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Multiscale assessment of construction and demolition waste aggregates stabilization through alkaline activation

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ABSTRACT

Recycled aggregates from construction and demolition waste (CDW) are a viable alternative to natural granular materials (NGM) in the formation of unbound layers of low to medium trafficked roads. Several methods to improve the mechanical and durability properties of CDW aggregates through stabilization techniques have been proposed. The recent use of alternative and more sustainable binders (i.e. alkali-activated by-products) in place of traditional ones (i.e. ordinary Portland cement, OPC) has been attracting interest in the scientific community. With the aims of (1) promoting the adoption of CDW aggregates and (2) avoiding the use of cementitious products, this research investigates the alkaline activation (AA) of fine particles of recycled aggregates as a new stabilization method for whole CDW mixtures. The laboratory investigation adopted a multiscale approach. At the smallest scale, the alkali-reactivity of fine particles ($d < 0.125$ mm) of the individual constituents present in CDW (concrete, asphalt, ceramics, natural aggregates, and undivided fraction) was evaluated. The larger scale assessment aimed at verifying the mechanical and durability properties of CDW aggregates in their typical particle size distribution stabilized as per the AA of their fines. An alkaline solution (AS) of sodium hydroxide and sodium silicate was prepared in different concentrations and employed to trigger the AA process.

A preliminary chemical analysis of CDW fines detected the presence of aluminosilicates needed for the AA process. The adequate compression and flexural strength values achieved by specimens made from alkali-activated CDW fines and cured for 28 days at room temperature demonstrated the effective reactivity of these precursors.

At the larger scale, cylindrical specimens of CDW aggregates were compacted with AS (in different concentrations) in place of water. Resilient modulus (RM), unconfined compressive strength (UCS), and indirect tensile strength (ITS) were measured after different curing times (7, 28, and 60 days) at room temperature. The results obtained showed that the AS concentration played a key role in strength and stiffness development. The mechanical properties of CDW aggregates compacted with the undiluted AS (AS-100%) were considerably higher than those of mixtures containing the half diluted AS (AS-50%) and water only (AS-0%). RM, UCS, and ITS of CDW-AS-100% mixtures were comparable to (1) those of an OPC-stabilized NGM studied for comparison purposes and (2) to mechanical properties of CDW aggregates and NGM stabilized with both ordinary and alternative binders available in literature.

The occurrence of AA in CDW-AS-100% mixtures apparently responsible for the formation of bonds between coarser grains was confirmed by microstructural observations performed through field emission scanning electron microscopy, coupled with the elemental analysis of the energy dispersive spectroscopy.

Durability tests carried out on compacted and cured CDW-AS-100% and NGM-OPC mixtures revealed, as expected, that recycled aggregates are more susceptible to freeze/thaw (F/T) degradation than stabilized natural aggregates. Mechanical properties decreased with an increment in F/T cycles. However, after 12 F/T cycles, the RM was greater than the highest values measured in a previous research on similar unbound CDW materials.

Leaching tests confirmed the environmental compatibility of investigated materials according to the European Council Decision 2003/33/EC.

The investigated stabilization technique is consistent with the most common practices in road constructions and promotes the use of CDW aggregates also in applications with higher mechanical requirements (i.e. road bases and subbases). The reuse of waste materials otherwise destined for landfill sites and the exclusion of environmentally harmful binders meet the demand for sustainability increasingly pursued in civil infrastructures.