Investigation of cracks development processes of cement matrix modified with a reactive and non-reactive secondary additive under thermal loading conditions

Composites based on a cement matrix (pastes, mortars, concretes) are the most common and widely used building materials on Earth. It is estimated that their annual production worldwide is about 30 trillion tons. Of all materials, only water is more commonly used by humans. Because of this high use of cementitious composites, many scientific teams around the world are involved in their multifaceted research. One of the leading research directions in this field is the study of the cement matrix cracking process, since cracks and their development are the main reason causing the reduction of the durability of cement composites. In addition, a characteristic feature of cement composites is that the development of cracking due to applied load (of any nature) does not lead to the formation of a single large crack, but to the formation of a whole branched cracks system, the so-called "cracking pattern". While the mechanics of cement matrix cracking under static loading conditions is already well understood, the mechanisms of cracks formation and its growth under thermal loading conditions are still not fully understood. The influence of structural changes resulting from the influence of an elevated temperature and the applied modification of the cement matrix on the process of cracks formation and the characteristics of the cracking patterns is also an unexplored issue.

The aim of the project is to investigate and thoroughly understand the processes of formation of high-temperature defects of the cement matrix structure modified with secondary reactive and non-reactive additives, and to determine the influence of these processes on the characteristics of the surface structure of thermal cracks. As a reactive additive the mesoporous silica with the MCM-41 structure type will be used, obtained by the templating method from the waste solution formed after the conversion of silica fly ash into synthetic zeolites. Basalt powder will be used as a non-reactive additive, which is a waste formed during the dust removal process of crushed aggregates. The results obtained will allow to analyze and explain the thermal processes of cracks development of the modified cement matrix. In addition, the use of secondary materials in the project is in line with the principles of sustainable development in the construction sector and will bring a number of environmental benefits.

Modification of the cement matrix will be done in two variants. In the first, the MCM-41 will be used as an additive, in the second – the basalt powder. This will finally allow to determine the influence of several factors on the process of formation and development of high-temperature defects of the cement matrix structure. In the course of the conducted research, a complete characterization of the raw materials will be performed. Then, the physical-mechanical, structural, textural and compositional transformation of the modified cement matrix, resulting from the effect of an elevated temperature, will be identified and described. Quantitative characterization of the cracking patterns will be performed using a digital image analysis. Then, the modified cement matrix will be tested to determine the level of stress initiating cracking under thermal loading conditions, using the acoustic emission method. According to available literature data, this will be the first attempt to determine the level of stress initiating cracking under thermal loading conditions. Finally, using the data from the conducted research, an intelligent prediction model based on artificial neural network will be developed to determine the fracture energy of thermally degraded cement matrix. The result of the intelligent modeling will be the development of an user-friendly set of empirical equations.

The obtained results of the project will contribute to the completion of the missing knowledge on the effect of MCM-41 and basalt powder on the characteristics of the cracking patterns of the modified cement matrix. The research planned in the project will allow to develop the relationship: material – thermal load – the structure of surface cracks and their development process. This will provide valuable knowledge for other researchers who are engaged in studies on the effects of elevated temperatures on the properties of cement composites. Knowing the relationships that occur between the characteristics of the cracking patterns and the level of stress initiating cracking will allow to understand the process of thermal degradation of modified cement matrix. This knowledge will enable the design of cement composites with better thermal resistance properties. The set of empirical equations developed in the project for the determination of fracture energy will have the potential for practical use, i.e., the assessment of the degradation of cement composites. The expected results will address a number of topics that have not been fully described to date, making a significant contribution to the scientific field related to the cement composites technology. The research project will be carried out in an international research group composed of experts in the microstructural analysis (Lulea University of Technology – Sweden).