METHODS OF CHECKING OF STEEL FIBRE DISTRIBUTION

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Abstract

UHPFRC cementitious composite materials reinforced by steel fibres find a practical application all around the world but also in the Czech Republic. This material has a big potential for modern structures but it has a lot of problems, theoretical, technological, etc. Homogeneity of the steel fibre distribution is one of these problems. Homogeneity of steel fibre distribution has a significant impact on mechanical properties of UHPFRC, especially tensile strength in bending. A lot of authors describe impact of steel fibre distribution on final mechanical properties, but lot of them do not describe methods for checking of the steel fibre distribution. This paper will summarize methods of checking distributions and will present practical results of checking homogeneity by optical method.

Keywords: UHPFRC, distribution, homogeneity, optical method

1. Introduction

In the Czech Republic, UHPFRC is a relatively new cementitious composite material that is used for reducing of weight of structures. It has been taking the place, partly or entirely, of conventional steel reinforcement bars. This type of material is a densely-packed cementitious material reinforced by steel fibres with compressive strength exceeding 120 MPa and tensile strength in bending exceeding 15 MPa. UHPFRC has been developing dynamically, mainly in France, Germany, the Netherlands, the United States, Canada, Japan, Korea and Australia.

The properties of UHPFRC are very different from common concrete. The first bearing component of UHPFRC is a fine grained aggregate (usually d_{max} < 4 mm) with optimal granulometric properties. Steel fibres are usually the second bearing component. The

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mechanical properties depend above all on the quality and the ratios of the mix composition components. However, a very important influence on the final results during preparation of structural elements is the mixing technology and casting UHPFRC to moulds.

This problems and its impact is well known. Lot of publications and authors describe the effect of the steel fibre homogeneity on fibre reinforced composite materials and also describes design rules for UHPFRC, but they do not have precisely specified methods for determining and assessing steel fibre distribution, which is necessary for developing this type of material.

2. Homogeneity of the steel fibre distributions

The homogeneity of the fibres is a crucial factor determining the final mechanical properties of UHPFRC. The steel fibre distribution is not dependent on the age of hardened cementitious composite materials. This parameter can be determined both for fresh concrete and for hardened concrete.

2.1 Homogeneity at fresh concrete

Homogeneity of fibres can be determined by cement and fine grained aggregates washing away and follow separation of fibres. Magnet can be used for steel fibres, manual collection for PVA fibres. Number of steel fibres can be determined by using dosometer, which works at magnet principle, or by fibre counter developed by BOSFA. The homogeneity of the steel fibres distribution cannot be determined by these methods and equipment.

2.2 Homogeneity at hardened concrete

Amount of steel fibres, their orientation and distribution at cross section can be checked by destructive and not destructive test methods. Amount of steel fibres in a given volume of hardened concrete can be determined by control drill holes. This destructive method is described in CSN EN 14488-7 but without modification it cannot be used to determine the steel fibre distribution. Next destructive methods for determining homogeneity of the steel fibres are optical method at fracture area and optical microscopic methods at cross section, which is describes in this paper. Not destructive methods are electromagnetic induction, electrical resistivity measurement, x-ray analysis and fuzzy method e.g.

3. Experimental research work

An optical microscopic method for determining the homogeneity of steel fibres at the cross section of the elements is applied and is under development at the Klokner Institute, Czech Technical University in Prague.

The first tests of this method were done at 28 test cubes made using 14 different mixture recipes. Some from the 14 recipes are shown by **Tab. 1**.Two cubes were made using the same mixture, one of them was vibrated while the other was no vibrated. The steel fibre distribution was measured on the left and right thirds of the test cubes at 60 subsectors 10 x 10 mm in size. The scanning surface was photographed by digital microscope and the photographs were then graphically evaluated, **Fig. 1**. The average number of steel fibres

(Y-axis) was counted in sub sectors with the same layout direction from the bottom of moulds (X-axis), **Fig. 2** to **Fig. 5**.

Tab.1: UHPFRC mix composition components [kg/m^3]

Type of material	Mix 622	Mix 794	Mix 796	Mix 891
CEM II/A-S 42,5 R	670	670	670	670
Slag	80	80	80	80
Silica fume – type I	105	105	105	-
Silica fume – type II	-	-	-	105
Sand 0/4	1215	1215	1215	1240
Steel fibres 13/0.2 mm	100	100	100	100
Superplasticizer – type I	40	40	40	-
Superplasticizer – type II	-	-	-	30
Stabiliser	-	2	1.1	-
Water	161	161	161	151

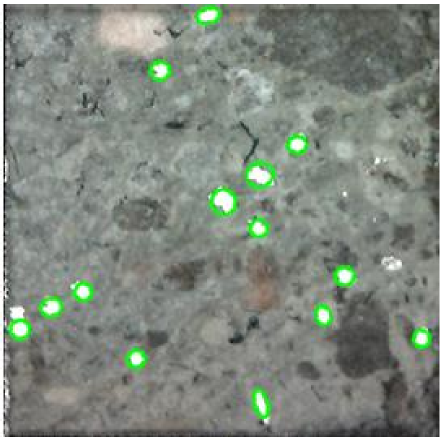

Fig. 1: Identifications of sectors for evaluation of the left part of the test cubes

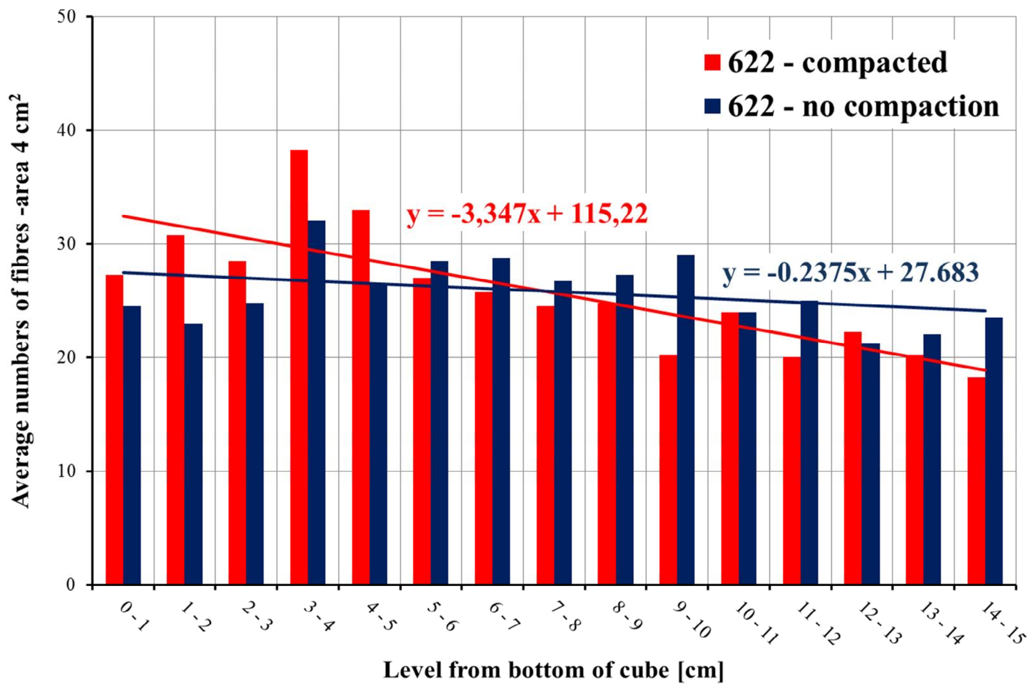

Fig. 2: Average numbers of steel fibres at mixture 622

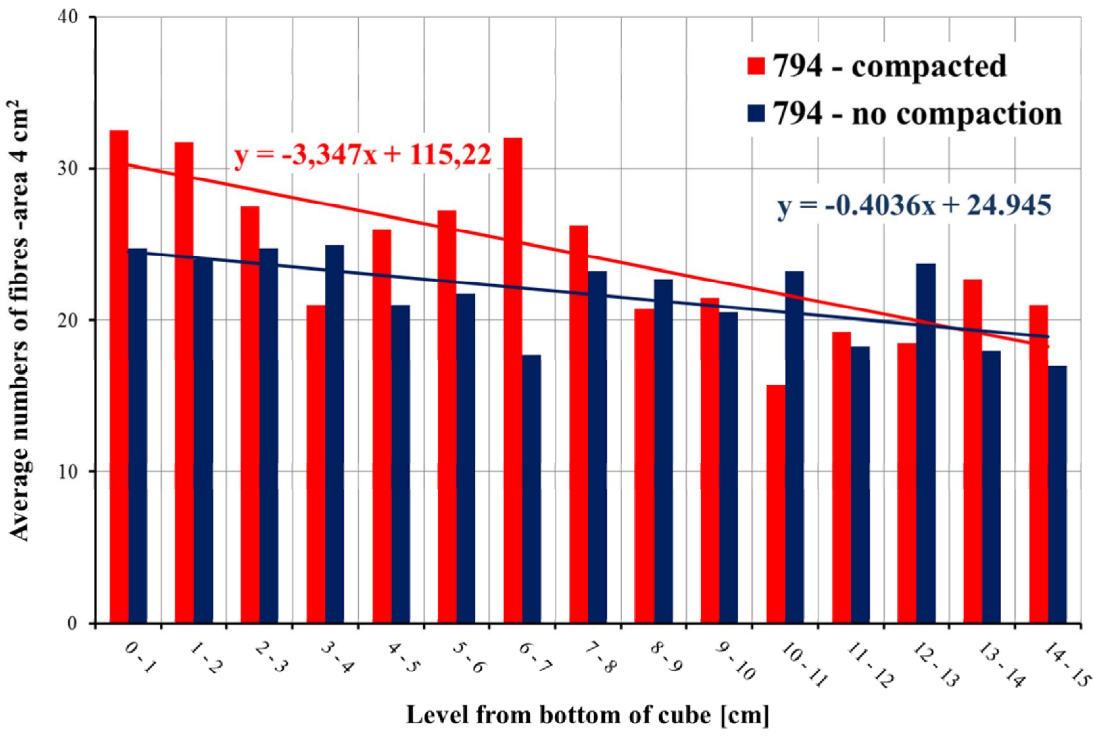

Fig. 3: Average numbers of steel fibres at mixture 794

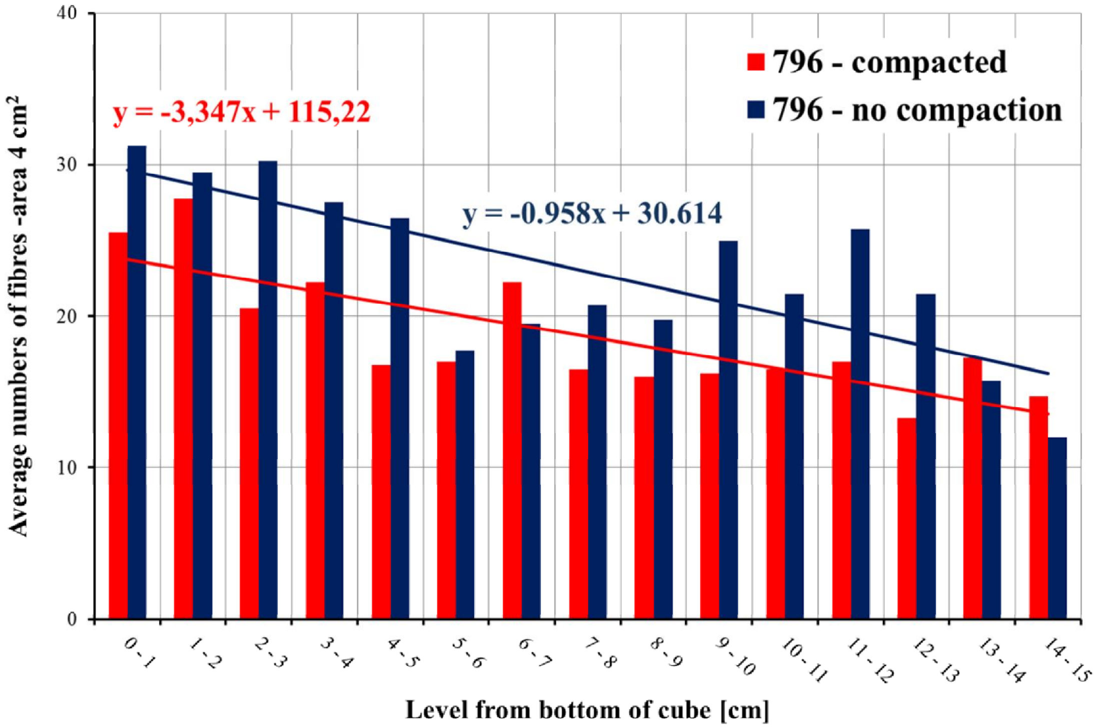

Fig. 4: Average numbers of steel fibres at mixture 796

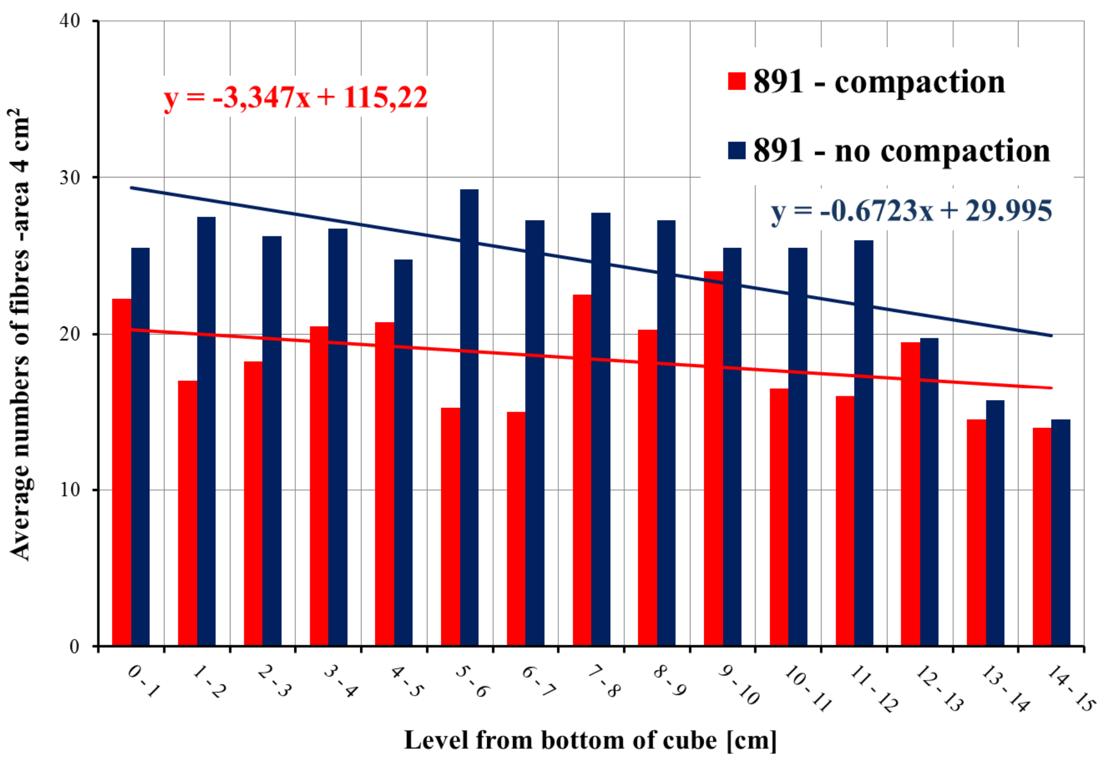

Fig. 5: Average numbers of steel fibres at mixture 891

4. Conclusions

There is no doubt that the homogeneity of the steel fibre distribution of UHPC and its matrix homogeneity are factors which determine the final mechanical and physical properties of this fine-grained cementitious composite material with fibres.

Optimizing the proportions of the UHPC recipe to minimize fibre segregation at the bottom of the framework has a fundamental impact on the successful manufacture of elements made from this type of material. The practical applications, research and results presented in this paper show that fibre segregation cannot be ignored. Our results show that the difference between the upper and lower part of a test cube may be 2:1. Satisfactory UHPC mix proportions can significantly affect fibre segregation. However, the effect of vibration on fibre segregation may not be significant, see Fig. 7.

A simple and applicable method for determining and checking steel fibre distribution has a fundamental impact on practical applications. The optical microscopic method developed at the Klokner Institute laboratory seems to be a time-efficient and cost-effective way to make an exact determination of the steel fibre distribution.

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