Laboratory tests of the steel fiber concrete road slab model

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Abstract. The results of experimental studies of bearing capacity and cracking resistance of road slab models made of steel-fiber concrete according to the span loading scheme are presented. The bearing capacity of the models has been fixed at 27.96 kN, which is 2 times higher than the load corresponding to the beginning of cracking (14.8 kN). At the moment of bearing capacity loss, the height of compressed zone was 1 cm, which is one third of its original size. The relative strains before the first crack appeared were 0.1175×10⁻⁴ and 0.235×10⁻⁴ in the compressed and stretched zones, respectively, and similar limiting relative strains reached values of 3.715×10⁻⁴ and 9.235×10⁻⁴. The maximum crack opening width was substantially less than in the same tests of the slabs without dispersion reinforcement and was 0.3 mm, which is explained by the more ductile properties of steel fiber concrete, which prevent crack opening. The final deflection in the middle of the plate model span was 10.4 mm, which is 5.5 times greater than the deflection before cracking began (1.9 mm).

1. Introduction
Road slabs are a good alternative to conventional asphalt pavement. They are used for the construction of temporary and permanent roads, airfields, warehouses and industrial sites, as well as where you want to get a durable surface that can withstand the weight of heavy machinery in the shortest possible time. Road slabs are also used in private construction, for example, for arrangement of yard area. A wide range of slabs allows you to choose the product with the most suitable performance characteristics.

The first road slabs appeared in the early twentieth century. It was an experiment in which it was wanted to compare the strength of conventional asphalt and concrete slabs. The experiment lasted for several decades, as it was necessary to compare the durability of the pavement. It turned out that asphalt needed to be replaced after 10 years, and every 3-4 years it had to be repaired. The concrete slabs lasted about 40 years without serious deformation [1]. All concrete slabs are characterized by high frost resistance, strength, resistance to rainfall and mechanical damage, high durability. The maximum load depends on what kind of concrete was used in the production. Slabs are produced in different sizes and shapes, different thicknesses, with different types of reinforcement and using different grades of concrete.

The undeniable advantage of concrete road slabs is the possibility of their multiple use. If the temporary roadway is no longer in use, its fragments are dismantled and transported to another place for subsequent laying of a new route. Used products are only visually different from the new fragments. The characteristics of durability remain unchanged, and the cost of recycled raw materials is 30%-40% lower than the price of new products. This makes it possible to reduce the cost of new roads without compromising their quality and durability.

2. Recent researches analysis
Theoretical and experimental studies of road slabs are reflected in the publications of many researchers. Thus, in [1] the calculation of road surface slabs for operational loads by the method of B. N. Zhemochkin was made. For temporary road slabs, 16 variants of loading are considered; for permanent road slabs and prestressed - 12 variants of loading. The slabs are calculated as structures on an elastic basis. The conducted research shows that during the operation, reinforced concrete slabs of
Temporary and permanent roads are subjected not only to bending moments and transverse forces in two orthogonal directions, but also to torsional moments. In this case it is impossible to avoid the joint action of torsional and bending moments. In this respect, it is recommended that the load-bearing capacity of the slabs for a given reinforcement and concrete class be checked for the strength of the normal and inclined sections as well as for the combined effect of torsional and bending moments.

The peculiarity of cement concrete pavements of highways is the presence of transverse and longitudinal joints, necessary for the possibility of deformation of the pavement without its destruction during operation. These joints serve as a potential fracture zone not only for the pavement, but also for all the layers of the pavement, and also affect the comfort and convenience of passenger traffic. The paper [2] considers the causes and physical processes that caused the destruction of transverse and expansion joints of compression. The technological causes and characteristic errors that are allowed during construction works, leading to the premature destruction of joints depending on the operating conditions, are analyzed in detail. On the basis of the material presented and the experimental data obtained in the course of full-scale inspections of cement concrete pavements of highways the mathematical model for predicting the destruction of expansion joints in compression in time has been proposed.

The study of road slabs is considered in detail in the work of Belarusian scientists [3] on the calculation of the cross-section of serial reinforced concrete slabs for road pavements. The determination of bearing capacity of road slabs of several types according to the strength of normal sections in the short and long direction, as well as the bearing capacity under the joint action of torsional and bending moments is studied. The calculation procedure of reinforced concrete road surfacing slabs according to the strength of normal sections and on the joint action of torsional and bending moments which has been developed on the basis of the experimental and theoretical researches has been proposed.

In the study of crack resistance in the standards of different countries different formulas are used to calculate the distance between cracks and the width of cracks occurring in bending elements [4]. Most of these formulas are based on the analysis of test results of beams or one-sided slabs. However, the behavior of reinforced concrete slabs with double-sided reinforcement has significant differences, and, therefore, the methods developed for beams cannot be applied directly to such slabs. A new theoretical equation for calculating the crack spacing for road slabs, the validity of which is confirmed by the results of experiments, is proposed in the paper.

Interesting results of the work, the purpose of which was to study the effect of steel fiber on the structural behavior of the slabs (the possibility of redistribution of forces, the nature of cracks and bearing capacity), are presented in the paper [5]. The experiments were carried out on octagonal slabs, which were freely supported on four edges and were loaded with a point load in the center.

The study of the behavior of reinforced concrete slabs exposed to fire is devoted to [6]. Let's also note the publications [7-11], where the calculations and modeling of the work of road pavement made of reinforced concrete were performed.

3. **The purpose of this work** is a laboratory study of models of steel-fiber concrete road slabs to develop recommendations for the manufacture of full-size natural structures of combined reinforcement slabs using steel fiber.

4. **Materials and methods**

The design of the road slab model (Figure 1) was developed, the requirements of the regulatory documents operating in Ukraine were taken into account in the design [12-14]. The geometric dimensions of the model are determined by the technological features of manufacturing and the conditions of correctness of the comparison of the results. The slab models are reinforced with a spatial framework consisting of two meshes (Figure 2).
The slab models were tested on a specially assembled stand (Figure 3). The force device of the stand consists of four racks connected in pairs by beams, on which the road slab is supported. The load is produced by means of a 100 kN jack, the lower plane of which presses on two-level cross-beam system and through it on the slab. The design and dimensions of the cross-beam system are referenced to the road slab loading schemes given in the regulatory literature [15, 16]. The loading was performed by applying two concentrated vertical strip loads along the width of the slab (Figure 4). The upper rod of the jack rests on an I-beam. The forces applied to the plate are controlled with a 500 kN sample dynamometer.
Taking into account the adopted loading scheme, two rows of indicators were installed on the top surface of the slab (Figure 5). The first group of four indicators (2, 3, 4 and 5) are mounted on the cantilever loading section of the model, and the other group (7, 8, 9 and 10) in the upper span of the slab. Indicators 1, 6 are mounted on the side faces in the support area of the cantilever section. A pair of indicators 11, 12 recorded the deformations of the compressed zone in the span section of the slab.

![Figure 5. Indicator layout.](image)

During the tests, the load, longitudinal deformations, deflections, and cracking process were recorded.

5. Research results
A series of road slabs model of dimensions 1375x825x60 made of concrete C20/25 and reinforcement Bp1 with the addition of steel fibers 1% of the volume of the product. The composition of the mixture was determined by the authors in previous studies [17, 18].

The load was applied in steps of 0.05 of the destructive load in accordance with the generally accepted methodology. Each loading step ended with a five-minute exposure time, at the beginning and the end of which readings were taken on the measuring instruments.

Figure 6 shows the values of relative deformations of individual fibers of concrete. As can be seen from the graphs, indicators 1-10 work in tension, and 11 and 12 in compression.

![Figure 6. Relative deformation according to indicator readings.](image)
The nature of the change in the deformations shown in Fig. 6, can be divided into two clearly defined stages. At the first, initial stage, all indicators without exception operate linearly. The values of relative deformations in the compressed and stretched zones, in the loaded cantilever and unloaded span of the slab differ very insignificantly. Such unity lasts until the load of 14.27 kN, corresponding to the moment of crack formation. After the formation of cracks (at the second stage), all the indicators were clearly divided into two groups. One group consisted of indicators 7-12, located in the span of the slab. They practically did not react to the cracking process, continuing to work linearly up to the breaking load of 24.78 kN. The relative deformations of this group of indicators at this stage increased 2.1 times, from $1.2 \times 10^{-4}$ to $2.6 \times 10^{-4}$.

The second group included indicators located on the cantilevered loaded section of the slab. With the beginning of cracking, the strain growth rate (deformation pattern) changed sharply, and the curves on the graph deviated significantly from the linear law of change. The relative deformations of the cantilever section at the second stage increased twelve times, from $2.1 \times 10^{-4}$ to $25 \times 10^{-4}$.

Figure 7 shows for comparison the relative deformations obtained with strain gauges. The results show that the strains measured by mechanical and electrical instruments are identical.

![Figure 7](image.png)

**Figure 7.** Relative strain according to the readings of indicators 7-12 and strain gauges 1t-4t.

Figure 8 shows the averaged deflections obtained using Maximov deflectometers in the cantilever and span sections of steel-fiber-concrete road slab models. The results show that up to the moment of crack formation, the deflections of the span and cantilever sections change linearly and practically by the same value equal to 5 mm. After the formation of cracks, the deflections in the span section of the plates continue to change linearly. By the time the load-bearing capacity of the slabs is lost, these deflections reach the value of 13 mm. At the cantilever section, the deflections growth rate is significantly higher. By the time of failure, the deflections of the cantilever loaded section increased 4.5 times in comparison with the first stage, reaching 25 mm.
6. Conclusions
Thus, laboratory tests were carried out on a series of model road slabs made of steel fiber concrete with 1% reinforcement. The tests were carried out according to one of the two loading schemes recommended by the regulatory documents acting in Ukraine - with the application of load to the cantilever part of the slab.

It was found that the deformations of concrete in the span unloaded section of the slabs almost at all stages of loading change according to the linear law, and by the time of failure reach the value of 3.2×10^-4.

The deformation of concrete in the cantilever section of the slab after cracking increases from 2.1×10^-4 to 25×10^-4, i.e. by a factor of 12. The beginning of the cracking process in the models of road slabs under cantilever loading occurs at the load level of 0.58 of the destructive load. The maximum deflections of the cantilever loaded section (25 mm) are almost 2 times greater than those in the middle of the slab span (13 mm).

The developed methodology and test results of road slab models will be used to test full-size natural structures of combined reinforcement slabs using steel fibers.

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