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Contribution to Sustainable Environment through Examination of Durability of Materials in an Aggressive Environment

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Abstract

The paper presents the results of leaching tests of concrete samples with 5 wt. % cement´s replacement by fly ash and applies the statistical approach to an interpretation the results. Concrete samples with of two types of fly ashes, originating from anthracite and lignite burning, respectively were exposed to solution of $Al_2(SO_4)_3$ to sulphate corrosion testing. Deterioration process was manifested by leaching the elementary components of concrete (Ca, Si, Fe, Al) and particular pH changes of leachates in 5 cycles. The leached-out concentrations of elements from concrete matrix measured by X-ray fluorescence method (XRF) and measured pH values were used for the subsequent statistical analysis. A dependency between pH of leachates and leaching trends of Ca and Al, respectively, was confirmed. The correlation coefficients ranged from 0.79 to 0.85. No significant differences between durability of concrete materials based on black or brown-coal fly ashes regarding to leachability were noticed.

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Keywords: Aluminium sulphate; concrete; correlation analysis; corrosion; leaching

1. Introduction

The building industry is connected with exhausting the natural resources, enormous energy consumption, gaseous pollutants emissions, and solid waste production. The European building industry is responsible for about 40% of

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the total environmental impacts in the region. Environmental benefits in civil engineering sector will therefore make a substantial contribution to sustainability overall. In fact, the issue of sustainability is a major spur to innovation in the building world. To study and improve a durability of building materials is a key factor in reduction the negative environmental impacts and save raw materials and energy. Obviously, become concrete has a large share of the building materials market, the environmental features of concrete are of major importance [1]. Nowadays, various supplementary cementitious materials, including both pozzolans and hydraulic materials, are of interest. Pozzolans that are commonly used in concrete include fly ash (FA), silica fume and others. Historically, FA has been used as supplementary cementitious material in the production of Portland-cement concrete at levels ranging from 15% to 25% by mass of the cementitious material component. The actual amount used varies widely depending on the application, the properties of the FA or specification limits [2]. In recent decades, research has demonstrated that high dosage levels (40% to 60%) can be used in structural applications, producing concrete with good mechanical properties and durability [3].

FA and slag were found to be able to increase not only concrete's strength but sulphate resistance as well [4]. Concrete made with Portland cement can be damaged when exposed to solution containing sulphate. Groundwater often contains sulphate, and so the foundations of building and other structures are frequently there damage due to sulphate attack is found. Sulphate attack causes expansion and cracking, and general loss of concrete strength, with ettringite often widespread within the cement paste in affected areas as studied by Torresan et al. [5]. A calculation of the cement content by chemical analysis, together with a determination of the sulphate content, can indicate that it may have occurred if the sulphate content is appreciably higher than would be expected from sulphate normally presented in the cement [6]. The ACI 318 Building Code [7] has limitation on the maximum water-to-cementitious-materials ration (w/c) for various durability requirements. In addition to improve concrete's sulphate resistance, FA was also found to mitigate alkali-silica reaction (ASR) in concrete [8], and decreases the shrinkage of cement paste [9]. Corrosion resistance performance of fly ash blended cement concretes was also studied in [10].

The objective of the paper was to interpret the experimental results of examination the durability of concrete samples in terms of their leachability, with two types of fly ashes, one originating from anthracite burning and the other from lignite burning, by using statistical approach

2. Material and methods

Concrete samples of two compositions, both with 5 wt. % replacement of cement by FA, were prepared for the experiment: first set of samples (marked ENO samples) contained FA originating from brown-coal burning; the second set of samples contained FA originated from black-coal burning (marked as TEKO samples). The FAs were used in cement mixtures without any modifications. The characterisation of FAs and concrete mixtures is described in more detail in our previous work [11]. Cylindrical concrete samples of a 32 mm diameter and 15 mm height were formed as a drilled core from concrete cubes (150x150x150 mm) using drilling mechanism STAM.

Experimental durability testing of concrete samples was based on the leaching experiments whereas the concrete samples were exposed to sulphate solution represented by 0.5 wt. % $Al_2(SO_4)_3$. The samples were prior to the experiment rid of impurity, treated to a constant weight and then immersed into aluminium sulphate solution (pH value 3.22) to simulate a sulphate corrosion. Experiments proceeded over a period of 50 days in five consecutive cycles. Each of the cycle consists of the following steps: seven-day exposure of sample to a liquid medium, removal the sample from the liquid, two-day drying at the room temperature and afterwards removing of precipitations, and re-immersion of sample into the medium. The leaching process was manifested by dissolving the main cement matrix´s components into the leachant. Concentrations of elementary ions in leachates were determined using X-ray fluorescence analysis (XRF). Besides leached-out masses, the pH of the liquid media was measured in leachates after every 7-day exposition using a pH meter PHH – 3X Omega.

Descriptive statistics is the discipline of quantitatively describing the main features of a collection of data [12]. The leached-out masses of the main elements (Ca, Si, Al, Fe) from concrete matrix and pH values of liquid media were used for the subsequent mathematical evaluation using a correlation analysis. In statistics, dependence refers to any statistical relationship between two random variables or two sets of data. Correlation refers to any of a broad class of statistical relationships involving dependence. Increase of the absolute value of the correlation coefficient (R_{xy}) is proportional to linear correlation. Information about two dimensional statistical data set gives correlation