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Review

Effect of Fly Ash characteristics, sodium-based alkaline activators, and process variables on the compressive strength of siliceous Fly Ash geopolymers with microstructural properties: A comprehensive review

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ABSTRACT

Geopolymer concrete (GPC) exhibits enhanced performance compared to conventional concrete across various dimensions. These include decreased CO_2 emissions, elevated mechanical strength, improved thermal insulation, greater fire resistance, the valorization of industrial wastes and increased efficiency in energy conservation and production costs. This review focuses on the impact of 11 factors such as class F Fly Ash (FA) characteristics (fineness, SiO_2/Al_2O_3 ratio, and iron content), sodium-based alkaline activators parameters such as molarity of sodium hydroxide (SH), Silicate Modulus (SM) of sodium silicate (SS) solution, ratio of SS/SH solution, alkaline liquid to binder ratio, water to binder (w/b) ratio, $H_2O/Na_2O_{equivalent}$, and process variables such as heat curing temperature and heating duration on the compression strength of low calcium (class F or siliceous) FA-based geopolymers (GP). Existing literature explicitly indicates that the molarity of NaOH solution is the primary strength parameter that significantly affects the compression strength of the GPC, among other factors. The range of alkaline activator parameters and heat curing temperature contingent on the SiO_2/Al_2O_3 ratio of FA moreover accurately the reactive SiO_2/Al_2O_3. Among all factors, one of the crucial parameter is the water content because of its importance in geopolymerization; the additional water released during the chemical reaction has to be considered in the mix design. The aforementioned eleven parameters are analysed and reported in the development of the compressive strength.

1. Introduction

Cement is defined as a binding substance capable of solidifying and combining fine and coarse aggregate through the utilization of water as a cohesive agent, ultimately resulting in the creation of an artificial solid structure known as concrete. China is the leading global producer of cement, manufacturing more than half of the world's cement. In 2022, China's predicted cement production is 2.1 billion metric tons (Bmt). India is a distant second, with a production of 370 million metric tons (Mmt) [1]. The manufacturing of cement clinker, along with the milling process, requires a significant amount of energy consumption. Producing one tonne of cement causes approximately 0.6–0.7 t and 0.3–0.4 t of CO_2 from the calcination of limestone and the burning of coal/fuel, respectively [2] about 0.7–1 t from each tonne of cement is released into atmosphere [3]. The emission of CO_2 resulting from the burning of limestone is a chemical reaction that cannot be mitigated via alterations

Abbreviations: T, tonnes; °C, degree Celsius; %, percentage; μm, micro meter; AAS, Alkaline Activator Solution; Al, Aluminium; Al_2O_3, Aluminium Oxide; ASTM, American Standard for Testing and Materials; Bmt, Billion metric tons; Ca, Calcium; CaO, Calcium Oxide; CC, Conventional Concrete; CO_2, Carbon dioxide; DTG, Differential thermo-gravimetry; FA, Fly ash; Fe, Iron; GGBFS, Ground Granulated Blast Furnace Slag; GP, Geopolymers; GPC, Geopolymer concrete; LOI, Loss on Ignition; M, Molarity; M^+, Metal ion; ML, Multispectral; Mmt, Million metric tons; MSW, Municipal Solid Waste; N-A-S-H, Sodium Aluminosilicate Hydrate; NaOH, Sodium hydroxide; Na_2O, Sodium Oxide; Ppm, parts per million; RHA, Rice Husk Ash; SBA, Sugarcane Bagasse Ash; SEM, Scanning Electron Microscopy; SF, Silica Fume; Si, Silica; SiO_2, Silicon Oxide; SH, Sodium Hydroxide; SM, Silicate Modulus; SS, Sodium Silicate; SSA, Specific Surface Area; TGA, Thermo-gravimetric analysis; XRD, X-ray Diffraction; XRF, X-ray Fluorescence; W/b, water/binder.

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