Experimental studies of road slabs

M Surianinov1,2, S Neutov1, I Korneieva1, D Kirichenko1

1 Odessa State Academy of Civil Engineering and Architecture, Didrikhsona st., 4, 65029, Odessa, Ukraine
2 Address all correspondence to this author

E-mail: sng@ogasa.org.ua

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
The general concept of calculation of road slabs was proposed by B. N. Zhemochkin and A. P. Sinitsyn [2]. Currently, regulatory documents on the calculation and design of road slabs developed in many countries. So in Ukraine it is DSTU B B.2.6-120:2010 [3], in European countries - EN 1992-1-1 (2004): Eurocode 2: [4]. Nevertheless, the interest of scientists to the problem does not weaken. So, in [5] the results of research of stresses in road slabs by polarization-optical method are stated. Experimental and theoretical studies of Belarusian scientists are given in [6, 7]. The evolution of precast concrete pavements in different countries and, in particular, in the USA is described in [8]. Here we present an overview of the results of accelerated loading tests with the help of heavy vehicle simulator. Extensive experimental studies to investigate the characteristics of steel fiber concrete road slabs (SFRC) are presented in [9]. The experimental results show that steel fibers significantly increase the bearing capacity and ductility of the slabs. Let us also note the works [10 - 12], which reflect various aspects of strength and deformability of road slabs.

3. The purpose of this work is to experimentally investigate the bearing capacity and fracture resistance of road slab models made of steel fiber concrete.

4. Materials and methods
The slab model design has dimensions in plan of 1375x825 mm and height of 60 mm. The series was made - three models of reinforced concrete, reinforced with Bp1 meshes, with the addition of steel fiber in the concrete mixture of 1% of the total volume of the product.

The laboratory tests were conducted in accordance with the current standards [13-15] according to the span loading scheme shown in Figure 1.

![Figure 1. Testing scheme](image)

On the upper and lower surfaces of the plate were mounted dial indicators with a base of 36 cm. The first four (1-4) - in the compressed zone, and two more (5, 6) - in the tensile zone (Figure 2). Load cells were also mounted - on the axis of symmetry, under indicators 2 and 4.

The load was applied in stages, and at each stage the longitudinal deformations were recorded according to the readings of indicators and strain gauges, as well as deflections by the Maximov deflectometers installed on both sides in the middle of the plate span.
Figure 2. Indicator layout  
\(a\) – scheme, \(b\) – indicator mount

5. Research results
The readings of all the instruments used on the three different models differed within the statistical error. Based on the data obtained, plots of relative strain vs. load were plotted, which can be used to trace the entire deformation process of the slab models (Figures 3-5).

Figure 3. Relative deformation according to indicators
Figure 4. Relative strain in the compressed zone according to the readings of indicators and strain gauges

Figure 5. Relative strain according to the readings of indicators 5 and 6 in the tensile zone

The nature of the deflections change in the slab graphically and visually is shown in Figures 6, 7.
Figure 6. Slab deflections

Figure 7. Deflections in the span
The readings of the deflectors mounted in the middle of the plate span on both sides differed little from each other at each stage of loading, which testifies to the correctness of the load application, i.e. to the observance of symmetry. Before the appearance of the first crack, the values of deflections changed insignificantly, and starting from the load of 14.80 kN, deflections began to increase gradually, and starting from the load of 21.38 kN, these increments became significant, which is reflected in the graphs.

During the tests, the appearance of cracks and the nature of their opening were recorded. The width of the opening was measured using a Brinell microscope with a division value of 0.1 mm. The first crack formed in the middle of the plate's span at a load of 14.80 kN. At the moment of its appearance, its width of opening was 0.05 mm. At the load of 18.09 kN the second crack with the opening width of 0.1 mm was fixed. During exposure at the same stage of loading, the third crack with the opening width of 0.05 mm was formed. First, measurements of the crack opening width were carried out on the side faces, and then on the bottom surface of the slab models. Figure 8 shows the bottom view of one of the plates at the end of the tests. All the cracks were formed in the area of maximum bending moment. At the maximum load of 27.96 kN a width of the central crack opening of 0.3 mm was fixed.

![Figure 8. Cracks on the bottom surface of the slab](image)

6. Conclusions
The conducted studies have fixed the bearing capacity of the road slab models tested by the flight loading scheme 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 loss of bearing capacity, the height of the compressed zone was 1 cm, which is one-third of its original size.

The relative strains before the first crack appeared were $0.1175 \times 10^{-4}$ and $0.235 \times 10^{-4}$ in the compressed and stretched zones, respectively, and similar ultimate relative strains reached values of $3.715 \times 10^{-4}$ and $9.235 \times 10^{-4}$.

The maximum crack opening width was significantly less than in the same tests of the slabs without disperse reinforcement and was 0.3 mm, which is explained by the more ductile properties of steel fiber concrete, preventing crack opening.

The final deflection in the middle of the slab model span was 10.4 mm, which is 5.5 times greater than the deflection before cracking began (1.9 mm).

References
[1] Radovskiy B S 2015 Cement concrete pavements in the USA - designing *Car roads* 2 pp 48-60
[2] Zhemochkyn B N, Synytsyn A P 1962 *Practical methods for calculating foundation beams and slabs on a firm base* Moscow p 239
[3] State standards of Ukraine V.2.6–120:2010 (HOST 21924.0–84, MOD) 2010 Structures of buildings and structures. Reinforced concrete slabs for covering urban roads. Technical conditions

[4] EN 1992-1-1 2004 Eurocode 2 Design of concrete structures - Part 1-1: General rules and rules for buildings [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC]

[5] Shyrnyyn Yu A, Cherniakevych V Y 2009 Investigation of the stresses of road slabs by the polarization-optical method YVUZ Forest Journal 6 pp 60-67

[6] Semeniuk S D, Kumashov R V, Ketner E A 2016 Bearing and operational capacity of reinforced concrete slabs of road cover Science and construction 3 pp 11-18

[7] Semeniuk S D, Kumashov R V 2018 Reinforced concrete slabs of road surface covering on elastic half-space International Journal for Computational Civil and Structural Engineering 14(2) pp 149–157

[8] Houben L J M, Poot S, Huurman M, Kooij J Van Der 2004 Developments on the ModieSlab Innovative Concrete Pavement Concept 9th International Symposium on Concrete Roads pp 4-7

[9] Sorelli L, Meda A, Plizzari G A 2006 Steel Fiber Concrete Slabs on Ground: A Structural Matter ACI Structural Journal Technical Paper 103 S58 pp 551-558

[10] Zhang Da Shan, Yu Li Dong 2011 Experimental Behavior of One-Way Concrete Slabs at Large Displacements Applied Mechanics and Materials 105–107 pp 1035–1039

[11] Brodzik R 2017 The influence of thermal loads on modern road concrete pavements in Poland Scientific Journal of Silesian University of Technology Series Transport 95 pp 27-37

[12] Lajcakova G, Melcer J 2011 Dynamic Effect of Moving Vehicles on the Road Concrete Slabs Communications Scientific Letters of the University of Zilina 13(3) pp 14-18

[13] State standards of Ukraine V.2.6-98:2009 [valid from 2011-07-01] 2011 Concrete and reinforced concrete structures. Basic provisions Ministry of Regional Development of Ukraine p 71

[14] State standards of Ukraine B.V.2.6-2:2009 [valid from 2010-06-30] 2010 Concrete and reinforced concrete products. General specifications Ministry of Regional Development of Ukraine p 34

[15] State standards of Ukraine B.V.2.6-122:2010 [valid from 2011-07-01] 2011 Reinforced concrete slabs with non-tensioned reinforcement for covering urban roads Ministry of Regional Development of Ukraine p 23