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NUMERICAL SIMULATION OF FIBER PULL OUT OF ELASTIC MATRIX WITH FRICTION

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Composite material made of elastic matrix with chaotically dispersed short fibers is under investigation in the present work. It has been proven by many researchers that for structural applications, high interest is focused on polymeric, ceramic and concrete matrixes. If such material has a macro-crack, fibers are bridging it and each fiber pulling out micromechanical process is governing the macro-crack opening and load bearing capacity. In the present investigation numerical (FEM) modeling of a single straight fiber pull-out of elastic matrix was realized. Fiber behavior was elasto-plastical, matrix was elastic. Numerical modeling was performed using 3D approach (see Figure 1).

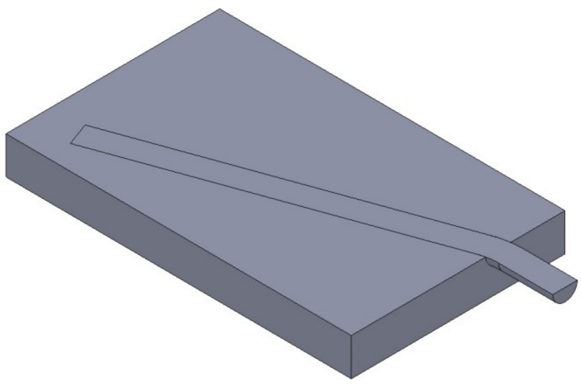

Figure 1. Pull out model geometry for the fiber is embedded under the angle to pulling out force direction and is pulling out.

Straight shape fiber pulling out in fiber direction, out of a concrete block, was investigated in [1-4]. In our investigation numerical modeling was performed for straight shape fiber was embedded into elastic matrix under variable angle to the direction of an applied pulling force and at a variable depth. Experimental data analysis [3, 4] 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 with friction, sliding surfaces erosion and fiber plastical deformation. All above mentioned stages were investigated numerically. Detailed 3D investigation for elasto-plastic single fiber pull-out of concrete matrix was realized. Simulations results were compared with obtained experimental data for: steel fiber in concrete matrix; steel fiber in epoxy matrix; polymeric fiber in concrete matrix. Was shown that model based on assumptions about friction with constant friction coefficient between fiber and matrix and elastic fiber and matrix deformations fail to predict experimentally obtained curves. Micro-mechanical mechanism of small matrix particles separation from the internal fiber channel surface, due to fiber friction and plugs formation around the fiber, was introduced as well as matrix surface local cracking. Plug in the channel between fiber and matrix is triggering fiber motion increasing resistance to motion. After that plug is failing, allowing fiber to move simultaneously decreasing applied pulling load. Small particles in the channel between fiber and matrix are rolling and after some time are forming a next plug. Improved model was elaborated. Fiber embedment depth and inclination angle to pulling out force was varied. Finally, simulation results were successfully approximated experimental data.

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