FRACTURE PARAMETERS OF ALKALI-ACTIVATED MATRIX BASED COMPOSITES

Hana Šimonová[a, b], Bojan Poletanović[a], Ildikó Merta[a]

[a]E207-01 − Institute of Material Technology, Building Physics and Building Ecology, Research Unit Building Materials and Technology
[b]Brno University of Technology, Faculty of Civil Engineering, Institute of Structural Mechanics, Brno, Czech Republic

INTRODUCTION

Although cement based composites are the most commonly used quasi-brittle structural materials in the building industry in the world, the environmental aspects related with their production and using of cement are increasingly being discussed. Their manufacturing process significantly contributes to the global emissions of CO_2[1]. Therefore, there has been an increasing effort to develop and use some alternative binders instead of ordinary Portland cement (OPC) during the recent decades. The alkali-activated aluminosilicate materials (AAMs) are one representatives of such type of binders. These binders are created through mixing of some non- or poorly-crystalline aluminosilicate based materials, such as blast furnace slag or fly ash, with an alkaline activator (hydroxides, carbonates or the most preferably silicates) and water [2, 3].

Like OPC based composites, AAMs also belong to quasi-brittle materials with a low energy absorption capacity under tensile load. Different types of steel or synthetic fibres can be used to overcome this problem. However, the environmentally guided requirements force to use sustainable alternatives to steel and synthetic fibres. Natural plant fibres (e.g. hemp, flax) which grown locally ensure a renewable, and relatively cheap alternatives [4].

Knowledge of mechanical fracture parameters of composites based on brittle matrixes is essential for both the quantification of their resistance against crack initiation and propagation as well as for the definition of material models used to simulate the quasi-brittle behaviour of the structures or their components made from this type of composite materials.

EXPERIMENTS / METHODS

An extensive research work aimed to investigate the effect of different fly ash and slag types, their dosage and the dosage of hemp fibres within the matrix on the durability, mechanical and fracture parameters of alkali-activated mortars was performed. In this contribution, the fracture parameters of one selected alkali-activated fly ash mortar (AAFAM) with 1 vol% of hemp fibres are presented and compared with reference AAFAM without fibres. The locally available fly ash from power plant in Serbia was used to produce AAFAM specimens. Sodium silicate solution (Na_2SiO_3) with a modulus of n = 1.91 was chosen as an alkali activator (AA). The AA solution concentration was 10% of Na_2O in respect to the dry fly ash weight. Mortar specimens were prepared using river sand with maximum grain size of 8 mm. The hemp fibres (Cannabis Sativa L) cultivated and processed in Hungary were used, the fibres length was approximately 10 mm.

The standard prismatic mortar specimens with nominal dimensions 40 × 40 × 160 mm were produced and provided with an initial central edge notch before testing and subsequently subjected to the fracture tests in the three-point bending configuration. The nominal depth of notch was about 1/3 of the specimen height and span length was set to 120 mm. The test procedure requires a constant increment of displacement which was set to 0.02 mm/min during the loading test.

The displacement was continuously recorded using the inductive sensor connected to the data logger during the loading test. In this way, the diagram of loading force F in relation to the displacement d (deflection in the middle of the span length) during the fracture test was recorded.

After the appropriate processing of measured diagrams, at first the initial parts of F–d diagrams were used to estimate the modulus of elasticity E values. Afterwards, the effective crack elongation and effective fracture toughness K_{Ice} values were determined using the Effective Crack Model[5]. The work of fracture and the consequent specific fracture energy G_F values were obtained from the whole F–d diagrams according to the RILEM method[6].

RESULTS / CONCLUSIONS

Results in the form of arithmetic mean (coefficient of variations) from three independent measurements of the specimens measured bulk density ρ, compressive strength f_c, flexural strength f_f, and mechanical fracture parameters obtained from recorded F–d diagrams are shown in Table 1.

Table 1 Selected mechanical fracture parameters of AAFAM specimens

Parameter Mixture	ρ (kg/m^3)	f_c (MPa)	f_f (MPa)	E (GPa)	K_{Ice} (MPa·m$^{1/2}$)	G_F (J/m^2)
AAFAM_REF	1850 (3.6)	30.7 (5.9)	4.3 (7.4)	16.0 (4.9)	0.554 (6.3)	43.5 (22.9)
AAFAM_1.0	1860 (2.0)	27.6 (5.1)	4.0 (8.5)	11.9 (7.8)	0.616 (7.7)	158.5 (8.2)

From the presented experimental research results the following conclusions can be drawn:

- The compressive and flexural strength of AAFAM decreased up to 10 % with the addition of hemp fibres;
- The modulus of elasticity decreased about 25% with the addition of hemp fibres;
- On the contrary, the fracture parameters increased up to 10% with addition of hemp fibres in the case of effective fracture toughness and about 265% in the case of specific fracture energy.

The addition of fibres into alkali-activated matrix should lead to reduced cracking tendency and improved tensile properties of these materials. It seems that the obtained results comply with these assumptions − fracture parameter values increased with the addition of hemp fibres. On the other hand, it is necessary to perform more tests or determine other parameters to affirm these results. One of the issue is also the degradation of natural fibres in alkaline environment, therefore it is important to monitored fracture behaviour during the materials ageing.

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