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INFLUENCE OF ULTRASONIC RADIATION ON THE AMORPHOUS ZEOLITE – PORTLAND CEMENT SYSTEM

L. Jakevičius\textsuperscript{1a}, D. Vaičiukynienė\textsuperscript{1b}, A. Demčenko\textsuperscript{2}

\textsuperscript{1a}Department of Physics, \textsuperscript{b}Faculty of Chemical Technology; Kaunas University of Technology, Kaunas [Lithuania]. \textsuperscript{2}Department of Engineering Technology; University of Twente, Enschede [Netherlands]

\textsuperscript{1a}Department of Physics, Kaunas University of Technology, Studentu str. 50, LT-51368 Kaunas, Lithuania; E-mail: danute.palubinskaite@ktu.lt

Abstract

This paper considers the investigation of influence of an amorphous synthetic zeolite with inserted Ca\textsuperscript{2+} ions additive (ASZ) on the hydration temperature of Portland cement paste. In this investigation the sonicated Portland cement paste is compared to the non-sonicated paste; and then the cement paste hydration process is analyzed by the means of temperature measurements. The temperature measurement results confirm that the sonication process accelerates the exothermic chemical reaction between the Portland cement and water.

Keywords: cement hydration, amorphous zeolite, ultrasonic radiation, sonication

Nowadays, there is much discussion concerning incorporation of natural and synthetic zeolites in blended cements [1–3]. Therefore, applications of blended cements, instead of ordinary Portland cement, are increasing rapidly in the industry.

In the reported study [4] a sonication process is applied by means of which a deagglomeration of larger particles of densified silica fume is achieved. This treatment enabled to increase quantity of submicrometric particles in samples. The effect of sonication process on densified silica fume produces a greater quantity of very fine particles, which improves the pozzolanic reactivity of silica fume and increases fixation of hydrated lime. This behavior also enables to achieve a higher mechanical strength in mortars which are produced with sonicated silica fume.

Silica fumes are subjected to ultrasonic treatment in order to decrease particle agglomeration and improve particle dispersion. The effectiveness of the sonication is observed as a reduction in particle size distribution of the sonicated silica fume (SSF) compared to the non-sonicated silica fume. SSF is added to Portland cement, and then the hydrated paste is analysed. Micro-structural characterization results show an increase in the reactivity of the silica fume after the treatment [5].

Uniform dispersion of carbon nanotubes is mandatory, and a sonication technique is adapted to disperse them [6]. Another method used for dispersion
of carbon nanotubes [7,8] is based on the sonication of ordinary Portland cement and carbon nanotubes simultaneously.

The paper describes a new, powerful, patented piece of sonic equipment that operates in the low sonic frequency range, at 104 Hz, with nominal power of 75 kW. It has been tested for both physical and chemical sonic effects. A large-scale industrial application is described — the conditioning and pacification of ash from utility coal combustion by fluidized bed combustion. A variety of additional applications is suggested, most of which have been briefly tested [9].

In this study, the properties and the hydration process of Portland cement pastes containing synthetic amorphous zeolite are investigated. The Portland cement pastes with amorphous zeolite additive and without additive are subjected to ultrasonic treatment in order to increase the hydration rate of the cement paste. The Portland cement CEM I 52.R (mineral composition C\(\text{3S} = 50.7\text{%; C}_{\text{2S}} = 18.5\text{%}; C_{\text{4AF}} = 14.2\text{%; C}_{\text{3A}} = 9.7\text{%} ) and amorphous synthetic zeolite (ASZ) with inserted Ca\(^{2+}\) ions is used in this study. The investigated zeolite contains: Al\(\text{2O}_3 = 23.3\text{%; SiO}_2 = 48.4\text{%; Na}_2\text{O} = 5.4\text{%; CaO} = 5.6\text{%} . The compositions are varied by the contents of the ASZ addition: 0; 5; 10 and 15 \text{%}.

The prepared cement paste, placed in 90 mm diameter cylindrical chamber, was treated by ultrasonic radiation for 15 min. The ultrasonic radiation was generated using 28 kHz ultrasonic transducer of 60 W power. The X-ray powder diffraction data were collected employing DRON-6 X-ray diffractometer equipped with Bragg-Brentano geometry using Ni-filtered Cu K\(\alpha\) radiation and graphite monochromator. Operating voltage of 30 kV and emission current of 20 mA were used in the experiments. The chemical composition of the zeolite was determined by digests energy X-ray spectrometer (EDS) with a silicon-type detector (SD3). The cement paste hydration temperature measurements were performed with 8-channel USB TC-08 Thermocouple Data Logger (temperature measurement range from -270 to 1820 °C).

ASZ was synthesized from sodium silicate and sodium aluminate solutions. The gel was formed immediately after mixing of solutions. The gel - ASZ was aged at room temperature for 72 hours. Ion exchange reactions were performed in the unstirred suspension: CaCl\(_2\) solution was filled up with zeolite. The final product of the synthesis was filtered, dried at 60 °C temperature and sieved through a 0.5 mm mesh sieve. The measured X-ray diffraction patterns of the ASZ showed that it was in amorphous state (Fig. 1).

Experimental investigations show that ASZ affects temperature of hydration process in the cement paste (see Fig. 2, a). The results for pastes with 5; 10 and 15% additive are compared with pastes without the additive. This additive increases the maximum hydration temperature in all investigated cases. A higher hydration temperature accelerates the chemical reaction during which
a greater amount of heat is released. The highest hydration temperature is observed in specimens where 10% wt of ASZ additive is added. The test results show that ASZ additive at 10% and 15% of the cement paste accelerates the hydration process from 733 min (without the additive) to 633 min and 567 min, respectively. Moreover, it increased the maximum temperature of Portland cement hydration process by 6 °C and 1 °C, respectively. Using 5% wt of ASZ additive, the cement paste changes the hydration process duration very little, but the temperature maximum increases up to 3°C.

The temperature measurement results show that the highest hydration process temperature is achieved after sonication for 15 min (sample 2 and 4) to compare with the control sample without sonication (sample 1 and 3). Moreover, the measurement results show that the highest hydration process
temperature is achieved after sonication for 15 min (sample 2 and 4) to compare with the control sample without sonication (sample 1 and 3). The effectiveness of the sonication is observed as an increase in the maximum of hydration process temperature. One can conclude that the ASZ additive and sonication process accelerate the exothermic chemical reaction between the Portland cement and water.

References

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