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Investigation of slag-based concrete by mathematical analysis considering air pollution prevention

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Abstract

Carbon dioxide is non-toxic greenhouse gas emitted from sources as cement production. Concrete samples with different percentage of cement replacement by slag and also samples prepared according to standard recipe were prepared for the experiment. Sets of samples were exposed to aggressive environment (acid solution and medium with bacteria *Acidithiobacillus thiooxidans*) during 6 months. Quantities of calcium and silicon leached out into the liquid solution have been measured. Dissolved quantities were used for statistical analysis of trend of leaching and its influence on properties of concrete samples.
Results point to the positive contribution of slag incorporation into concretes (exposed to chemical attack) and its important role in air pollution prevention by reduction of CO_2 cement emissions.

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Keywords: acidithiobacillus thiooxidans; biocorrosion; calcium; silicon; sulphuric acid

1. Introduction

Cement manufacturing accounts for around 5 % of global carbon dioxide (CO_2) emissions. It belongs to the industries which are intensive from the energy demand point of view and leads to high pollution to the surrounding [1].

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Carbon dioxide is emitted to the air during the cement production directly (by decomposition of limestone - calcination process) and indirectly (burning of fossil fuels to heat the kiln - also cause CO_2 emissions). More than 40 % of CO_2 is released during breaking down of limestone into lime (where side product is CO_2). For the clinker formation high temperatures are needed and it also provokes carbon dioxides emissions. Based on many studies it was confirmed that relationship between the processing of mineral products and climate change exists [2–4].

The cement industry has a potential to reach important progress in absolute CO_2 emissions reduction by using alternative source of energy [5] and supplementary cementitious materials [6, 7]. Supplementary material contains fly ash from energy production, granulated slag as by-product from iron manufacturing and another natural pozzolans. Using wastes in ordinary Portland cement directly decreases the carbon dioxide emission. At the present more than 170 kinds of concrete of concrete mixtures can be applied. In addition waste utilization contributes to the effective waste management within circular economy strategy. In paper by [5] cement production data across the world to delve into production trends and determinant factors were examined. Among others factors they found that regional characteristics play a significant and substantial role in determining cement production levels, even after controlling income and country area. Greenhouse gases in industrial processes are emitted mainly by mineral production in Thailand [8] (accounting for 97.9 % in 2000). China with its extremely high potential of cement production could substantially reduce CO_2 emissions and local pollutants such as mercury and particular matters by replacing the excessive cement production by waste incorporation into cement-based materials. Attention to blast furnace slag incorporation to cement with the aim of air, soil and underground water pollution prevention was paid in [9]. High strength concrete based on slag as cement replacement was investigated in [10]. The authors reported 10 % slag replacement to be an optimal content regarding to strength and durability performance of concrete. Similar conclusions of sorptivity and strength investigation have been conducted by Vijayasarathy and Dhinakaran in [11] studied high performance concretes.

Alkali activated granulated blast furnace slag (GBFS) in a mixture with calcined kaolinitic clay proved good resistance against microbial and chemical attacks under various temperatures and under different humidity [12]. As granulated blast furnace slag increases chemical resistance of cement with its glassy phase, it also increases resistance to acidic metabolites of microorganisms in a form of mineral and organic acid [13]. The activity of the bacteria leads to the formation of the sulphur cycle in the system, and consequently to the formation of sulphuric acid, whose presence causes corrosion of concrete.

Biologic corrosion of concrete is a serious problem wherever the suitable conditions for a life of the particular microorganisms, such as temperature and moisture conditions of the environment, pH of the environment, aerobic conditions, radiation, input of nutrients and others, have come to existence. Biodeterioration reduces the utility efficiencies of concretes and their useful life. Biologic corrosion, as a specific type of chemical corrosion, is caused by various biogenic organic acids, mineral acids (H_2SO_4, HNO_3…) as well as corrosive hydrogen sulphide (H_2S) and ammonia (NH_3), which results from metabolic activity of microorganisms [14].

The paper deals with investigation of leaching trends of calcium and silicon of concrete samples prepared according to standard recipe and of concrete samples with 60 % and 95 % cement replacement by slag, respectively. First sets of samples were exposed to influence of sulphur – oxidising bacteria (simulation of biological corrosion) and second sets of samples were exposed to sulphuric acid (simulation of chemical corrosion). Leaching trends were evaluated using correlation analysis and conclusions were stated.

2. Materials and Methods

Concrete specimens of three various compositions were prepared for the experiment. First set of samples was designed according to a standard recipe, based only on Portland cement (marked as Mixture 0), second set of samples consisted of a mixture where 65 wt. % of Portland cement was replaced by GBFS (marked as Mixture 65) and last set of samples represented a mixture with 95 wt. % of cement replacement by granulated blast-furnace slag (marked as Mixture 95). The compositions of all three concrete mixtures without and with cement replacement by slag are presented in detail in Table 1.