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Durability and Microstructure of Cement Composites Containing Qatar's Municipal Wastes

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Qatar produces more than 2.5 million tons of municipal waste per year with an average waste generation rate of 1.8 kg/day/capita which is one of the highest rates in the world. The rapid growth of municipal solid waste has become one of the serious environmental problem that Qatar is facing with. Qatar's municipal waste is composed of organic and recyclables materials. Municipal solid waste incineration has been performed in Qatar since 2011. By incineration of wastes, not only the volume and weight of wastes are reduced but also energy is generated. Prior to incineration of municipal wastes, recyclables are separated from the waste and the remaining waste is incinerated at a minimum temperature of 850°C. Bottom ash and fly ash are produced as a result of incineration process. These by-products may contain heavy metals and pose a threat to the environment hence needs treatment and/or special disposal. Approximately 60 tonnes of fly ash is generated daily from municipal waste incineration in Qatar and this ash called as municipal solid waste incineration (MSWI) fly ash. This MSWI fly ash is stabilised with cement and then disposed into special landfill. However, cementitious property of MSWI fly ash due to similar mineralogical composition with cement and its finer particle size may favor its potential utilisation in cement based materials. As aforementioned before, 40% of municipal waste of Qatar is composed of recyclables of which 14% is plastic. The major portion of plastic wastes, about 90% of total, are composed of light density polyethylene (LDPE) and high density polyethylene (HDPE) wastes. Therefore, there is a huge potential for recycling of PE wastes in Qatar considering the shortage of raw materials i.e. natural aggregate for construction industry. The scarcity of available land for disposal of municipal wastes and limited natural resources of raw materials for construction industry has opened new research areas for proper disposal and recycling of municipal wastes. Therefore, in this research work, municipal solid waste incineration (MSWI) fly ash and municipal polymeric wastes were used as secondary raw materials for the preparation of cement based composites. MSWI fly ash was utilised as partial replacement of cement by 10% by weight. Polyethylene wastes in granular form were utilised as partial replacement of natural

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aggregate by 10% by volume. Portland cement, silica fume (10% by weight) and MSWI FA (10% by weight) at constant rates were used as binder in all cement-based composites. Three different cement based composites were fabricated by partial substitution of natural aggregate with LDPE and HDPE wastes at 0 and 10% by volume. The mixture without PE waste substitution was called as the reference mixture, with LDPE waste was called as Mix 1 and with HDPE waste was called as Mix 2. Besides mechanical performance, durability of fabricated cement composites containing municipal wastes was investigated to determine if their utilisation has positive contribution or adverse impact. The durability properties were examined by performing drying shrinkage and expansion under sulfate exposure tests. Scanning electron microscopy coupled with EDX were used to determine the degradation products of sulfate exposure. In terms of mechanical strength, samples containing PE wastes showed lower strength at early ages due to weaker bonding between LDPE/HDPE and the cement matrix. At later ages, strength improvement was observed and comparable strength values for Mix 1 and Mix 2 were measured with respect to the reference. The effect of utilisation of municipal wastes on the dimensional stability of cement composites was evaluated by measuring the variation of length change at 4, 11, 18, 25, 126 and 168 days of air drying. This test showed that incorporation of PE wastes (Mix 1 and Mix 2) reduced the drying shrinkage and provided better dimensional stability compared to the reference. Sulfate attack is known as one of the most deleterious effects on cement based composites due to the formation of expansive degradation products. To investigate the sulfate resistance of fabricated composites, the length change at 1 week, 2 weeks, 3 weeks, 4 weeks, 8 weeks, 13 weeks, 15 weeks, 4 months and 6 months of sulfate exposure was measured. Both the reference and samples containing PE wastes did not show any visual deterioration except a white and soft layer formed on top of all samples. The length change indicated that composites containing PE wastes experienced reduction in expansion compared to the reference and hence considered as more durable for external sulfate attack. More voids and pores were present in PE incorporated samples, therefore sulfate degradation products probably filled these pores and resulted in lower expansion compared to the reference. There was no significant difference between the mechanical performance and durability of cement composites containing LDPE and HDPE. The microstructure and composition of sulfate degradation products were investigated by SEM-EDX. The decalcification of the C-S-H phase were detected in each sample. Gypsum, calcite and thaumasite were identified as the major deterioration related products, while ettringite was found at trace level. This laboratory study showed that MSWI fly ash and PE wastes can be utilised together to produce durable cement based materials with a lower carbon footprint.

Keywords

Municipal solid waste incineration, sulfate attack, thaumasite, ettringite, shrinkage, expansion