Iowa State Highway Commission

Materials Department

Special Investigations Section

FINAL REPORT OF R-247

Durability Study of Type II Cements

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By

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Durability Study of Type II Cements

INTRODUCTION

A study of type II cements at the Iowa State Highway Commission concluded that the amount of tricalcium aluminate in the cement appears to have an inverse effect on concrete durability.[1] This conclusion agrees with the results of the Kansas Highway Department's study to determine the combination of cement and aggregate which would produce the best possible durability factor.[2]

This study is a result of the questions raised following the completion of the project at the Iowa State Highway Commission. This project is being conducted on a larger scale so that more definite conclusions can be drawn.

PURPOSE

The purpose of this project is to determine if the amount of tricalcium aluminate in type II cements has an inverse effect on the durability of concrete.

MATERIALS

The following type II cements were used:

1. Missouri Portland
2. Dewey Portland
3. Marquette
4. Lehigh
5. Ash Grove

also, an R-11 blend (composed of equal amounts of seven type I cements) was used for control purposes.

The coarse aggregate was from the following locations:

1. Ferguson Quarry, Marshall Co.
2. Bente Quarry, Clayton Co.
3. Logan Quarry, Harrison Co.
4. Camanche Quarry, Van Buren Co.
5. Moscow Quarry, Muscatine Co.

These aggregates were chosen because they had previously demonstrated that they could produce concrete with durability factors in the 30-90 range.

The fine aggregate was from Hallett's Pit in Ames and complied with section 4110 of the standard specifications.

Ad-Aire, a neutralized vinsol resin manufactured by the Carter-Waters Corporation was used as an air-entraining agent in the concrete.

1. Marks, V. J. and Grubb, R. E., "A Study of Curing Methods and Type II Cements on the Durability of Concrete". Research Project R-11-Z(1), Iowa State Highway Commission, June 17, 1969.
2. Stingley, J. D. et al., "The McPherson Test Road: Tenth Year Report". Highway Research Board Proceedings, 39:191-204 (1960).

LABORATORY PROCEDURE

All type II cements were subjected to a chemical analysis before they were used in this study.

All concrete mixed for this study was made using C-3 mix proportions as specified under article 2301.04 of the standard specifications.

The coarse aggregate was in a saturated surface dry condition for mixing. It also had 100% passing the 1" screen, with the larger aggregate being discarded.

The mixing procedure used was as follows:

1. Proportion sand and cement.
2. ~~Mix for one minute.~~
3. Proportion coarse aggregate.
4. Mix for one minute.
5. Add water and air-entraining agent to adjust to a slump of 3"± 1/2" while mixing for three minutes.

Two sets of three 4"x4"x18" beams were made using all possible combinations of cement and aggregate. Each identical set was made from a separate mix. Consolidation in the molds was by external vibration.

The beams were initially cured by covering with plastic. They were removed from the molds at an age of 20-24 hours and placed in the moist room for 90 days. The beams were then placed in a 40°F water bath for one day and then put in the freeze and thaw apparatus.

Durability factors were determined per ASTM C-291 with the exception that the beams were 18" long and they were not weighed.

RESULTS

The results of the chemical analysis performed on the type II cements are shown in table I. The percent of tricalcium aluminate was computed by the formula in ASTM C-150. The table indicates that there is a descrepency between the manufactures's specifications and the actual chemical analysis. This discontinuity presented strong uncertainties at the start of the study and could have only been rectified by long, expensive, painstaking additional investigation as to the reliability of all chemical analysis.

The results of the actual durability study are shown in table II. An examination of this table shows no concluding evidence that the amount of tricalcium aluminate has an inverse effect on durability. Lehigh cement, which had the largest amount of tricalcium aluminate, was shown to exhibit the lowest durability in only 40% of the test specimens. Moreover, Marquette and Missouri Portland Cements (both low in tricalcium aluminate) indicated the highest durability in only 30% of the specimens. Thus, no tendency is evident in the specimens tested to warrant any prediction of the effect of tricalcium aluminate on the durability of concrete.

A comparison of sets 1 and 2 in table II indicates an obvious lack of repeatability in the freeze and thaw testing. Specimens from identical mixes not only failed to reproduce the same growth, they also failed to repeat reasonable magnitudes of durability. In the 180 specimens tested the average difference in durability between indentical sets was 7.3 while the growth showed a 0.023 percent average difference. With this type of descrepency it would be unreasonable and experimentally erroneous to conclude that a cement with 4.70% tricalcium aluminate and showing a durability of 92 is any more durable than a cement with 6.98% tricalcium aluminate and showing a durability of

87. Thus, it is concluded that before a project to determine the effects of a small difference of tricalcium aluminate can be conducted, there must be an improvement in the dependability and repeatability of the freeze and thaw test procedure.

SUMMARY

This study has shown that:

1. There is no justification for concluding that the amount of tricalcium aluminate has an inverse effect on the durability of type II cements when measured by ASTM C291. This conclusion is a direct result of chemical analysis discrepancies and inconsistant test data.
2. There must be a complete investigation as to the dependability and repeatability of the freeze and thaw test procedure before projects of this magnitude can be conducted in the future.

Possible areas of more stringent control might be:

A. Mixing Atmosphere
B. Vibration Time
C. Frequency Determination

Table I

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Chemical Analysis of Type II Cements

Cement	Manufacturer's Certification		% of Tricalcium Aluminate (manufactures)	ISHC's Chem. Analysis		% of Tricalcium Aluminate (ISHC)
	% AL_2O_3	% FE_2O_3		% AL_2O_3	% FE_2O_3	
Ash Grove	4.21	3.11	5.89	4.61	3.19	6.82
Marquette	4.9	4.0	6.22	4.35	3.97	4.81
Missouri Portland	4.7	4.3	5.18	4.27	3.91	4.70
Dewey Portland	4.95	3.67	6.91	4.58	3.38	6.42
Lehigh	5.0	3.6	7.16 (7.3 specified)	4.88	3.52	6.98

Table II

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Results of Type II Cement Durability Study

Coarse Aggregate	Type II Cement	Set No. 1		Set No. 2	
		Durability Factor	Growth %	Durability Factor	Growth %
Ferguson Quarry Lab. No. AACO - 36	R-11 Blend	95	0.011	92	0.026
	Mo. Portland	92	0.015	89	0.027
	Dewey	96	0.010	90	0.028
	Marquette	97	0.014	90	0.026
	Lehigh	95	0.020	90	0.030
	Ash Grove	94	0.016	91	0.023
Logan Quarry Lab No. AACO - 37	R-11 Blend	76	0.071	63	0.152
	Mo. Portland	71	0.095	62	0.104
	Dewey	85	0.051	60	0.172
	Marquette	70	0.078	66	0.093
	Lehigh	64	0.107	69	0.121
	Ash Grove	85	0.050	68	0.125
Bente Quarry Lab. No. AACO - 45	R-11 Blend	88	0.062	64	0.190
	Mo. Portland	86	0.041	85	0.037
	Dewey	92	0.017	86	0.037
	Marquette	91	0.022	80	0.057
	Lehigh	68	0.111	62	0.151
	Ash Grove	69	0.072	83	0.067
Moscow Quarry Lab. No. AACO - 45	R-11 Blend	87	0.044	78	0.065
	Mo. Portland	84	0.042	86	0.034
	Dewey	86	0.053	87	0.056
	Marquette	69	0.098	83	0.085
	Lehigh	82	0.058	84	0.079
	Ash Grove	86	0.046	85	0.043
Camanche Quarry Lab. No. AACO - 46	R-11 Blend	94	0.023	99	0.024
	Mo. Portland	92	0.017	96	0.018
	Dewey	93	0.017	97	0.012
	Marquette	89	0.028	92	0.021
	Lehigh	87	0.033	94	0.020
	Ash Grove	93	0.018	97	0.017