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MICROCT ANALYSIS OF STEEL FIBER ORIENTATION IN CONCRETE REINFORCEMENT

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ABSTRACT

MicroCT is widely used for different materials inspection in a non-destructive manner. The technique allows visualization of internal structure and quantify objects morphologically. In this work we perform microCT analysis of steel fiber of concrete reinforcement also called reinforced cement concrete or RCC that is a composite material made up of concrete and some form of reinforcement. This combination is made to utilize the compressive strength of concrete and tensile strength of steel simultaneously. Steel rebar is most commonly used as a tensioning devise to reinforce concrete to help with tensile states. In this context, the evaluation of the orientation of the steel fibers is very important. In this work, the microCT was applied as a useful tool for inspect and classified the concrete reinforcement of the steel fibers.

Keywords: X-ray microtomography, concrete reinforced, steel fibers orientation

1. INTRODUCTION

X-ray microtomography (microCT) is widely used for different materials inspection in a non-destructive manner. The technique allows visualization of internal structure and quantify objects morphologically [1]. In this work we perform microCT analysis of steel fiber of concrete reinforcement also called reinforced cement concrete or RCC that is a composite material made up of concrete and some form of reinforcement. This combination is made to utilize the compressive strength of concrete and tensile strength of steel simultaneously. Steel rebar is most commonly used as a tensioning devise to reinforce concrete to help with tensile states. Concrete is a material that is very strong in compression, but virtually without strength in tension. To compensate for this imbalance in a concrete slab behavior, reinforcement bar is cast into it to carry the tensile loads.

Concrete contains numerous microcracks and it is the rapid propagation of microcracks under applied stress that is responsible for the low tensile strength of the material. Years of experimental studies showed that with the volumes and sizes of fibers that could conveniently be incorporated into conventional mortars or concretes, the fiber-reinforced products did not offer a substantial improvement in strength over corresponding mixtures without fibers. Only in recent years, it has been possible to obtain fiber-reinforced concrete with improved strength and toughness. It is important to emphasize the role of fiber size on the mechanical behavior of the composite. To bridge the large number of microcracks in the composite under load and to avoid large strain localization it is necessary to have a large number of short fibers. It is not difficult to optimize the mixture proportions to incorporate these short fibers and obtain high workability. The uniform distribution of short fibers can increase the strength and ductility of the composite. Long fibers are needed to bridge discrete macrocracks at higher loads; however, the volume fraction of long fibers can be much smaller than the volume fraction of short fibers. The presence of long fibers significantly reduces the workability of the mix and its volume fraction should be determined with care (Mehta and Monteiro, 2006).

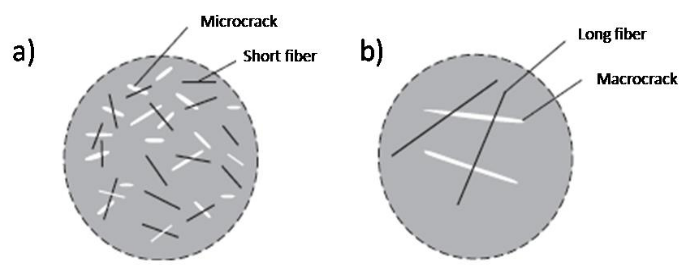

FIGURA 1: A) EFFECT OF SHORT FIBERS ON THE MICROCRACKING; B) EFFECT OF LONG FIBERS ON THE MACROCRACKING (FROM: (MEHTA AND MONTEIRO, 2006)).

The type of the fibers and its volume fraction modify the properties of fibers reinforced concrete. If the fraction of volume is less than 1%, the fibers are used to reduce shrinkage cracking. If it is between 1 and 2%, the fibers increases the modulus of rupture, fracture toughness and impact resistance. And if it is higher than 2%, the fibers lead to strain-hardening of the composites [2].

2. MATERIALS AND METHODS

2.1 MicroCT

The sample were imaged using a GE phoenix v|tome|x m microCT system. A voxel size of 49µm and 4.03 of magnification. Voltage of 130kV and current of 350µA. Also a 0.3 mm of copper filter to reduce noise and beam hardening effect. Five frames were averaged for each image projection to better signal to noise ratio. The flat panel detector is the dynamic 41|100 with 410 x 410 mm^2 of detection area and 100 µm pixel size. The sample was rotated 360° at 0.23° that produced a total of 1500 projections. The system has a cone-beam geometry and the source to detector distance are fixed in 807.68 mm for this image acquisition the source to object distance were 199.95 mm. The reconstruction were performed with Datos|x software and some adjustments are performed: (i) alignment where the first and last slice is checked to generate the 3D volume correctly; (ii) smoothing to correct grainy effect in image; (iii) the beam hardening effect correction that is caused by geometry of the sample and how the beam are absorbed and transmitted during image acquisition (iv) also a reduce noise filter was used to correct the metal sparkling artifacts due X-ray interaction with the steel fiber presents in the sample.

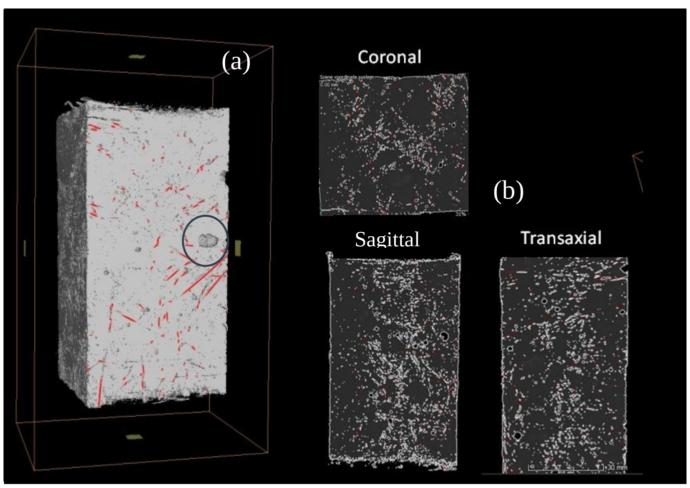

FIGURE 1 - A CUT FROM 3D VOLUME THAT SHOW EXISTENCE OF POROSITY IN THE SAMPLE, BLUE CIRCLE (a) 2D SLICES FROM DIFFERENT VIEWS OF RECONSTRUCTED SLICES (b). THE IMAGES WAS OBTAINED USING THE SOFTWARE VGSTUDIO MAX 3.0.

2.2 Segmentation Process

To perform quantitative measurements the software CTAnalyzer was used. The segmentation process consists in separate the voxels of reconstructed images into two logical segments based on the property of the image. The image is segmented into two based on the intensity of the grey levels. The most commonly used segmentation method is the global histogram based where a single threshold (th) is determined by using the histogram of the image [3]. Each pixel in the image is compared with a threshold value. If the pixel intensity is less the th value, then the corresponding pixel is assigned the zero value which correspond to no selected phase. If the pixel intensity image is greater that the th value, is assigned a value of 1 which corresponds to the binarized solid phase (figure 2b).

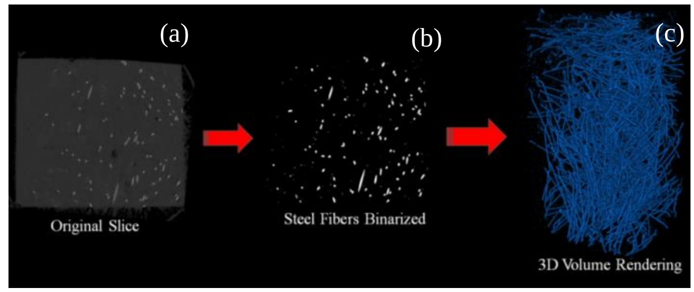

FIGURE 2 - ORIGINAL SLICE FROM RECONSTRUCTED IMAGE (a) PROCESS OF SEGMENTATION OF STEEL FIBERS (b) AND (c) 3D VOLUME RENDERING OF THE ARRANGEMENT OF STEEL FIBERS.

3. RESULTS AND DISCUSSION

The orientation analysis was performed also using CTAnalyzer in the morphometry orientation function for the segmented fibers. Is possible calculate the histogram of distribution of the fibers by it degree of orientation and provide the corresponding color of the volume of interest for fibers. The results we can see in figure 3.

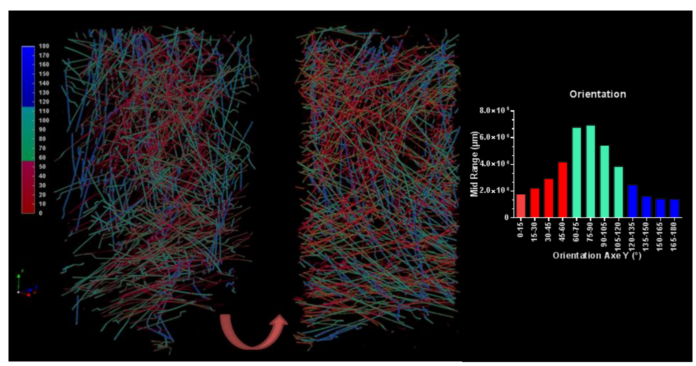

FIGURE 3 - STEEL FIBER ORIENTATION DISTRIBUTION. THE COLOR CODE IS CORRELATED TO THE ANGLE OF ORIENTATION IN Y-AXIS OF THE SAMPLE FROM 0 TO 180°.

The quantitative results show a standard deviation of thickness of the fibers around 141.37 mm and a average of 577.54mm. The total volume of the fibers analyzed in this sample was 39,737.50 mm³ and a concentration of steel fibers around 2.14% being classified as a high concentration.

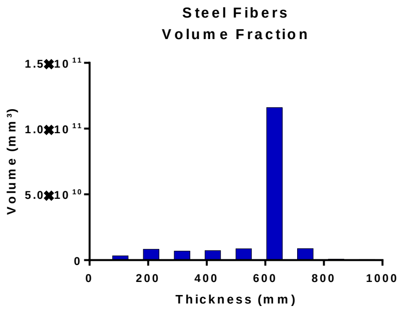

FIGURE 4 - DISTRIBUTION OF FIBER THICKNESS FOR VOLUME.

4. CONCLUSION

This work demonstrates how microCT can be used to obtain valuable information about the internal structure of concrete in a non-destructive manner. In addition to the visual inspection, it is possible to perform quantitative and morphological analyzes, which can be used for the classification of reinforced steel fibers in relation to the percentage of fibers for the total volume. Another important information is the quantitative orientation distribution of the steel fibers along the sample.

ACKNOWLEDGEMENTS

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