Interlaboratory Study of the Concrete Prism Expansion Test for the Alkali-Carbonate Reaction

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ABSTRACT

In Canada, the concrete prism expansion test is used for measuring expansion of potentially alkali-carbonate reactive concrete aggregate. This report describes a study sponsored by Canadian Standards Association Committees A5 and A23 of the precision of this test. Twelve laboratories participated in this study. They tested three aggregates of known field performance: non-expansive, mildly expansive and highly expansive (0.008%, 0.030% and 0.077% expansion respectively at 1-year). For expansion less than 0.014%, results of two properly conducted tests in different laboratories, on the same aggregate, should not differ from each other by more than 0.009%. For expansion greater than 0.014%, the results should not differ by more than 65% of their average.

INTRODUCTION

In early studies of the alkali-carbonate reaction, the mortar bar expansion test gave insufficient expansion (Swenson, 1957). Swenson developed a concrete prism expansion test that has been adopted by the Canadian Standards Association (CSA A23.2 - 14A). Three concrete prisms (75 x 75 x 350 mm to 120 x 120 x 450 mm) are made using the suspect coarse aggregate in a mix with 310 kg m^3 of normal portland cement and a non-reactive fine aggregate. The alkali content of the cement should normally be 0.9 ± 0.1% Na_2O. Sodium hydroxide is added to the mix to give a final equivalent alkali content of 1.0% Na_2O by mass of cement or the highest cement alkali content likely to be encountered. On demoulding, the prisms are stored in a moist room and expansion measured periodically and reported as a percent change in initial length. The average of the three prism expansions is reported as the final test result.

The 1977 Canadian Standard recommended (CSA A23.1, Appendix B) in a non-mandatory appendix, that expansions in excess of 0.02% at 84 days were considered harmful for concrete exposed to moist conditions. Expansions in excess of 0.03% at any age were also considered to indicate potentially deleterious reactivity. More recent data has shown that expansions in excess of 0.025% at 1-year, when tested with 1.25% Na_2O equivalent alkalies by weight of cement, are potentially harmful for concrete exposed to a moist environment with sodium chloride (Rogers, 1986a).

DESIGN

The primary purpose of this study was to gain data to formulate a multilaboratory precision statement over a range of expansion values for the concrete prism expansion test. A secondary purpose was to gain information about possible sources of variation in the test. The ASTM Practice for conducting interlaboratory test programs to determine the precision of test methods was followed as far as possible (ASTM C802-80).

The study was separated into two parts as follows:

Part 1 - Mixes 1, 2 and 3: Three different coarse aggregates of different expansive properties were tested according to CSA A23.2 - 14A. Each laboratory tested each coarse aggregate using their own standard fine aggregate and cement meeting the requirements of the test procedure. If necessary, each laboratory adjusted the alkali content of each mix to 1.0% Na_2O equivalent by the addition of NaOH to the mix water.

Part 2 - Mix 4: The mildly expansive aggregate (Part 1, Mix 2) was tested. Samples of the fine aggregate and cement were supplied by the co-ordinating laboratory. The cement had an equivalent alkali content of 1.1 % Na_2O.

Twelve experienced concrete testing laboratories participated, ten in Canada and two in the U.S.A. Four of the laboratories had no previous experience with this test method.

Three coarse aggregates (4.75 - 19 mm) were chosen from different levels of the McLeod Quarry near Cornwall, Ontario, Canada. The rock in this quarry is horizontally bedded, Middle Ordovician limestone and dolomitic limestone with occasional dolostone interbeds. Three 60-tonne stockpiles from different levels in the quarry were established by the quarry operator. Sixty-five canvas bags, each of about 30 kg capacity, were filled from each stockpile for mixes 1, 2, 3 and 4. The bags were taken to the coordinating laboratory, oven dried and assigned randomly to each of the twelve laboratories. No attempt was made to grade or split the bulk material, the reason being, that this rarely occurred in normal practice. "Precision estimates for inclusion in a test method must be obtained under conditions...that are representative of the situations in which the test method will be used in practice" (ASTM C802-80).

Forms were sent to each laboratory to record data on equipment used and mix proportions and properties. Forms were also sent to each laboratory to record and report expansion measurements at 28, 56, 84, 112, 168, 275 days and 1 year.

RESULTS

Expansion data is reported elsewhere (Rogers, 1986b). The statistical treatment of the data followed that described in ASTM C802 except for determination of within laboratory precision which was not determined.

Multi-laboratory Precision

Following the rejection of outlying data, the coefficient of variation and standard deviation at each age was plotted against expansion. This gave

information about the best way to formulate a precision statement. In Figure 1, it can be seen that the coefficient of variation was high and variable for expansions less than about 0.014%. For expansions greater than 0.014%, the coefficient of variation was relatively low and stable (average 23%). Figure 2 shows that the standard deviation increased progressively with increase in mean expansion, but did not decrease to zero at low expansion values. For expansion less than 0.014%, the pooled standard deviation was 0.0032%. These results were formulated into a precision statement, as defined by ASTM C670, as follows:

Multi-laboratory Precision (average expansion less than 0.014%) - The multi-laboratory standard deviation of a single test result (mean of measurements on three prisms) for average expansions less than 0.014% has been found to be 0.0032%. Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ by more than 0.009%.

Multi-laboratory Precision (Average Expansion Greater than 0.014%) - The multi-laboratory coefficient of variation of a single test result (mean of measurements on three prisms) for average expansions greater than 0.014% has been found to be 23%. Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ from each other by more than 65% of their average.

Range Within a Laboratory

Using the individual prism measurements, it has been possible to formulate a statement about the expected range in values obtained with three prisms in a single laboratory. This is not the same as within laboratory precision. It is useful, however, in seeing whether the range in individual values used to calculate a single test result is extraordinarily wide and therefore suspect.

Laboratory variances were calculated from the individual prism expansion data reported by each laboratory for each material at each age. These variances were then pooled and standard deviations and coefficient of variance calculated. A graphical analysis of this data showed that using a pooled standard deviation (0.0025%) for expansion values less than 0.02% and an average coefficient of variation (12%) for values greater than 0.02% gave the most accurate picture of the range that was encountered. Multiplying the standard deviation and coefficient of variation by 3.3, since three values are used to calculate a single test result (ASTM C670, para. 3.2.2.), gave a statement about expected range as follows:

Range for a single test result (average expansion less than 0.02%) - For average (mean of three prisms) expansions of less than 0.02%, the multi-specimen, single operator standard deviation has been found to be 0.0025%. The range (difference between highest and lowest) of the three individual prism measurements used in calculating a test result should not exceed 0.008%.

Range for a single test result (average expansion greater than 0.02%) - For average (mean of three prisms) expansions of more than 0.02%, the multi-specimen, single operator coefficient of variation has been found to be 12%. The range (difference between highest and lowest) of the three individual prism measurements used in calculating a test result should not exceed 40% of the average of the three.

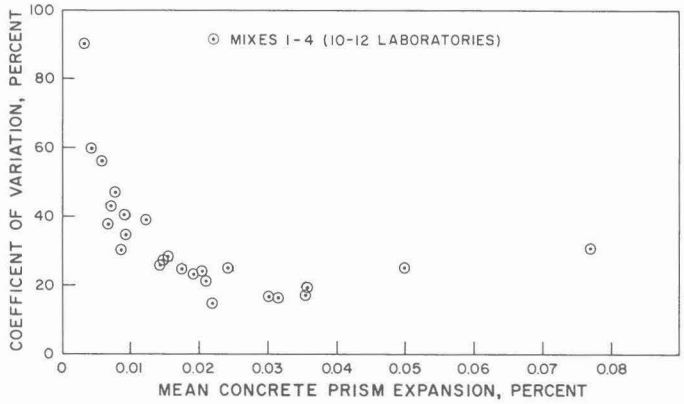

Figure 1, MULTILABORATORY COEFFICIENT OF VARIATION AGAINST MEAN EXPANSION

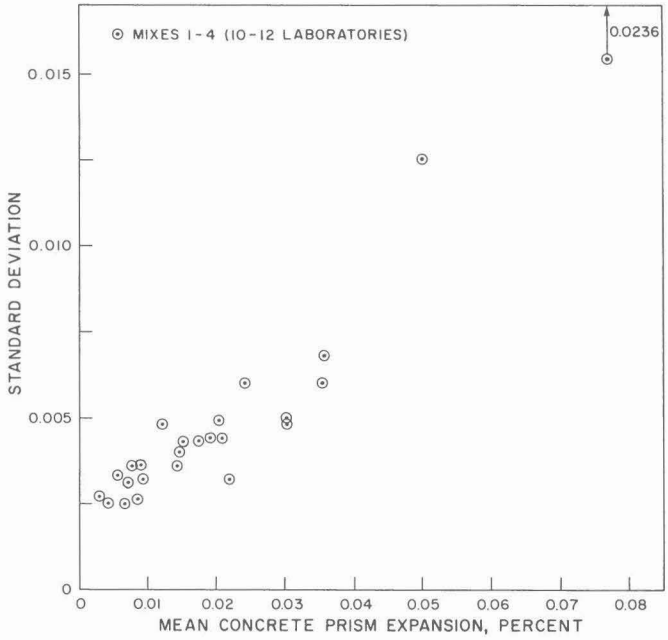

Figure 2, MULTILABORATORY STANDARD DEVIATION AGAINST MEAN EXPANSION

DISCUSSION

A comparison of the data obtained for mixes 2 and 4, made with the same coarse aggregate, is interesting. Mix 2 was made by individual laboratories using their own mix design, fine aggregate and cement. In mix 4, the mix

proportions were specified and the fine aggregate and cement supplied by the co-ordinating laboratory. The pooled standard deviations for mixes 2 and 4 were about the same (0.0043% and 0.0050%) and the average coefficients of variation were similar (27.5% and 25.0%). There was no significant improvement in precision by a more strict definition of the mix proportions or material properties than allowed by the current test procedure.

One laboratory conducted an independent investigation of the effect of storage conditions on expansion. Wrapping prisms in plastic or placing them in a closed container resulted in a 300% increase in expansion at 1 year compared to uncovered storage in the humid room. This difference may be caused by leaching of alkalies by continuous exposure to moisture in an uncovered condition. Slight variations in the amount of free moisture falling or condensing on the prisms may have significant effects on the leaching of alkalies from the concrete and subsequent expansion. This would account for the wide variation found between the various laboratories. Those laboratories which obtained high amounts of expansion may have had small amounts of free moisture in the humid room. Those laboratories with low values may have had high amounts of free moisture with considerable leaching of alkalies and reduced expansion.

ACKNOWLEDGEMENTS

This study was sponsored by C.S.A. committees A5 and A23. The following principals and laboratories participated in this study: A.D. Buck, U.S. Army Corps of Engineers, Vicksburg, Miss.; J. Bickley, Trow Ltd., Brampton, Ont.; A. Bisaillon, Laboratoire de Beton Ltee, Montreal; N. Elmhirst, and the late C. Fremming, Canada Cement Lafarge, Belleville, Ont.; P. Grattan-Bellew, National Research Council, Ottawa; J. Gillott, University of Calgary; L. Hill and K. Lenz, Manitoba Hydro, Winnipeg; D. Hooton, Ontario Hydro, Toronto; R. Northwood, Ministry of Transportation and Communications, Toronto; J. Soles, CANMET, Ottawa; D. Stark, Portland Cement Association, Skokie, Ill.; L. Zimmerman, St. Lawrence Cement Co. Ltd., Mississauga, Ontario.

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