PERSPECTIVES OF THE USE OF MODERN BUILDING MATERIALS IN ROAD CONSTRUCTION

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Abstract: The authors analyzed the foreign experience of using keyed joints in reinforced concrete span structures of bridges. Fiber concrete with polypropylene fibers was chosen as the investigated material. Such fibers are chemically neutral, water-resistant, have a high resistance to dynamic loads, reduce the risk of formation and development of cracking, increase abrasion what is important in the manufacture of road construction. Optimization of concrete composition with polypropylene fibers for concreting joints by physical and mechanical parameters was carried out. Parameters of optimization were compressive strength, tensile strength at bending, axial tensile strength, prism strength and abrasion. The authors performed a series of tests to study the behavior of fiber concrete in keyed joints. The analysis of obtained results out depending on the nature of failure, the value of the ultimate load and fiber concrete deformations were carried out.

The influence on the joints strength of the cross-section reinforcement percentage and the nature of placement of the reinforcing rods was considered.

It was established if to place a cross-reinforcement in two levels it increases the strength of joints in comparison with a single level with the same percentage of reinforcement. It was noted that the fracture of all samples occurred from the sear key. Cracking of fiber concrete experimental samples occurred at later stages of loading compared with samples of ordinary concrete, and the fracture was not brittle, without tearing off parts of concrete. Increase in strength is due to the chaotic placement of polypropylene fibers in concrete, and therefore, to remove fibers from concrete, it is necessary to spend more energy, which ultimately leads to an increase in strength of joint.

Experimental data suggest possibility and feasibility of polypropylene fibers in concrete joints in precast concrete structures of bridges.

Keywords: experimental research, precast reinforced concrete bridge, polypropylene fiber, fiber concrete, keyed joint.

1. Introduction

The speed and time savings spent on building is the reason that precast reinforced concrete bridges are the most widespread in many countries. Their profitability may increase by the factory manufacturing not only metal elements of construction, but also by the factory manufacturing reinforced concrete slabs of the carriageway (especially for highways). During the build of such structures, considerable attention is paid to the joints, which ensure compatible operation of building in general.

Research conducted in the United States, Sweden, and the United Kingdom confirms the advantages of prefabricated span structures in the field of bridge building [1]. For example, in the United States, there are different degrees of prefabricated: by application of individual prefabricated span blocks to completely prefabricated bridges. For joining elements of the last type are used reinforcement bars followed by concreting the seams.

In France, joining prefabricated blocks bridges made dry and concrete keyed joints. In Sweden, in prefabricated slabs of the carriageway for the transmission of both longitudinal and transverse forces trapezoid form of keyed joints are used [1]. In the Russian Federation, the basic provisions on design, arrangement and calculation of joints of composite along the length of structure of reinforced concrete bridges are presented in [2].

The purpose of the article is the theoretical justification and experimentally confirmation of the possibility of using a concrete with polypropylene fibers in the joints of precast structures of bridges.

2. Methods

Experimental studies were carried out in accordance with current normative methods and state standards. Methods of statistical processing and mathematical planning have been used to planning and processing of research results.

3. Results

By [2] concrete joints constructed along the length of structures of reinforced concrete bridges can be flat, jagged (triangular) or trapezoidal. A flat joint is used when the transverse forces that operate in design at different stages of its work, are perceived by the friction forces between adjoining blocks or by the adhesive forces of the material, which fills seam with concrete construction.

The jagged joints are arranged in cases where frictional or adhesive forces are not sufficient to accommodate the transverse forces that operate in construction during construction and operation. In the sections that work on the action of the transverse force of different signs, trapezoidal keys are arranged, and to improve the work of the joints on the effect of transverse force against short-term loading in the concrete seam, slabs of the carriageway are fitted with a reinforced concrete key.

At present, use of special disperse-reinforcing fibers instead of traditional reinforcement has become widespread [3, 4]. They can be considered as an alternative to a steel mesh or as a replacement for structural reinforcement. However, this option of reinforcement should not be offered as a working reinforcement.

The fiber concrete, which has a number of advantages over concrete with use of other types of fibers, is considered in [5, 6].

When using polypropylene fibers: risk of crackling with plastic shrinkage decreases; increases resistance to penetration of water and chemicals. Such concrete is widely used in hydraulic structures, reservoirs, settling tanks for sewage, ports, concrete bridges and roads, where particularly high resistance to penetration of salts, oils and other chemicals [7]; there is a significantly higher impact resistance and cracking resistance compared to ordinary concrete. The addition of fiber makes concrete more plastic, providing protection against the fracture of the edges of joints in concrete slabs of coatings and prefabricated reinforced concrete structures [6]; polypropylene fibers, increasing the resistance of concrete to cracking, reducing amount of water channels in concrete and as a result reduce the permeability, which increases the resistance to freezing; fiber increases the erosion of concrete, where constant erosion leads to wear of surface [8]; use of polypropylene fiber for supporting, span structures allows to increase inter-repair period, due to increased resistance to vibration loads.

Experimental researches of physical and mechanical characteristics of fiber concrete were carried out, and the work of keyed joints with its use was studied.

In order to determine optimal volumetric concentration of fiber and water-cement ratio, a second-order planning matrix was implemented. The basis of the matrix consisted of a complete factor experiment of linear approximation type 2^K. In the experiment, volume content of the fiber varied from 1 to 3 %. Optimization parameters were the bending strength and compression strength.

As experimental samples, the beam sizes 4×4×16 mm from fine-grained concrete of the same class were made.

The value of the abrasion samples was only 0,12 g/cm^2. In study of impact strength, it was found that at V_f=1 % it has the highest value (940 kg·m/m^2).

According to results of the obtained data, it was found that optimal for fiber concrete mix is a fiber volume content of 1 %, and the water-cement ratio of 0,5.

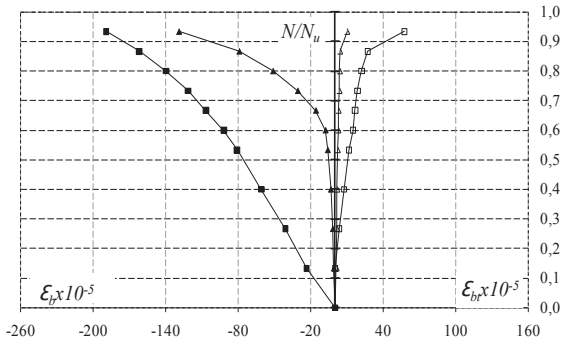
5 single-jointed samples of fibers concrete were tested. The geometric characteristics of the prototype are shown in **Fig. 1**. The ratio of the depth l_k to the height h_k of the key was 0,5. Concreting of samples was carried out in two stages. At the first, concrete parts of sample were concreted with ordinary concrete, and on the second one a central part of fine-grained fiber concrete of the lower class was made, in compared with lateral parts, to ensure the fracture of the keys [8].

The keyed joint of all samples were reinforced with a cross-section reinforcement of the class A240C in the shear plane. The percentage of reinforcement ranged from 0 to 2,89 %. Also, the effect of reinforcement on the strength of seam was studied: for example, samples of ОШФ-0,5-Тр-Ф-1,99-2 and ОШФ-0,5-Тр-Ф-1,81-1 had the same percentage of reinforcement, but in the first – the transverse bars was located in the middle of height of key, and in the second sample was spaced at a height of two levels (**Fig. 1**).

Together with concreting joints from the same mixture, control prisms and cubes were made to determine strength characteristics of concrete. According to the values of the strain gauge, graphs of relative longitudinal and transverse concrete deformations were constructed, which were obtained when testing standard prisms. As can be seen, the deformation dependence of fiber concrete prisms during compression from the level of loading does not have a fundamental difference from work of prisms made of ordinary concrete (**Fig. 2**).

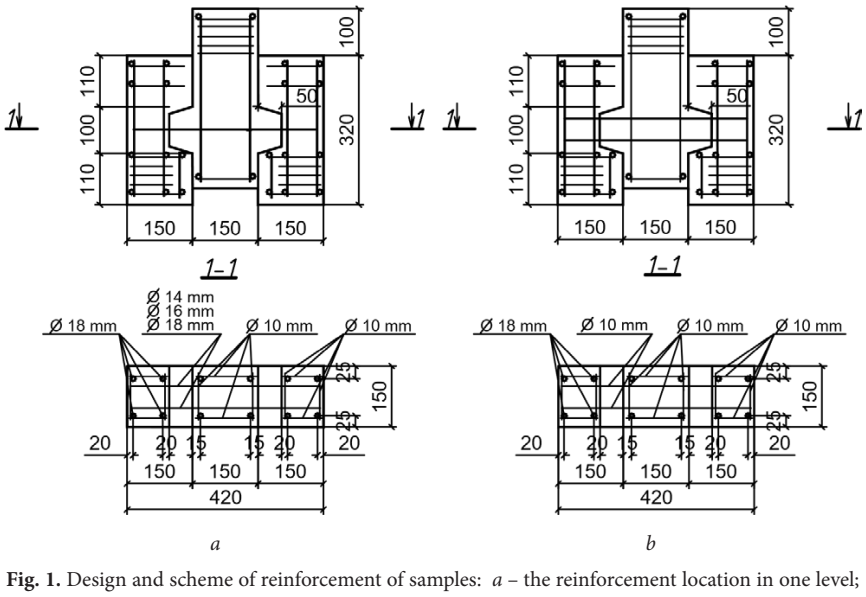
During the test, nature of cracks formation, the limiting load, influence of percentage and the nature of the placement of reinforcing rods on the strength of keyed joint were studied (**Fig. 3**).

a



b

Fig. 2. Determination of mechanical characteristics of fiber concrete: *a* – photo test of prisms on compression; *b* – dependency graphs «$N/N_u - \varepsilon_{b(bt)}$»



a *b*

Fig. 1. Design and scheme of reinforcement of samples: *a* – the reinforcement location in one level; *b* – the reinforcement location in two levels

When studying the behavior of concrete, which is filled with polypropylene fibers, it is necessary to distinguish state of material prior to the appearance of the first structural cracks and after its appearance, and to the complete fracture of material. To the first crack, composition can be defined as an elastic material, and only after its appearance, fibers with increasing load begin to elongate and material acquires the properties of pseudo plastic [9].

The fracture was not brittle, without tearing off parts of concrete. At loading ≈0,6 from the fracture appeared the first micro cracks, which, with further increase in load, did not grow significantly and did not reveal. At loading $0{,}85Q_u$ the surface of destruction was defined. All samples were fracture from the shear, which provided the highest strength [10].

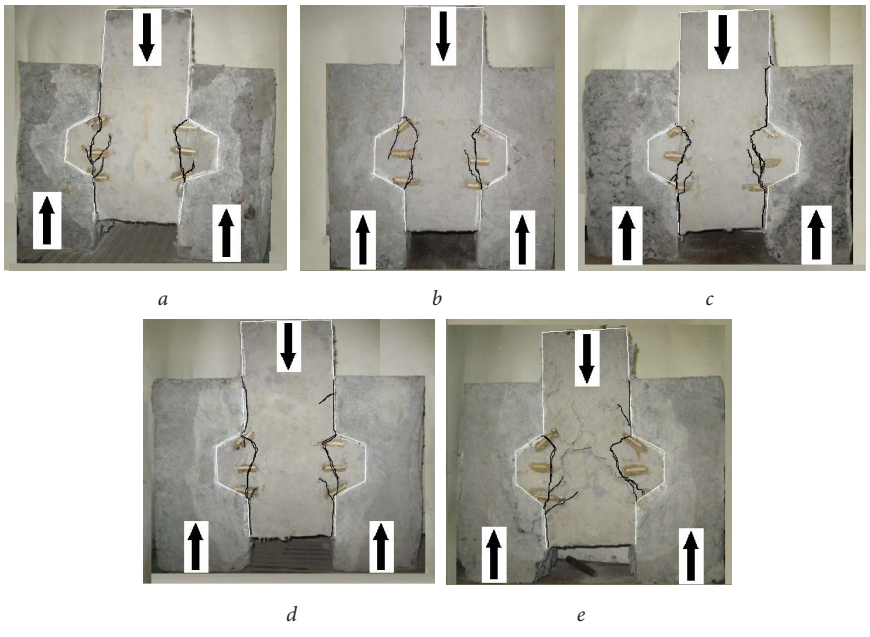


Fig. 3. Photos of samples after the test: *a* – ОШФ-0.5-Тр-Ф-0-0;
b – ОШФ-0.5-Тр-Ф-1.99-2; *c* – ОШФ -0.5-Тр-Ф-1.81-1; *d* – ОШФ-0.5-Тр-Ф-2.28-1; *e* – ОШФ-0.5-Тр-Ф-2.89-1

4. Discussion

1. Mechanical properties of fiber concrete with polypropylene fibers and its work in the structure of reinforced concrete element are widely studied.

2. The performed experimental research is a continuation of scientific work on the improvement of design of joints.

3. In the future, it is planned to conduct experimental research using a fiber concrete with basalt and steel fibers.

4. After analyzing the foregoing, it can be concluded that fiber concrete with polypropylene fibers can be used in arranging joints of precast span reinforced concrete structures and of composite along the length of bridges structure.

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