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Mechanical and Durability Characteristics of Roller Compacted Geopolymer Concrete Using Recycled Concrete Aggregate

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Abstract : Every year a huge quantity of recycling concrete aggregate (RCA) is generated in the United States of America. Utilization of RCA can solve the storage problem, prevent environmental pollution, and reduce the construction cost. However, due to the overall low strength and durability characteristics of RCA, its usages are limited to a certain area like a landfill, low strength base material, replacement of a few percentages of virgin aggregates in Portland cement concrete, etc. This study focuses on the improvement of the strength and durability characteristics of RCA by introducing the concept of roller-compacted geopolymer concrete. In this research, developed roller-compacted geopolymer concrete (RCGPC) and roller-compacted cement concrete (RCC) mixtures containing 100% recycled concrete aggregate were evaluated and compared. Several selected RCGPC mixtures were investigated to find out the effect of mixture variables, including sodium hydroxide (NaOH) molar concentration, sodium silicate (Na_2SiO_3), to sodium hydroxide (NaOH) ratio on the strength, stiffness and durability characteristics of the developed RCGPC. Sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) were mixed in different ratios to synthesize the alkali activator. American Concrete Pavement Association (ACPA) recommended RCC gradation was used with a maximum nominal aggregate size of 19 mm with a 4% fine particle passing 0.075 mm sieve. The mixtures were made using NaOH molar concentration of 8M and 10M along with, Na_2SiO_3 to NaOH ratio of 0 and 1 by mass and 15% class F fly ash. Optimum alkali content and moisture content were determined for each RCGPC and RCC mixtures, respectively, using modified proctor test. Compressive strength, semi-circular bending beam strength, and dynamic modulus test were conducted to evaluate the mechanistic characteristics of both mixtures. To determine the optimum curing conditions for RCGPC, effects of different curing temperature and curing duration on compressive strength were also studied. Sulphate attack and freeze-thaw tests were also carried out to assess the durability properties of the developed mixtures. X-ray diffraction (XRD) was used for morphology and microstructure analysis. From the optimum moisture content results, it was found that RCGPC has high alkali content, which was mainly due to the high absorption capacity of RCA. It was found that the mixtures with Na_2SiO_3 to NaOH ratio of 1 yielded about 60% higher compressive strength than the ratio of 0. Further, the mixtures using 10M NaOH concentrations and alkali ratio of 1 produced about 28 MPa of compressive strength, which was around 33% higher than 8M NaOH mixtures. Similar results were obtained for elastic and dynamic modulus of the mixtures. On the other hand, the semi-circular bending beam strength remained the same for both 8 and 10 molar NaOH geopolymer mixtures. Formation of new geopolymeric compounds and chemical bonds in the newly formed novel RCGPC mixtures were also discovered using XRD analysis. The results of mechanical and durability testing further revealed that RCGPC performed similarly to that of RCC mixtures. Based on the results of mechanical and durability testing, the developed RCGPC mixtures using 100% recycled concrete could be used as a cost-effective solution for the construction of pavement structures.

Keywords : roller compacted concrete, geopolymer concrete, recycled concrete aggregate, concrete pavement, fly ash
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