Potential New Test for Alkali-Aggregate Reactivity

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ABSTRACT

This paper describes a simple and rapid concrete core test method which distinguishes between deleterious and non-deleterious expansions in concrete. By testing the finished concrete, all effects from sand, aggregate, cement, water-cement ratio, additives and concrete curing are included in the results. The test may be used to classify laboratory trial mixes, and to evaluate existing concrete structures ranging in age from one month to one hundred years old.

INTRODUCTION

Preliminary results on a proposed new test method are presented in this paper. Water is necessary to generate alkali-aggregate reactive expansions in concrete. Heat accelerates these expansions. It was found that some concrete samples, after drying in a hot oven and soaking in distilled water, expanded profusely in a short period of time, and others would expand very little. The concrete that did expand was known to have an alkali-aggregate reaction problem, and the concrete that expanded less did not. After several series of heat-treatment and water-immersion trial tests on concrete cores, the most appropriate test procedure was finally decided upon.

SIX WEEK TEST FOR DETECTION OF ALKALI REACTION IN CONCRETE - DUGGAN EXPANSION TEST

A minimum of five cores measuring 22 mm diameter by roughly 65 mm long are wet drilled from:

a) either concrete cylinders or concrete cubes, which have been lab cured for only 7 days in a manner as similar as possible to that of the proposed concrete structure,

b) any concrete structure from one month to 100 or more years old.

A vacuum grip drill stand suitable for mounting on laboratory bench or vertical wall of field structure is most convenient. Cores are cut to 50 ± 5 mm in length, and end faces are ground smooth and parallel. The cores are number identified with marker pen, and one vertical line from top to bottom of core is drawn on one side. The core is then placed in a length measurement jig, such that its bottom center is supported on a 12 mm diameter ball bearing and it is lightly pressed against two 6 mm diameter rods bent at 90° to retain the core in both horizontal directions at roughly its one-quarter length points. The vertical line on the core is lined up with a centering line on the base of the jig. The initial length of the core is measured with a length comparator measuring to an accuracy of .003 mm. For continual calibration checks, a steel core 22 mm diameter by exactly 50 mm long was machined. For all subsequent core measurements, the change in core length relative to the steel was measured.

The heat treatment - distilled water immersion cycle, which has been called the Duggan Cycle, is straightforward and simple. It is depicted in Figure 1.

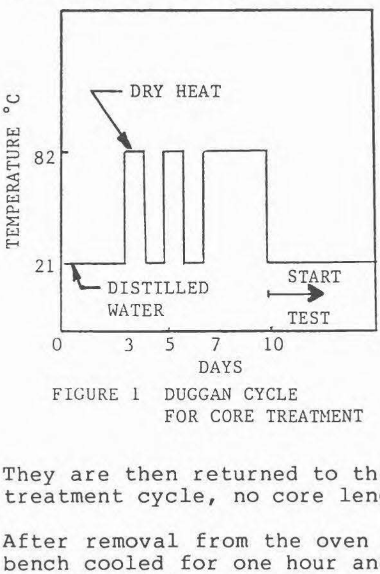

FIGURE 1 DUGGAN CYCLE FOR CORE TREATMENT

The cores are placed in plastic containers and totally immersed in distilled water at room temperature (21°C). Lids are placed on the containers. After 3 days, the cores are taken from the water and placed directly into a dry air oven preheated to 82°C. They are held for one day at this temperature, are then removed and allowed to bench cool for one hour before being placed back in the distilled water. After one day, the cores go back in the 82°C oven for another day, and then, after one hour bench cooling, back in the distilled water for another day.

They are then returned to the 82°C oven for 3 days. During this treatment cycle, no core length measurements need be taken.

After removal from the oven for the final time, the cores are bench cooled for one hour and then length measurements are taken relative to the steel core (zero reference). The cores are then put into the distilled water at 21°C and length change measurements should be taken at 3 to 5 day intervals. The cores are lightly swabbed in an absorbent towel before measurement, and are immediately placed back in the water following measurement. The distilled water is not changed during the course of testing. While over 50 cores of various concretes have been placed in one container, it is recommended that each set of 5 cores be placed in a separate container.

TEST RESULTS

A. EXISTING STRUCTURES

The quickest way to gain an appreciation of the test is to look at results from concrete cores drilled from structures of various ages and various conditions. A badly cracked 27 year old bridge abutment is shown in Figure 2, and core expansion results are shown in Figure 3.

FIGURE 2 MAP-CRACKED
27 YEAR OLD CONCRETE

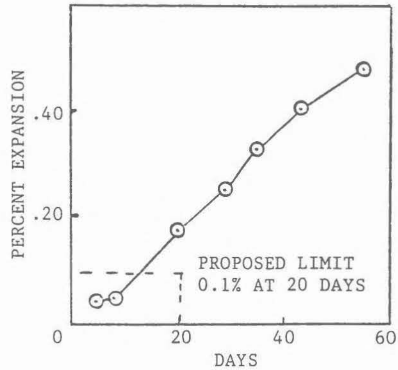

FIGURE 3 CORE EXPANSION
SEE FIGURE 2

Within 3 weeks following treatment, the cores had expanded roughly 0.2 percent. In comparison, cores from a 15 year old bridge abutment in excellent uncracked condition (Figure 4) expanded only 0.08 percent in 20 days (Figure 5).

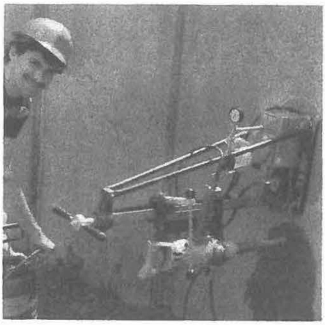

FIGURE 4 UNCRACKED
15 YEAR OLD CONCRETE

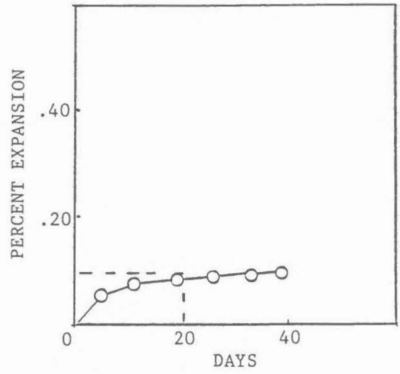

FIGURE 5 CORE EXPANSION
SEE FIGURE 4

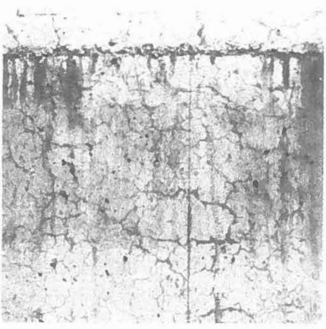

FIGURE 6 MAP-CRACKED
12 YEAR OLD CONCRETE

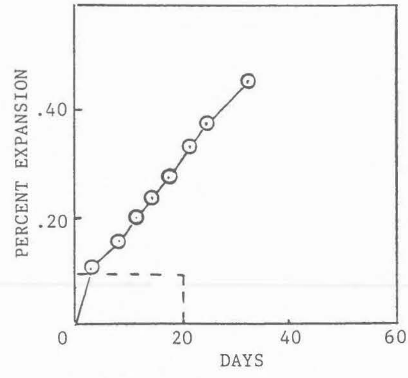

FIGURE 7 CORE EXPANSION
SEE FIGURE 6

Cores from a 12 year old map-cracked structure (Figure 6) expanded 0.3 percent in 20 days (Figure 7).

Cores from a 78 year old structure (Figure 8), in good condition considering its age, expanded less than 0.08 percent at 20 days (Figure 9).

FIGURE 8 NO MAP-CRACKS
78 YEAR OLD CONCRETE

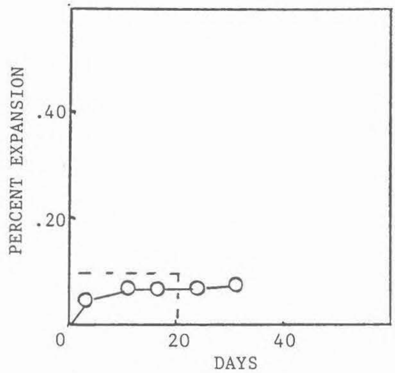

FIGURE 9 CORE EXPANSION
SEE FIGURE 8

Similar results have been obtained on roughly 20 structures drilled to date, and all core expansions correlate well with the observed concrete conditions.

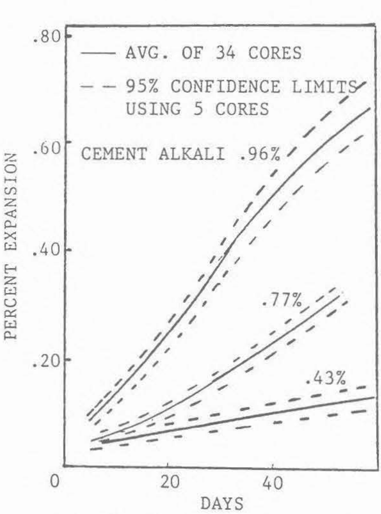

FIGURE 10 95% CONFIDENCE
LIMITS FOR TEST

In order to check on the scatter and statistical validity of the test, 34 cores were drilled from each of three different concretes containing cements of different alkali (Na_2O equivalent) contents. The solid lines in Figure 10 represent the average expansion for the 34 cores, and the dotted lines represent the 95 percent confidence limits if the average of only 5 cores had been used in the tests. The scatter was low and repeatability was good. The higher alkali cements produced higher expansions, as would be expected if alkali aggregate reactivity has a role in the expansion.

B. LABORATORY TRIAL MIXES

An aggregate known to cause deleterious expansions in structures was used with five different high - early strength cements to make 150 mm cubes which were lab cured for 7 days. Cores were drilled from the cubes, and expansion test results are shown in Figure 11.

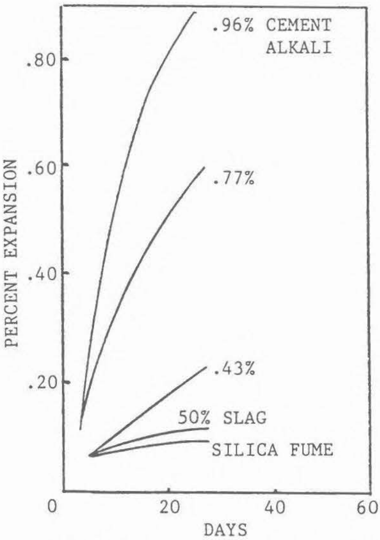

FIGURE 11 CORE EXPANSION WITH SAME AGGREGATE AND 5 DIFFERENT CEMENTS

Again, as would be expected, the higher alkali cements generated higher expansions. Expansions with 50 percent slag cement and silica fume cement were low. Similar type tests, run with crushed pyrex glass and with Kingston, Ontario, limestone, known to be reactive, generated high rapid expansions. Other tests on aggregates believed to be non-reactive generated low expansions.

It is believed, but not confirmed, that the heating cycles prior to immersion activate chemicals and micro-crack the cores, allowing water to penetrate rapidly and greatly accelerate the reactions. Concretes that may take years to expand in the field can be shocked into very rapid expansions.

DISCUSSION

The results obtained with the proposed rapid test method, so far, have been encouraging, but a lot more testing with known reactive and non-reactive aggregates will be necessary in order to confirm that the method can indeed differentiate between reactive and non-reactive aggregates. The reader is also cautioned that although the expansions obtained with concretes made with cements with varying alkali contents appear to correlate with the alkali content of the cements, Figure 11, we have not been able to rule out the possibility that part or all of the expansion may be due to physical causes e.g. micro-cracking due to the treatment cycle and absorption of water by the sample rather than alkali-aggregate reactivity.