STUDY ON ENGINEERED CEMENTITIOUS COMPOSITE USING DIFFERENT MINERAL ADMIXTURES FOR BRIDGE DECK OVERLAY APPLICATION

Abstract

Concrete exhibits brittleness under normal and impact loads, and its tensile strength is approximately one-tenth that of its compressive strength. To address this issue, reinforcement is introduced to enable concrete to withstand tensile stress and compensate for its lack of ductility and strength. In addition, inclusion of fibres in reinforcement concrete significantly enhanced the concrete strength. However, to achieve homogeneous tensile properties, it is crucial to control the development of micro-cracks. The introduction of fibres into concrete serves as a solution for creating concrete with improved flexural and tensile strengths. The addition of fibres extensively enhanced the post-cracking behavior, significantly boosted the energy absorption capacity, and improved the ductility of the composite.

Engineered cementitious composites (ECC) in diverse applications have surged owing to their distinctive tensile strain hardening characteristics. This is in contrast to the quasi-brittle nature typically associated with fibre-reinforced concrete (FRC). ECC distinguishes itself from its remarkable ductility, particularly with moderate fibre content. The mixture comprises cement, fly ash, silica sand, water, fibre, and super plasticizer, deliberately excluding coarse aggregates to sustain the unique properties of ECC. This composition results in a higher tensile strain value, ranging from 3% to 6%, which is 500–600 times greater than that of conventional concrete. Notably, ECC exhibits a high strain capacity with a fibre volume fraction of approximately 1.5% to 2%.

This study focuses on enhancing the properties of ECC for bridge-deck overlay application by incorporating various types of mineral admixtures (MA's). The aim of this study is to achieve improved tensile strength, strain, ductility, and enhanced resistance to impact and abrasion. The primary objective of this study is to develop an environmentally friendly and cost-effective ECC using locally available materials, including Ground granulated blast furnace slag (GGBS), Bagasse ash (BA), Rice husk ash (RHA), and

Manufactured sand (M-sand). The development of ECC involves the utilization of different mineral admixtures (GGBS/BA/RHA) to replace cement. This replacement is carried out at six distinct percentages ranging from 10 to 55 (specifically, 10, 20, 30, 40, 50, and 55 by mass). The blending process includes a consistent percentage of fibre (2%), M-sand, and a constant water-to-binder ratio.

To evaluate the characteristics of MA-blended ECC specimens in both fresh and hardened states, a series of experimental investigations were conducted. These investigations encompass wet density, flowability, compressive strength, direct tensile strength, and strain using dog-bone specimens as well as flexural strength, drying shrinkage, modulus of elasticity, bond strength through slant shear, split cylinder, and split prism tests. Additionally, investigations include the bond strength between ECC and steel bars, impact resistance, abrasion resistance, bulk density, saturated water absorption, porosity, sorptivity, rapid chloride permeability tests, alkalinity measurement, acid resistance, and seawater resistance. Also, experimental studies on the properties of fresh and hardened concrete (M40) have been conducted. These studies involved the use of a slump cone, compressive and flexural strengths, and modulus of elasticity to meet the basic requirements of the substrate concrete in bond strength tests. In addition, the experimental studies on structural behaviors of RCC slab with different ECC overlays were examined. Moreover, investigations were conducted to examine the impact of cement mortar and cement paste with various percentages of MA's.

According to the test results obtained for the compressive strength of cement mortar, the replacement of mineral admixtures (GGBS/BA/RHA) of up to 10% exhibited a higher strength across all testing ages. Specifically, at 28 days, the compressive strengths of the cement mortars with 10% GGBS (G10), 10% BA (B10), and 10% RHA (R10) reached 56.26 MPa, 56.09 MPa, and 53.80 MPa, respectively. Similarly, mixes G10, B10, and R10 showed 3.45%, 2.00%, and 0.89% higher flexural strengths, respectively, than the control mix at 28 days. Furthermore, there was an increase in the water absorption of the cement mortar with an increase in the percentage of mineral admixtures from 10 to 55. Notably, the cement mortar with RHA attained the maximum water absorption, followed by GGBS and BA.

The inclusion of various mineral admixtures at different percentages in ECC resulted in strain-hardening properties similar to those of conventional ECC. Specifically, the G40 (40% GGBS), B10, and R10 blends exhibited optimal mechanical properties, including compressive strength, tensile strength, strain, flexural strength, and modulus of elasticity. For example, blends G40, B10, and R10 achieved tensile strengths of 3.935 MPa, 2.826 MPa, and 2.399 MPa, respectively, with corresponding strain values of 3.784%, 3.000%, and 3.732% at 28 days. Similarly, G40, B10, and R10 reached the maximum compressive strengths of 66.59 MPa, 54.12 MPa, and 53.14 MPa, respectively. In contrast, blends G50 (50% GGBS), B20 (20% BA), and R20 (20% RHA) demonstrated optimal durability properties in the rapid chloride permeability test, porosity, sorptivity, acid resistance, and seawater resistance. Furthermore, mixes G40, B30 (30% BA), and R40 (40% RHA) exhibited high impact and abrasion resistance due to the fibre bridging ability and multiple micro-cracking behaviors inherent in ECC.

Furthermore, the bond strength between the conventional concrete substrate and ECC blended with different percentages of MA's was examined using four textures (smooth, horizontal, rough, and diagonal) through slant shear, split cylinder, and prism tests. According to the test results, G40, B10, and R10 mixes achieved the optimal bond strength when employing a diagonal texture, followed by smooth, horizontal, and rough textures across all testing types. Specifically, under the slant shear test using diagonal textures, G40, B10, and R10 demonstrated high bond strengths of 21.789 MPa, 15.405 MPa, and 15.127 MPa, respectively. However, ECC blends with varying percentages (10 to 55) of MA's using diagonal textures achieved the required bond strengths of 7 MPa for slant shear and 1 MPa for split cylinder and prism, as per the ACI 546R-04 standard. Similar to the mechanical properties, the structural behavior of the RCC slabs with overlays of G40, B10, and R10 exhibited a maximum load-carrying capacity with less deflection compared to the corresponding RCC slabs without MA-blended ECC overlays. Consequently, based on the experimental results, it was observed that the incorporation of different percentages of mineral admixtures in ECC effectively improved various properties, thereby enhancing the potential utilization of MA-blended ECC in bridge-deck overlay applications.