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VIBRATION METHOD OF STEEL FIBRE REINFORCEMENT FOR DISPERSED REINFORCED CONCRETES

The paper provides the results of studying adhesion of the fibres made of used steel wire rope to concrete. The analysis included finding the impact of a controlled mechanical centrifugal unbalance vibration exciter on the extent of adhesion of the fibre vibration treatment with loose abrasive medium in the process tank.

Keywords: *dispersed reinforced concrete, steel fibre, cohesion, vibration training method, controlled mechanical centrifugal unbalance vibration exciter, adhesion.*

Introduction. The issue of saving energy and introducing various material and energy-saving technological processes is currently vital for the global economy and especially for economy of Ukraine. It is common that these questions are relevant and relate to different sectors of construction industry. On the other hand, contemporary industry development more and more frequently demand higher requirements to physical and mechanical properties of buildings, structures and materials. To produce these ones the use of reinforced concrete is widely used, it is necessary to improve its crack resistance, tensile and local impact strength, reliability and durability of reinforced concrete elements. Possible efficient ways to solve the above mentioned problems are:

the use of dispersed reinforced concrete, where reinforcement is made of steel fibre – this improves physical and mechanical performance of fibre concrete products;

manufacturing of fibre with used and rejected steel wire ropes (or cables) – this evidently saves resources (e.g., according to the data of the Research Institute of Concrete and Reinforced Concrete the Soviet Union construction industry required up to 15 thousand tons steel fibre in 1985-1990; at the same time the annual volume of rejected used steel wire ropes and cables was approximately 650thousands tons [1]).

Literature review. Manufacturing of concrete products, reinforced with steel fibre, may be divided into the following key process stages: fibre production, its processing, preparation of homogeneous steel fibre concrete mix and forming finished products. Therewith, the quality of the above products considerably depends on the interrelated factors below:

equability distribution of fiber by volume of concrete matrix;

fibre reinforcement parameters;

sufficient grip of steel fiber and concrete;

favourable conditions for forming cement crystals at the stage of steel fibre concrete hardening.

It is known [2–5] that the equability of fibre distribution in the concrete mix significantly depends on the relation of μ length ℓ of a separate fibre to its diameter d, whose value shall be within $\mu = \ell / d = 75...125$. Provided $\mu = 50$ steel fibre manufacturing in standard mixers does not involve any difficulties, but in this case it does not provide sufficient coupling of each fibre filament with concrete. Provided $\mu = 150$ typical fibre clusters, clots and balls emerge at the stages of mixing and forming. Even if the correlation is optimal, $\mu \approx 100$, but fibres are long, using the wire with large diameter, the probability of their adverse clustering increases, which encourages decreasing the length ℓ and taking additional measures to improve coupling of the fibres and concrete or restricting the diameter d of the wire used for fibre manufacturing (most often the accepted sizes in the steel fibre concrete production are $d = 0,5 \div 0,8\,mm$,).

Steel fibre concrete production on the conventional process equipment providing $\mu \approx 100$, the fibre volume content is approximately 3, since under high fibre content there occur difficulties at the stag $\ell = 30 \div 80\,mm$ e of forming product surfaces. Normally, the volume content of broken stone, used in manufacturing of steel fibre concrete, does not exceed 25, the maximum grain size is $15\,mm$; the increase of these indicators also leads to fibre clots and balls.

In case of producing the fibre from used wire rope (or cable) it is subject to thermal treatment, removing oils from surfaces; after cooling down the wire rope is cut into the pieces of required length and split into separate fibres. The disadvantage of the above process flow is its high energy consumption and certain deterioration of the wire rope physical and mechanical features under the impact of thermal treatment high temperature. To improve the coupling of the steel wire fibre and concrete there are also other techniques, and all of them may be divided into chemical and mechanical ones. Considering mechanical techniques of fibre preparation and accepting the value of a smooth clean (degreased) filament cohesion with concrete as a unit, the coupling factors for some techniques have the following values: sandpaper treatment along the fibre axis – $1{,}4$; the same treatment across the fibre axis – $1{,}8$; pressing in clamps – $3{,}4$; denting – $3{,}7$; twisting – $1{,}6$; splicing the ends of fibre filaments – $8{,}9$; end bending – $5{,}5$; loop bending at ends – $10{,}8$; fibre filaments zigzag bending – $4{,}7$ [6].

Identifying the problem to be solved. The above list that may be continued shows:

1) attention, paid by researchers to different ways of fibre preparation;

2) unavailability of any indication of the application of vibration preparation.

Problem description. One of the varieties of mechanical preparation of fiber - process them in an environment free of abrasive in the working capacity of the technological vibration machines will be discussed and its efficiency will be identified.

Results and Discussion. To evaluate the efficiency of the above technique the following experimental studies were planned and performed: fibres, prepared in different ways, were taken out of sand and concrete cubes identifying the value of the applied force.

Therefore, the used steel wire rope was cut into fibres with the diameter of $d = 0{,}7\ mm$ and the length of $\ell_1 = 50\,mm$ and $\ell_2 = 70\,mm$, which corresponds to the following factor values: $\mu_1 = \ell_1 / d \approx 71$ and $\mu_2 = \ell_2 / d = 100$. The fibres were distributed depending on their preparation technique in 10 types:

1 – non-treated (with oil remnants);

2 – degreased with acetone;

3 – degreased with acetone and treated with sand paper along the fibre axis;

4 – degreased with acetone and treated with sand paper across the fibre axis;

5, 6, 7 – degreased with acetone and processed in an environment free of abrasive in the working capacity of the technological vibration machines for 1, 2 and 5 minutes, respectively;

8, 9, 10 – not degreased and processed in an environment free of abrasive in the working capacity of the technological vibration machines for 1, 2 and 5 minutes, respectively.

In this way we prepared 120 fibres, six of each type and lengths ℓ_1 and ℓ_2. The fibres of types 5-10 were processed by the screw vibration field [7, p. 59, fig. 2.14] in the working capacity of vibration machine VIO-8 [8] for the volumetric finishing of small parts in an environment free of abrasive from the mix of various broken sand discs grain sized $5 \div 15\,mm$.

To manufacture sand and concrete cubes with a side of $30mm$ we used Balakleya Portland cement, grade 400, and Dnipro fractioned quartz sand, which was sieved through sieve $0{,}63$ and stayed on sieve $0{,}36$; based on the conditions of the readily stowing the fibre concrete mix according to [9] the stock of concrete matrix was accepted as $C : S = 1 : 2$ (weight) and $W / C = 0{,}4$. The cubes were formed by six pieces at a time in the standard rigid metal casings, which was firmly attached to the top horizontal face of machine VIO-8, and compressed over one minute with the progressive vibration field [7, p. 62, fig. 2.15]. At the end of the compression time each cube was vertically dipped by $30mm$ according to the type of fibre preparation. All 120 cubes were made on the same day from the same sand and concrete primary mix, cut on the next day and stored for 28 days in a bath with a hydraulic gate at temperature $20 \pm 2°C$.

Next the fibres were pulled out of the cubes. The applied pulling forces, averaged by types of fibres, are given in table 1, which shows calculated factors of fibre-concrete coupling (the applied pulling force to take out a degreased smooth fibre was accepted as one).

Table 1 shows that degreasing and processing of emery paper actually improve the fibre-concrete coupling, and the obtained values coincide with those given above.

Vibration treatment in the preliminarily degreased in acetone fibres raises their coupling with concrete, and the fibre-concrete coupling factor at set time intervals increased according to the increase of treatment time. Somewhat unexpected results were obtained under the vibration treatment of non-degreased fibres: the cohesion factor has the maximum value at the treatment over 1 minute, whereas its further treatment decreased the factor value. It is evident that identification of the optimal period of vibration treatment requires further studying. However, in the carried out experiment, in all cases, vibration treatment provided better cohesion of fibres with concrete compared to sandpaper treatment.

Table 1 – The Values of Fibre Pulling Forces from Concrete Cubes

Type of fibre depending on treatment	1	2	3	4	5	6	7	8	9	10
Pulling force (N)	129	182	235	251	274	302	379	389	297	281
Fibre-concrete coupling factor	0,71	1,00	1,29	1,38	1,51	1,66	2,08	2,14	1,63	1,54

Another factor, which also improves cohesion of the vibration treated fibre, not assessing the impact value, may be noted. It is known that under the vibration treatment in an environment free of abrasive the phenomenon of abrasive particle adhesion is observed on the surface of the treated part. At the same time the particles so tightly adhere to the sample base metal that the connection line is not visible [10, p. 18-19]. In other words during the diffusion molecules of the abrasive material engross into the molecules of the fibre surface layer. Besides, there is wedging of the flexible material with hard particles with uneven edges, owing to which they remain in the surface layer" [10, p. 21]. Thus, the above molecules and abrasive micro-particles turn out to be concentrators of cement crystallization under steel fibre concrete hardening, which also increases cohesion.

Conclusion. These results clearly show the benefit of vibration training metal fibre made from used cables: the vibration treatment in an environment free of abrasive over a specific period removes oil remnants from the fibre surface and covers it with a thick net of line micro-cut traces, which improves firm cohesion. Further research and developments should be oriented on considering the issue of the possible vibration treatment of the metal fibres in the granite macadam medium of the identified fraction, which after the vibration preparation is used in manufacturing the concrete mix together with the fibres. This technology would free from the need of separating the fibres from the abrasive medium.

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