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TECHNICAL NOTE

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SUBJECT Performance of Tests for Cement-Aggregate Reaction

During the investigation of cases of excessive expansion in concrete in Canada by the Division of Building Research, certain results were obtained which may be of interest in the appraisal of the methods of test for alkali-aggregate reaction. The scope of this work covered the Quick-Chemical and Mortar Bar tests carried out in this laboratory, final petrographic evaluation by recognized authorities in the U.S.A., and other special tests.

Case I

Petrographic evaluation of a deteriorated concrete slab and of aggregate samples from the original sources revealed unmistakable evidence of alkali-aggregate reaction: fractures, secondary chemical deposits, alkalic silica gel, reaction rims, and pattern cracking resulting from excessive expansion. A high alkali cement had been used. The rate of expansion in the field cases was very slow.

The reactive components in the crushed boulders and the coarse fraction of the sand were phyllites and smaller amounts of chalcedonic sandstone, meta-sandstone, and chalcedonic limestone.

The Quick-Chemical test, A.S.T.M. C289-54T, gave values of Reduction of Alkalinity and Silica Release well within the region of deleteriously reactive aggregate, as proposed by Mielenz, Green and Benton, Journ. A.C.I., Vol. 19, No. 3, p.193-219, November 1947.

The standard Mortar Bar test, A.S.T.M. C227-52T, gave negative results for both stone and sand materials as obtained from the original sources.

Since the proportion of deleterious materials in these samples may have differed from those in the field cases, a repeat series was tested in which dilutions were made. To date, at ages up to nine months, the expansion in these mortar bars shows no indication of approaching the critical limits.

The Conrow Test, A.S.T.M. C342-55T, also gave negative results for these materials. The accelerated reactivity test on concrete beams, the method originally proposed by the Bureau of Reclamation, was also negative. A wetting and drying test on concrete beams (similar to the Scholer method) produced excessive expansion on beams made from these materials, but had similar effects on beams made from known unreactive materials.

Case II

Concrete sidewalks, floor slabs, and other concrete elements exposed to high humidity conditions showed excessive expansion accompanied by map cracking. Preliminary tests indicated that a crushed limestone aggregate was the cause of the trouble. A high alkali cement had been used in this case also. The rates of expansion in the field concrete and in the laboratory concrete beams exposed to 100% relative humidity conditions were very rapid, being in the order of 0.1% in three months and 0.2% in six months.

Opinions expressed by independent authorities in the field, who had made careful analyses, agreed that alkali-aggregate reaction was the cause. An unusual feature of this case was that gel formation, usually associated with this reaction, was almost non-existent. The degree of definition of reaction gel rims was a matter of minor disagreement, and the nature of the reactive component was somewhat uncertain.

The Quick-Chemical test gave negative but rather unusual results, with a very high Reduction in Alkalinity and a low silica release. According to Mielenz, Green and Benton, these results should indicate a very safe material as far as alkali-aggregate reaction is concerned. Mortar Bar test results, as far as they have now progressed, may be considered as borderline. The percentage expansion at six months ranged from 0.025 to 0.045.

Replacement of 25% of the high alkali cement by a pozzolanic material had the positive effect of considerably reducing the expansion. The low alkali cement had the same effect. Concrete beams made with crushed limestone as coarse aggregate expanded rapidly under conditions of: (a) outside exposure, (b) exposure to wetting and drying, and (c) exposure to 100% relative humidity at 23°C.

The possibility that the "pessimum" was missed has prompted further work on "diluted" materials, particularly since this case appears to be the type where optimum expansion occurs with a low percentage of deleterious material. To date no conclusive results have been obtained.

The Conrow Test on this material was negative.

Tentative Conclusions

1. In Case I, all evidence indicates alkali-aggregate reaction except the results of the Mortar Bar test. It appears to be similar in nature to the reaction occurring in the Buck Hydro-electric Dam, and represents a type which, reportedly, is not too well understood. Pending further study, it would seem necessary to clarify the status of C227-52T by correcting the impression that the Mortar Bar test is the most reliable of the three procedures for detecting cases of alkali-aggregate reaction, and providing an explanatory note in C227-52T with suggestions for the blending of materials in order to ensure that the proportions of deleterious materials will include the expansive combination.

2. Case II is apparently a very unusual type of alkali-aggregate reaction in which the Quick-Chemical test fails and the Mortar Bar test is borderline. In view of the results obtained it is my opinion that alkali reactivity in limestones should be re-examined in order to determine more precisely the differences that exist in their response to present test methods as compared with siliceous aggregates. This applies particularly to the Quick-Chemical method. The effect of carbonates on the reduction of alkalinity warrants study. It would also seem logical that a suitable factor should be used in calculating silica release from limestones which would be dependent upon the total amount of silica material present in the aggregate.

The borderline nature of the Mortar Bar test results in Case II, and the very rapid expansion of concrete specimens, seem to indicate the need for extending C227-52T to include blends for the Mortar Bar test and the exposure of companion concrete samples to selected conditions. The reduction of stone size to sand size for the Mortar Bar test may, in this case, have reduced the expansive tendency of the mortar in accordance with recent theories.