TENTATIVE PROGRAMME OF INVESTIGATION TO PREVENT CEMENT-AGGREGATE REACTION OCCURRING IN HARDENED CONCRETE

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ABSTRACT

"Map-cracking", followed by disruptive expansion, is occurring in a few concrete structures in the Cape Area. It is associated with abnormally wet conditions and a particular type of coarse aggregate, which appears to react with $Ca(OH)_2$ liberated from hardened cement. It is thought that it may be possible to prevent this reaction by incorporating a pozzolanic material in the cement. A series of exploratory tests are described, and a programme for further investigation is suggested.

THE PROBLEM

Abnormal cracking of concrete at several localities in the Cape Peninsula and Western Cape area has been observed during the past 5 to 10 years. This specific phenomonem ("map-cracking") in concrete about 3-5 years old seems to occur only under the particular condition where moisture is present either continuously or frequently. Dr. Oberholster (1) and Mr. Flanagan (2) will have described the problem fully by now.

In the course of his investigations, at the National Building Research Institute, Dr. Oberholster found that a reaction occurred between lime water and a sample of Malmesbury Shale (frequently used for coarse aggregate) in his possession. The reaction product had an appearance similar to an aliminium-hydroxide precipitate.

Although our Company has no direct interest in the manufacture or use of coarse aggregate or concrete, as the major manufacturers of cement in the area the management of the Cape Portland Cement Company felt that we should interest ourselves in this problem and see whether we could do anything to alleviate it.

POSSIBLE SOLUTIONS

We previously manufactured a Marine cement containing a pozzolan (calcined shale), and one of the main functions of this pozzolan was to react with the calcium-hydroxide set free during the hydration of the portland cement portion of the "Cemarine", rendering it insoluble, so reducing the ultimate porosity of concrete structures and, inter alia, adding to their ultimate strength.

It seemed logical, therefore, to carry out tests in an attempt to determine whether calcined shale, in finely divided form, in concrete, would tend to react with liberated calcium-hydroxide BEFORE this material could react with the coarse aggregate, and so prevent the disruptive expansion which has occurred in some concrete structures, as mentioned above, An alternative solution, of course, may be to incorporate finely ground Malmesbury Shale in the concrete.

As full scale "in situ" tests would obviously take years to yield results, we gave consideration to devising some form of test method which would at least give an indication of the efficacy, or otherwise of the proposed remedial measures.

EXPERIMENTAL PROCEDURE

An "extract" of the soluble hydration products (mainly calcium hydroxide) of cement was made by shaking 10 grams of cement with 100 ml water, in a closed vessel in an automatic shaker, for seven days. This gave the cement a reasonable time to hydrate, and kept the reaction products in intimate contact with the water. The mixture was then filtered, and the clear filtrate kept in a tightly stoppered vessel.

Similar extracts were made using two ordinary portland cements (one "high" and one "low" alkali) and one sulphate resisting cement (low alkali).

These extracts were then placed in 250 ml rubber-stopped erlenmeyer flasks, together with 50 grams of coarse aggregate (crushed to minus half-inch size). In some cases finely ground calcined shale was added as well. The flasks were shaken for a few minutes, then allowed to stand undisturbed in a constant temperature room (22 to 25°C), and observed weekly.

TABLE 1

Details of experiments set up

No.	Date	Aggregate Wt. gm.	Aggregate Type	Calc. Shale gm.	Liquid ml	Liquid Type
0	April'76	300	D.H. Limestone	-	300	$Ca(OH)_2$ sat.soln.
1	"	300	Malmesbury shale	-	300	" " "
2	May '76	±100	Dolomitic	-	±100	" " "
3	"	±200	Granitic	-	±200	" " "
4	"	±100	Dolomitic	-	±100	" " "
5	4.6.76	50	Malmesbury shale	-	100	Ext.OPC high alk.
6	"	50	" "	0,5	100	" " "
7	"	50	" "	2,5	100	" " "
8	"	50	" "	-	100	Ext.SRC low alk.
9	"	50	" "	0,5	100	" " "
10	"	50	" "	2,5	100	" " "
15	2.7.76	50	" "	-	100	Ext.OPC low alk.
16	"	50	" "	0,5	100	" " "
17	"	50	" "	2,5	100	" " "
18	July'76	±850	" "	-	±850	$Ca(OH)_2$ sat.soln.

Numbers 11 and 14 were mixtures of 5 gm OPC, 25 gm M. shale and 100 ml water. Numbers 12 and 13 were the same, but with added calcined shale. The mixtures were shaken for a week and then allowed to stand. It is impossible to see whether reactions are occurring or not.

OBSERVATIONS

In table 2 below the symbols have the following meanings with regard to visible reaction (or lack of it):

- \- Definite negative
- 0 Uncertain
- \+ Definite positive

TABLE 2

Observations recorded weekly

Number	Observation for week ending:									
	11/6	18/6	25/6	2/7	9/7	16/7	23/7	30/7	6/8	13/8
0	-	-	-	-	-	-	-	-	-	-
1	+	+	+	+	+	+	+	+	+	+
2									-	-
3									+	+
4									-	-
5	-	0	+	+	+	+	+	+	+	+
6	-	-	-	-	-	-	-	-	0	0
7	-	-	-	-	-	-	-	-	0	0
8	-	0	+	+	+	+	+	+	+	+
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
15					-	0	+	+	+	+
16					-	-	-	-	-	-
17					-	-	-	-	-	-
18*					+	+	+	+	+	+

* Reaction showed up after 4 days

The positive reactions between the limewater/cement extracts and the Malmesbury shale show up quite definitely after 3 to 4 weeks and can be clearly seen on colour slides and colour photographs. (The reaction with the granite sample took over two months to show up and is still mild compared with that of the Malmesbury shale). Where the powdered pozzolan is present it is not really possible to say that there is definitely no reaction occurring because of the "masking" effect of the powder. There is certainly no "floc" floating around in the supernatant liquid, as is the case in numbers 5, 8, 15 and 18 (this can also be seen on the slides and photos). Hopefully the $Ca(OH)_2$ is reacting with the calcined shale instead of with the Malmesbury shale. At any rate the reaction appears to be independent of the alkali content of the cement.

FUTURE PROGRAMME

It is suggested that future tests should be based on the ASTM C227 test for potential alkali reactivity of cement-aggregate combinations (mortar-bar method) - an expansion test.

The test will have to be modified, however, to use concrete specimens instead of mortar bars, and similar bars will have to be stored under different conditions, e.g. one lot in air (dry), a second lot in a high humidity cupboard, a third lot under water, and a fourth lot subjected to alternate wetting and drying cycles.

Each of the above lots will need to be made up with "pure" cements and with cements containing varying proportions of calcined shale and varying proportions of finely ground Malmesbury shale. It will probably be worthwhile trying a few samples in the autoclave to see whether it is possible to speed up the reaction, but any results obtained would have to be treated with considerable reserve until such time as long-term results were available for confirmation.

References:

(1) Session IV Dr. R.E. Oberholster, C.S.I.R., South Africa, "Report of reactive concrete aggregate from the Cape Peninsula South Africa".

(2) Session IV Mr. J. Flanagan, P.C.I., South Africa, (Cement-aggregate reactivity problems in South Africa).