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Inclined Single Elasto-Plastic Fiber Pull Out of Elastic Volume with Friction

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I. INTRODUCTION

It is well known that the main disadvantage of concrete is its low tensile strength. It has been proven by many researchers that the overall behaviour of concrete can be improved by the addition of fibers. A wide range of fibers is used for the production of fiber reinforced concrete (steel, plastic, glass, etc.). The positive effect of the fibers is not obvious until the first crack occurs in the concrete. Increasing the applied loads the matrix fracture process is initializing: micro-cracks start to open to grow and to coalescent finally forming one or few macro-cracks. The fibers are bridging the crack.

II. FIBER PULL-OUT PROCESS

Each fiber pull-out process is starting with debonding between fiber and concrete matrix and is resulting to fiber sliding with friction out of concrete matrix. The present study is limited to the use of steel fibers.

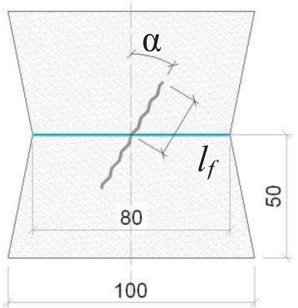

Fig. 1. Configuration of a pull-out test specimen

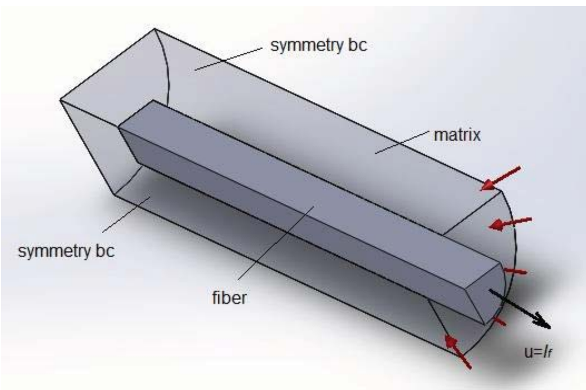

Fig.2. FEM model

Attention is restricted to systems with residual compressive stress acting across the fiber/matrix interface. Single fiber pull-out law was determined experimentally for fibers embedded into concrete at different depth and under different angle. The configuration of the moulded specimen and its dimensions are given in Fig.1. In Fig.1 l_f shows the embedded length of the fiber and α is the inclination angle of the fiber with respect to the applied pull-out load direction.

III. PULL-OUT PROCESS FEM SIMULATIONS

The same pull-out curves were obtained numerically using FEM simulations. The interference fit problem is solved in form of a contact analysis. The complete pull-out process of fiber is modelled, during which suitable displacement is applied to the fiber end. The bonding strength between fiber and matrix is assumed to be negligible and the largest contribution to pull-out resistance is expected to occur from friction, which is magnified by the residual compression. Fiber is sliding with friction and is deforming (bending) elasto-plastically when it is pulling out of the curved channel in concrete matrix. FEM model and the boundary conditions are represented in Fig.2. The results of the numerical model are compared with experimental data.

IV. COMPRESSIVE STRESS

The concrete matrix is forced to correspond to the given fiber diameter and a certain degree of compressive stresses are formed on the contact surface as the external load applied to the concrete matrix. The significance of residual stresses can be studied in detail through a parametric analysis. And since the experimental pull-out curves are available, the value of the contact pressure for particular cases can be found from the best fit with the experimental results.

$$p_C = \frac{2p_E}{\left(\frac{r_f}{r_m}\right)^2 (1-\mu) + (1+\mu)},$$

where p_c – compressive stress acting across the fiber/matrix interface, p_E – external stress of the concrete matrix, r_f – fiber radius, r_m – matrix radius, μ - Poisson´s coefficient.

V. CONCLUSIONS

Single fiber pull-out law was determined experimentally for fibers embedded into concrete at different depth and under different angle.

The same pull-out curves were obtained numerically using FEM simulations. Fiber is sliding with friction and is deforming (bending) elasto-plastically when is pulling out of the curved channel in concrete matrix.

VII. REFERENCES

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