VERIFICATION OF THE HOMOGENEITY OF THE FIBRE-CONCRETE CALIBRATION SAMPLES

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Abstract

Fibre-concrete structures have many advantages compared to standard reinforced concrete, for example, higher strength and higher tensile strength of fibre-concrete. However, fibres are often incorrectly distributed in structure during their manufacture. Wires are often clustered, which reduces the overall homogeneity as well as the quality of fibre-concrete structures. The aim of the research team of the workers from two technical universities in the Czech Republic was to develop an objective method of control that would allow establishing the homogeneity of fibre distribution in finished fibre-concrete structures.

Keywords: non-destructive testing, fibres, homogeneity, radiography

1. Introduction

A homogeneous structure of fibre-concrete is one of the most important factors to secure the reliability of such fibre-concrete structures. If the homogeneity of fibre-concrete is not observed, the material has different properties in various parts of the structure, which can lead to the defects in the structure [1]. The relevant lower reliability of the structure which is caused by unequal distribution of fibres in concrete volume can lead to damage of the property as well as the safety and the human lives can be jeopardized. Hence it is necessary to secure the effective control of the fibre-concrete homogeneity in ready support fibre-concrete structures. It is not difficult to evaluation homogeneity of fresh concrete samples retrieved during casting. For example, the “Dozometer” tool (Fig. 1) allows separation of steel fibres by permanent magnets and by their weighing to determine the concentration of fibres in the fibre-concrete. However, it is rather difficult to obtain reliable information about homogeneity of fibre-concrete inside load-bearing structure.

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One of the possible methods of checking is retrieval of specimens by core drilling in different parts of a structure and their subsequent analysis, which includes crushing of specimens for separation of steel fibres (Fig. 2 and Fig. 3).

Fig. 1: Dozometer device for determination of fibre concentration in fresh concrete

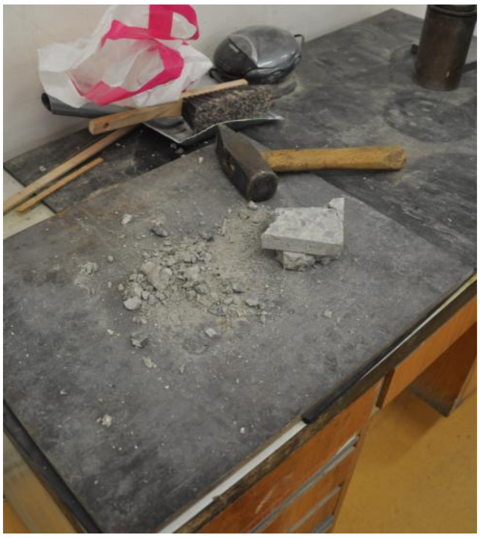


Fig. 2: Crushing of fibre-concrete specimen for precise determination of fibre concentration

This method, although accurate, provides information only about concentration of steel fibres at given location, but does not allow assessment of orientation of the fibres. Moreover the specimens are destroyed during this testing. Therefore, the research institutes try to develop other non-destructive or semi-destructive methods for checking the concentration of steel fibres at selected locations. The testing methods which utilized the magnetic properties of steel fibres seem promising.

2. Development of magnetic testing methods for fibre-concrete

Testing of fibre-concrete which utilizes the ferromagnetic properties of steel fibres seems logical. However, the measuring method which takes into account the different response of dispersed fibres depending of their position with respect to the source of the electromagnetic field causes problems. The workers at the Braunschweig University, for example, use for measuring of concentration of steel fibres in fibre-concrete a cube-shaped coil with the internal dimensions of 150 x 150 x 150 mm, while hardened fibre-concrete specimens, core-drilled specimens or fresh fibre-concrete placed in a special container can be inserted inside this coil [4]. The calibration curve then provides the concentration of fibres based on the measured induced voltage.

Fig. 3: Separation of fibres in under-crushed fibre-concrete by a permanent magnet

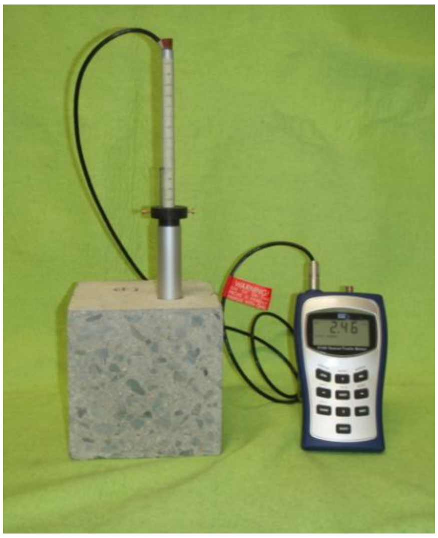


Fig. 4: Magnetic probe developed for fibre concentration determination in fibre-concrete

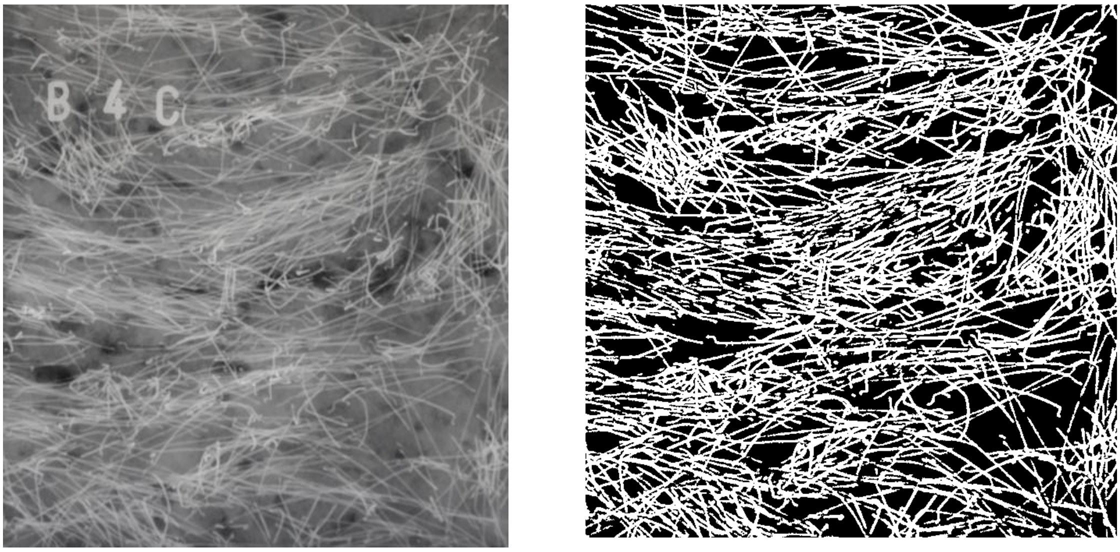
Unlike this stationary checking method, the workers at BUT in Brno and CTU in Prague developed a probe, which can be used in the drilled holes on construction sites (Fig. 4). The drilled holes of the diameter of 25 mm should not affect the structure and should allow measuring of concentration of steel fibres based on the magnetic properties of the environment within a certain distance from the hole. One of the serious problems during development was to produce referencing specimens for calibration of the developed probe. It was observed that even during very careful production of the fibre-concrete calibration specimens some irregularities in distribution of steel fibres occurred, which affected the measurement. The X-ray method being developed at FCE, BUT in Brno, proved as suitable for precise determination of concentration of steel fibres in the fibre-concrete calibration specimens.

3. Radiographic control method for fibre-concrete homogeneity

Radiography belongs to the non-destructive testing methods (NTM) which provide the testing of the internal material structure without its damage. Voltage of about 160 kV is used under usual conditions which can be applied for the concrete samples with a thickness of up to 100 mm. The higher thicknesses can be irradiated with a higher energy; however, the resolution of material details will be remarkably lost.
To assess fibre-concrete homogeneity by magnetic methods, the concrete calibration blocks with dimensions of 150 x 150 x 150mm and with the pre-defined fibre concentrations of 0.5%, 0.75%, 1.0% and 1.25% were manufactured. Each set of the calibration specimens consists of three blocks, and of those one was tested by radiography to verify objectively the fibre concentration in the set.
The TRI-TREG fibres with a length of 50 mm were used as reinforcement.

However, such prepared and selected samples were not possible to expose directly to x-rays (due to high thicknesses). Hence, the samples were divided into smaller parts which were, additionally to radiography, subject to other non-destructive methods. Always two control plates with dimensions of 150x150x75 mm were cut for radiography. Such dimensions of the control plates can determine the fibre layout with a sufficient precision in the selected area (with dimensions of 150x150 mm and irradiated thickness of 75mm). The plates were subsequently x-rayed on radiographic films in the cassettes with voltage of 125 kV at the x-ray tube.

Even if fibre-concrete radiography was used earlier [2], an objective method should be found based on today's assessment which would be able to analyse quantitatively the radiograms much better regarding their quantity of fibres. The image processing method has appeared as a satisfactory method. The x-ray images of the test samples were digitized by means of a desk scanner which was provided with a glass lid for scanning the positive and negative films. The images with 300 dpi resolution in the TIFF format were generated which were further processed by means of the Matlab Image Processing Toolbox and NIS Elements packages. The line objects (fibres) were detected in each of analyzed images (see Fig. 5a) by means of the image processing method; the image was converted by "thresholding" [3] into a binary form (white fibre objects on the black background; Fig. 5b).



a) b)

Fig. 5: The image processing for determination of the volume percentage and orientation of fibres in concrete: a) initial x-ray image of fibre-concrete sample, b) binary image (white objects of fibres on black background)

The next parameter which can be determined by the image analysis is a volume percentage of fibres in concrete. This parameter was approximately estimated from the area percentage of fibres in the image. The area percentage was measured in the binary images (Fig. 5b). The values found are shown in Table 1. The measured value was compared with that of the calculated quantity of fibres in the control samples (150 x 150 x 75 mm), that is, 270 pieces for 0.5%, 404 pieces for 0.75 %, 540 pieces for 1.0 % and 674 pieces for 1.25 %. For comparison the results were plotted in the chart, see Fig. 6. It is evident that both curves for mass concentration from 0.00 to 0.75 % are consistent (the dependence of the area portion of fibres on the concentration corresponds to the curve of the real fibre number versus the mass concentration). If this value is exceeded, fibres which are displayed (control thickness of 75 mm) are overlapped, and the number of fibres in the specimen can be identified experimentally from the curve [5].

Based on radiography of the calibration samples cut to smaller thicknesses (for example, to 20mm), it is evident that overlapping will not occur even for higher fibre concentrations, and linear relationship between the surface fibre fraction (based on radiogram) and total fibre number in the specimen will exceed 1 % (this was proved by an experiment).

Tab. 1 The volume percentage of fibres in the concrete samples determined by the image analysis

Sample with indicated fibre concentration in [wt %]	0 %	0.5 %	0.75%	1.0%	1.25 %
Area percentage of fibres [vol. %]	0	18	27	32	36

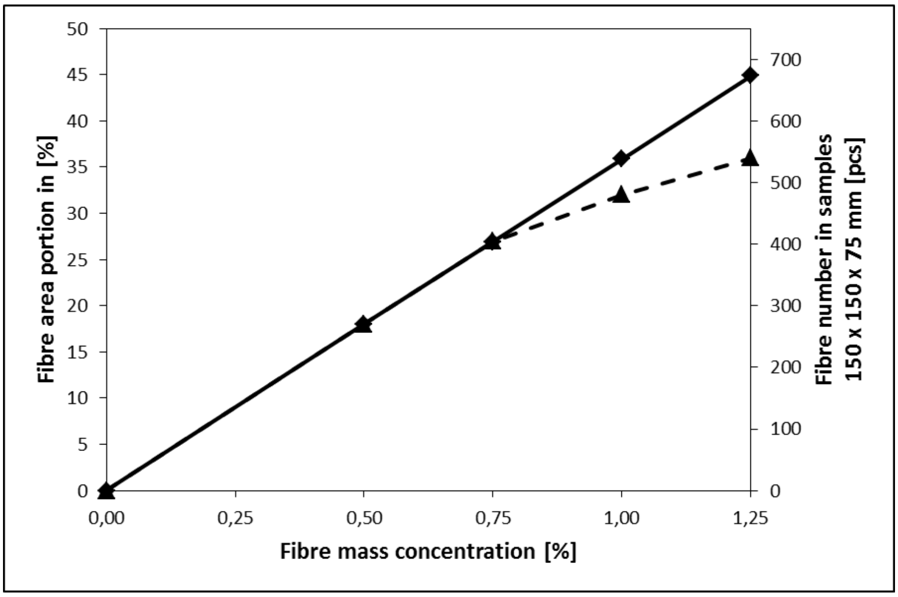


Fig. 6: The dependence of the area percentage of fibres in the image on the volume fibre concentration in fibre-concrete as well as on the real number of fibres in the control samples (150 x 150 x 75 mm)

4. Conclusion

The questions of fibre-concrete homogeneity verification in support structures must be studied, and the new, more precise and simple methods should be developed than now available. Their application for homogeneity control in fibre-concrete has been tested by the authors at the present days, and according to the results obtained, this method seems to be very perspective. However, other methods are also tested which are used to test the magnetic properties of fibres.

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5. References

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