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The Influence of Microsilica on the Cluster Cracks' Geometry of Cement Paste

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Abstract : The changing nature of environmental impacts, in which cement composites are operating, are causing in the structure of the material a number of phenomena, which result in volume deformation of the composite. These strains can cause composite cracking. Cracks are merging by propagation or intersect to form a characteristic structure of cracks known as the cluster cracks. This characteristic mesh of cracks is crucial to almost all building materials, which are working in service loads conditions. Particularly dangerous for a cement matrix is a sudden load of elevated temperature – the thermal shock. Resulting in a relatively short period of time a large value of a temperature gradient between the outer surface and the material's interior can result in cracks formation on the surface and in the volume of the material. In the paper, in order to analyze the geometry of the cluster cracks of the cement pastes, the image analysis tools were used. Tested were 4 series of specimens made of two different Portland cement. In addition, two series include microsilica as a substitute for the 10% of the cement. Within each series, specimens were performed in three w/b indicators (water/binder): 0.4; 0.5; 0.6. The cluster cracks were created by sudden loading the samples by elevated temperature of 250°C. Images of the cracked surfaces were obtained via scanning at 2400 DPI. Digital processing and measurements were performed using ImageJ v. 1.46r software. To describe the structure of the cluster cracks three stereological parameters were proposed: the average cluster area - $\bar{A}$, the average length of cluster perimeter - $\bar{L}$, and the average opening width of a crack between clusters - Γ. The aim of the study was to identify and evaluate the relationships between measured stereological parameters, and the compressive strength and the bulk density of the modified cement pastes. The tests of the mechanical and physical feature have been carried out in accordance with EN standards. The curves describing the relationships have been developed using the least squares method, and the quality of the curve fitting to the empirical data was evaluated using three diagnostic statistics: the coefficient of determination – R2, the standard error of estimation - Se, and the coefficient of random variation – W. The use of image analysis allowed for a quantitative description of the cluster cracks' geometry. Based on the obtained results, it was found a strong correlation between the $\bar{A}$ and $\bar{L}$ – reflecting the fractal nature of the cluster cracks formation process. It was noted that the compressive strength and the bulk density of cement pastes decrease with an increase in the values of the stereological parameters. It was also found that the main factors, which impact on the cluster cracks' geometry are the cement particles' size and the general content of the binder in a volume of the material. The microsilica caused the reduction in the $\bar{A}$, $\bar{L}$ and Γ values compared to the values obtained by the classical cement paste's samples, which is caused by the pozzolanic properties of the microsilica.

Keywords : cement paste, cluster cracks, elevated temperature, image analysis, microsilica, stereological parameters
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