Mechanical Behaviour Studies of Shale Ash Based Artificial Aggregates in Cementitious Matrix

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Abstract

The modern construction industry is focusing on materials—with increasing volume and quality, the need for lighter structures, and the introduction of green technologies. Researchers are increasingly focused on substituting natural materials with artificial alternatives while maintaining essential properties [1]. Artificial aggregates are an excellent substitute for natural aggregates, as they also exhibit excellent physical and mechanical properties [2]. Their production often involves alternative binders to cement, such as ash, slag, and construction waste [3].

In this study, shale and wood ash are used to produce lightweight artificial aggregates, and the properties of the resulting samples are determined. Utilizing these materials not only addresses landfill accumulation and environmental pollution but also promotes the development of sustainable new materials.

Carbonization technology was used to produce lightweight artificial aggregates using shale ash combined with hydrated lime ($Ca(OH)_2$) as a binder. Various compositions with differing ash-to binder ratios were prepared, initially with shale ash, followed by the addition of wood ash. The physical and mechanical properties of the aggregates – such as water absorption, strength, and analyses via XRD and SEM were tested. The results show that these artificial aggregates meet requirements and can substitute natural materials in applications including construction, building materials, masonry blocks or bricks, and other products. Concrete products with artificial aggregates exhibit low density while maintaining stability and stiffness.

To test the artificial aggregates with shale ash, we conducted a non-standardized compressive strength test on square cement specimens (20 mm × 20 mm × 20 mm) with the aggregates placed centrally. This test was used to determine not only the compressive properties of the specimen but also the fracture behavior, indicating how the aggregates adhere to the cement matrix. This technique is used to evaluate the viability of artificial aggregates in construction materials by considering both load-bearing capacity and adhesion to the mineral matrix.

The results show that the main differences in the properties of the lightweight artificial aggregates are due to the use of a binder (lime) in the mix. For example, increasing the binder from 180 g to 300 g (40% increase) resulted in a 6% increase in density and a 0.7% reduction in the aggregate's compressive strength, while the compressive strength of the cementitious sample containing the aggregate decreased by approximately 33.63%.

Keywords

Shale ash, wood ash, artificial aggregates, carbonization, density, compressive strength.