Calculation of flat reinforced concrete slabs strengthened by post-stressed rebars in two directions.

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ABSTRACT

The purpose of the dissertation research is to carry out theoretical calculations and the experimental confirmation of the possibility of strengthening the flat reinforced concrete slabs with external stressed reinforcement, and influence of such strengthening on the subsequent operation of the slab under the increased load.

The results of theoretical researches of the calculation of flat reinforced concrete slabs strengthening by external stressed reinforcement in linear and nonlinear formulation of problems are presented, and the results of two calculation variants are compared.

1. Introduction.

During the arrangement of monolithic reinforced concrete flat roofs, problems with over-deflection and cracks occur. They can occur both during operation and during construction. The reasons that cause excessive deflections can be attributed to: deviation from manufacturing technology, design errors, etc. For large spans of monolithic plates (more than 6 m) it is recommended to use pre-stressed fittings. To
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reinforce reinforced concrete slabs you can use external tensile reinforcement, which will serve as external reinforcement. In the last 30-40 years, and in the countries of Europe and the United States, the use of pre-stresses with tension on concrete (post-stress) is becoming more and more successful, which allows an effectively pre-stressed monolith of construction. In our country, this technology has become widespread in the construction of monolithic overpasses and bridges, while civil construction is very rarely used. This is partly due to the lack of norms and recommendations for the calculation and design of these designs. In practice of modern construction, more and more are used pre-tensioned in two directions reinforced concrete slab structures. These include inter-floor overlays and coverage of public and industrial buildings, walls and roofs of tanks.

However, the study of such structures, working in conditions of a complex stressed state, is not exhaustive. Existing norms do not give concrete recommendations for the calculation of such a class of structures.

2. The main part.

The calculation strengthening of direct reinforcement was made, that is, the reinforcement were parallel to the axes, for the experimental model of the slab at a scale of 1: 6. To calculate used software suite Lira 9.6.

Four calculation models were created: 1 - linear calculation of the model without strengthening, 2 - linear calculation of the model with strengthening by direct reinforcement, 3 - nonlinear calculation of the model without strengthening, 4 - nonlinear calculation of the model after strengthening. In the future, it is planned to carry out an experimental research and compare the result with the theoretical calculation.

![Fig. 1. Scheme of placing external reinforcement strengthening of slab: a) on the top side of the slab; b) on the bottom side of the slab. Linear calculation reinforced concrete slab with strengthening by external reinforcement.](image-url)
For the calculation of flat reinforced concrete, slabs used software suite Lira 9.6. The size of the plate is $2500 \times 2500$ mm. Console 250 mm along the perimeter of the plate. The pitch of the columns is 1000 mm. The useful load applied to the plate is 9.8 kN/m², concrete slabs of class C40, plate thickness 25 mm. As a result of the linear calculation the displacement along the $Z$-axis plates and the moments $M_x$, $M_y$ before and after amplification was obtained (Table 1 and Fig. 2–4).

**Table 1. Linear calculation reinforced concrete slab before and after strengthening**

<table>
<thead>
<tr>
<th></th>
<th>Before strengthening</th>
<th>After strengthening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical deflection, mm</td>
<td>-1.62</td>
<td>-1.2</td>
</tr>
<tr>
<td>Bending moment $M_x$, kNm/m (-)</td>
<td>2.481</td>
<td>2.308</td>
</tr>
<tr>
<td>Bending moment $M_y$, kNm/m (+)</td>
<td>0.645</td>
<td>0.477</td>
</tr>
<tr>
<td>Bending moment $M_x$, kNm/m (-)</td>
<td>2.481</td>
<td>2.308</td>
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<td>0.645</td>
<td>0.477</td>
</tr>
</tbody>
</table>

Based on the above values in Table 1 it can be said that the gutter in the plate with reinforced outer reinforcement decreased by 25.9%. Also, moments on supports and in the span were reduced by 6.97% and 26.0%, respectively.

**Fig. 2. Vertical deflection along the axis $Z$ before and after strengthening, mm.**
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Linear calculation reinforced concrete slab with strengthening by external reinforcement.

For the nonlinear calculation, a new model with the same characteristics was created with the same characteristics that for linear. However, elements of the slab were defined by finite elements of type 241 - a physically nonlinear universal rectangular finite elements shell. When determining the rigidity of the plate, the dependence of $\sigma$-$\varepsilon$ was taken into account (Fig. 5) [1].

When conducting a nonlinear calculation of the slab, concrete creep was taken into account at the age of 365 days, so the values obtained as a result of the calculation are a real reflection of the work of the slab and external reinforcement reinforcement.

![Fig. 3. Bending moments $M_x$, before and after strengthening, kNm/m.](image1)

![Fig. 4. Bending moments $M_y$, before and after strengthening, kNm/m.](image2)
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As a result of the nonlinear calculation, the displacement along the Z-axis plates and the moments $M_x$, $M_y$ before and after amplification was obtained (Table. 2 and Fig. 6–8).

**Fig. 5. Diagram exponential dependence for reinforced concrete**

**Fig. 6. Vertical deflection along the axis Z before and after strengthening, mm.**
Investigation of single- and double-layer slabs supported on four sides.

Table 2. Nonlinear calculation reinforced concrete slab before and after strengthening

<table>
<thead>
<tr>
<th></th>
<th>Before strengthening</th>
<th>After strengthening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical deflection, mm</td>
<td>-12.2</td>
<td>-6.57</td>
</tr>
<tr>
<td>Bending moment $M_x$, kNm/m (-)</td>
<td>1.927</td>
<td>1.649</td>
</tr>
<tr>
<td>Bending moment $M_x$, kNm/m (+)</td>
<td>0.597</td>
<td>0.351</td>
</tr>
<tr>
<td>Bending moment $M_y$, kNm/m (-)</td>
<td>1.927</td>
<td>1.649</td>
</tr>
<tr>
<td>Bending moment $M_y$, kNm/m (+)</td>
<td>0.597</td>
<td>0.351</td>
</tr>
</tbody>
</table>

Fig. 7. Bending moments $M_x$, before and after strengthening, kNm/m.

Fig. 8. Bending moments $M_y$, before and after strengthening, kNm/m.
Based on the above values in Table 2 it can be said that the gutter in the plate with reinforced outer reinforcement decreased by 46.15%. In addition, moments on supports and in the span were reduced by 14.43% and 41.2%, respectively.

**Conclusions**

To analyze the structures before amplifying and calculating the gain, it is better to use a nonlinear calculation method, since it shows the actual work of the structural reinforced concrete elements and allows you to see the complete picture of deformations stresses and fractures in the element. Subsequently, it is advisable to carry out an experimental study and compare the result with a theoretical calculation.

**References**


