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Influence of scoria and pumice on key performance indicators of Portland cement concrete

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Abstract

Cement industries have a huge CO₂ signature that can be reduced in an effort to mitigate climate change via precise cement substitution with supplementary cementing materials (SCMs). The substituting materials and their amounts ought not to degrade the key performance indicators of concrete such as slump, flow, permeability, shrinkage, modulus of rupture, compressive, and tensile splitting strength. In this study, the influence of natural scoria (SN) and pumice (PN) binders on the key performance indicators of the fresh and hardened Portland cement (PLC) concrete was successfully examined. The performance indicators were tested at PLC substitution (with SN or PN) levels of 10, 20, 30, and 40% and the results compared to the control (CTRL) made of PLC only. The results show that 10% is the optimum substitution level for both SN and PN. The compressive strength, modulus of rupture, shrinkage, permeability, and thermal stability of the concrete were not compromised at this substitution level. The 28 days modulus of rupture, shrinkage, and compressive strength for SN and PN at 10% substitution were 6.0 and 6.4 MPa; 0.02 and 0.01 mm; 44.2 and 43.1 MPa, respectively. These compared remarkably well with 6.3 MPa modulus of rupture, 0.01 mm shrinkage, and 43.1 MPa compressive strength of the control. Moreover, SN and PN delivered higher % residual compressive strength of 59.2 and 57.8%, correspondingly, after subjecting the concrete to high temperatures of 600 °C, compared to 52.6% for the control. Likewise, the coefficient of permeability (K) for SN (5.2526E–08 m/s) was similar to that of PLC (5.35714E–08 m/s). At substitution levels higher than 10%, more than one key performance indicators were negatively affected. These results show the utility of SN and PN in reducing the amount of cement used in construction and thus the CO₂ emission associated with cement industries while at the same time preserving the strength, permeability, thermal and volume stability and hence the durability of the concrete.

Keywords

Modulus of rupture Scoria; Pumice; Compressive strength; Slump; Flow; Shrinkage; Residual strength