Research Project Brief

Report 27-R10: Effect of Carbon-Negative Carbon Black on Concrete Properties

VTRC Virginia Transportation Research Council

Background

Cement production is a major contributor to global greenhouse gas emissions, responsible for roughly 5 to 8% of total emissions. Carbon black, a fine and electrically conductive carbon-based material, can be produced from captured carbon dioxide. This method has generated interest in using carbon-negative carbon black as an additive to help offset the emissions associated with cement in concrete, thereby reducing the overall carbon footprint of concrete.

Research Objectives

The objective of this study was to explore the feasibility of integrating Type IL cement with alternative supplementary cementitious materials (calcined clay and reclaimed coal ash) and carbon black to produce concrete materials with a reduced carbon footprint while maintaining the necessary workability, strength, and durability characteristics.

Approach

To accomplish the research objective, this project was organized into two main tasks:

- Characterize carbon black.
- Evaluate the fresh, hardened, and durability properties of VDOT Class A4 General concrete incorporating the different cementitious binder systems.

Outcomes

Results show that carbon black consists almost entirely of elemental carbon with negligible reactivity, functioning as an inert filler. At the evaluated dosage (3% cement replacement by mass), concrete meeting VDOT Class A4 General requirements can be produced. However, incorporating carbon black sharply increased admixture demand (approximately 1.5 to 2 times more high-range water reducer and 20 to 45 times more air-entraining admixture), reduced compressive strength by 8 to 23%, and slightly increased chloride-transport indices and drying shrinkage, while having minimal effect on elastic modulus and Poisson's ratio. Accordingly, carbon black provided no performance benefits beyond a potential reduction in embodied carbon, the magnitude of which depends strongly on its source. Carbon black may nevertheless offer transportation-relevant functionalities, such as self-heating for de-icing and self-sensing for structural monitoring; however, these effects generally require higher dosages than those considered in this study.

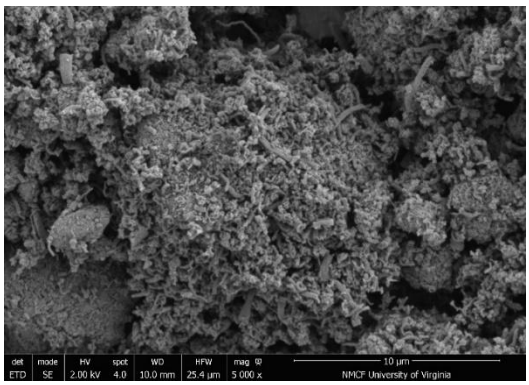
Research Benefits

This study provides VDOT information on emerging carbon-based additives, which may play an increasingly important role in the future of concrete. The knowledge generated equips VDOT to critically evaluate the novel products, ensuring the agency is prepared to assess and implement new materials as they enter the market.

Carbon Black



Carbon Black in Saturated Surface Dry Condition Used in Concrete



Scanning Electron Microscopy Image of Carbon Black (5,000x magnification)

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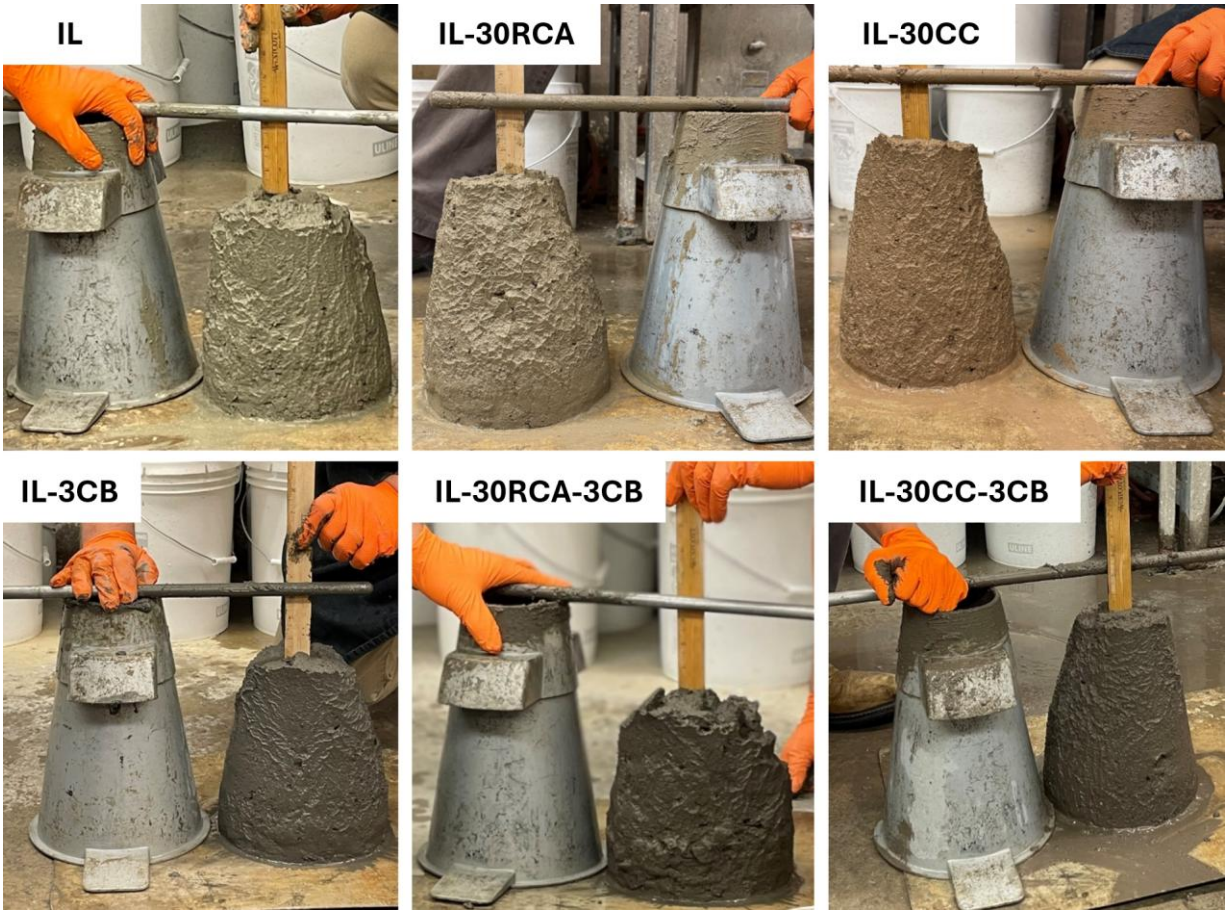
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Research Findings



Consistency of Concrete Mixtures with and Without Carbon Black After Slump Test. CB = carbon black; CC = calcined clay; IL = Type IL Cement; RCA = reclaimed Class F coal ash.

Carbon Black Is a Filler

Carbon black does not demonstrate the reactivity levels (ASTM C1897) typically associated with supplementary cementitious materials. Accordingly, carbon black primarily functions as a filler material in concrete.

Performance in Concrete

Carbon black provided no performance benefits beyond the potential reduction in carbon footprint. Nevertheless, concrete meeting VDOT Class A4 General requirements can be produced incorporating carbon black.