.59	3.35
27	.476	3.03	3.04	2.97	3.02	3.00	3.01
28	.451	3.82	3.87	3.92	3.76	3.77	3.83
29	.465	3.58	3.56	3.50	3.61	3.57	3.56
30	.479	2.76	3.01	2.48	3.07	2.06	2.68
31	.451	3.73	3.51	3.70	3.81	3.89	3.73
32	.465	3.52	3.56	3.48	3.48	3.44	3.50
33	.479	2.45	2.73	3.23	3.14	2.56	2.82
34	.451	4.04	4.07	4.05	4.03	4.11	4.06
35	.465	3.53	3.58	3.39	3.60	3.42	3.50
36	.479	2.44	2.49	2.41	2.42	2.18	2.39
37	.451	3.59	3.88	3.87	3.74	3.60	3.74
38	.465	3.89	3.75	3.74	3.73	3.67	3.76
39	.479	3.00	3.05	2.83	3.16	3.01	3.01
40	.451	3.33	4.43	3.51	4.24	3.36	3.77
41	.465	3.65	3.72	3.60	3.51	3.57	3.61
42	.479	3.16	3.17	3.07	3.13	3.17	3.14
43	.451	4.18	4.41	4.13	4.41	4.30	4.29
44	.465	3.70	3.65	3.76	3.72	3.84	3.73
45	.479	3.16	3.30	3.12	3.38	3.23	3.24