Development of Corrosion Inhibiting Geopolymers Based Cement for Transportation Infrastructure

Optimizing the composition of Geopolymer Cement for improved corrosion protection of steel reinforcement rebars in transportation infrastructure

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19CTAM02

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$60,000

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Texas A&M University
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$120,000

Geopolymers are gaining attention as affordable, sustainable, and eco-friendly replacement for Ordinary Portland Cement (OPC) in concrete 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 (e.g. fly ash) or abounded natural sources (e.g. clay) and thus reduce significant CO2 production. Although, research has been done on improving mechanical properties of GPC, there are only a few studies on the effects of GPC concrete on steel rebar reinforcement. This study will investigate the long-term durability of reinforced GPC concrete against chloride-induced corrosion. Durability tests under simulated marine environment will be conducted on reinforced GPC concrete over long periods of time. Both material characterization studies related to micro to macro behavioral changes during long-term exposure of reinforced GPC concrete and steel rebar will also be carried out. In addition, in order to improve the durability of the transportation infrastructure affected by corrosion in the most efficient manor, a procedure to manage corrosion in reinforced GPC bridges will be developed. The desirable features of this management system will include the methods for preliminary corrosion condition evaluation and in-depth corrosion condition evaluation, the methods for assessing the structure condition rating and monitoring, methodology for selecting best corrosion prevention and controls, reliability model, and procedure for tracking repair or design performance.

Problem Statement

At the present time, Ordinary Portland Cement (OPC) is key material for transportation infrastructure as it has been widely used for concrete structures and stabilization of base and subgrade materials. However, production of OPC involves large energy consumption to achieve the high temperatures that are required for reaction between clay and calcium-carbonate (CaCO3). This process also results in the release of carbon dioxide (CO2), and since OPC is the most produced man-made material, it is estimated that 5-6% of CO2 emission is due to OPC production. GPC as alternative to OPC constitute a family of materials consisting of covalently bonded alumino-silicates, non-crystalline networks and are generally substituted for many engineering applications due to their high strength. They have received much attention as an ecofriendly and sustainable alternative to OPC because they can be processed at room temperature inexpensively from waste materials or natural sources, thus providing the plentiful worldwide raw material supply. More importantly, the use of GPC rather than OPC can reduce CO2 emission for 44-64%. Over the last decade, there has been a need to repair and replace the current reinforced concrete structure, especially those exposed to highly corrosive agents such as chloride ions. GPC have been also consider as an attractive alternative to OPC in reinforced concrete structures, not only because of their good mechanical properties, but also because they can prevent extensive corrosion of the reinforcement.

Objectives

The overall objective of project is to develop an innovative, sustainable, eco-friendly and durable GPC for reinforced concrete infrastructure in egion 6, using natural and waste materials that are abounded in the region.

More specific objectives of the proposed projects are: (a) conduct electrochemical testing of GPC concrete reinforced with steel rebar in simulated corrosive marine environment using both AC and DC methods; (b) determine corrosion mechanism and kinetics of the reinforcement steel in GPC concrete; (c) optimize GPC composition for maximum corrosion protection of reinforcing steel rebar; (d) provide guidance for the industry on optimizing GPC composition for maximum corrosion protect and disseminate those guidance to the industry of interest; and (e) develop corrosion management system would include the methods for preliminary corrosion condition evaluation and in-depth corrosion condition evaluation, the methods for assessing the

structure condition rating and monitoring, methodology for selecting best corrosion prevention and controls, reliability model, and procedure for tracking repair or design performance in GPCs.

Intended Implementation of Research

Workforce Development: The outcome of this research will lead to a comprehensive report that will provide design methods and guidance for utilization of Geopolymer in reinforced concrete, capable of long-term performance in marine environment. Workforce development will also take place trough series of the outreach activates targeting broader audience of corrosion, civil and materials engineers, and industrial partners with the goal of increasing their awareness on importance of developing new technologies for eco-friendly and durable transportation infrastructure. The information will also be disseminated in various venues including technical publications, and conference presentations. Research team will also disseminate research findings at American Ceramics Society (ACerS) and Nation Association of Corrosion Engineers (NACE). Result of this project will be also presented in at least two papers published in the peer review journals.

Outreach activities and education: Train and educate two PhD students in developing reinforced geopolymer based concretes, characterization of their structural properties and carrying our independently complex electrochemical and corrosion testing. Multidisciplinary training of student will contribute to their unique position on the job market in the future. Presentations will be made at the Graduate invitational visits at Texas A&M University to demonstrate effects of development of ecofriendly substations for OPC. PI (Castaneda) and Co-Pi (Radovic) have an excellent record of supervising research of K-12 and undergraduate students during summer for different programs for the National Corrosion Center and Materials Performance. In addition, there have been ongoing interactions with high school for corrosion science and engineering program.

Develop class experimental demonstrations in electrochemical methods in corrosion studies. The results from this research will be incorporated into several courses at Texas A&M University including MSEN410 Materials processing, MSEN 643 Materials Electrochemistry and Corrosion, and MSEN 644 Corrosion Laboratory. In each course, a module will be developed do demonstrate effects of the processing, structure and properties of new concrete on the corrosion resistance of reinforcing steel. Students working on this project will benefit from exposure to advanced materials and characterization tools and linking laboratory samples within corrosive (atmospheric) environments and high-resolution characterization technologies that are not typical for traditional civil or materials engineers but will likely be part of everyday life of future engineers. This proposal provides an ideal environment for the education and training of students at the graduate level in a highly interdisciplinary area that encompasses civil engineering, materials engineering, corrosion, and application to real-world durability and reliability of reinforced concrete structures.

Anticipated Impacts/Benefits of Implementation

Both extended lifetime of transportation infrastructure and low carbon footprints in using Geopolymer are anticipated, which eventually lead to green transportation infrastructure.

Web Links

- TranSET's website (https://transet.lsu.edu/research-in-progress/)
- TRB's Research in Progress (RIP) database (https://rip.trb.org/View/1644237)

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".

Learn More

For more information about Tran-SET, please visit Our Website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.