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# Long-Term Durability and Mechanical Performance of Alkali-Activated, Slag Cement.

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## ABSTRACT

Alkali activated (AA) cements are considered less harmful to the environment than Portland cements (PC), as they consist of a silicate waste in lieu of a PC clinker, and this implies lower green-house gas emissions and no exhaustion of unrenewable material sources. This paper investigates cements made with ground granulated blast furnace slag (GGBS) activated with sodium hydroxide (NaOH) and sodium silicate ($Na_2SiO_3$), both combined and separately, and cured at 20 and 60°C. The 28-day and 270-day strengths are compared. Furthermore, the materials are subject to accelerated weathering tests (wet-dry, salt crystallization and freeze-thaw cycles), and the strength loss, mass loss and macroscopic changes after cycling studied.

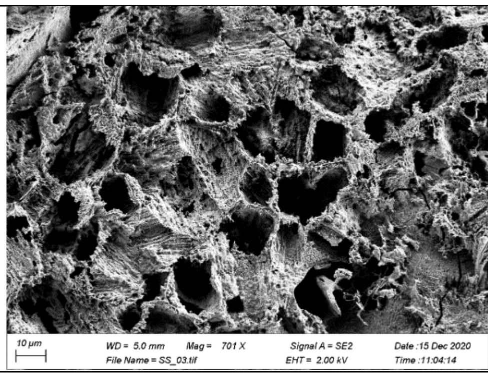
The GGBS is characterized using analytical techniques. Previous work concluded that it complies with standard requirements for the use of slags in concretes and mortars (Alelweet and Pavia 2019). The results indicate that the strength tends to increase between 28 and 270 days. The strength increase at late ages does not conform with former authors such as Collins and Sanjayan (2001) who found strength reductions at late ages due to microcrack networks that appear at late age.

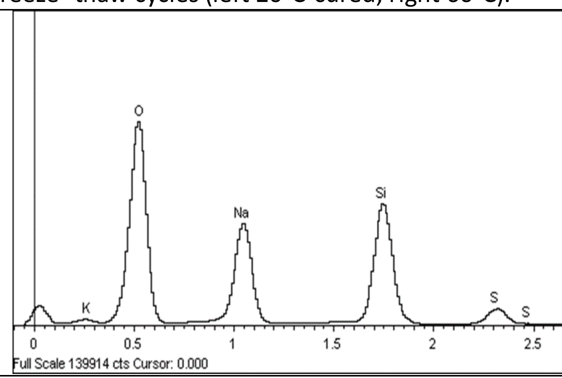
Increasing the curing temperature enhances mechanical strength at 28 days when the activator is $Na_2SiO_3$ + NaOH agreeing with Fernández-Jiménez et al.1999. In contrast, at late ages (270 days) despite occasional contradictions, increasing the curing temperature does not generally enhance mechanical strength also agreeing with former literature.

The strength loss due to artificial ageing is highly inconsistent as some of the weathered specimens show greater strength than the unweathered (control) ones. However, the $Na_2SiO_3$/NaOH activated GGBS materials clearly show the greatest resilience to the effects of frost, thermal/moisture cycles

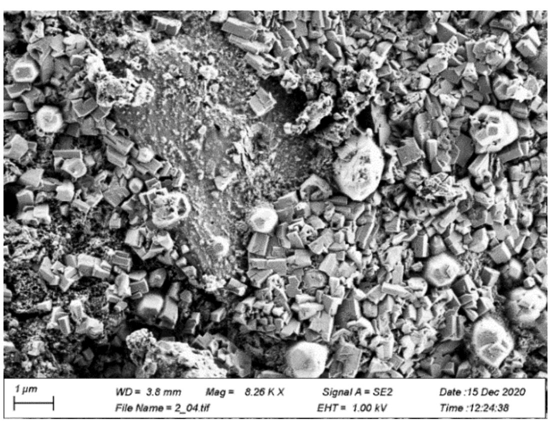
and salt action as they remained intact after cycling, while both the NaOH and the $Na_2SiO_3$ activated GGBS materials developed slight decay including efflorescence, swelling and cracks.

Efflorescence on NaOH activated GGBS after 20 freeze- thaw cycles (left 20°C-cured; right 60°C).




The scanning electron microscope (SEM) and EDX analyses indicate that the salts are alkali sulphates.




The microstructural (SEM) study of the best performers ($Na_2SiO_3$+NaOH activated, GGBS materials) revealed areas of unreacted GGBS particles bound with scattered silica cements alternating with abundant alumino-silicates. The SEM image (left) shows the isometric and tabular alumino-silicates in the $Na_2SiO_3$+NaOH activated GGBS materials.

***Keywords:*** *GGBS, alkali activation, freeze-thaw, salt crystallization, wet-dry cycles, 270-day strength.*

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