EFFECT OF ELECTRIC CURRENT ON ALKALI-SILICA REACTION

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SUMMARY

Passage of direct electric current through a mortar specimen containing reactive siliceous aggregate appears to accelerate the disruption due to reaction with alkali.

Introduction

The first cases of damage to concrete by alkali-aggregate reaction on mainland Britain which came to the notice of C and C A were at three electrical substations in S.W. England. This suggested that stray currents might play a part in inducing or accelerating the reaction. Discussion with engineers in the generating industry indicated that while considerable alternating fields obviously exist at sub-stations, direct "earth loop" currents of the order of a few amps could also occasionally flow, even in the absence of any applied A.C.

Experimental I

U-shaped mortar test pieces were made, with 40mm square cross-section, 200mm high. (See Appendix for mix proportions). Each leg was placed in a (plastic) beaker containing about 150 ml distilled water, the electrical connection to the water being made by platinum electrodes connected to a 180 v DC supply. The whole experiment was enclosed in a polythene bag, with some water in the bottom to maintain a humid atmosphere, but no other steps were taken to exclude CO_2. With a specimen about 14 days old, the current rose over a few hours to stabilise at about 15mA*. The current fell slowly over about 50 days to 10mA (Spec. res. 7.5K Ω/cm^3) and after a year to about 1.0mA (Spec. res. 75K Ω/cm^3). After the first five weeks the water in the two beakers was analysed; that in the beaker attached to the negative pole had pH 11.5 and contained 1.0gm/1 K_2O and 0.6gm/1 Na_2O. This represents about 5% of the alkali originally in the cement in the test piece, with the Na_2O contents proportionately slightly higher than the K_2O. (The alkali contents of the cement were 0.68% K_2O, 0.34% Na_2O.) The pH of the water in the beaker attached to the positive pole was 5.

* This current would hydrolyse water at a rate of 0.75ml/week.

The aggregates used in this experiment were Thames Valley flint gravel and sand. The proportion of flint to quartz increases from 50% in the 150 - 300 µm fraction to 95 - 98% in the 5 - 10 m/m fraction, so that the overall flint concentration is well above 50% when coarse and fine are used together. This aggregate has been used in the London area for a considerable time, occasionally in combination with crushed rock, but no evidence of alkali-aggregate reaction has been reported. If it were reactive it is possible that the high concentration of flint in the sand sizes takes it above the pessimum proportion, even when used with crushed rock coarse.

Experimental - II

A similar U-shaped specimen was made with embedded thermocouples. When kept in a polythene bag inside a foamed polystyrene box (1" thick walls) the temperature at the centre line of the specimen was 37°C for 15mA, and the differential between centre and surface was 2°.

Three similar test pieces were made using a high alkali cement (K_2O = 1.3%, Na_2O = 0.3%) and with the same mix proportions, using Beltane opal* for the fractions 0.6 to 2.4mm. These were kept in the fog room for eight days, then 'demec' gauge points were applied, one pair (10cm apart) to each leg, with the lower points 4cm from the bottom so that they were not submerged by the water in the beakers. The testpiece was then wrapped in self-vulcanising tape, to ensure that the mortar remained saturated, leaving small gaps for the gauge points, and leaving the mortar uncovered below the waterline. One piece was then connected to the 180 v DC supply, another to 180 v AC, and the third was stored over a water bath at 36°C.

The test piece on DC showed 2000 µstrain expansion and extensive cracking after 4 days. The other two pieces expanded slowly over the next 30 weeks, the current falling to 5.0mA in the piece connected to AC, (Spec. res. 15K /cm^3), the temperature to 24°C. When cooled to room temperature the net expansions were 1000 µstrain for the AC piece and

* An opal containing mainly cristobalite and tridymite, from the Beltane quarry, California, supplied by Prof. S Diamond.

500 µstrain for the 35°C control.

This concentration (13.5%) of Beltane opal is somewhat above the pessimum for this size range, which may explain why the AC and control pieces did not fail. There is also, of course, the possibility that Thames Valley flint is reactive but not rapidly enough to take the Beltane opal out of the pessimum range, when DC is applied. Bearing in mind that the temperature of the AC piece was lower than that of the control for the majority of the test, it is interesting that the AC piece showed a significantly greater expansion. Presumably there is a slight rectifying action in the cement paste.

Discussion

It seemed possible that an accelerated test method might be developed from these experiments, particularly for the investigation of pessimum proportions, but later work with direct current, on less reactive mixes, showed that the positive leg expanded less than the negative leg, presumably because sufficient alkali was moved out to affect the rate of reaction. An investigation by Yarkov and Petrishcheva[1] on the effect of electric current on hardening of cement, mortar and concrete showed that the most effective treatment was direct current, reversing direction at frequencies of a few seconds. The effects are probably analagous, and this seems well worth trying. It remains possible however that the induced movement of the alkali can give a false impression of pessimum concentrations.

Reference

1. Yarkov, A.A. and Petrishcheva, R.I. 'On the question of the effect of electric current on the hardening of cement, mortar and concrete'. Izvestiya Vysshikh Uchebnykh Stroitel 'STVO I Arkhitektura, 1977, pp 69-72.

Appendix

Mix Proportions:-

Aggregate	Weight Proportions
10 - 4.8mm	1.1
4.8 - 2.36	0.09
2.36 - 1.18	0.135
1.18 - 0.6	0.135
0.6 - 0.3	0.36
0.3 - 0.15	0.18
	2.0
Cement	1.0
Water	0.344