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PERFORMANCE OF RECYCLED CONCRETE AGGREGATES TREATED BY ALGINATE-IMMOBILIZED MICROBIALLY INDUCED CALCITE PRECIPITATION

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Abstract

The rapid growth of the global population has significantly increased the demand on the construction sector, consequently generating substantial waste and straining natural resources. Recycling this waste to create recycled concrete aggregates (RCA) has emerged as a promising solution to mitigate these adverse impacts. However, RCA properties do not align with those of natural aggregates (NA), thereby affecting the performance of concrete. This research introduces an innovative treatment agent created with alginate immobilized microbially induced calcite precipitation (AIMICP) for use in enhancing the properties of locally supplied RCA to promote their adoption by the construction industry. To develop the treatment agent, two bacterial strains were used, namely Lysinibacillus sphaericus (DSM 28) and Priestia megaterium (DSM 32). The efficacy of the proposed AIMICP, employed with using different treatment methods and considering different levels of concentrations for its constituents, was evaluated based on the mass gain, water absorption, and resistance to abrasion and impact of the treated recycled concrete aggregates (TRCA). Furthermore, microstructure analysis was conducted to characterize the precipitate material. Besides, the fresh, mechanical, and durability properties of concrete mixes utilizing TRCA were evaluated. Finally, the environmental and economic feasibility of using TRCA in concrete was investigated by applying the life cycle assessment methodology of ISO 14040. Analysis of the mass gain data indicated that treatments 1, 3, and 6, at concentration levels ×12, ×14, and ×20, respectively, exhibited the highest percentage of mass gain among all treatments, ranging from 4.4% to 6%. Results regarding water absorption revealed an 88% reduction due to the treatment techniques, with an inverse correlation between mass gain and water absorption. Notably, treatments 1, 3, and 6 demonstrated the most significant reduction in water absorption when both bacteria were used at concentration levels ×12, ×14, and ×20. These treatments decreased the initial water absorption of RCA from 6.67% to 1.1%, 1.6%, and 0.8%, respectively. Furthermore, impact and abrasion resistance improved by up to 58%, with X-ray diffraction and scanning electron microscopy imaging revealing that the precipitates were indeed calcite precipitates on the TRCA surface. Furthermore, the use of TRCA in concrete resulted in an increase in the workability, in contrast to the reduction caused by the RCA. The compressive strength improved by up to 15% upon TRCA incorporation compared to the mix made with NA. TRCA mixes exhibited enhanced impact and abrasion resistance, and reduction in water absorption and permeability. The variations in the performance of the TRCA concrete were owed to the different TRCA substitution percentages, treatment methods, and bacterial type. Mixes with a 50% substitution performed better than those with 100% substitution. Among TRCA treatments, soaking methods (treatments 1 and 6) were more effective than spraying (treatment 3). Different bacterial strains yielded varying enhancements, with DSM 32 showing slightly better performance over DSM 28. The impact assessment results revealed that utilizing TRCA led to a negligible increase in the environmental impact of the mixes utilizing them, ranging between 2 to 7%, compared to the control mix. The assessment also showed that utilizing TRCA led to a 17 to 52% increase in the cost of concrete production, compared to the control mix. Finally, multifunctional performance indexing provided evidence of the environmental and economic viability of producing structural grade concrete (30 MPa) made with TRCA.

Keywords: Recycled concrete aggregates, microbially induced calcite precipitation, MICP, recycled aggregates concrete, concrete properties, life cycle assessment.