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Consideration of external reinforcement based on carbon fibers for the redistribution of bending moments in slabs

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Abstract. Girderless monolithic floors represent the main constructive technique primarily for residential buildings – an important component is the saving of space in contrast to girder structures. In addition, these structures are typical for other buildings. The issue of punching in monolithic girderless ceilings is one of the most important issues. At the same time, as a rule, only one task is solved – reinforcement from punching and the issue of the stress-strain state of the structure as a whole is completely ignored. This fact leads to an uncharacteristic redistribution of forces in the structure, which ultimately leads to destruction. This article discusses specific examples of calculations and objects with an analysis of the redistribution of moments and the final convergence of the calculation results. In conclusion, the key conclusions are made

1 The status of the issue of strengthening the punching zone

Analyzing previously performed works [1-8], the following types of rigid capitals can be distinguished (it is understood not to strengthen the punching zone with reinforcement, but to introduce elements into the system that significantly increase the rigidity of the support section)

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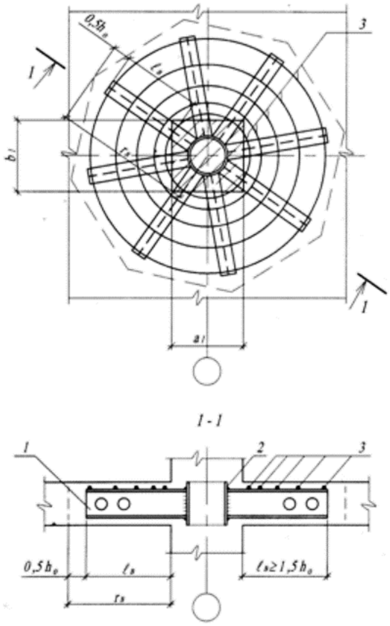
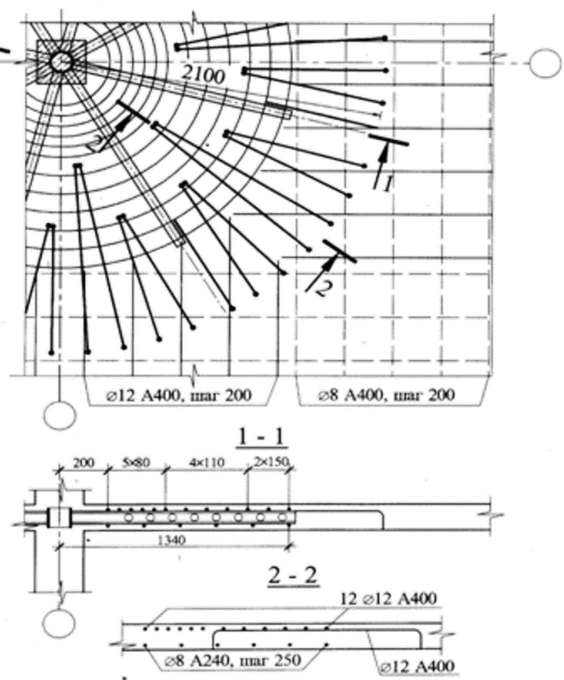
a)



1 – rigid transverse reinforcement (I–beam)
2 – steel pipe
3 – ring fittings

It is possible to use a sheet steel system [4, 7]

b)



c)

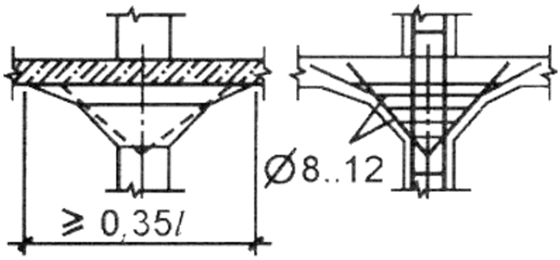


Fig. 1. Variants of rigid capitals a) radial rigid transverse reinforcement; b) hidden capital with rigid radial reinforcement extended to the full width of the support zone; c) capital with a height of more than three plate thicknesses

In the course of the conducted research, a specific task was set – to solve the issue of punching. At the same time, the issue of the rigidity of this section, with the exception of individual works, has not been fully investigated (a number of authors carried out movement control and concluded that there was a significant increase in the rigidity of the zone at the column).

Not taking into account the actual rigidity of the capital leads to incorrect design calculation, determination of forces and as a result errors in reinforcement.

Illustrative examples are shown in Figure 2 – the result of not taking the capital into account in the calculations led to the formation of cracks in the support zone (actually along the contour of the rigid capital). Then again, the incorrect interpretation of the problem and an attempt to solve it with a napkin around the column.

Fig. 2. Erroneous reinforcement of the support zone of the column from above is an incorrect definition of the problem

A number of scientists have raised the issue of redistribution of bending moments in complex systems [9, 10], also taking into account the age of concrete [11]. At the same time, this issue is not fully disclosed in the norms, and therefore cases of incorrect calculations are often detected.

In order to analyze this phenomenon, numerical models were developed that are close to the real object on which field studies were conducted.

To assess the impact of the stiffness of the hidden capitals, a calculation will be performed for the following models:

- the construction of a girderless ceiling (model figure 3) with the actual stiffness (taken according to the dimensions of concrete and actual reinforcement) of the elements, taking into account the physical nonlinearity (Model 1);

- the construction of a girderless ceiling with the rigidity of the shells for both reinforced concrete and the actual rigid reinforcement of the capitals (Model 2);

- girderless floor structures with a 50% increased rigidity of the support zone with rigid reinforcement (based on the analysis of previously conducted experimental studies), as well as taking into account the formation of cracks along the boundary of the zone with a rigid capital (Model 3).

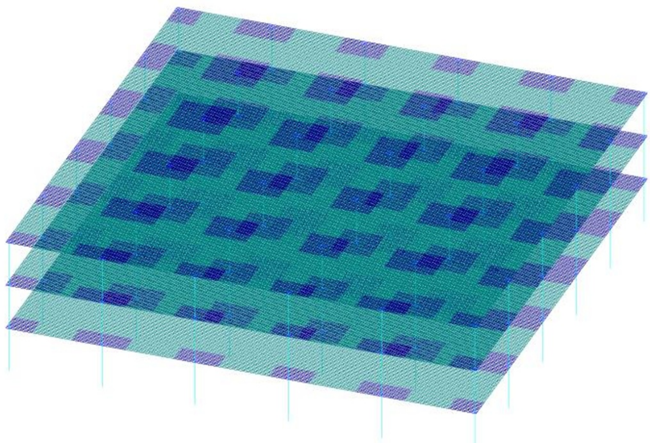
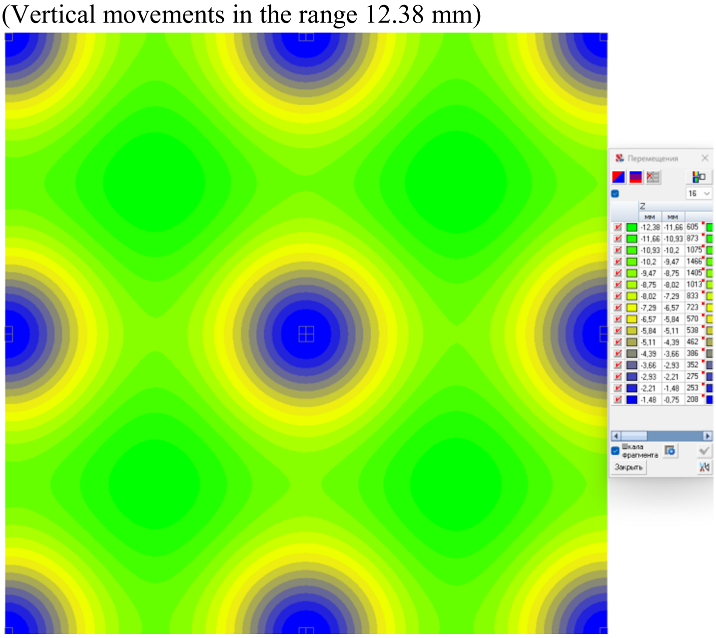


Fig. 3. Calculation model

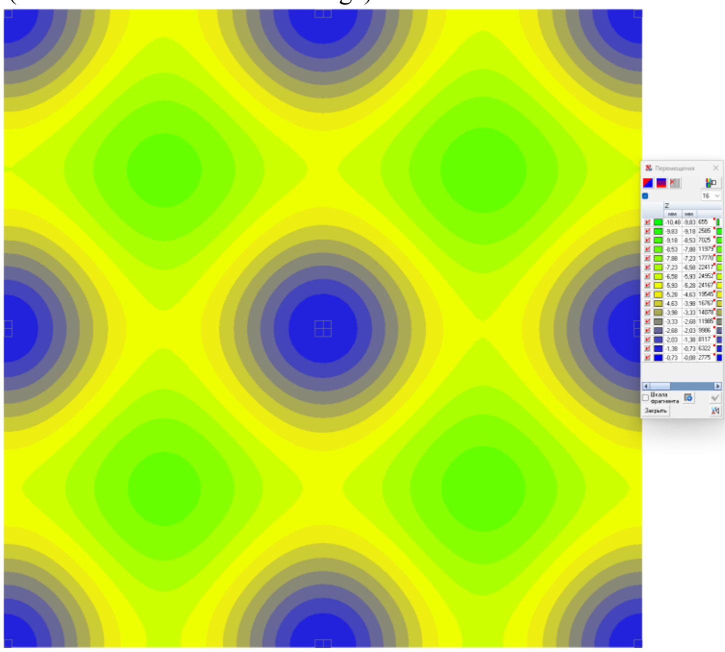
The stiffness characteristics of the sections were modeled using a two-line diagram of the deformation of reinforced concrete.

Results of the distribution of vertical displacements in structures:

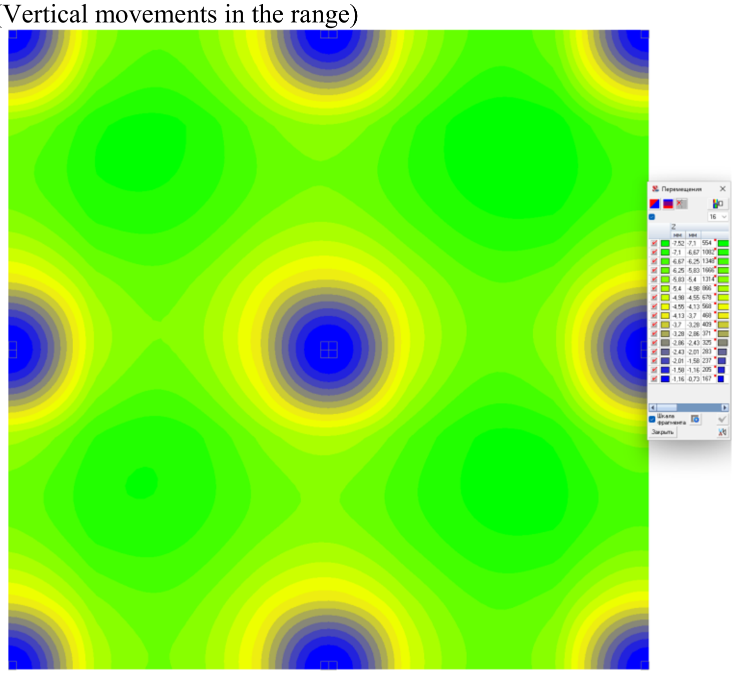
Model 1 (Vertical movements in the range 12.38 mm)



Model 2 (Vertical movements in the range)

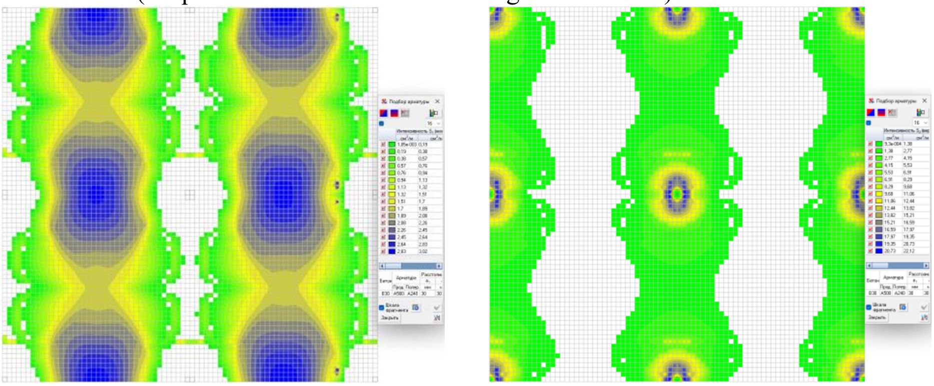


Model 3 (Vertical movements in the range)

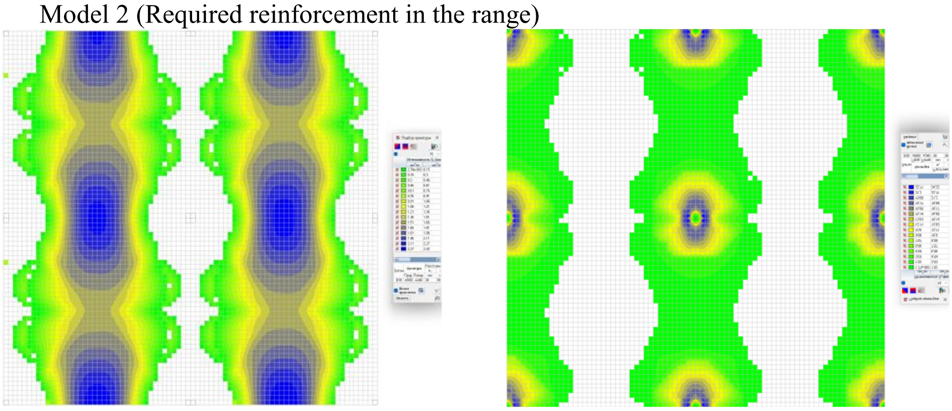


The results of the selection of reinforcement in the central zone of the structure (required reinforcement)

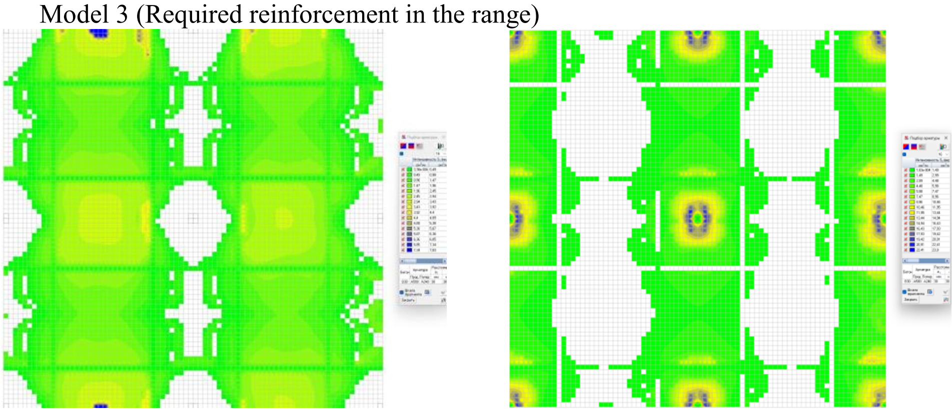
Model 1 (Required reinforcement in the range 3.02 sm2/m)



Model 2 (Required reinforcement in the range)



Model 3 (Required reinforcement in the range)



The summarized data are given in Table 1.

Table 1. The numerical results of the analysis

	Model 1	Model 2	Model 3
Required bottom reinforcement	3.02 (0%)	2.42 (-20%)	4,4 (46%)
Required upper reinforcement	22.12 (0%)	24,22 (+9%)	23,9 (+8%)

2 Conclusion

Based on the results of the data obtained , the following conclusions can be drawn:

1. The choice of a mechanism for modeling an overlap with a rigid capital has a significant character, including the nature of the stress-strain state and the final selection of reinforcement.
2. The generalized results show a significant deficit of the lower reinforcement in relation to the standard method of norms. The results obtained fully correspond to the results of field tests of building structures in terms of a significant up to 2 times deficit of lower reinforcement. At the same time, it is dangerous that this fact is practically not fixed by the deflection of the structure, and the main cracks are located along the upper face of the plate.
3. It is necessary, in addition to the calculated recommendations for punching, to perform additional surveys and prepare recommendations for taking into account the real rigidity of the capital when determining the forces in the overlap structure.

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