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Factors Controlling Durability of Geopolymer Concretes in Chloride Determined via Growing Self-Organizing Maps

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ABSTRACT

Geopolymer concrete offers a promising alternative to traditional Portland cement concrete, exhibiting comparable mechanical and durability performance while reducing environmental impacts. However, its mechanical and durability properties depend on many factors, such as the water/binder ratios, concentration of activator and curing temperatures. This study proposes using an unsupervised Artificial Neural Network (ANN) Self-Organizing Map (SOM) to predict the factors that control the durability of geopolymer concrete in a chloride environment based on experimental datasets. This research aims to identify the impact of various water-to-binder ratios and molarity of activators on the durability of geopolymer concretes by applying the Growing Self-Organizing Maps (GSOM) model to predict the durability of the design mix. A series of geopolymer concrete mixes with varying water-to-binder (w/b) ratios and activator molarity were prepared to achieve these goals. These cylindrical samples of 100 mm height x 50 mm diameter size were cured for 24 hours at 80°C and subject to chloride migration test at 28-day curing age. The data collected was analyzed and modeled using statistical methods and machine learning techniques, i.e., SOM modeling. This modeling approach effectively revealed patterns and relationships within the dataset, providing crucial insights into the chloride migration behavior. Based on the GSOM modeling, this study highlights efficient data analysis, pattern recognition, and optimization of outcomes, such as geopolymer concrete durability prediction in a chloride environment based on the selected parameters.

Keywords: Artificial Neural Network (ANN); durability; geopolymer concrete; Self-organizing map (SOM)

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INTRODUCTION

Geopolymer concrete represents an innovative and sustainable paradigm in construction materials. It departs from the dependency on conventional Portland cement-based concrete by utilizing industrial byproducts, natural sources, or waste materials with high silica and alumina content, such as fly ash, slag, and metakaolin (Cong & Cheng, 2021). The precursors go through a geopolymerization process, where these source materials react with an alkaline activator solution, typically composed of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). During geopolymerization, these constituents undergo a chemical transformation, forming a robust three-dimensional network of interconnected polymeric chains, which serve as the binding matrix for the concrete (Gunasekara et al., 2019). This unique chemistry not only reduces the environmental footprint by diminishing carbon dioxide emissions related to traditional Portland cement production but also offers geopolymer concrete with remarkable attributes, including exceptional fire resistance (Cong & Cheng, 2021), rapid early strength development (Amran et al., 2021), and formidable resistance to chemical aggression (Wong, 2022), making it an eco-friendly and high-performance choice for various construction applications.

Chloride-induced corrosion of steel reinforcement in concrete is primarily attributed to the penetration of chloride ions into the concrete matrix. This penetration is influenced by several factors, including the chloride ion concentration at the surface of steel, with critical levels around 0.4% by weight of cement being a potential threshold for corrosion initiation (Zofia & Adam, 2013). The porosity of concrete plays a pivotal role in facilitating chloride ingress. Chloride ions permeate concrete through three key mechanisms: capillary absorption, hydrostatic pressure, and diffusion. The predominant mechanism is diffusion, driven by concentration gradients and dependent on factors such as ion concentration differences and continuous pore fluid Sirivivatnanon and Khatri (2011), and Shobeiri et al. (2021). It occurs predominantly in submerged conditions, where the concentration disparity between contaminated and uncontaminated surfaces and the diffusion coefficient determine the ingress rate. Concrete, characterized by solids and voids filled with fluid and air, can also experience chloride penetration due to hydraulic pressure caused by the presence of chloride ions at the concrete surface (Halim et al., 2017). Capillary absorption relies on moisture gradients to facilitate chloride ion movement into concrete pores (Titi & Tabatabai, 2018).

Several critical factors influence the durability of geopolymer concrete, and one of the most significant concerns is the risk of chloride-induced corrosion. This corrosion process can be complex and is influenced by several key factors (Chen et al., 2021; Chindaprasirt & Chalee, 2014). The initial chloride concentration in the environment, the exposure duration, the geopolymer concrete's specific mix design, and the prevailing environmental conditions all play vital roles (Tennakoon et al., 2017; Titi & Tabatabai, 2018).