Development of Corrosion Inhibiting Geopolymers Based Cement for Transportation Infrastructure

Assessing the viability of metakaolin (MK) in preparing reinforced geopolymer concrete (GPC)

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Geopolymer (GP) is gaining attention as affordable, sustainable, and eco-friendly replacement for ordinary portland cement (OPC) in concrete-based civil structures. More importantly, geopolymer-based cement (GPC) provide sustainable and environmentally friendly alternative to OPCs as GPC can be processed at room temperatures from aqueous solutions of waste materials or abounded natural to reduce significant CO_2 production associated with processing of OPC. The objective of this study is to evaluate the effect of parameters including ratios of Si/Al, water/solids, and alkali ions/Al against the chloride-induced corrosion. Electrochemical evaluations are performed to assess corrosion of the GPC concrete. Furthermore, corrosion performance have compared among GPCs to examine the effect of the varied parameters for chloride-induced corrosion.

Background

Geopolymer is a class of amorphous inorganic aluminosilicate that is charged balanced by alkali metal cations. The chemistry of GPs can be describe with the formula $M_n[-(SiO_2)_z-AlO_2-]\cdot wH_2O$ where M is the alkali metal cation (usually Na^+ or K^+), n is the degree of polymerization or molar ratio of M/Al, z is the molar ratio of Si/Al, and w is the molar water quantity. The precursor materials for the synthesis of GP are rich in aluminosilicate that dissolves into $[(SiO)OH_3]^-$, $[(SiO_2)OH_2]^{2-}$, $[(AlO)OH_4]^-$ etc.

The geopolymerization starts with the dissociation of aluminosilicate precursor into monomeric and oligomeric species of Si and Al through hydrolysis. As GPC cures, the Si and Al species begin to chain together forming -Al-O-Si- and -Si-O-Si bonds through polycondensation process, in which the gel becomes more rigid with the curing time and excess water is released.

Project Summary

The main objective of this study is to assess the feasibility of using metakaolin as precursor in producing GPC. Specific objectives are to: (i) prepare GPCs with different parameter ratios, (ii) evaluate the effect of the varied parameters against the chloride-incuded corrosion. These objectives will be accomplished by testing GPC samples in the laboratory and through electrochemical testings. Electrochemical properties of the reinforcing steel over the immersion period including corrosion potential, layer capacitance, resistance, and polarization resistance at different GPC parameters have evaluated.

Status Update

Electrochemical properties of reinforcing steel in GPC-based concrete used in this study have been compared using open-circuit potential (OCP) and electrochemical impedance spectroscopy (EIS). It appears that neither potassium- nor sodium-based GPC concrete provide long term corrosion prevention of the reinforcing steel. Compared to the potassium-based, the sodium-based GPC concrete showed longer protection of the reinforcing steel (Figure 1).

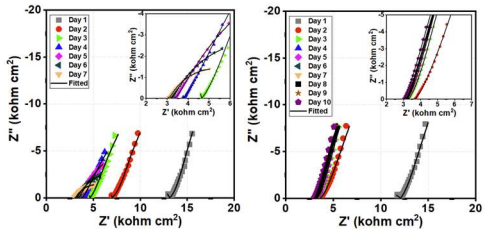

Figure 1. Nyquist plots of GPCs with different cation (left: K3(2.5)(1), right: Na3(3.5)(1.2)).

During the immersion testing, the research team observed the precipitation of the salt-like material on the surface of the potassium-based GPC concrete samples as shown in Figure 2. According to the x-ray powder diffraction (XRD) results, it is revealed as potassium chloride. Considering the concrete samples are immersed in 3.5 wt.% sodium chloride solution, this represents the cation exchange capability observable in potassium-based GPC concrete samples.

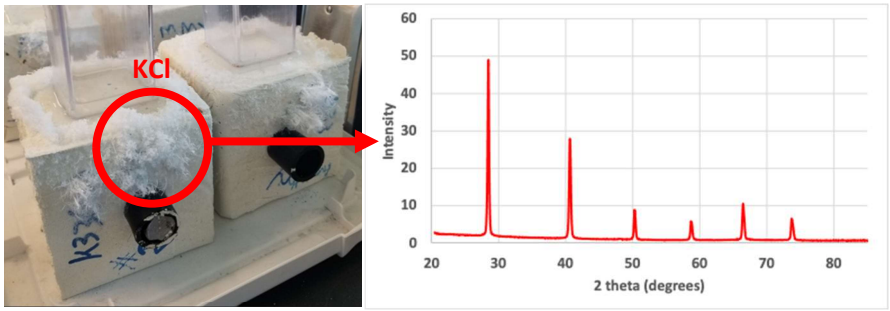

Figure 2. Precipited potassium chloride on the surface of the potassium-based GPC concrete samples and its XRD pattern.

Impacts

The main benefits of this study are: (a) re-use of waste materials in transportation construction projects, (b) enhance training opportunity for students in the region, (c) contribute to concrete industries to be more economically and environmentally sustainable, and (d) enform a more prepared workforce. The expected deliverables of this project are: (1) a technical report containing performance data and guidelines of MK-based GPC concretes and (2) showcase the findings of the study at the annual Technical Research Committee (TRC) meeting at the Tran-SET Conference.

The outcome of this study is expected to be important in setting the direction of the sustainable re-use of waste materials in producing GPC concretes – and lead to significant CO_2 savings for concrete and construction industries. This study will also help future replacement of the conventional OPC usage to pursue more economically and environmentally sustainable concrete production.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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