INFLUENCE OF THE RANDOMNESS OF FIBER DISTRIBUTION ON THE DISPERSION OF FATIGUE RESPONSE IN STEEL FIBER REINFORCED CONCRETE USING MICRO-COMPUTED TOMOGRAPHY

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Abstract
In this work, the dispersion in the flexural fatigue behavior of steel fiber reinforced concrete is studied. For this purpose, the random distribution of the fibers inside the specimens is analyzed by means of micro-computed tomography. The results reveal that fibers are better positioned in some specimens than in others, which partially explains the scatter of the results. In particular, fiber density or average height around the crack plane show a strong correlation with fatigue life.

1. Introduction

The flexural fatigue strength of concrete shows, as with other types of fatigue, a wide dispersion of results. This causes that two equal specimens manufactured with the same dosage and subjected to the same load range can exhibit a difference in fatigue life of up to 2 or even 3 orders of magnitude. In the particular case of steel fiber reinforced concrete, this phenomenon may be explained by the fibers themselves. Although it is assumed that the fibers are randomly distributed within the specimens, it is likely that in some cases the distributions are more favorable against withstanding fatigue stresses than in others.

In this work, the influence of fiber distribution on the flexural fatigue behavior of fiber reinforced concrete is studied. To this end, a series of notched prismatic specimens measuring 75x75x300 mm^3 with a fiber content of 0.6% by volume were fabricated. Prior to testing, the specimens were analyzed with a micro-CT scanner. After applying digital image processing techniques, the steel fibers of each specimen were segmented, obtaining their individual main geometrical parameters: coordinates of the centroid, orientation, etc. Finally, the specimens were subjected to 3-point bending fatigue under the same load range.

The results confirm that the apparently random distribution of fibers explains, at least in part, the fatigue dispersion. In particular, significant correlations are observed between the fatigue response and some fiber parameters, such as fiber density, fiber vertical position with respect to the specimen depth and mean orientation.

2. Results

Figure 1 shows the linear least-squares fits between the fatigue life (N) of the specimens and two geometrical parameters of the fibers, which are defined below.

a) Fiber density (ρ_f), defined as:

$$\rho_f = \frac{V_f}{V_s} \qquad (1)$$

Where V_f is the volume of material corresponding to fibers, and V_s is the total volume of specimen considered. Therefore, only one value of this parameter is obtained per specimen.

b) Fiber height index ($h_{f,i}$), defined as:

$$h_{f,i}(y_i) = 0, \qquad 0 \leq y_i < \lambda \cdot H_s \qquad (2.1)$$

$$h_{f,i}(y_i) = \frac{y_i - \lambda \cdot H_s}{(1-\lambda) \cdot H_s - h_n}, \qquad \lambda \cdot H_s \leq y_i < (H_s - h_n) \qquad (2.2)$$

$$h_{f,i}(y_i) = 0, \qquad (H_s - h_n) \leq y_i < H_s \qquad (2.3)$$

Where y_i is the vertical position of each fiber, H_s is the specimen depth, h_n is the notch depth and λ is the percentage of the specimen depth assumed to be in compression. The value of λ is complex to determine and depends on multiple factors, so for simplicity a value of 0.15 has been assumed.

The height index $h_{f,i}$ varies between 0 and 1, and its purpose is to weight the contribution of each fiber to withstand fatigue stresses. It is established that the fibers in the compression zone and above the notch do not contribute at all. As for the fibers in the tension zone, their contribution increases linearly from the neutral fiber ($h_{f,i} = 0$) to the most tensioned fiber at the notch edge ($h_{f,i} = 1$). One value of $h_{f,i}$ is obtained per fiber, so for each specimen the mean value $\overline{h_{f,i}}$ has been calculated.

Finally, the figure with the results of the linear fits is shown.

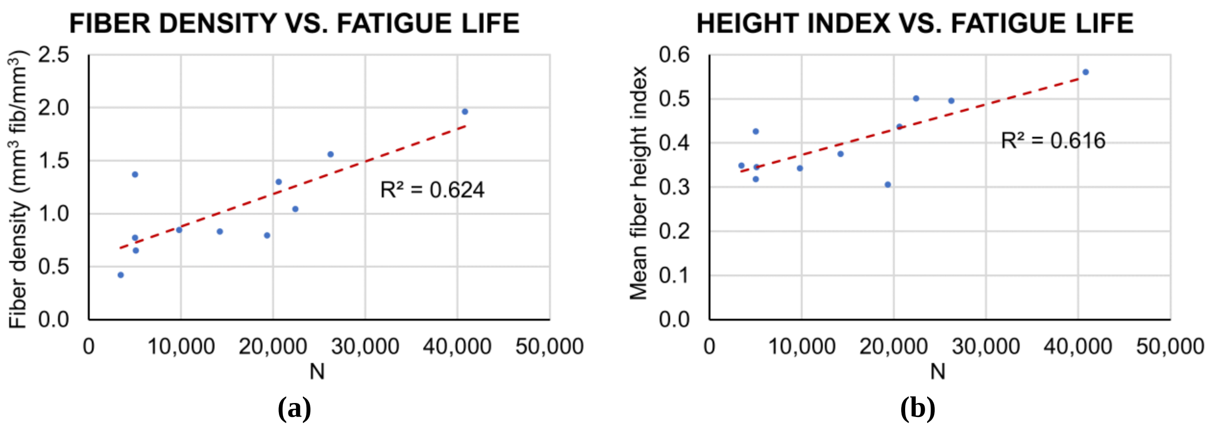

Fig.1 – Correlation between fatigue life and geometrical parameters of steel fibers: (a) fiber density, (b) mean fiber height index.

The results reveal that there is a strong correlation between fiber distribution and flexural fatigue strength. On the one hand, it is observed that the higher the fiber density in the midplane of the specimen, the higher the fatigue life (Fig.1a). On the other hand, the higher the average fiber height index, the higher the fatigue life (Fib.1b). This indicates that a higher percentage of fibers located in the most tensioned zone of the specimen will result in a higher fatigue strength.

3. Conclusions

The findings of this work demonstrate that fiber distribution explains, at least partially, the dispersion in flexural fatigue results. The random nature of the fiber distribution necessarily means that in some cases the fibers are better positioned to support fatigue stresses than in others. With the aid of micro-computed tomography, it is possible to determine the exact distribution of each specimen. Fiber density and height index have been proven to correlate well with fatigue response.

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