EXPERIMENTAL INVESTIGATION OF BASIC PROPERTIES OF FIBRE CONCRETE

Jan Vodička, Jitka Vašková

Abstract

Application of fibre concrete in the building industry is becoming more common. Fibre concrete is not only beneficial from the economic viewpoint in some structures, it can be even essential for design of the structure. This holds also for those cases when fibre concrete is used in structures with common rebars or prestressed structures. Verification of fibre concrete properties which are considered in design is not unified so far regarding the size of specimen, test configuration and processing of the test results. There is no conformity is designation of the strength classes, as it is common with the plain concrete. This contribution aims at unification of testing methods for fibre concrete and unification of designation.

Keywords: Fibre concrete, material properties, testing.

Introduction

Fibre concrete with suitable fibres (steel or synthetic) should be enlisted among structural materials. Fibre concrete can be used in plain concrete structures, reinforced concrete structures or even in prestressed structural members. All types of those structures may not be suitable for application of fibre concrete, which is decided with regard to special structural requirements, production technology and economic potentials.

Application of fibre concrete in any case depends on a substantial knowledge of its properties and their testing with suitable evaluation. It is true that the current state is not satisfactory. Diversity in types of tests, their configuration and diversity in test specimens can only confirm this concern. It is hard to compare results obtained from different tests, or even to derive some fibre concrete characteristics applicable in design of fibre concrete structures. The reason for all this inconsistence may come from the fact that fibre concrete is still a rather new structural material. This holds despite all the knowledge from applications which were realized over the few past decades. Moreover, it is necessary to take into account the fact that fibre concrete, as a composite with cementitious matrix which is reinforced with the fibres, exhibits much more complex behaviour than a composite with cementitious matrix without fibre, the plain concrete. That means it is necessary to establish a suitable testing method for evaluation of fibre concrete which would show various characteristics of fibre concrete. A list of destructive testing methods is given in this paper, whose results should be reflected in designation of fibre concrete. The strength specification of fibre concrete cannot be described by mere compressive strength. It is necessary to account for the tensile strength the post-crack behaviour. Other characteristics may be necessary in the future, which can be delivered upon demand.

Destructive testing methods for fibre concrete

Compressive strength

Compressive strength test is performed on test cubes or cylinders. Concrete class is therefore given by two characteristic values of strength (e.g. C25/30). The ratio of these two values for plain concrete test cubes and cylinders is set by $\alpha_c = f_{c,cyl} / f_{c,cub} = 0.8$. This ratio also account for the fact that the cube specimens are loaded perpendicularly to the placed layers of concrete while the cylindrical specimens are loaded along the direction of compaction (Fig. 1).

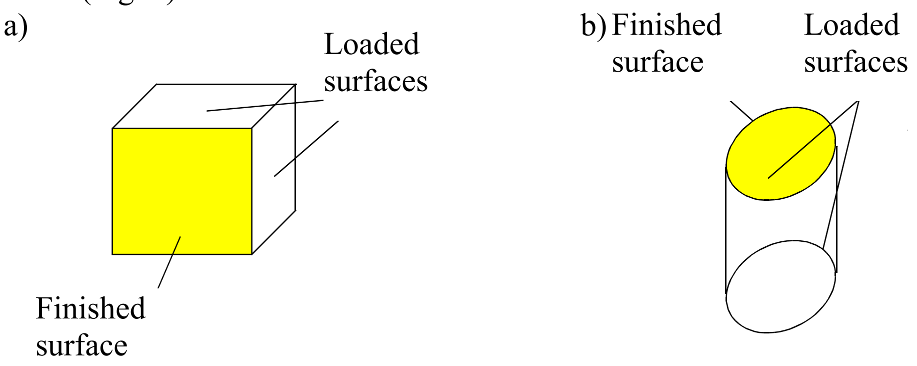


Fig. 1 Position of test specimens in compressive strength test: a) cube b) cylinder

It is assumed that the cylindrical compressive strength can describe behaviour of concrete in the structures better. The effect of composition of concrete is neglected. The inaccuracy in the value of α_c is even more pronounced in fibre concrete when effect of materials, form and amount of fibres needs to be taken into account. On the other hand, it has been learned from experiments that the effect of fibre on compressive strength measured on the cubic test specimens made of fibre concrete with commonly used amount of fibres can be assumed as $\alpha_c = 0.8$. Therefore, consideration of the compressive strength similar to that of plain concrete in design is safe. Moreover, the effect of organized distribution of fibre and tendency to sink of fibres during compaction is less in the cube test specimens.

Tensile strength

The tensile strength is much more important for behaviour of fibre concrete, which is most prominent in fibre concrete structural members without conventional steel bar reinforcement, where it decides their load bearing capacity. Dispersed steel fibres can affect significantly not only the initiation of cracks but also to provide some residual resistance of the structural member and ductility. Tensile strength at crack initiation can be considered in design. This strength characteristic should be declared in the class of fibre concrete, taken as the guaranteed tensile strength after cracking.

The recommended designation of the strength class of fibre concrete should contain, beside the compressive strength, both tensile strengths, i.e. the characteristic tensile strength at crack initiation and the equivalent tensile strength:

$$\text{FC } f_{fk,cube} / f_{ftk,sp} / f_{ftk,eq}, \quad \text{např. FC } 20 / 3.8 / 1.6$$

The fibres influence the tensile strength more significantly than the compressive strength. Therefore, it is impossible to used the simplified relations (neglecting the aggregate particle shape) for estimation of the tensile strength from the value of the compressive strength, as it is in case of plain concrete. The tensile strength of fibre concrete, especially of steel fibre reinforced concrete, then needs to be obtained experimentally on suitable test specimens. Such experiments provided guaranteed values of strengths which are necessary for classification of the material for design of fibre concrete structures. These are the tensile strength at crack initiation and the equivalent tensile strength after cracking, which is used for calculation of load bearing capacity.

The uniaxial tensile strength is difficult to measure, therefore, alternative test configuration are used, such as the splitting tensile strength test (Fig. 2) and the bending test (Fig. 3).

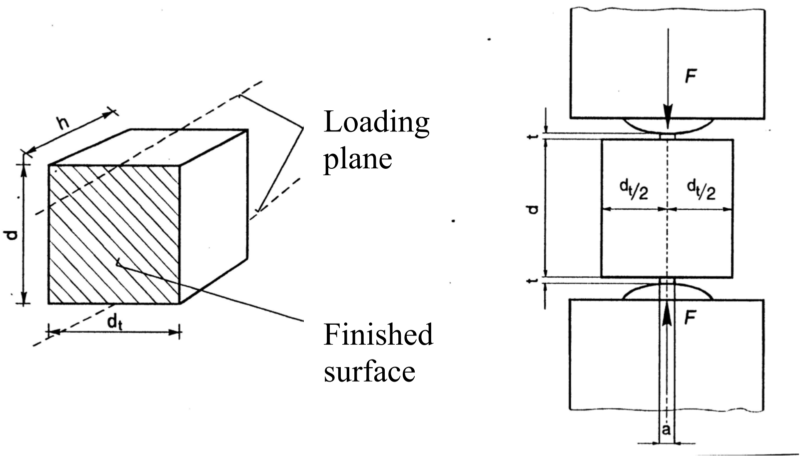
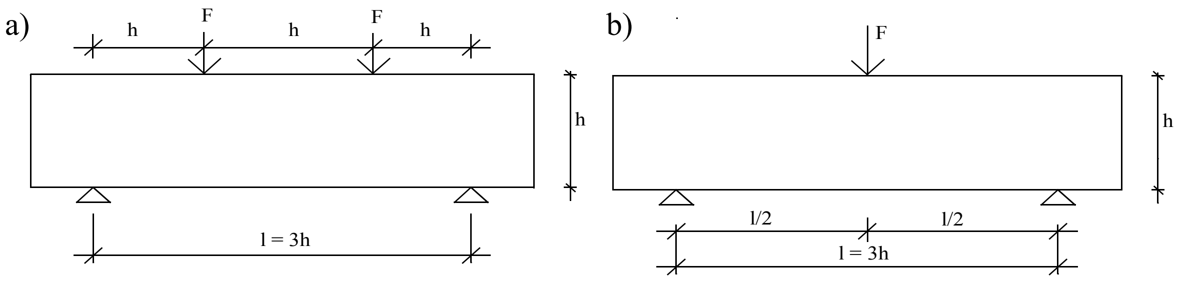


Fig. 2 Splitting tensile strength test configuration

The relation between the strengths has to be obtained from experiments. The ratios of the strengths are defined as follows: for splitting tensile strength $\alpha_{t,sp} = f_{t,ax} / f_{t,sp}$ and for flexural tensile strength $\alpha_{t,fl} = f_{t,ax} / f_{t,fl}$, where $f_{t,ax}$ is the uniaxial tensile strength. The following ratios are known $\alpha_{t,sp} \cong 0.85$ and $\alpha_{t,fl} \cong 0.55$ for plain concrete, however, these values may differ for fibre concrete, especially for steel fibre reinforced concrete. The following value, $\alpha_{t,sp} \cong 0,85$, can adopted and considered safe for conversion of the splitting tensile strength to uniaxial tensile strength of fibre concrete, which is obtained on cubic specimens.

Three configurations are used for bending tests (Fig. 3). The configuration affects the measured value of $\alpha_{t,fl}$ as the measured value of $f_{t,fl}$ varies according to the configuration used. In case of plain concrete these differences are small, but for fibre concrete these may be more pronounced (Table 1).The advantage of the four-point bending test (Fig. 3a) is that the critical cross-section is not know in advance. However, with higher volume of fibres the shear crack may occur at the outer thirds of the beam, which prohibit measuring the true strength $f_{t,fl,A}$.

The three-point bending (Fig. 3b) defines the critical cross-section in advance and thus the measured strength, $f_{t,fl,B}$, is higher. In order to reduce the difference in the results the critical cross-section is reduced with a notch of the depth of $h/4$ (Fig. 3c) and the strength $f_{t,fl,C}$ is often smaller than $f_{t,fl,A}$. Table 1 shows results obtained for plain concrete and fibre concrete with the synthetic Forta Ferro fibre (4.8 kg / m^3 (SSFC)).



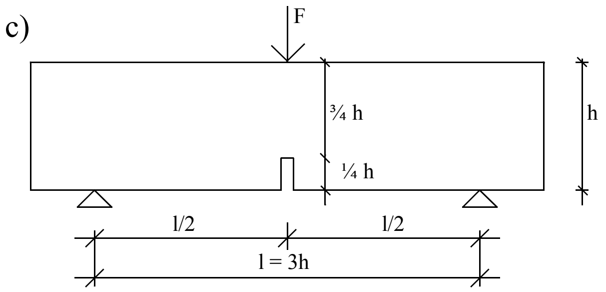


Fig. 3 Bending test configuration
a) four-point bending test
b) three-point bending test
c) three point bending of beam with notch

Tab. 1 Comparison of ultimate forces F_u and tensile strengths $f_{t,fl}$, $f_{t,eq}$ obtain in bending tests (configuration A is in Fig 3a, configuration C is in Fig. 3c)

	F_u [kN]		$f_{t,fl}$ [MPa]		F_{eq} [kN]		$f_{t,eq}$ [MPa]	
Test config.	C	A	C	A	C	A	C	A
PC	9.57	24.92	7.66	7.48	0	0	0	0
SSFC	8.50	20.60	6.18	6.80	3.56	10.52	1.08	0.97

Conclusions

This contribution shows those types of testing methods which should become the basis for evaluation of fibre concrete these days. The tensile strength at crack initiation can be obtained from the splitting tensile strength test. The four-point bending test configuration is recommended for evaluation of flexural tensile strength. The three-point bending with the notched beam should be avoided due to unclear stress distribution around the notch.

The recommended tests can be conducted at any laboratory with standard equipment and the evaluation of the resulting strengths can help to classify the fibre concrete. Unification in experimental evaluation of fibre concrete is essential for any progress in design of fibre concrete structures. Thus the presented work helps to broaden the range of application of fibre concrete as a standard building material.

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