Tests of reinforced concrete floor slab with initial crack

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Abstract. This study presents the results of the examination of precast reinforced concrete floor slab with initial crack of continuous rectangular cross-section with nominal dimensions 6380*3230 mm and a height of 160 mm. The slab was manufactured in the factory during summer. Concrete curing took place in natural conditions without the use of heat and humidity treatment. The slab has an initial crack that appeared before the test, located in the middle of the span in the direction of the channel-former in the layer of concrete with minimum thickness. Information on the testing procedure is presented, the results of calculations and full-scale tests are given. The analysis of the slab deformation dependence diagram on the load value is carried out. The conformity of crack resistance, stiffness and load-carrying capacity of a slab with an initial crack to the normative requirements has been checked, and the theoretical and experimental results have been compared. The influence of the initial crack in the slab on its stiffness and crack resistance has been established.

1 Introduction

Prefabricated reinforced concrete floor slabs are widely used in construction of civil and industrial buildings. Their distribution is due to their high-performance characteristics: reliability, strength, durability, fire resistance and safety. Issues of calculation, design, manufacturing of building structures, the use of new structural forms and materials are covered in many scientific papers and articles [1-16]. In order to expand the application areas of the slabs, the use of modern technologies of their production, it is necessary to continue the research on these issues. In this connection experimental investigations are of a great importance: the data obtained allow to acquire the most reliable information on the behavior of structures under load. The separate direction of researches is connected with tests of full-scale constructions. The experimental data and the analysis of the obtained results are presented in this work.

The technique and results of the tests of reinforced concrete floor slab with an initial crack are given in the work. The tests are performed to check the compliance of crack resistance, stiffness and bearing capacity of the slab with the initial crack with the normative requirements and to determine the influence of the initial crack in the slab on its stiffness.
2 Materials and methods

2.1 Slab characteristics

Precast reinforced concrete floor slab was calculated, designed and manufactured in the construction organization of Petrozavodsk in the Russian Federation in 2019. The slab was manufactured in the factory in summer. Curing of concrete took place in natural conditions, the use of thermal and moisture curing conditions was not required. At the time of installation lifting of the slab in the manufacturing plant, an initial crack appeared in it in the middle of the span. The crack appeared in the concrete layer of minimum thickness in the channel-forming direction.

It was decided to test the slab to determine the effect of the initial crack on its stiffness, strength, crack formation and crack opening, as well as to justify the use of such slabs in civil and industrial floor slabs.

The examined reinforced concrete slab is rectangular in plan, of continuous section, with nominal dimensions of 6380*3230 mm and a thickness of 160 mm. The slab is designed to be supported by three sides: two sides with a length of 3230 mm and one side with a length of 6380 mm. The fourth side with a length of 6380 mm is unsupported (unsupported edge) and can serve to connect with the adjacent board, which increases the area of the room. In the slab there are plastic ducts with a diameter of 32 mm for the subsequent placement of electrical wires in them. The design of the slab is shown in Fig.1.

Fig.1. Slab design: 1 - embedded parts; 2 - pipes (ducts); 3 - boxes; 4 - mounting loops.

Design class of concrete B20. The actual strength of concrete was determined by testing of standard concrete samples by destructive method and was 30.5 MPa, which corresponds to the class of concrete B22.5.
Fig. 2. Scheme of the slab reinforcement.

The calculations of the slab were performed for the first and second groups of limiting states according to the Russian regulatory documents (BC 63.13330.2018). The concrete specifications are taken according to the results of tests of standard concrete cubes. The characteristics of the reinforcement are taken according to BC 63.13330.2018.

2.2 Slab testing

The test methodology involved step-by-step loading of the slab to the design values of the design loads. Before the test, measurements of the geometric dimensions of the slab and deflection were made. During the production of the structure under study, in order to control and determine the actual class of concrete, concrete cubes were made and tested simultaneously with the tests of the slab.

Slab loading was carried out in accordance with GOST 8829-2018 with piece weights bricks weighing 2.64 kg. View of the slab during the tests is shown in Fig. 3.

Fig. 3. Floor slab loading before failure. General view. Photo by Selutina L.F.
To measure deformations during loading, “Etalon” clock type indicators with a scale value of 0.01 mm, 6 PAO deflectometers with a scale value of 0.01 mm, and MPB-2 microscope with a scale value of 0.05 mm were used. Indicators were used to measure support settlement. To measure sagging, deflectometers installed in the quarters and in the middle of the span on the long side of the slab were used.

Control loads without taking into account the slab's own weight:
- 6.14 kPa - control breaking load;
- 2.21 kPa - when evaluating the stiffness with a reference value of deflection of 1.24 cm at point A (Figure 1);
- 3.45 kPa - on checking the crack formation and crack opening;
- 0.22 mm - control crack opening width.

2.3 Crack formation and opening

Fig. 4. The crack on the lower surface of the floor slab. Photo by Selutina L.F.

At the section of crack propagation along the middle of the channel-former, the crack opening is observed in the area of the slab’s minimum concrete layer thickness. To the left and right of the crack a change in the color of the concrete, caused by an increase in the thickness of the concrete layer from the minimum to 160 mm, can be seen (Fig. 4).

At the section of the crack approach to the box under the chandelier, the crack opening is also observed in the area of the slab’s minimum concrete layer thickness. The change in the color of the concrete caused by the increase in the thickness of the concrete from minimum to 160 mm can be seen on the left and right of the crack (Fig. 5).
2. Cracks in the concrete of the slab during testing

The cracks in the test slab are normal to the longitudinal axis of the slab. Their width increased before the slab collapsed with a step of 17–30 cm. The first cracks along the span of the slab appeared at a distance of 1.9 m from the left support and 2.17 m from the right support.

The view of the slab with the crack that appeared during the test is shown in Fig. 6.

Cracks in reinforced concrete slabs can appear at the following stages:

1. During heat and moisture treatment of the slab due to the heterogeneity of the concrete cross-section (solid section with a height of 160 mm, sections with channel formers with a height of 132 mm, sections with mounting loops). These cracks are temperature-shrinkage cracks. The investigated slab was not subjected to thermal and moisture working.

2. When lifting the slab in the process of stripping: cracks can appear in the tensile zone of the concrete at the mounting loop location. At the stage of lifting the slab works as a double-span bending element, the scheme of work of the slab is different from the scheme of the structure in operation.
3 Results

3.1 Slab sagging

![Diagram of slab deformations](image.png)

**Fig. 7.** Dependence diagram of the slab deformations on the load value.

Diagram analysis (Fig. 7)

In the load interval of $59.3 \text{kN} - 81.65 \text{kN}$ the load increased by 1.377 times; the deflections increased by 2.33 times. In the load range of $81.065 \text{kN} - 115.88 \text{kN}$ the load increased by 1.429 times; the deflections increased by 3.21 times. As a result of significant reinforcement deformations, new cracks formed and existing cracks opened, deflections increased, height of concrete compression zone decreased and stresses in concrete increased. The character of the slab fracture is plastic.

**Area I** is the elastic behavior of concrete. The opening width of the initial crack is 0.05 mm.

**Area II** - the emergence of cracks in the middle of the slab span is observed. The distance between the cracks is 20 - 35 cm.

**Area III** - there is a development of existing cracks and appearance of new ones. The cracks appeared closer to the left and right supports.

**Area IV** - there is an increase in the opening width and height of the existing cracks. Intensive crack formation occurred in the areas II and III. Tests showed that under the control load in terms of stiffness, the sag of the slab is less than the design value.
results show high stiffness of the slab with initial cracking. This conclusion is in agreement with the results of the studies of V.M. Mitasov, M.A. Logunova, and N.V. Statsenko. In the researches of V.M. Mitasov, M.A. Logunova, N.V. Statsenko the effect of pre-arranged cracks on the floor slabs and reinforced concrete beams deformability under short-term loading was estimated. The results of the scientists’ experiments confirmed the earlier hypotheses about the greater stiffness of slabs and beams with pre-arranged cracks in comparison with stochastic cracks during operation. It was found that the presence of pre-arranged cracks reduces the deflections of beams and slabs, compared with the samples of continuous section, actually being a regulator of the stress-strain state of reinforced concrete structures.

3.2 Slab failure

The destruction of the slab occurs when there is excessive deflection and excessive crack opening width normal to the longitudinal axis. The loading section of the floor slab in the middle of the span before failure is shown in Fig. 8.

The comparison of theoretical and experimental data is presented in the table 1.

Table 1. Comparison of theoretical and experimental results.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Theoretical results</th>
<th>Experimental results</th>
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<tbody>
<tr>
<td>Breaking strength</td>
<td>6.14 kPa</td>
<td>6.42 kPa</td>
</tr>
<tr>
<td>Stiffness test load</td>
<td>2.21 kPa</td>
<td>2.21 kPa</td>
</tr>
<tr>
<td>Control sagging value in A</td>
<td>1.24 cm</td>
<td>6.5 mm</td>
</tr>
<tr>
<td>Crack formation and opening</td>
<td>3.45 kPa</td>
<td>3.45 kPa</td>
</tr>
<tr>
<td>For a slab without an initial crack</td>
<td>3.45 kPa</td>
<td></td>
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</table>

This value is used to analyze fracturing

Control crack opening width

0.22 mm

0.07 - 0.1 mm

Fig. 8. Loading of the floor slab before failure. The section in the middle of the slab span. Photo by Selutina L.F.
The paper gives the characteristics of the investigated reinforced concrete floor slab, gives the methodology and test results. The results of the study are as follows:

1. The tests of precast reinforced concrete slab of continuous cross-section with nominal dimensions 6380*3230 mm and a height of 160 mm have been conducted. Concrete class of compressive strength B22.5; reinforcement with unstressed reinforcement of A500 class.

2. The floor slab has an initial crack. The crack is in the layer of concrete with minimum thickness in the middle part of the span and is located in the direction of the channeling 32 mm in diameter.

3. Calculations of the slab in terms of crack resistance, stiffness and bearing capacity according to the Russian normative documents have been performed.

4. Information about the test methodology is presented.

5. In the process of testing with loads not exceeding the design reference values, inclined cracks in the slab were not found; the width of the opening of cracks normal to the longitudinal axis of the slab and the deflection did not exceed the theoretical values.

6. Stress of crack formation in the experimental slab exceeded the theoretical one by 2.2-3.14 times.

7. Slab deflection at point A under control load is less than the theoretical value by a factor of 1.95.

8. The character of floor slab fracture is plastic.

9. Experimental destructive load of the slab is greater than the theoretical value by 1.046 times.

10. The conclusion about the significant stiffness of the slab with the initial crack is consistent with the results of tests of a series of reinforced concrete structures with pre-arranged cracks, carried out by V.M. Mitasov, M.A. Logunova, N.V. Statsenko.

11. The results of these studies are recommended to be used to improve methods of calculation for reinforced concrete structures with initial cracks, reinforced with A500 class reinforcement.

4 Discussion

Experimental studies of a reinforced concrete floor slab with an initial crack showed that with loads not exceeding the calculated reference values, diagonal cracks do not occur, the width of the opening of cracks normal to the longitudinal axis of the slab and the deflection do not exceed the calculated values. At the moment of new cracks formation, the load in the investigated slab exceeded the theoretical one by 2.2-3.14 times. At the control load at point A, the slab got the deflection less than the theoretical value by 1.95 times. The experimental breaking load of the slab exceeded the theoretical value in 1.046 times.

The influence of the initial crack in the slab on its stiffness, strength, crack formation and crack opening has been established. The stiffness of a slab with an initial crack is higher than the theoretical one, which corresponds to the results of the tests for reinforced concrete structures with pre-arranged cracks by V.M. Mitasov, M.A. Logunov and N.V. Statsenko.

5 Conclusions

The precast reinforced concrete floor slab of continuous cross-section was produced in the factory in summer. The concrete was cured in natural conditions without the use of heat and moisture treatment. The slab has been pre-calculated for crack resistance, stiffness and...
At the time of installation elevation of the slab at the manufacturer's plant, an initial crack appeared in the layer of minimum thickness concrete in the direction of the channel-former in the middle of the span. Nominal dimensions of the slab are 6380*3230 mm, thickness 160 mm. Concrete class of compressive strength has been determined by testing the standard concrete samples by the destructive method and corresponds to class B22.5. Reinforcement is carried out by unstressed reinforcement of class A500.

The paper provides data on the test methodology, test results, a diagram of the dependence of deformation of the slab on the load value, the analysis of the diagram, deformations and test results is carried out. The verification of crack resistance, stiffness and load-carrying capacity of the slab with an initial crack to normative requirements is carried out, the comparison of theoretical and experimental results is given.

The conclusion about the initial crack's influence on the slab's stiffness, durability, crack formation and crack opening has been made. The results of these studies can be used in the field of improving the calculation methods of reinforced concrete structures with initial cracks.

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