SUSTAINABILITY AND MULTIFUNCTIONALITY FOR NEXT-GENERATION CONSTRUCTION MATERIALS

Michael Di Mare, École de technologie supérieure, Université du Québec, Montréal, Canada
michael.di-mare.1@ens.etsmtl.ca

Key Words: Bauixte residue, Red mud, Self-sensing, Piezoresistivity, Dielectric constant

Alkali activated materials (AAM) offer numerous benefits over other cementitious construction materials including greater sustainability and superior functional properties. This presentation addresses two topics at the heart of their use in construction and the focus of this conference: (1) making AAM an accessible replacement to Portland cement by valorizing high-volume waste products and (2) exploring the multifunctional properties of AAM that make them a superior alternative for smart, next-generation construction.

The first topic of this presentation is the production of high-strength AAM for construction from bauxite residue. Bauxite residue (red mud) is a high-volume waste product of the Bayer process that cannot be effectively valorized in cement. Literature on the production of AAM from bauxite residue shows a clear trade-off between bauxite residue content and compressive strength, unless the bauxite residue is pretreated with high-temperature processing. In this study, a new mixing methodology has been developed that triples the content of unmodified bauxite residue that can be used in the AAM, up to 76%, while maintaining a compressive strength above 30 MPa to meet structural norm requirements. This technique does not require thermal treatment of the bauxite residue and improves the viability of AAM as a sustainable alternative to other cementitious construction materials.

The second topic is functional properties of AAM that can be leveraged for multifunctional construction products. As noted in the introduction for this conference, the dielectric constant of AAM can be 1000x greater than conventional dielectric ceramics. This is a desirable property for applications of electromagnetic pulse interference (EMI) shielding. However, investigations of this property in the literature are limited and little is known about the effect of compositional factors, which strongly influence an AAM's chemical and mechanical properties, on the dielectric performance. The results of this study reveal that the dielectric constant is strongly influenced by the AAM composition, and, when optimized, can be increased above 10^9, a one-million times improvement over dielectric ceramics. This offers a substantial improvement for EMI shielding applications as well as opening new doors to applications in low-cost supercapacitors.

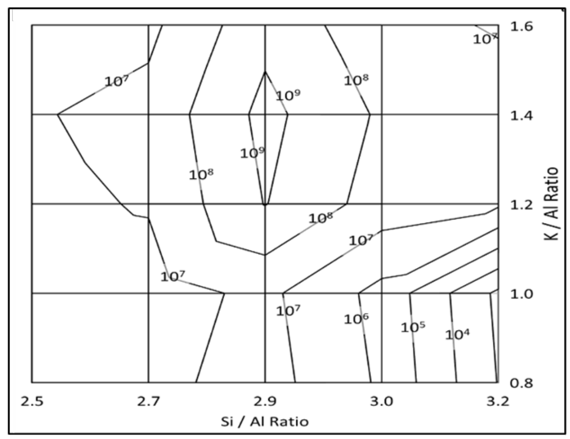

Figure 1– The dielectric constant of AAM as a function of the composition.

In addition, a new functional property has been discovered that creates another application for multifunctional AAM in smart construction. Self-sensing materials are a class of multifunctional structural materials capable of detecting corrosion, crack propagation, and other structural defects. Cement-based self-sensing materials rely on the incorporation of hydrophobic, carbonaceous nanoparticle additives and, consequently, are limited by the high cost and low dispersion reproducibility of these additives. An investigation of the electromechanical behavior of AAM revealed that AAM exhibit self-sensing as an intrinsic material property, eliminating the need for additives. This finding circumvents the drawbacks of conventional self-sensing options and presents a new application to realize AAM as a value-added, multifunctional improvement over other construction materials.

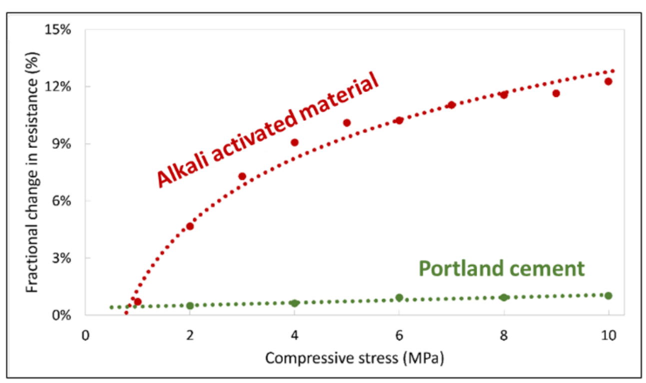

Figure 2 – The self-sensing performance of AAM without additives compared to that of cement.