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PhD Dissertation Defense

Entitled

CHARACTERIZATION AND STRUCTURAL SHEAR BEHAVIOR OF RECYCLED AGGREGATE CONCRETE BEAMS REINFORCED WITH BASALT FIBERS AND BASALT BARS

By

Shahrukh Shoaib Ahmed Zia Ul Haq

Faculty Advisor

Prof. Tamer El Maaddawy, Department of Civil and Environmental Engineering

College of Engineering

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Abstract

Recycling construction waste material offers a sustainable solution to the problem of disposing of concrete construction and demolition waste. The use of basalt fibers (BF) and basalt fiber-reinforced polymer (BFRP) reinforcing bars in concrete structures made of recycled concrete aggregate (RCA) would prolong their service life and reduce the maintenance cost. This research aims to investigate the potential use of BF, RCA, and BFRP reinforcing bars to produce sustainable and steel-free structural concrete. The study consisted of material characterization testing, numerical simulation, and large-scale beam testing.

Material characterization tests were performed on normal-strength concrete (NSC) and high-strength concrete (HSC). The RCA replacement in characterization tests varied as 30, 60, and 100%. Three different sizes of BF i.e., 20, 43, and 50-mm in length were used in the characterization tests. The volume fraction (v_f) of BF varied in the range of 0.5–1.5%. Fresh and hardened properties of concrete mixtures with different RCA replacement ratios and various combinations and volume fractions of BF were examined. Plain concrete mixtures made with RCA exhibited inferior properties relative to those made with NA. The negative effect of RCA was more pronounced for HSC than NSC. The incorporation of BF improved the tensile properties of NA- and RCA-based concrete mixtures. The effectiveness of BF in improving the properties of concrete tended to be more pronounced for NSC than HSC. New tensile softening constitutive laws characterizing the post-cracking behavior of NA- and RCA-based concrete mixtures were established using an inverse analysis of characterization test data. The new tensile softening laws were used as input data in numerical simulation models of large-scale concrete beams made with RCA, BF, and BFRP reinforcing bars. The accuracy and validity of the numerical models developed in the present study were examined through a comparative analysis with experimental results of large-scale concrete beams tested in the UAEU laboratory. Experimental tests revealed that the addition of BF had an insignificant effect on the shear capacity of NA-based beams, irrespective of BF sizes and combinations. However, the beam with RCA exhibited a strength gain of 51% with the addition of the BF. The developed numerical models predicted the shear capacity of the tested beams with good accuracy.

A parametric study was conducted to examine the effect of varying the RCA replacement percentage and BF volume fraction on the shear behavior of BFRP-reinforced concrete beams. Test variables comprised RCA replacement (30, 60, and 100%) and BF volume fractions (0.5, 1.0, and 1.5%). Results of the parametric study indicated that the incorporation of the RCA in concrete mixture resulted in strength reduction of the beam models in the range of 10-28%. The inclusion of BF at a v_f of 0.5% to the beam models with 30 and 60% RCA fully restored the original shear capacity of the control beam model with NA. The addition of BF at v_f = 1.5% to the beam model with 100% RCA restored 93% of the original shear capacity of the control beam model with NA. Research findings are anticipated to contribute to the advancement of the concept of circular economy through the development of sustainable construction materials and simulation models capable of predicting the shear behavior of concrete beams made of RCA and BF internally reinforced with BFRP composite reinforcing bars.

Keywords: Basalt fiber, beams, BFRP, recycled aggregates, shear, tensile softening.