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MODELLING OF FATIGUE IN FIBER REINFORCED CONCERETE

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Abstract: Paper presents experimentation on fiber reinforced concrete (FRC) samples for determination of its fatigue properties. Investigation comprises dynamic and static experiments with force and displacement recording. The recordings are a basis for inverse determination of model parameters. The underlying mathematical model of fatigue is based on a combination of a statistical and deterministic relations among parameters.

Keywords: softening materials, fiber reinforced concrete, dynamic model, fatigue, inverse parameter estimation

1. Introduction

Fiber reinforced concrete (FRC) is a rather new type of concrete but with an increasing use in civil engineering structures. By 'new', we mean there are no established procedures for design of structures made of FRC and, especially, there are no procedures for assessment of fatigue properties of that type of concrete. Here we present experimental investigation on specimens of fiber reinforced concrete in order to establish relations between parameters that could help us to predict fatigue behavior of the material. At the same time, we are developing a mathematical model that would expose and relate the relevant parameters of a fatigue process in FRC.

2. Experimental analysis

Experimental analysis begins with the production of specimens, FRC cubes of about 4*4*4 cm, with a steel fiber standing out of the concrete specimen, as in Fig.1.a). Insertion of a steel fiber is a delicate procedure that has to be done in a manner that could not disturb the concrete specimen. Experimental investigation comprises two stages, dynamic one and static one.

During dynamic testing specimens are vibrated with vibration exciter Bruel&Kjaer type 4809. Force is introduced into the steel fiber with a force transducer connected in the line. Connection of the vibration exciter and a force transducer is enabled by a special threaded attachment glued to the steel fiber, as seen in Fig.1.b).

a)

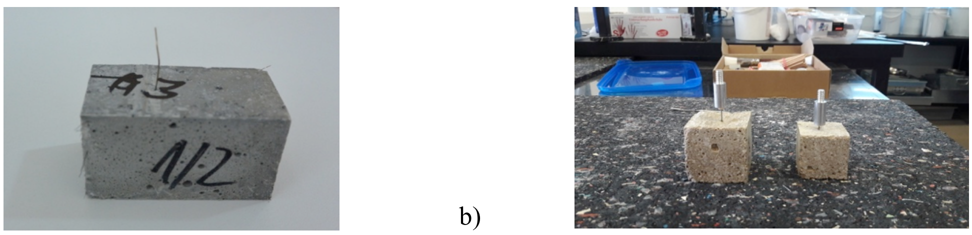

Fig. 1. FRC specimens for testing: a) specimen with one fiber extended; b) pullout of a fiber.

A power amplifier that is excited with a signal generator drives the vibration exciter. The excitation signal is a pure sinusoid with a frequency of 83 Hz so that there are approximately 5000 excitations in a minute. Duration of vibration of samples varies; some are vibrated for 5 min, some for 10 min and some for 20 minutes. Experimental setup for dynamic testing is visible in Fig. 2. b).

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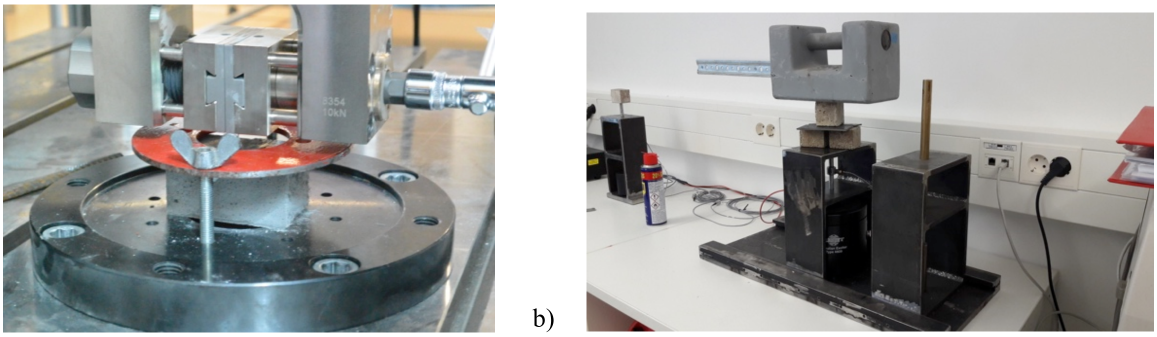

a) b)

Fig. 2.Preliminary testing of specimens: a) IR camera monitoring during pullout; b) PPR-3.

Static testing is performed after vibration and consists of pull out of the embedded fiber, as seen in Fig. 2.a). Before commencement of tests, preliminary static analysis is required where we measure pull out force from pristine samples. One reason is to obtain the reference value for comparison of pull out force degradation, the other to assess the quality of samples regarding the placement of steel fibers. Fig. 3. presents a graph of force - displacement relation for two pristine samples with different embedment lengths (28 mm and 32 mm).

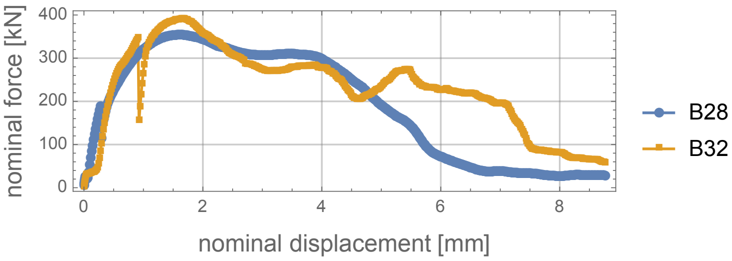

Fig. 3.Preliminary testing of specimen's pullout force for different embedment lengths.

3. Mathematical model

Mathematical model for fiber behavior is based on the statistical approach [1] combined with theory of nonlinear dynamical systems and is an extension of our previous work described in [2]. The underlying nonlinear dynamical system comprises nonlinear springs and dashpots and is described with the following equation

$$\dot{\boldsymbol{X}}(t) = \boldsymbol{A}(\boldsymbol{x}, \boldsymbol{v}, t) + \boldsymbol{B} \cdot \boldsymbol{f}(t) \tag{1}$$

where $\boldsymbol{A} = \begin{bmatrix} \boldsymbol{0} & \boldsymbol{v} \\ -\boldsymbol{M}^{-1} \cdot \boldsymbol{K}(\boldsymbol{x}) & -\boldsymbol{M}^{-1} \cdot \boldsymbol{C}(\boldsymbol{x}, \boldsymbol{v}) \end{bmatrix}$ and $\boldsymbol{B} = \begin{bmatrix} \boldsymbol{0} \\ \boldsymbol{M}^{-1} \end{bmatrix}$; $\dot{\boldsymbol{X}}(t)$ is vector of displacements $\boldsymbol{x}(t)$ and velocities $\boldsymbol{v}(t)$ and $\boldsymbol{f}(t)$ is external loading. Depending on the applied material model, matrix $\boldsymbol{A}$ can take somewhat different form. Numerical results of pullout force of fiber specimens were compared with some experimental results and a reasonably good agreement was observed.

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