Polymer Fiber Pull Out of Elastic Matrix

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Progress in polymer fibers production technologies leads to possibility use such fibers in structural applications as micro reinforcement in composite materials with polymer and concrete matrix. Comparing to another fibers (steel, glass, carbon etc.) polymer fibers are characterized by relatively large elastic deformations and pronounced Poisson's effect during stretching. Concrete prisms 10x10x40cm were made contained different amount of 3cm long 0,75mm in diameter polymer fibers. All prisms were matured 28 days and then were tested under 4 point bending conditions. Typical load – deflection curves are shown in figure.1. First peak on the curves corresponds to macro crack formation (in the weakest prism cross-section) and splitting the tensioned part of the bended prism cross-section. Beam midpoint vertical deflection is reaching tenth part of mm, fibers in material aren't loaded.

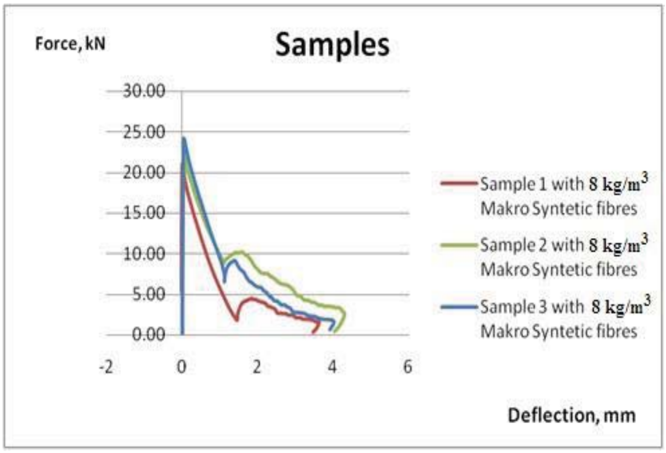

Fig.1. Load - deflection curves for fiberconcrete samples with polymer fibers content 8kg/m^3.

After that fibers in cross-section start to stretch. Debonding is growing (bond is weak and each fiber Poisson contraction is high) reaching the length dependent on each particular fiber orientation to crack surface. All fibers bridging the crack are stretched (load is increasing- second peak on the curves). After that fibers start to rupture and its' ends with friction are pulling out (curves after second peak). Relatively low polymer material Young modulus is leading to the formation of two peaks on the curves what were not recognized for materials with high modulus fibers. Single polymer fiber is embedded into elastic matrix and is subjected to external applied pulling load (numerically simulated). Numerical modeling was performed using 3D FEM approach. Fiber is deforming elastically. Experimental data analysis shown that the pull-out process can be divided into three stages- a) fiber pull-out with perfect bond between fiber and concrete matrix; b) fiber pull-out with partial debond (cylindrical crack) between concrete matrix and fiber, started from concrete matrix surface; c) fully debonded fiber pull-out of concrete matrix. All above mentioned stages investigated theoretically, using Solid Works and ANSYS software and experimentally. Figure 2 shows experimentally obtained curves for 3cm long 0,75mm in diameter polymer single fiber which was embedded into concrete in the depth of 15 mm under 30^0 angle and pulled out (10 samples were tested). Is easy to see that all fibers were ruptured inside the matrix and each fiber end was pulled out with friction. Numerical model based on FEM were elaborated for all three failure steps. Simultaneously simplified shear–lag analytical model (improving approach observed in [1]) was elaborated and executed. Simulations results were compared with performed pull out experiments. Comparison was allowed to obtain numerical values for micromechanical process- friction coefficients on the fiber/matrix interface during fiber sliding motion with friction out of concrete matrix.

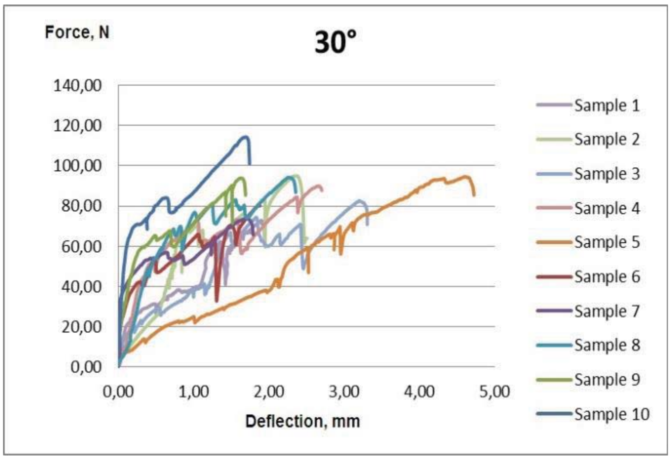

Fig.2. Load – pulled out length curves for 3cm long 0,75mm in diameter polymer fiber embedded at the depth 15 mm under the angle 30^0.

The results of the numerical modeling were compared with experimental data and are discussed.

REFERENCES

[1] Hutchinson J.W. and Jensen H.M., "Models of fibre debonding and pullout in brittle composites with friction // *Mechanics of Materials*, No 9, pp. 139-163, 1990.