BUILDING MATERIALS AND PRODUCTS

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Kazan State University of Architecture and Civil Engineering
D. Sc. in Engineering, Prof., Head of Dept. of Technology,
Organization and Mechanization of Construction
V. S. Izotov
Ph. D. student of Dept. of Technology, Organization and Mechanization of Construction
R. Kh. Mukhametrakhimov
Ph. D. in Engineering, Assistant lecturer of Dept. of Technology,
Organization and Mechanization of Construction
L. S. Sabitov
Russia, Kazan, tel.: (843)510-47-31; e-mail: rustemmail@yandex.ru

V. S. Izotov, R. Kh. Mukhametrakhimov, L. S. Sabitov

EXPERIMENTAL RESEARCH OF EFFICIENCY OF DISPERSE REINFORCEMENT OF STRETCHED ZONE OF FLEXURAL CONCRETE ELEMENTS

Problem statement. The method of disperse reinforcement of flexural concrete elements by fiber introduction in concrete stretched zone is described.

Results and conclusions. The method provides more efficient use and economy of disperse reinforcement, materials consumption reduction at the maintenance of specified flexural strength, high impact elasticity, and fracture strength. The comparative assessment of disperse reinforcement efficiency for two types of metal fibers is given at reinforcement of stretched zone of flexural concrete elements is made for the first time.

Keywords: disperse reinforcement, fibrous concrete, materials consumption, flexural strength, impact elasticity, fracture strength.

Introduction

The vast majority of building constructions is made up by those of concrete and ferroconcrete. However, among its various undoubtful advantages, concrete has a low elasticity resistance, which leads to development of cracks in concrete and to a lower operative reliability and durability of ferroconcrete constructions. The constructional properties of concrete allow for disperse reinforcement [1].

Disperse reinforcement is accomplished by fibres evenly distributed through concrete matrix. For this to be achieved, various types of metal and non-metal fibres of mineral or organic origin are applied [2]. In [3] application of special disperse reinforcing fibres in the concrete technologies is discussed. Besides, a recommended fibre content depending on the type, function and price of a compositional material and the comparative characteristics of concrete modified by micro-reinforcing fibres are given.

At the present time, fibre concrete is intensively researched, since its application in construction is widening, so that the traditional reinforcement is more frequently substituted by the fibre or combined one. Most fibre concrete research suggest that reinforcement should be performed through a whole concrete or ferroconcrete construction. Research of fibre reinforcement of stretched zones of concrete elements is insufficiently considered. It is of significant interest, since during the process fibre expenses decrease and cracks resistance increases.

In [4] it is proved that fibre reinforcement of stretched zones of a flexural element produces a peculiar medium that assists in delaying the process of main cracks development and in forming a great number of them. Consequently a crack-disclosure width largely drops, thus the operating conditions for effective application of high-duty steel reinforcement are created. The experimental research of strength, rigidity and cracks resistance of flexural and eccentrically pressed ferroconcrete elements with zonal steel-fiber concrete reinforcement is presented in [5]. Zonal reinforcement of flexural elements without bar reinforcement is not discussed in the works [4, 5].

Disperse reinforcement to a larger degree allows for compensating concrete major flaws, i. e. its low strength during stretching and fragility during failure.

Fibro-concrete use allows for the application of more effective construction solutions than ordinary bar reinforcement does and it also permits to reduce steel flow rates. This acquires great significance in the production of thin-walled constructions, constructions without bar-mat distribution and transverse reinforcement, thin-walled constructions with bar tensile reinforcement as well as in their application together with bar reinforcement in flexural elements, etc. For example, according to the data given in [6], preliminary calculations for carrying capacity of the blocks of rings of the Kazan subway showed that if they are produced from steel fiber concrete, expense of steel per cubic meter of a product is 39.44 kg; if they are made with ordinary reinforcement, it is 99.4 kg.

A concrete beam (a non-reinforced one) lying on two supports under cross-bending is stretched in one zone and compressed in the other. Since fibres are receptive to stretching stresses occurring during a beam bending and thus increases the strength limit of an element being bent, it is appropriate to place them not throughout the whole volume but in a stretched zone only.

1. Imitation modeling of steel fibrous concrete beam operation

The examinations carried out in the ANSYS program complex on the basis of a numerical method for finite elements allowed to perform an imitation modeling of the operation of the beam under discussion. For this to be achieved, the detailed descriptions of its geometry, physics of the processes being modeled and of the properties of the materials applied were used.

As a result, the concentration zone of stretching tensions was determined (Fig. 1) and the optimal reinforcement thickness was selected.

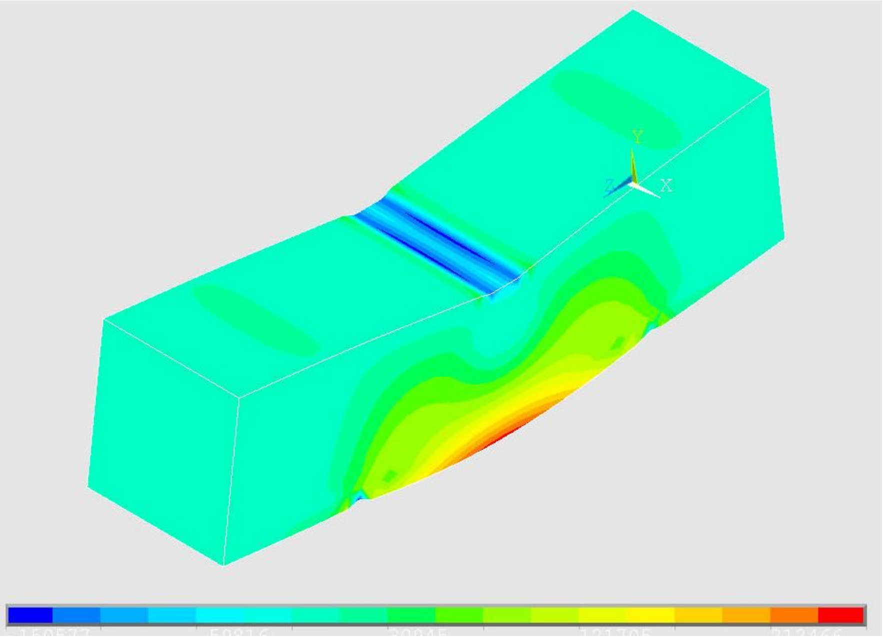

Fig. 1. Major stretching tensions

The use of metal fibre and a beam reinforced solely in a stretched zone allows for the effective and economic expense of dispersed reinforcement thus providing a high durability of a beam during bending, a high impact strength and resistance to cracks.

2. The beam operation test

The test of the operation of steel fibrous concrete beams (100×100×400 mm) during bending was performed with various reinforcement coefficients μ. The beams were reinforced in two ways. In the first case, the pattern was completely reinforced. In the second case, considering the results of the numerical examinations, the lower layer which is 1/3 of the section height, was reinforced. In both cases the samples were reinforced with two types of metal fibres, which are characterized in Table 1. The experiments were performed in compliance with GOST (State Standard)10180-90.

Table 1

Characteristics of the fibres

Fibre name	Wire diameter, mm	Width, mm	Length, mm	Corrugation length, mm	Corrugation height, mm	Temporary rupture resistance, MPa
Wired (brass)	0.3	-	20	0.8	2	2450
Slab-milled	-	3	33	-	-	900

The experiment was aimed at determining the efficiency of fibre reinforcement of the lower layer of a beam as wells as finding out the optimal fibre reinforcement coefficient.

The steel fibrous concrete mixture preparation was in two stages. In the first stage a concrete mixture was prepared. Initially, the dry components were mixed, water was then added in small portions. The stirring continued for 10 minutes. Cement/Sand = 1/3, Water/Cement = 0.45 for all the samples. In the second stage fibre is introduced into the mixture and further stirred. After having been stirred, the mixture was packed into a mold and then compacted.

For the samples with the lower-layer (stretched zone) reinforcement, the experimentally determined amount of the concrete mixture necessary for the formation of 1/3 sample section height was selected, reinforced and packed into the molds. The mixture was thereafter compacted, the mold filled with the concrete mixture without the fibres with repeated compaction. The samples were kept under laboratory conditions at the temperatures of $t = 18$—20 °C and air humidity $\varphi = 95$—100 %. Before the test all the samples were examined and measured. If any defects (cracks, facet misalignment) were detected, the flawed samples were rejected. Places for support and loading were marked on each sample. The experiment results are given in Table 2.

Table 2

The experiment results

Series code*	Fibre length L_f, mm	Fibre diameter D_f, mm	Fibre content μ, %	Strength limit during bending $R_{bending}$, MPa
B-20-0-s	20	0.3	0	1.13
B-20-0.9-s	20	0.3	0.9(3)***	1.23
B-20-1.5-s	20	0.3	1.5(5)***	1.34
B-20-2.1-s	20	0.3	2.1(7)***	1.61
B-20-2.7-s	20	0.3	2.7(9)***	1.88
B-20-3.3-s	20	0.3	3.3(11)***	1.94
B-33-0-s	33	0.3**	0	1.12
B-33-0.9-s	33	0.3**	0.9(3)***	1.55
B-33-1.5-s	33	0.3**	1.5(5)***	1.93
B-33-2.1-s	33	0.3**	2.1(7)***	2.41
B-33-2.7-s	33	0.3**	2.7(9)***	2.81
B-33-3.3-s	33	0.3**	3.3(11)***	2.92
B-20-0-v	20	0.3	0	1.12
B-20-0.9-v	20	0.3	0.9	1.2
B-20-1.5-v	20	0.3	1.5	1.25
B-20-2.1-v	20	0.3	2.1	1.35
B-20-2.7-v	20	0.3	2.7	1.42
B-20-3.3-v	20	0.3	3.3	1.59
B-33-0-v	33	0.3**	0	1.12
B-33-0.9-v	33	0.3**	0.9	1.25
B-33-1.5-v	33	0.3**	1.5	1.52
B-33-2.1-v	33	0.3**	2.1	1.77
B-33-2.7-v	33	0.3**	2.7	2.12
B-33-3.3-v	33	0.3**	3.3	2.32

Notes on the table: * — in a series code: the first code figure is a characteristic under examination (bending); the second one is the fiber length; the third one is a reinforcement percentage by volume; the fourth one is a reinforcement method (*v* – volume, *s* –stretched zone reinforcement);

** — the given fibre diameter from a sheet;

*** — reinforcement percentage of a low-layer element.

According to the experimental results, the relative fibre concrete strength was plotted against fibre content in the concrete mixture (Fig. 2, 3).

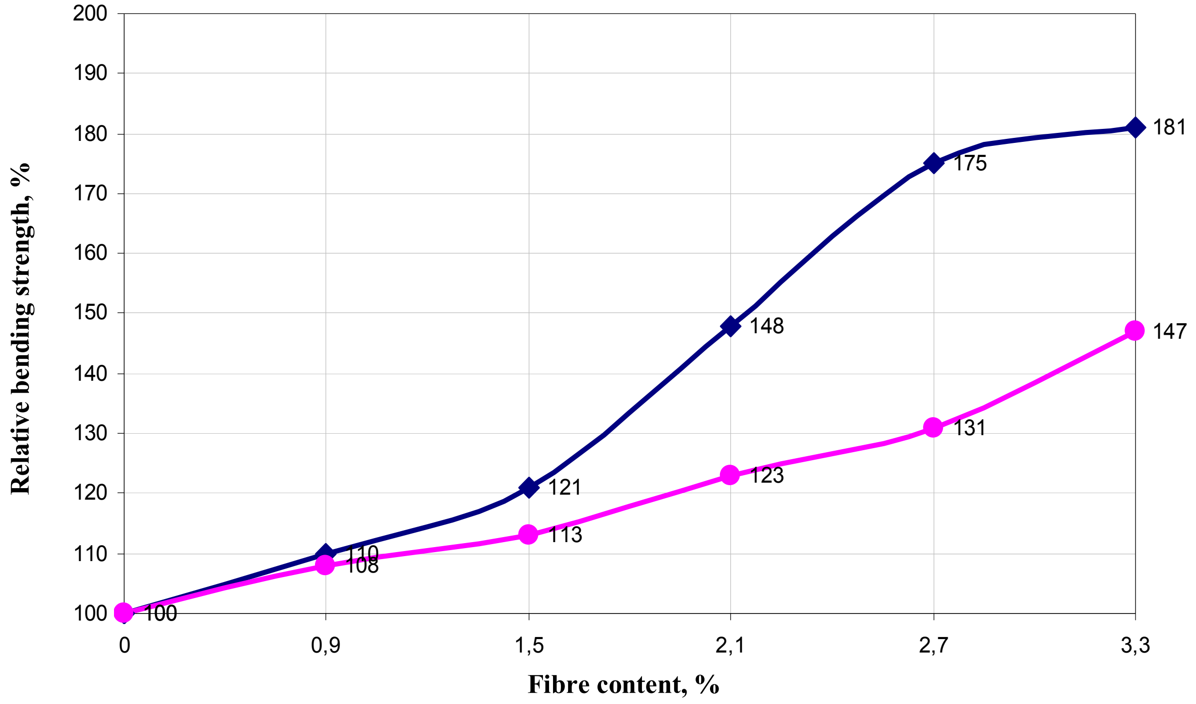

Fig. 2. The plot of fibre concrete strength index with the first fibre type against fibre content:
—◆— — reinforcement of the stretched zone; —●— — volume reinforcement

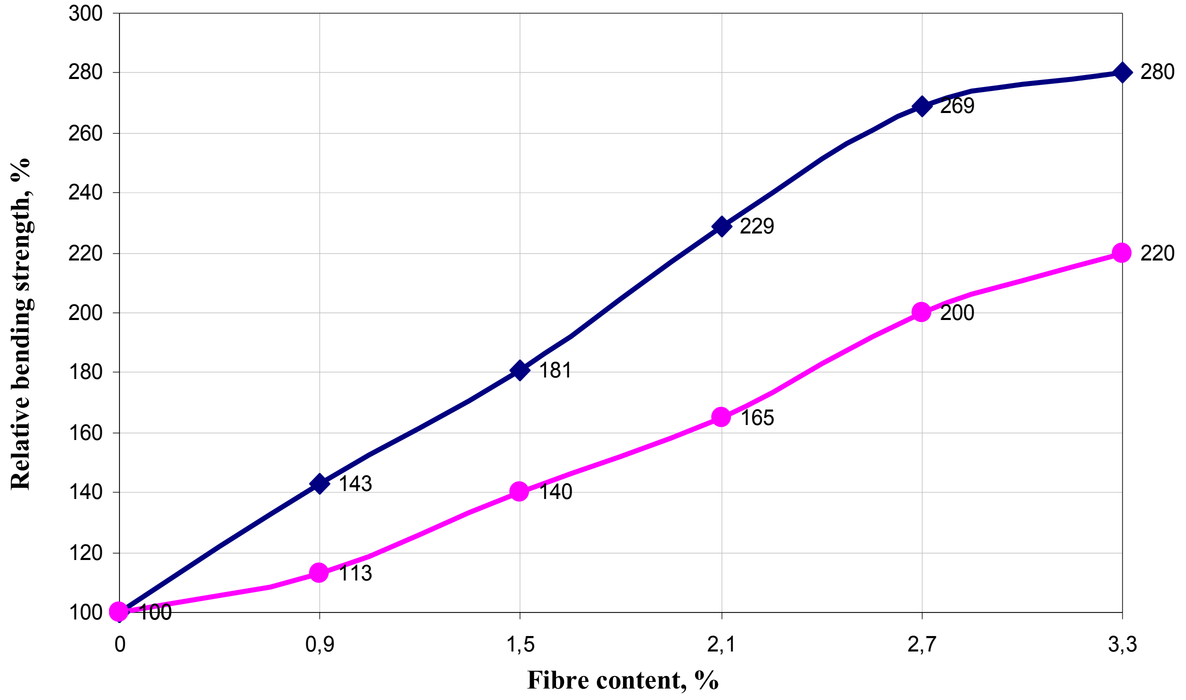

Fig. 3. The plot of fibro concrete strength indexes with the second fibre type against fibre content:
—◆— — reinforcement of the stretched zone; —●— — volume reinforcement

3. The research results

The experiments showed that the samples of the B-33-9-s series with the reinforcement index of the stretched zone equal to 9 % have the highest strength. In this case, the lower layer reinforcement efficiency as compared to the volume reinforcement is 32 %. The efficiency index was estimated against concrete strength during bending during the reinforcement of the stretched zone and concrete strength during bending during volume reinforcement.

During the sample failure fibre rupture did not practically occur. They were practically all pulled out of the concrete matrix due to insufficient anchorage (Fig. 4).

Fig. 4. Failure character latching

Conclusions

According to the research results, it can be concluded that in both cases an increase in reinforcement percentage leads to an increase in strength during bending. However, the sample with the lower-layer reinforcement are stronger at the same fibre flow rate.

The optimal fibre reinforcement coefficient is 9 %. The second fibre type efficiency in this case is 53 % higher than that of the first one. Hence, low materials consumption, high impact value and resistance to cracks can be achieved if a given strength during bending is kept in the process of the manufacturing of building items and constructions.

The scientific novelty of the present research lies in the comparative estimation given for the first time to disperse reinforcement of the two metal fibre types during the reinforcement of a stretched zone of concrete flexural elements.

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