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Statistical Evaluation of Three and Four-Point Bending Tests of FRC

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Abstract: Paper compares and discusses three-point bending and four-point bending tests of fiber reinforced beams. A numerical modeling, stochastic and statistical analysis are used to determine which layouts of testing are more suitable for identification of mechanical and fracture properties of fiber reinforced concrete.

Introduction

Mechanical properties of fiber reinforced concrete (FRC) are commonly tested on the beam-shaped specimens loaded by bending moment and by the corresponding shear force.

The mechanical approach according to the RILEM and Eurocode [5] recommendations, use the three-point bending test of notched specimens. Presence of the notch clearly predefines the position of the initial crack which generally is not able to respect the actual fiber distribution.

When the engineering approach according to Czech and German standards [2, 3] is used, the fracture characteristics of FRC are tested using the four-point bending tests. At the specimens without the notch, the macro-crack propagates at the weakest cross-section.

For decision which method is more suitable for identification of material characteristic of FRC, three methods were used: method of tensile chord, method of direct evidence and method of dispute.

Method of tensile chord [7] is quite simple, but very effective. The expected damage zone is divided into elements (10 in case of four-point, 1 above the notch in the case of three-point). The value of tensile strength was randomly generated and then statistically evaluated. On this example, it was shown that due to lower statistical sensitivity, the four-point bending test without notch is more suitable for testing of material characteristics of FRC specimens.

More sophisticated method of direct evidence follows up the method of tensile chord and confirms the greater statistical sensitivity of three-point bending test arrangement. The numerical simulations and probabilistic approach were used in this method. The primary assumption of the numerical approach was to perform the numerical analysis of FRC based on previously published approaches [1, 4, 8, 9]. The material model 3DNLC2U was used for the non-linear analysis. Only this material model 3DNLC2U can appropriately describe real behavior of FRC including its characteristic peak and following hardening or softening (see Fig. 1).

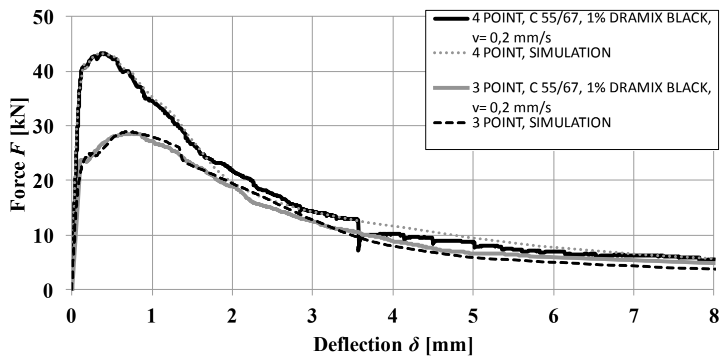

Fig. 1: Comparison of numerical simulations and experiments

It was determined that the selected material parameters are not mechanical properties of real material, but only parameters of material model. There is no generation of random simulations.

Therefore, the method of dispute must be used. The numerical simulations and probabilistic approach were again used in this method. Main idea was that the mechanical properties of the weakest cross-section determine mechanical properties of whole specimen and it´s absolutely necessary determine it. For both types of bending tests, the typical weakened cross-sections in the damage zone were chosen. These weakened cross-sections must be located around the notch in case of three-point bending test, because bending moment is reduced with the increasing distance. The sections considered are located 5, 15, 30 and 45 mm from the notch. The arbitrary position is in the middle third of span in the case of four-point bending test. The selected parameters of the material model of these weakened sections were assigned to probabilistic models according [6]. The results confirmed that three-point bending test cannot locate the weakest cross-section (cross-section with the lowest tensile strength and/or with the smallest amount of fibers). On the contrary, the four-point bending test always locates the weakest cross-section (in the middle third of span).

Summary

The main purpose of this paper was to determine which bending test is more suitable for testing of mechanical and fracture properties of FRC. It was determined that three-point bending test arrangement with the notch is not able to locate the weakest cross-section, which is absolutely essential for non-homogeneous material, such as FRC. The four-point bending test can precisely localize the weakest (representative) cross-section, which is the basic assumption to obtain representative results. Moreover, four-point bending test investigates about 40-200 times larger area of possible crack appearance. Based on the above statements it is possible to argue that four-point bending test is only suitable for identification of the material parameters of FRC.

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