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Research Summary

Field Implementation and Monitoring of Behavior of Economical and Crack-Free High-Performance Concrete for Pavement and Transportation Infrastructure Constructions – Phase II

Economical and crack-free high-performance concrete (Eco-HPC) is a new class of environmentally friendly and cost-effective high-performance concrete (HPC) that is made of low binder content, high volume of supplementary cementitious materials (SCMs), and shrinkage mitigating materials. The initial phase of research that involved an extensive laboratory investigation indicated that the designed Eco-HPC can secure high resistance to shrinkage cracking, and high strength and durability.

The aim of this project was to validate findings of the previous research via field implementation and develop guidelines for the use of Eco-HPC for sustainable transportation infrastructure construction.

Two classes of Eco-HPCs were developed for field demonstrations: Eco-Pave-Crete made for pavement construction and Eco-Bridge-Crete for bridge construction.

Fresh, mechanical properties, and shrinkage of these Eco-HPC mixtures were validated through laboratory and prototype-scale testing and compared to those obtained using a MoDOT reference mixture. The Eco-Pave-Crete, Eco-Bridge-Crete, and MoDOT reference mixture were proportioned with binder contents of 320 kg/m3 (540 lb/yd3), 350 kg/m3 (590 lb/yd3), and 375 kg/m3 (632 lb/yd3) cementitious materials, respectively.

Test results indicate that it is possible to design Eco-HPC with low drying shrinkage ($<$ 300 μstrain after 250 days) and no restrained shrinkage cracking up to 55 days. Prototype-scale slabs cast with Eco-Bridge-Crete exhibited lower shrinkage compared to the reference concrete.

Further prototype-scale reinforced concrete beams made with Eco-Bridge-Crete containing more than 50% replacement of cement to SCMs and either 0.35% structural synthetic fibers or recycled steel fibers developed significantly higher flexural strength and toughness.

A comprehensive probabilistic life-cycle cost analysis methodology was carried out to quantify the life cycle costs of Eco-HPC and conventional materials that link laboratory-measured parameters to actual field performance.

Compared to the MoDOT reference mixture, the optimized Eco-HPC mixtures developed for pavement and bridge applications exhibited approximately 40% lower embodied energy and 55% lower global warming potentials. The use of the proposed Eco-HPC mixtures could lead to reductions of about 4.7% of agency costs and 17.3% of the total life-cycle cost for bridge deck construction and 3.2% of agency cost and 6.2% of the total life-cycle cost for pavement construction in high traffic conditions.

*"Use of the proposed Eco-HPC mixtures could lead to reductions of about 4.7% of agency cost and 17.3% of total life-cycle cost for **bridge deck construction** and 3.2% of agency cost and 6.2% of the total life-cycle cost for **pavement construction in high traffic conditions**."*

Thermocouple used for concrete temperature measurement

This study is a follow-up to the earlier Phase I report Economical and Crack-Free High-Performance Concrete for Pavement and Transportation Infrastructure Construction published in May 2017.

Project Information

PROJECT NAME: Crack-free HPC

PROJECT START/END DATE: July 2016-July 2018

PROJECT COST: $69,687

LEAD CONTRACTOR: Missouri University of Science and Technology

PRINCIPAL INVESTIGATOR: Kamal H. Khayat, Ph.D., P.Eng.; Iman Mehdipour, (Ph.D.) Post-Doctoral Fellow; and Zemei Wu, (Ph.D.) Post-Doctoral Fellow

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Project Manager

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