RESEARCH
PROJECT CAPSULE
22-2C
February 2022
TECHNOLOGY TRANSFER PROGRAM

Optimizing Aggregate Gradation to Reduce Concrete's Permeability

JUST THE FACTS:

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January 17, 2022

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24 months

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January 16, 2024

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POINTS OF INTEREST:

Problem Addressed / Objective of Research / Methodology Used / Implementation Potential

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PROBLEM

Concrete durability has become an increasingly important design parameter as state highway agencies look to increase the service life of concrete infrastructure. While there are several approaches to produce durable concrete (e.g. by reducing its permeability), one factor that often gets overlooked in a mixture design is the aggregate gradation. In practice, most concrete producers tend to use the grading limits specified in ASTM C33 for aggregates. However, the use of these limits may not necessarily produce durable concrete mixtures because the grading limits happen to be too broad to guarantee optimum packing density. By maximizing the aggregate's packing density, the concrete's cement demand can be reduced, resulting in a less permeable concrete.

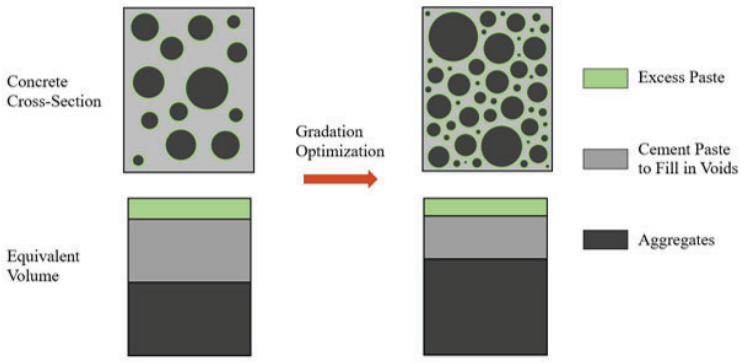

Figure 1. Influence of aggregate gradation on cement paste required to fill in voids between aggregates [adapted from Mamirov, M., Hu, J., Kim, Y. "Evaluation Reducing Cement Content in NDOR Class R Combined Aggregate Gradations" Report No. SPR-P1(18) M069, 2019]

There is a need to optimize aggregate gradations for concrete mixture designs to maximize durability. This study will focus on preparing concrete mixtures with optimal gradations based on five different aggregate gradation techniques in order to minimize permeability. Durability tests through surface resistivity (AASHTO T358) and formation factor (AASHTO 119-15, Option A) are proposed to assess how different gradations perform versus typical ASTM C33 gap-graded mixtures.

OBJECTIVE

The objective of this study is two-fold. The first objective is to measure the influence of aggregate gradation on concrete's permeability. The second is to optimize concrete mixture designs that meet strength, permeability, and workability criteria for construction.

METHODOLOGY

To achieve the objectives of this study, the research team will complete multiple tasks. First, an extensive literature review will be completed to determine the state-of-practice and current research endeavors regarding the influence of aggregate gradations on concrete's permeability.

A historical review of past DOTD-approved mixture designs will be conducted to determine

what aggregate gradations and techniques were used. When available, records of actual performance with regard to strength and permeability will also be obtained.

Five different aggregate gradation techniques will be used (Shilstone chart, Power curve, 5-20 band, Tarantula curve, Gap gradation). Different gradations will be used for each technique, and the packing density of each gradation will be assessed based on the aggregate's void contents (ASTM C29). Gradations with the highest and lowest packing density for each technique will be selected for the comparative testing phase of this study.

Table 1 summarizes the proposed variables for the comparative testing. A total of 60 concrete mixtures will be prepared. For each mixture, nine cylinders will be prepared to test for compressive strength, surface resistivity, and formation factor. Fresh concrete properties (e.g., slump, air content, and unit weight) will also be evaluated.

Table 1. Description of proposed design variables

Variable	Levels	Description
Aggregate gradation techniques	5 x 2	Shilstone chart, Power curve, 5-20 band, Tarantula curve, Gap gradation
w/cm ratio	1	0.45
Coarse aggregate type	1	Gravel
Cementitious material systems	3	100% portland cement, 70% portland cement and 30% class C fly ash, 50% portland cement and 50% slag cement
Cement content	2	650 lbs/yd^3 (baseline), and a tailored amount based on a 1.5 paste-to-voids volume ratio

Once the data is collected, a statistical analysis will be conducted to evaluate the influence of aggregate gradation on concrete's permeability. The optimal gradation will be selected based on its performance, cement demand, and workability. In addition, correlations between surface resistivity readings and formation factor measurements will be examined.

IMPLEMENTATION POTENTIAL

This study will measure the influence of aggregate gradation on concrete workability, strength, and durability. Gradations will be optimized for best possible performance. The results of this research may be used by DOTD to specify aggregate gradations that promote durability for concrete construction.