

Chloride ion (Cl) plays an important role in the long-term deterioration of reinforced concrete by promoting the corrosion of steel. The Cl diffusion coefficient is the key parameter that determines the rate of transport. However, obtaining a value for this parameter involves wet chemistry methods to determine the chloride content along a depth profile. This gradient is then fitted to a Fickian diffusion model to obtain the diffusion coefficient. The sample crushing and chemical analysis steps are time consuming and labor intensive. Prompt gamma neutron activation analysis (PGAA) is an alternative method for obtaining the spatial distribution of chlorine atoms non-destructively. It works by irradiating the object with a beam of neutrons which are captured by the nucleus of elements in the sample, exciting the nucleus, which then deexcites by emitting gamma rays of characteristic energies. The gamma spectra are analyzed to provide a quantitative estimate of the elemental composition and, specifically, Cl content of the sample. PGAA is particularly suited for detecting Cl because of its high neutron capture cross-section.

To evaluate the feasibility of PGAA for this application, two 50 mm concrete cylinders, one with limestone coarse aggregate and the other granite coarse aggregate, were cored from 100 mm diameter and 50 mm thick disk in which Cl gradients were implanted using the Rapid Chloride Permeability Test (ASTM C1202) apparatus. This imposes an electric potential across the sample that increases the Cl ingress by several orders of magnitude over standard diffusion tests in the same time period, to provide a useful profile for comparison of wet chemistry to the neutron beam analysis. The potentials were applied for up to 5 hours. The cored cylinders were then scanned at about 2.5 mm increments over the height of 25 mm in the neutron beam. The prompt gamma rays were collected through a Pb slit collimator resulting in a vertical resolution of about 2 mm. The volume irradiated by the neutron beam at each position was approximately 1 cm³. With a 10 min counting time at each height, the Cl concentration was determined with an uncertainty of < 1% based on counting statistics. For comparison, the Cl gradient was measured in a duplicate set of cylinders using the conventional wet chemistry. There was good qualitative agreement between the gradients measured by PGAA and the wet chemistry method as shown in Fig. 1. The results differed by a constant scale factor because the wet chemistry data is in total Cl concentration while the PGAA data are reported as the Cl/Si ratio (Fig. 2). Nevertheless, a relative concentration profile suffices for the calculation of the diffusion coefficient which requires the normalization of either type of data by the value at the surface. As an alternative to the spatially-resolved mode of operation, PGAA can be applied in a time-resolved mode which involves measuring the Cl concentration at a fixed position as a function of time. This will enable the investigation of the effect of the individual driving forces -Fickian, electrochemical and osmotic – on the observed Cl gradient.

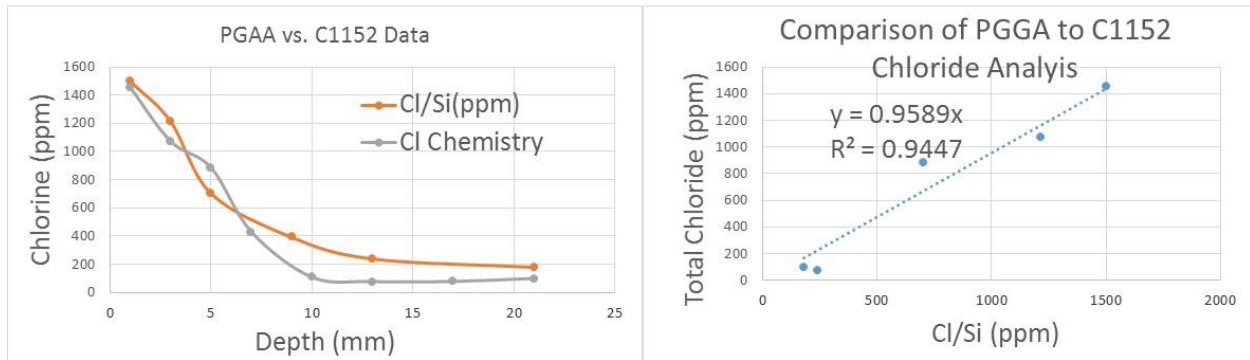


Figure 1: Comparison of Granite Specimen G7 B profiles after 2 hours at 60 V.

Figure 2: Plot of wet chemistry data vs PGAA from Fig. 1