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The Effect of Using Alkaline Adhesives on the Durability of Lightweight Structural Concrete against Harmful Environments

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Abstract

The use of lightweight stone materials and alkaline adhesives to replace gravel and ordinary Portland cement in concrete production prevents the emission of a significant portion of greenhouse gases, saves energy, and reduces the dead load of the structure. In this study, porous coarse-grained lava rock has been used to reduce the density of concrete, and slag and fly ash, as alternative materials to ordinary Portland cement in concrete production. Alkaline activation of the pozzolans was performed by solutions of 14 M sodium hydroxide and sodium silicate with a mass ratio of 1: 2. Chloride ion invasion, sulfate invasion, and the combination of sulfate and chloride invasion are on the research laboratory agenda. Concrete with alkaline slag and different ratios of slag and fly ash for alkaline activation and hydrated Portland cement have also been selected for comparison. According to the obtained results, Portland cement concrete tolerated the fastest deterioration against combined aggression with a reduction of almost 10% in compressive strength, the highest compressive strength was 55 MPa slag concrete, and with increasing fly ash replacement, the short-term mechanical properties are weakened, but with decreasing water absorption loss, on average, by about 12%, the long-term durability, and protection of reinforced concrete increases.

Keywords: *Alkali activated concrete, Durability, Lightweight concrete, Aggressive environment, Reinforcement corrosion.*

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Extended Abstract:

1. Introduction

Cement production is associated with the consumption of large amounts of energy (the required temperature of the furnace for firing is 1550-1450) in addition to other environmental consequences (Taylor, 1990). The variability of OPC concrete durability against environmental aggression has also provided a good basis for studying and using conventional Portland cement alternative binders. Exposure of concrete to chloride and sulfate ions will weaken the cement gel and corrode the reinforcement. The penetration of chloride ions in concrete and the loss of the active oxide layer around the reinforcement is the cause of the onset of reinforcement corrosion in concrete structures implemented in coastal areas (Habert, 2013). Studies have also been performed on alkaline mortars consisting of slag and fly ash, which show that their behavior is more resistant to sulfate attacks compared to OPC concrete (Ismail et al., 2013; Wang et al., 2015; Valencia et al., 2016; Albitar et al., 2017). According to the researches in this field and the existence of some research gaps, study and comparison of mechanical properties and durability of OPC and Alkali Activated Slag lightweight concretes against the invasion of sodium chloride, magnesium sulfate solution and composition, as well as measuring the corrosion intensity of buried reinforcement. In concrete, it was on the agenda of the research program.

2. Materials and methods

The fly ash and slag used in alkaline and geopolymer concrete are not associated with Portland cement and their reactivity in the presence of alkaline solutions such as sodium hydroxide and sodium metasilicate forms the main binder to bind the aggregates. The density of compacted aggregates volume, also known as bulk density, was measured according to ASTM C29 (ASTM C29, 2017). The test of relative density of aggregates in the saturated surface dry state (SSD) and water absorption percentage of aggregates was performed according to ASTM C128-88 (ASTM C128, 2015). Preliminary tests on fresh concrete such as slump test were performed according to the method mentioned in ASTM C143 (ASTM C143, 2012) and the density of the samples was measured by measuring the mass of 10 × 10 × 10 cm cubic samples. Also, the compressive strength of concrete according to BS 1881 (BS 1881, 1993) and tensile strength by cylindrical detachment according to ASTM C496 (ASTM C496, 2004) have been investigated. Accelerated corrosion test of reinforcement has been used to evaluate the corrosion intensity of reinforced concrete buried. The concretes were produced and tested for 90 days and their mechanical properties and durability were compared.

3. Results

Alkali activated slag (AAS) concrete with lower adhesive grade has less workability than OPC concrete, and the workability and slump of concrete have increased with increasing replacement of fly ash in alkali activated slag-based concrete. The highest rate of increase in compressive strength

from 7 days to 90 days of high-strength concrete is related to S3F1 plan with 57% increase and the highest compressive strength at the end of 90 days is related to plan S with more than 55 MPa. Sulfate invasion up to 90 days causes a relative 21% increase in compressive strength in the C mixing scheme, a 4% decrease in S and a 14% increase in S3F1. The highest changes with 70% increase in compressive strength belong to the S1F1 mixing design and the highest compressive strength after sulfate invasion belongs to the C mixing design with 40.48 MPa. The beginning of the decrease in compressive strength of concrete in C mixing plan and sulfate invasion is visible at the age of 90 days and compared to its 28-day age, it has lost 9.3% of its compressive strength. In sulfate-chloride combination aggression, the highest reinforcement corrosion with 53.95% occurred in concrete with Portland cement. In sulfate-chloride combination aggregate, slag-reinforced concrete showed the lowest corrosion rate of buried reinforcement at 11.22% with the highest reinforcement protection in this aggressive environment.

4. Conclusion

Results of this study showed that using equal binding mass, alkaline concretes, depending on their constituents, can provide more mechanical properties and durability than OPC concrete. In the samples studied in this study, the use of alkali activated slag binder in concrete instead of hydrated Portland cement has significantly increased the compressive strength so that it can be used to provide more compressive strength of concrete with ordinary Portland cement, especially in the high strength range as over 40 MPa, used this adhesive in concrete production. Using equal adhesive quantity, alkali activated concretes, depending on their constituents, can provide more mechanical properties and durability than OPC concrete.

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