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Cracking and Durability in Sustainable Concretes

SP-336

Editors:
Ralf Leistikow and Kimberly Waggle Kramer



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Cracking and Durability in Sustainable Concretes

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PREFACE

Cracking and Durability in Sustainable Concretes

ACI Committees 130 and 224 sponsored and moderated two sessions at The ACI Concrete Convention and Exposition – Fall 2017, held in Anaheim, California. The objective of the sessions was to review the use of innovative mixture designs which incorporated sustainable admixtures and supplemental cementitious materials, and the effect these sustainable technologies have on the cracking performance and durability of these concretes. In particular, cracking behavior in sustainable concretes or practices for mitigation of cracking in sustainable concretes was reviewed. This information was shared based on completed research and case studies of sustainable concrete mixture designs. The learning objectives of the two sessions follow:

- 1) Learn about innovative mixture designs that incorporate sustainable admixtures and supplemental cementitious materials;
- 2) Learn about the effect these sustainable technologies have on the cracking performance and durability of these concrete mixes;
- 3) Gain an understanding of the cracking behavior of sustainable concrete mixtures; and
- 4) Learn about practices used to mitigate cracking in sustainable concrete.

Twelve presentations were given, and the presenters came from all over the world. Following the sessions, some of the presenters authored papers that provided more extensive information about their research. This SP include copies of these seven research papers.

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Internal Curing and Supplementary Cementitious Materials in Bridge Decks

James Lafikes, Rouzbeh Khajehdehi, Muzai Feng, Matthew O'Reilly, David Darwin

Synopsis: Supplementary cementitious materials (SCMs) in conjunction with pre-wetted fine lightweight aggregate to provide internal curing are being increasingly used to produce high-performance, low-shrinking concrete to mitigate bridge deck cracking, providing more sustainable projects with a longer service life. Additionally, the SCMs aid in concrete sustainability by reducing the amount of cement needed in these projects. This study examines the density of cracks in bridge decks in Indiana and Utah that incorporated internal curing with various combinations of portland cement and SCMs, specifically, slag cement, Class C and Class F fly ash, and silica fume, in concrete mixtures with water-cementitious material ratios ranging from 0.39 to 0.44. When compared with crack densities in low-cracking high-performance concrete (LC-HPC) and control bridge decks in Kansas, concrete mixtures with a paste content higher than 27% exhibited more cracking, regardless of the use of internal curing or SCMs. Bridge decks with paste contents below 26% that incorporate internal curing and SCMs exhibited low cracking at early ages, although additional surveys will be needed before conclusions on long-term behavior can be made.

Keywords: bridge decks, cracking, high-performance concrete, internal curing, sustainability

Zeolite Based Concrete- Durable Solution for Nation's Infrastructure

Nidhi M Modha and Pratanu Ghosh

Abstract: In this research, a natural pozzolanic cementitious material known as zeolite is being utilized to investigate the performance of High-Performance Concrete (HPC). Several binary (cement+zeolite) and ternary (cement+zeolite+other supplementary cementitious material) based concrete mixtures including a control mixture of Ordinary Portland Cement (OPC) with water - cementitious (*w/cm*) ratios of 0.40 and 0.44 are cast by replacing cement with different percentage level of zeolite material. The purpose of this study is to investigate effectiveness of zeolite material by means of long term compressive strength (7 to 91 days), tensile strength, modulus of elasticity and corrosion resistance in several concrete mixtures from 7 to 28 days. The compressometer is utilized for the measurement of the modulus of elasticity and Universal Testing Machine (UTM) is utilized to measure the compressive and tensile strength of concrete. In addition, a 4-point Wenner Probe resistivity meter is tested to determine the surface electrical resistivity of concrete, which provides an indirect indication of permeability and in turn, chloride induced corrosion durability in reinforced concrete structures. Overall, zeolite based concrete mixtures with 0.40 *w/cm* ratio and ¾ inch aggregate size provide promising results in terms of compressive strength, tensile strength and remarkable improvement on corrosion resistance in terms of achievement of surface resistivity data.

Freeze-Thaw and Salt Resistance of a Fly Ash Based Pervious Concrete

Gang Xu, Luis Gerardo Navarro, Kafung Wong, and Xianming Shi

Synopsis: In this work, the freeze/thaw resistance and ambient-temperature salt resistance of fly ash geopolymer pervious concrete specimens were investigated separately, to isolate the physical and chemical phenomena underlying their deterioration during “salt scaling”. The laboratory investigation examined four groups of samples, with portland cement or activated fly ash as the sole binder, with or without graphene oxide (GO) modification, respectively. The incorporation of GO significantly improved the resistance of pervious concrete to freeze/thaw cycles and ambient-temperature salt attack, regardless of the binder type. The specimens were then examined by using X-ray Diffraction (XRD) method, which revealed that the mineralogy and chemical composition of fly ash pastes differed significantly from those of cement pastes. Nuclear magnetic resonance (NMR) was also employed to study the chemical structure and ordering of different hydrates. This work provides an enhanced understanding into the freeze/thaw and salt scaling resistance of fly ash pervious concrete and the role of GO.

Keywords: pervious concrete, fly ash, geopolymer, freeze-thaw, salt attack, wet-dry, X-ray diffraction (XRD), nuclear magnetic resonance (NMR)

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Multifunction Green Corrosion Inhibiting Admixtures for Mortar under Chloride Environment

Yu Jiang, Gang Xu, Zhipeng Li, and Xianming Shi

Synopsis: In this study, we tested compressive strength, rheology, initial setting time and transport properties of mortar samples mixed with green corrosion-inhibiting admixtures were tested. Four types of green corrosion inhibitors were adopted, which were extracted from peony leave, Kentucky blue grass, sugar beet leave and dandelion. All of them affected the compressive strength adversely, but improved other properties of mortar samples. Resistance of mortar to chloride induced corrosion was evaluated using open circuit potential (OCP), electrochemical impedance spectroscopy (EIS) and linear polarization resistance (LPR) techniques. The results indicated that these green corrosion-inhibiting admixtures provided promising inhibiting performance under chloride environment. The results also suggested these green corrosion-inhibitors have the potential to be used as multifunction corrosion inhibitors for concrete, such as serving as water reducer and set retarder. Future work would focus on chemical mechanism of green corrosion inhibitors and the comparative evaluation of these green corrosion inhibitors with other commercially available corrosion inhibitors.

Keywords: green corrosion inhibitor, chloride induced corrosion, setting time, flowability, water absorption, gas permeability, EIS, LPR

Understanding Shrinkage in Alternative Binder Systems

Lisa E. Burris, Prasanth Alapati, Kimberly E. Kurtis, Amir Hajibabae, M. Tyler Ley

Synopsis: Cement production is one of the largest contributors to CO₂ emissions in the U.S. One method of reducing emissions associated with concrete is through usage of alternative cements (ACMs). Some of the more common ACMs include calcium sulfoaluminate cement, calcium aluminate cement, ternary calcium aluminate-calcium sulfate-portland cements, and chemically-activated binders, all of which have been shown to have lower carbon footprints than ordinary portland cement (OPC). However, the durability, and more specifically, the shrinkage behavior, of these cements has not been adequately examined, and must be better understood and able to be controlled before ACM concrete can be effectively used in the field. As a first step in increase understanding of shrinkage in ACMs, this paper examines chemical, autogenous, and drying shrinkage in the ACMs listed above. Results show that, despite greater quantities of chemical shrinkage, CSA, CAC, and chemically activated fly ash binder undergo less autogenous and drying shrinkage than OPC.

Keywords: Alternative cementitious materials; calcium sulfoaluminate cement; calcium aluminate cement; alkali activated binders; shrinkage; durability

Durability of Recycled Aggregate Concrete

Nariman J. Khalil and Georges Aouad

Synopsis: The results of an experimental investigation into the mechanical properties and durability of recycled and natural coarse aggregates concrete are reported. A total of thirty-six specimens were tested. The percentages of replacement of coarse aggregates with recycled aggregates in the concrete mixes were 0%, 50%, and 100%. The source of recycled aggregates in this study was the concrete specimens tested in the laboratory. These specimens were crushed and then sieved into medium aggregates (4.75-9.5 mm) [0.19-0.37 in.] and coarse aggregates (9.5-19mm) [0.37-0.75 in.]. The replacement of fine aggregates was not considered in this study. The properties of concrete mixes containing natural aggregates as control mix and those containing Recycled Concrete Aggregates (RCAs) have been studied, including fresh properties, mechanical properties and durability. The influence of saturation state of RCA (dried or saturated) on the properties of concretes of identical compositions has first been studied. The theoretical amount of absorbed water is added at the beginning of mixing. Durability performance of hardened concrete made with recycled aggregates as partial or full replacement of natural coarse aggregates is reported. Resistance to pure water and sulfate attack is investigated. The results show that a replacement ratio of 50% does not have a significant effect on the performance of recycled aggregate concrete mixes. Moreover, the recycled aggregate concrete performs relatively satisfactorily under various conditions and has a comparable durability to natural aggregate concrete if properly designed.

Keywords: recycled aggregates, durability, mechanical properties, absorption, sulfate attack.

Low-Cracking High-Performance Concrete (LC-HPC) for Durable Bridge Decks

David Darwin, Rouzbeh Khajehdehi, Muzai Feng,
James Lafikes, Eman Ibrahim, Matthew O'Reilly

Synopsis: The goal of this study was to implement cost-effective techniques for improving bridge deck service life through the reduction of cracking. Work was performed both in the laboratory and in the field, resulting in the creation of Low-Cracking High-Performance Concrete (LC-HPC) specifications that minimize cracking through the use of low slump, low paste content, moderate compressive strength, concrete temperature control, good consolidation, minimum finishing, and extended curing. This paper documents the performance of 17 decks constructed with LC-HPC specifications and 13 matching control bridge decks based on crack surveys. The LC-HPC bridge decks exhibit less cracking than the matching control decks in the vast majority of cases. Only two LC-HPC bridge decks have higher overall crack densities than their control decks, which are the two best performing control decks in the program, and the differences are small. The majority of the cracks are transverse and run parallel to the top layer of the deck reinforcement. The results of this study demonstrate the positive effects of reduced cement paste contents, concrete temperature control, limitations on or de-emphasis of maximum concrete compressive strength, limitations on maximum slump, the use of good consolidation, minimizing finishing operations, and application of curing shortly after finishing and for an extended time on minimizing cracking in bridge decks.

Keywords: bridge decks, consolidation, cracking, curing, finishing, high-performance concrete, temperature control