## ABSTRACT

Concrete is the second most consumed material in the world after water and is an essential element of constructed infrastructure. Over 14 billion $m^3$ of concrete are being produced annually, resulting in a serious impact on the environment. The production of cement, which is the main component of concrete, is responsible for 5 – 8 % of global $CO_2$ emissions. As a result, several global initiatives have been undertaken to achieve carbon neutrality by 2050. This carbon neutrality target coincides with the Paris Agreement's goal to limit global warming to 1.5 °C. A well-known, and successful strategy to reduce $CO_2$ emissions in the concrete industry is to use supplementary cementitious materials (SCMs) as a partial replacement for cement. However, in 2030 the demand for two of the most commonly used SCMs, fly ash and slag cement, will exceed their supply. Using nontraditional and natural pozzolans (NNPs) can help to close this supply gap, but there is a lack of knowledge on the reactivity and long-term performance of these materials.

The purpose of this research was to perform experiments on several NNPs, some of which can be supplied in commercially viable quantities. The main objective of this research was to evaluate the performance of these materials in cementitious systems (mortars and concretes) with the goal of accurately assessing their potential for use as alternative SCMs. The mortar study was performed using a total of 11 different NNPs, belonging to 4 distinctive groups and distributed as follows: 3 from the group of calcined clays (CCs) - CC1, CC2, and CC3, 3 from the group of natural pozzolans (NPs) - NP1, NP2 and NP3, 2 from the group of fluidized bed combustion (FBCs) ashes - FBC1 and FBC2, and 3 from the group of bottom ashes (GBAs) - GBA1, GBA2, and GBA3.

The concrete study was performed on 4 different materials, one from each of the previously mentioned groups. The materials selected for concrete study were the worst-performing members of each group, as determined by the analysis of the test results obtained from mortars. These included CC2, NP3, FBC1, and GBA3 materials. This approach was adopted under the assumption that achieving adequate concrete characteristics with lowest-quality materials will all but assure satisfactory performance of concretes with higher-quality materials.

The findings generated from this research indicate that several of the NNPs used in this study present a viable alternative to traditional SCMs. As an example, out of the 11 NNPS, 9 were found to conform to the requirements of the ASTM C618-19. Results obtained from tests performed on mortars demonstrated that, when used at the replacement level of 25%, all 11 NNPs produced mixtures with characteristics similar to those obtained from the plain cement (OPC) mortar. For that reason, this level of replacement was selected to prepare concrete specimens. The results collected from concrete specimens showed that, when compared to plain concrete, mixtures with all 4 NNPs attained comparable (or improved) mechanical (compressive and flexural strength), durability (freeze-thaw resistance), and transport (formation factor and rate of water absorption) properties. As in the case of traditional SCMs, the mixtures with NNPs were found to require extended curing times to fully realize their property-enhancing potential associated with pozzolanic reactions. Overall, the best performing materials were those from the CCs group, followed by those belonging to, respectively, NPs, GBAs, and FBCs groups.