RP1020

COMMERCIAL ADAPTATION OF CONSTRUCTION MATERIALS WITH LOW-EMBODIED-CARBON

Research Question

Carbon emissions from conventional concrete containing Portland cement (OPC) is second only to fossil fuels; about 6-7% of total man-made greenhouse gas emission is attributed to OPC production.
Up to 80% reduction in carbon emissions can be achieved using the Geopolymer concrete (GPC), an innovative alternative produced from industrial by-products such as fly-ash and slag. The major barrier to GPC adaptation is the lack of both standard specification and knowledge related to its durability. In the absence of a track record of successful durability performance, proper experimental as well as numerical investigation of phenomena such as corrosion of reinforcing bars, as one of the main causes of the premature failure of concrete structures, is required.

Figure 1: Corrosion of reinforcing bars leads to serious problems with millions of dollars spent for maintenance, repair or replacement of damaged structures.

Methodology

The project aims to gather field data from GPC real-life constructions to develop greater confidence in GPC use. Using the field and laboratory data as well as numerical analysis, a comprehensive handbook for GPC specification will be developed and published through Standards Australia. Due to the very different chemistry of geopolymer concrete compared to OPC concrete, all governing parameters of the electrochemistry of steel corrosion in geopolymeric binders are investigated. Also, a multiphysics finite element model is being developed which solves the coupled system of the governing partial differential equations of moisture, oxygen and charge transfer and uses the experimentally measured corrosion kinetic parameters to assess the corrosion rates (Figure 2).

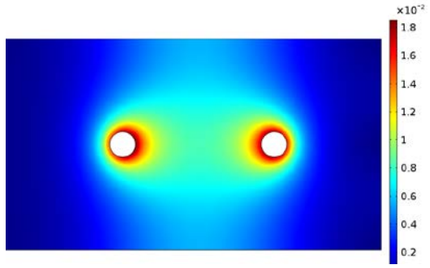

Figure 2: Corrosion current density between a corroding reinforcing bar and a sound reinforcing bar in a concrete member

Results

Figure 3 compares the Polarization resistance of reinforced low-calcium fly ash-based GPC and OPC concrete. Polarization resistance (R_p) is the resistance at the steel-concrete interface against the charge transfer from reinforcing bars to the electrolyte (concrete here) and vice versa. It is inversely proportional to the corrosion current density which is the rate of dissolution of steel bar and can be used to estimate the service life of the structure.
The average polarization resistance trends for GPC and OPC concrete samples exhibit a remarkably good match and as a result, a similar performance of Portland cement binders and geopolymeric binders in chloride contaminated environments during the propagation phase of corrosion (after depassivation of reinforcing bars) can be inferred.

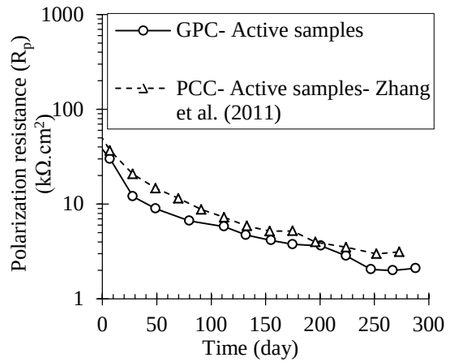

Figure 3: Comparison of the Polarization resistance of geopolymer and OPC concrete samples

Conclusions

Although low calcium fly ash based GPC can perform as well as OPC concrete in propagation phase of corrosion, some conventional reference values of corrosion parameters which are indicative of the severity of the steel corrosion in OPC concrete might need some recalibration for GPC. Furthermore, all the commonly used electrochemical test methods can be successfully employed to assess corroding reinforced concrete members made up of geopolymeric binders within an acceptable level of accuracy.

Anticipated impacts

Geopolymer alternatives can achieve up to 80% reduction in carbon emission, depending on the type and amount of activators used.

The major barrier to geopolymer concrete adaptation is the lack of both standard specifications and knowledge related to its durability aspects.

For a relatively moderate uptake of 10% geopolymer/concrete replacement, for example, 640 thousand tonnes per annum less carbon will be emitted to the atmosphere per year from Australia alone. This uptake will not be realised without the development of production and design guidelines for engineers and practitioners approved through Standards Australia, which this project will deliver.

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