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Developing Sustainable Rammed Earth Material Using Pulp Mill Fly Ash as Cement Replacement

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Abstract : Rammed earth (RE) is a traditional soil-based building material made by compressing a mixture of natural earth and binder ingredients such as chalk or lime, in temporary formworks. However, the modern RE uses 5 to 10% cement as a binder in order to meet the strength and durability requirements as per the standard specifications and guidelines. RE construction is considered to be an energy-efficient and environmental-friendly approach when compared to conventional concrete systems, which use 20 to 30% cement. The present study aimed to develop RE mix designs by utilizing non-hazardous wood-based fly ash generated by pulp and paper mills as a partial replacement for cement. The pulp mill fly ash (PPFA)-stabilized RE is considered to be a sustainable approach keeping in view of the massive carbon footprints associated with cement production as well as the adverse environmental impacts due to disposal of PPFA in landfills. For the experimental study, as-received PPFA, as well as PPFA-based geopolymer (synthesized by alkaline activation method), were incorporated as cement substitutes in the RE mixtures. Initially, local soil was collected and characterized by index and engineering properties. The PPFA was procured from a pulp manufacturing mill, and its physicochemical, mineralogical and morphological characterization, as well as environmental impact assessment, was conducted. Further, the various mix designs of RE material incorporating local soil and different proportions of cement, PPFA, and alkaline activator (a mixture of sodium silicate and sodium hydroxide solutions) were developed. The compacted RE specimens were cured and tested for 7-day and 28-day unconfined compressive strength (UCS) variations. Based on UCS results, the optimum mix design was identified corresponding to maximum strength improvement. Further, the cured RE specimens were subjected to freeze-thaw cycle testing for evaluating its performance and durability as a sustainable construction technique under extreme climatic conditions.

Keywords : sustainability, rammed earth, stabilization, pulp mill fly ash, geopolymer, alkaline activation, strength, durability
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