Development of Cocoa Pod Husk Biochar-Integrated Mortar for Carbon Footprint Reduction

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Abstract

This research aimed to produce and evaluate the physical, mechanical, and chemical properties, as well as the CO_2 sequestration efficiency, of mortar integrated with cocoa pod husk biochar as a natural sand replacement. The biochar was synthesized via pyrolysis and utilized to substitute natural sand at weight ratios of 0% (C0), 3% (C3), 6% (C6), 9% (C9), and 12% (C12). The specimens were water-cured and tested for their properties at 28 days in compliance with the TIS 1776-2560 standard. The experimental results: Formulas C3 and C6 are highly suitable for structural applications, characterized by high density and outstanding compressive strengths ranging from 150.51 - 93.63 kg/cm^2, respectively, which surpass the minimum TIS standard threshold by 3 to 5 times. Formulas C9 and C12 are ideal for lightweight walling and insulation applications; the honeycomb-like porous structure of the biochar reduced the material density to a minimum of 1.64 g/cm^3, imparting excellent thermal insulation properties while maintaining compressive strengths of 54.34 - 38.10 kg/cm^2, respectively, which still exceed the minimum standard requirement (25.49 kg/cm^2). Furthermore, the porous architecture combined with surface hydroxyl and carbonyl functional groups on the biochar enhanced CO_2 capture via dipole-quadrupole interactions that are stronger than those of silanol groups in conventional sand. Synergized with the carbonation reaction, this mechanism permanently immobilized carbon within the hardened mortar matrix by up to 5.91%. Additionally, the maximum water absorption was strictly controlled at only 16.62%, which is significantly lower than the standard limit of 25%.

Keywords: Cocoa pod husk biochar, Low-carbon mortar, Carbon dioxide sequestration, SEM