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NDOR Research Technical Brief

Nebraska Department of Roads

Research Project Title:
Durability of Portland Cement Concrete: Aggregates, Cements, and Pozzolans

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PROBLEM:

The Nebraska Department of Roads in 2001 initiated an effort to improve the durability of concrete for state paving projects. The objectives were to evaluate the alkali-silica reactivity (ASR) potential of selected aggregates, and to identify the specific amounts of supplementary cementing materials, such as fly ash, slag and silica fume, to effectively mitigate ASR.

DESCRIPTION:

The testing included 4 sources of fine aggregates, 1 source of limestone, 5 sources of portland cement, 2 sources of Class C fly ash, 1 source of Class F fly ash, 1 source of slag, and 1 source of silica fume. ASTM C 1293 and performance tests, including compression strength, flexural strength, split-tensile strength, freeze-thaw resistance, NDOR wet & dry and chloride ion penetration were conducted on the same concrete mixes.

RESULTS:

The percentages used for cement replacement by mass included C ash at 17%, 25% and 35%, C ash at 20% plus silica fume at 3%, F ash at 17% and 25%, and slag at 20% and 35%. A synthesis of the data analysis indicates that using 17 to 23.5% of Class F fly ash, or 20 to 35% of ground slag, would effectively control the ASR expansion without compromising the mechanical strength and durability of concrete per Nebraska 47B Specifications. It was necessary to use high volume of Class C fly ash (> 35%) to mitigate ASR expansion which inadvertently would compromise the concrete strength and durability. However, a combination of 20% of Class C fly ash and 3% silica fume proved to be very effective in controlling the ASR expansion as well as enhancing the concrete strength and durability.

CONCLUSIONS:

The ASTM C1293 test data showed that the PE and RR aggregates are fast reactive, while the PC and PW aggregates are slowly reactive. It is anticipated that if the above recommended SCM percentages are used in concrete production according to the Nebraska 47B Specifications, the ASR expansion potential would be effectively mitigated while providing adequate mechanical strength and concrete durability.

A recent report by Folliard et al. disputed the validity of the accelerated ASTM C1293 tests (Method A). Their findings indicated that the expansions at 140^{O}F were significantly less than (or about 60%) the long-term expansions obtained at 100^{O}F. The reduction was mainly due to the increased specimens drying, increased alkali leaching at 140^{O}F as well as the accelerated cement hydration. These test results are preliminary from an on-going research. Nevertheless, the findings of the current study hinge on the validity of the accelerated version of the ASTM C1293 tests.

One objective of this study was to develop guidelines and specifications for durable concrete production in Nebraska. However, the regular ASTM C1293 tests conducted did not produce significant ASR expansions due to insufficient amount of total alkali contents (i.e., 564 pounds of cement at 1.25% Na_2O_e per cubic yard of concrete). Further, the validity of the accelerated version of the ASTM C1293 is questionable at this point of time. Therefore, it is recommended that the regular ASTM C1293 tests specified in the test matrix be re-conducted, using 708 pounds of cement at 1.25% Na_2O_e per cubic yard of concrete, to confirm the findings from this study.

IMPLEMENTATION PLAN:

Portland Cement Concrete (PCC) pavements are inherently durable and are expected to be relatively maintenance-free during many years of service. Unfortunately, a number of pavement distresses can occur as a result of the interaction between the concrete and the environment in which it is exposed.

One of the objectives of this research was to evaluate different mix designs and their effect in reducing Alkali Silica Reactivity (ASR) based on the selection of different supplementary cementing materials (SCM). The purpose of the research was to give NDOR guidelines for producing durable PCC through material selection and mitigation alternatives. However, the tests conducted did not produce significant evidence of ASR expansion with any of the mixes evaluated, primarily due to the modification to ASTM 1293 that was made, which utilized a lower alkali cement than was suggested in the test method. This modification, in effect did not provide enough alkalis for the test method to capture the expansion that happens in the field, with certain slowly reactive aggregates.

Upon the conclusion of this study, further studies have put into question the ASTM Accelerated 1293 test methods, also used in this study to predict the amount of expansion that would be experienced. Researchers who developed the ASTM Accelerated 1293 test, have recently indicated that the modifications they made to the Regular ASTM 1293 test, to develop an accelerated test, did not provide results that appropriately correlated with the regular test, as they had originally claimed. As a result of these new findings, some of the conclusions drawn from this research report are no longer valid. Several additional NDOR in-house testing was performed, which provides results that contradict some of the recommendations made by this research project. For instance, the recommendation in this report, which indicates that 17% Class F Fly Ash, effectively mitigates ASR was proven false according to additional testing done by NDOR. In summary, in order to clarify some of the contradicting research findings, additional research must be performed, with an expanded scope to include the new ternary and quaternary blends available in the market today.

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