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SUMMARY REPORT

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Impact of Aggregate Gradation on PCC Performance Properties

EXECUTIVE SUMMARY

Introduction

Aggregates make up a significant volume fraction of portland cement concrete and play a major role in determining its fresh and hardened properties. One of the important aggregate properties that influence the concrete behavior is the aggregate gradation. Increasingly, aggregates in South Carolina are failing to meet the standard SCDOT requirements for gradation for use in portland cement concrete. The effect of such failed aggregate gradations on concrete properties and the consequent effect on short- and long-term performance of the structures are poorly understood. Furthermore, a rational basis to accept or reject concrete containing such out-of-specification aggregate is not available at the present time.

The principal objective of this investigation was to study the influence of variations in aggregate gradations on selected properties of concrete and provide guidance to SCDOT on a rational basis to accept or reject concrete containing out-of-specification aggregate.

Experimental Methodology

The experimental methodology for this research study consisted of separating individual size fractions of aggregate from a standard No. 57 aggregate and then recombining the individual fractions in definite proportions to create a range of aggregate gradations. In this study, the percent passing through the three middle sieve size fractions of No. 57 aggregate (3/4 in., ½ in. and 3/8 in.) and fine aggregate (No. 16, No. 30 and No. 50) were varied. Considering that the standard specifications for acceptable aggregate gradation consists of a range of allowable percent passing values, in this study three control gradations were developed. While Control-1 and Control-3 gradations followed the outer limits of allowable percent passing values on the lower and higher ends, Control-2 gradation.

represented a gradation that embraced an average percent passing value on each of the sieves in the No. 57 aggregate. In addition to these three Control gradations four out-of-specification gradations were fabricated, two of them failing by different levels beyond Control-1 gradation and two additional gradations failing by different levels beyond Control-3 gradations. Concrete specimens were prepared with aggregate meeting each of the three Control gradations and all the four failed gradations. A range of fresh and hardened properties of concrete were evaluated to study the impact of failed aggregate gradation. This experimental methodology was repeated on two sets of coarse aggregates and two sets of fine aggregates. When a failed coarse aggregate was employed a Control-2 fine aggregate was used in the concrete. Similarly, when a failed fine aggregate was employed, a coarse aggregate meeting the Control-2 gradation was employed.

Results

Results from these studies indicated that deviations in fine aggregate gradation from the Control-2 gradation had relatively larger influence on properties of concrete compared to the deviations in coarse aggregate gradations evaluated in this study. The properties most influenced by the changes in the fine aggregate gradation included fresh air content, slump, split tensile strength, rapid chloride ion permeability and water absorption of concrete. However, much of the variation in the properties of concrete occurred due to variation in the gradation of aggregate within the limits of acceptable gradation, i.e. between Control-1 and Control-3 gradations. Although some additional change in properties of concrete was observed when the aggregate gradation deviated out of specification limits, i.e. beyond Control-1 or Control-3 gradations, the change was not as much as that observed when deviating from Control-1 to Control-3 gradations.

Based on the findings from this study, it is recommended that as long as plastic properties of concrete such as slump and air content of concrete are within acceptable limits and the concrete is of adequate quality to achieve proper consolidation and finishing characteristics, aggregates that fail to meet the standard requirements by a margin of ± 12% of the acceptable cumulative percent passing on any sieve (i.e. beyond either Control-1 or Control-3 gradations) may still be used to produced concrete that has a comparable performance to that of an aggregate meeting the standard requirements. However, considering that some of the properties of concrete that are most affected by the deviations in aggregate gradation are also properties that affect cracking and durability in concrete, such as split tensile strength and rapid chloride permeability, particularly with failing fine aggregates, it is important to consider the consequences of deviation in aggregate gradation based on the nature of the structure and the stresses imposed on the concrete.

Conclusions and Recommendations

The changes in concrete properties associated with changes in gradations of aggregate, even within the acceptable limits, are rather large. Use of aggregate gradations that fall out of specification within a range of ± 12% of the cumulative percent passing from the boundaries of acceptable gradation, did cause deviations in properties of concrete compared to an ideal gradation (Control-2) that is exactly in the middle of the specification band. However, compared to aggregate gradations that embrace the limits of the existing specifications (i.e. Control-1 and Control-3); the use of failed gradations did not produce concrete that is significantly different. The precise impact of changes in aggregate gradation on concrete behavior is very specific to individual properties of concrete as well as the failure of gradation on specific sieves and the magnitude of the failure in the gradation. Considering these findings, it is recommended that the impact of failure of aggregate gradations be weighed considering the sensitivity of the specific structure for which the aggregate is to be used, and the potential impact of properties of concrete such as the split tensile strength and rapid chloride permeability have on the structural integrity and durability of the structure.

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