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STIFFNESS OF POST-TENSIONED GIRDERLESS FLOORS WITH DIFFERENT COLUMN GRIDS

The paper considers models of monolithic flat floor slabs with five spans in both directions. The cell sizes are 6×6m, 6×9m, and 6×12m. The calculation method is based on the application of temperature load and rope modeling of rod elements. It is shown that post-stressing should be used for slab side lengths over 7 m, as the installation of pre-stressed reinforcement for shorter lengths is less feasible and causes high economic costs.

Keywords: *reinforced concrete slab, stiffness, deflection, column grid, post-tension.*

Introduction

When designing structures with a prestressed system without adhesion to concrete, it should be taken into account that prestressed reinforcement does not transfer forces to the concrete over the entire length, but only at the anchor points at the ends of the structure, as well as at the bends in the ropes. Accordingly, the prestress must be assumed in the calculation as external forces applied to the structure. The forces formed at rope bends depend primarily on the rope geometry and the forces in it.

Works [1-8] are devoted to studies of girderless structures with prestressed reinforcement.

The calculation of prestressed elements in deformations (stiffness) is carried out according to the normative document[1]. The compression force *Np* is determined by taking into account all losses and $\gamma sp = 0.9$. Deflections are calculated by considering the strength of concrete at different stages of loading, including the transfer of compression forces.

The deflections of reinforced concrete elements are calculated under the condition:

$$f \leq f_{ult}, \tag{1}$$

where f is the deflection of the reinforced concrete element from the external load,

f_{ult} is the value of the maximum permissible deflection of a reinforced concrete element.

For bendable elements of a constant cross-section, along the length of the element without cracks, the deflections are determined by the general rules of structural mechanics using the stiffness of the cross-sections determined by the formula:

$$D = E_{b1} \cdot I_{red}, \tag{2}$$

where E_{b1} is the deformation modulus of compressed concrete, determined according to the load duration and taking into account the presence or absence of cracks,

I_{red} is the moment of inertia of the given cross-section in relation to its center of gravity, determined taking into account the presence or absence of cracks.

Materials and methods

The calculation method is based on the temperature load application and the modeling of ropes with rod elements [9].

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[1] Posobiye k SP 63.13330.2012 «Konstruktsii zhelezobetonnyye monolitnyye s napryagayemoy armaturoy bez stsepleniya s betonom. Pravila proyektirovaniya» (in Russian).

The modeling of the reinforcement of the central cell structure is carried out using a rod element in LIRA SAPR. The cross-section of the rod element is similar to the area of prestressed reinforcement in the floor slab as well as to the computer synthesis [10].

In this paper, models of flat floor slabs with five spans in both directions are investigated. The cell sizes are 6×6*m*, 6×9*m* and 6×12*m*, with the thickness of h = 0.3*m* (Fig.1). The size of the finite elements is 0.3×0.3*m*.

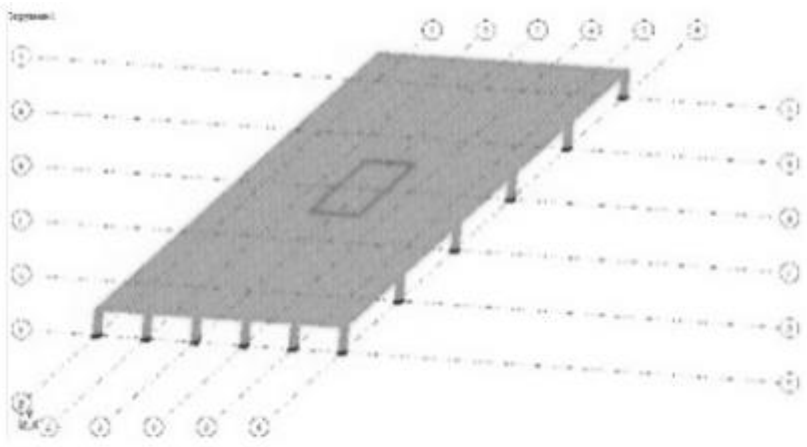

Fig. 1*. Scheme of a monolithic floor with rope-mounted reinforcement of the central cell*

Main characteristics of construction materials

Concrete class B30. Post-tensioned reinforcement in form of ropes (monostrends): K7O ($R_{sp,n}$ = 1860·10^3 kN/m^2, E_{sp} = 1.95·10^5 MPa, d = 15.7*mm*, *Asp* = 1.54cm^2). For calculation 5, 7 and 9 ropes are taken.

A uniformly distributed load q = 5 kN/m^2 is applied to the slab.

The reinforcement of the central cell is modeled by the rod elements in the structure, the section of which is similar to the prestressed reinforcement area in the element. To simulate prestressing in the reinforcement, a temperature load is applied to it, which is calculated according to the formula:

$$\Delta t = \varepsilon_0 / \alpha , \tag{3}$$

where $\varepsilon_0 = \sigma_0 / E_p$,

E_p is the modulus of elasticity of the prestressed reinforcement,

σ_0 is the controlled tension of the prestressed reinforcement,

α is the expansion coefficient of the reinforcing steel.

The deflections will be considered at characteristic points of the cell (Fig. 2).

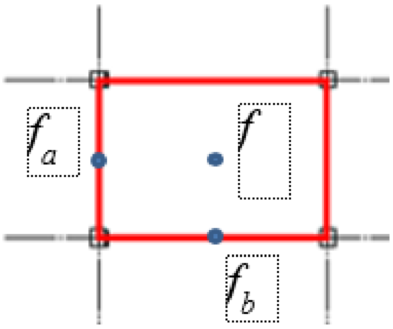

Fig.2. *Characteristic points of the central cell: f - deflection in the center of the cell, f_a - deflection in the center of the smaller side of the cell, f_b - deflection in the center of the larger side of the cell*

The prestress, calculated by the formula (3), is equal:

$$\varepsilon_0 = \frac{0.7 \cdot 1860}{1.95 \cdot 10^5} = 667 \cdot 10^{-5}.$$

$$\Delta t = \frac{667 \cdot 10^{-5}}{0.000012} = 556\ {}^0C.$$

The reinforcement of the structure's central cell was modeled using a rod element in LIRA SAPR 9 (Fig. 3).

A 6x6*m* slab cell with 5 ropes along the contour is modeled using flat (floor slab) and volumetric (columns) elements. The size of the finite element is 0.3x0.3*m*.

The floor slab is defined as a plate with a thickness of 300*mm*. The section of the column is 600x600*mm*.

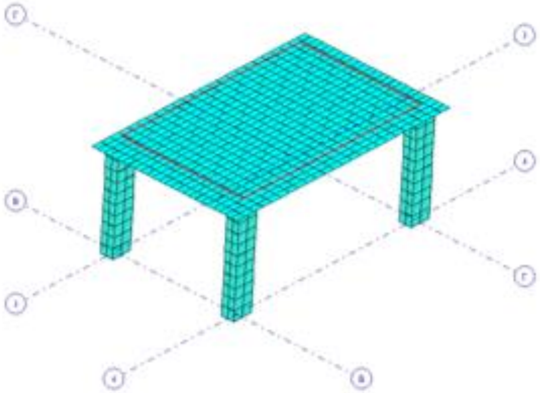

Fig. 3. *Calculation scheme for a 6x6m central cell with 5 ropes*

The results of the calculation are shown in Figures 4 and 5.

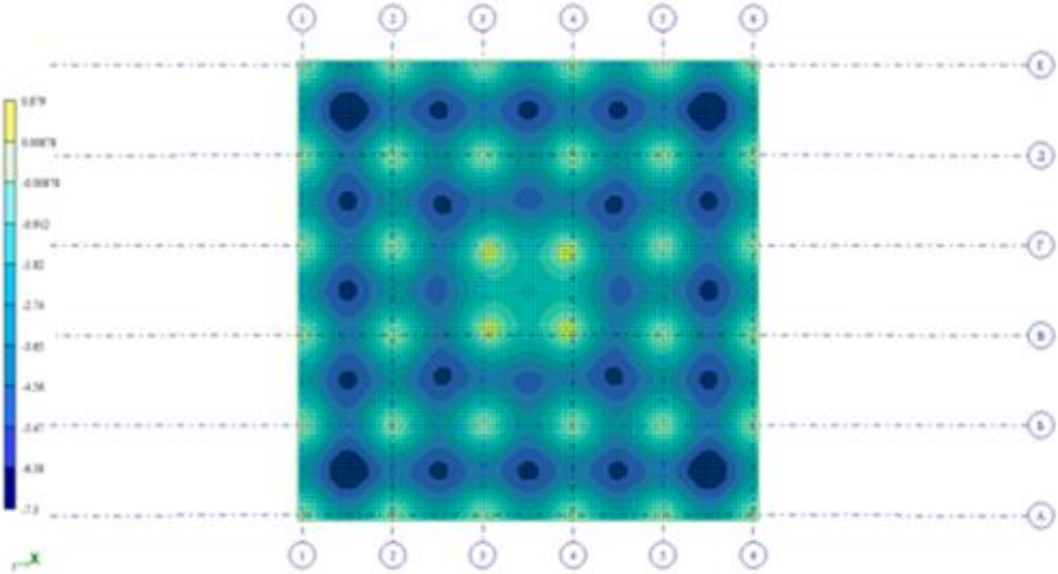

Fig. 4. *Travel along the Z axis of the entire slab*
with 6x6m cells and a central cell reinforced with 5 ropes

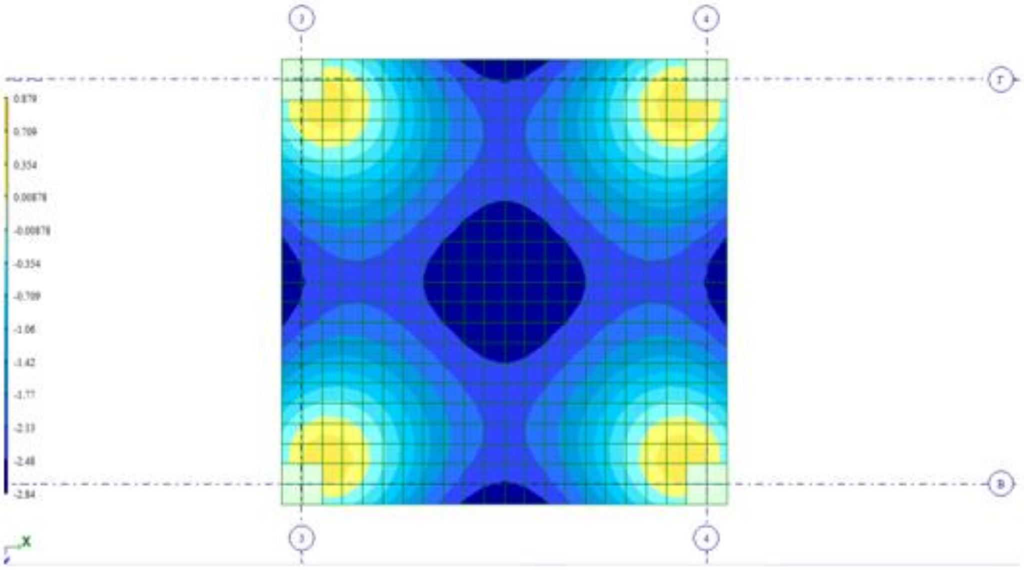

Fig. 5. *Travel along the Z axis of the central cell reinforced with 5 ropes*

Results

Based on the calculations carried out for the central cells 6x6, 6x9 and 6x12*m* with different numbers (5, 7, 9) of ropes, the deflection values were obtained, which are summarized in Table 1.

Table. Deflections of central cells with different numbers of ropes

Cell, *m*	Deflections (5 ropes), *mm*			Deflections (7 ropes), *mm*			Deflections (9 ropes), *mm*		
a×b	f_1	f_{a1}	f_{b1}	f_2	f_{a2}	f_{b2}	f_3	f_{a3}	f_{b3}
6×6	2.84	2.52	2.52	1.81	1.88	1.88	0.936	1.43	1.43
6×9	14.4	5.03	14.8	13	3.99	13.7	11.7	3.52	12.7
6×12	44.9	5.7	46	42.1	4.95	43.6	39.6	4.29	41.5

Table 1 shows that for a 6×6*m* square cell, with an increase of prestressing ropes from 5 to 7, the deflection in the center decreases from 2.84 to 1.81*mm* (1.57 times or 36.3%), and for 5 to 9 ropes - from 2.84 to 0.936 (3.03 times or 67%), in the center of "a" and "b" sides with an increase of the ropes from 5 to 7, the deflection decreases from 2.52 to 1.88*mm* (1.34 times or 25.4%) and for 5 to 9 ropes - from 2.52 to 1.43 (1.75 times or 43%).

For a 6×9*m* rectangular cell, with an increase of prestressing ropes from 5 to 7, the deflection in the center decreases from 14.4 to 13*mm* (1.1 times or 9.7%), and for 5 to 9 ropes - from 14.4 to 11.7 (1.23 times or 18.8%), in the center of the short side "a" with an increase of the ropes from 5 to 7, the deflection decreases from 5.03 to 3.99 *mm* (1.26 times or 20.7%), and for 5 to 9 ropes - from 5.03 to 3.52 (1.43 times or 30%), with an increase of the ropes from 5 to 7 in the center of long side "b", the deflection decreases from 14.8 to 13.7*mm* (1.08 times or 7.4%) and for 5 to 9 ropes - from 14.8 to 12.7 (1.17 times or 14.2%).

For a 6×12*m* rectangular cell, with an increase of prestressing ropes from 5 to 7, the deflection in the center decreases from 44.9 to 42.1*mm* (1.07 times or 6.2%), and for 5 to 9 ropes - from 44.9 to 39.6 (1.13 times or 11.8%), in the center of the short side "a" with an increase of the ropes from 5 to 7, the deflection decreases from 5.7 to 4.95*mm* (1.15 times or 13.2%), and for 5 to 9 ropes - from 5.7 to 4.29 (1.33 times or 24.7%), in the center of long side "b" with an increase of the ropes from 5 to 7, the deflection decreases from 46 to 43.6*mm* (1.06 times or by 5.2%), and for 5 to 9 ropes - from 46 to 41.5 (1.11 times or by 9.8%).

The results show that with an increase of the long side of the slab cell from 5 to 7*m*, the effect on the deflection of the installation along the contour of a larger number of ropes is reduced significantly. For example, for the center of the cell, the effect on the deflection of installing 9 ropes compared to 5 ropes is reduced from 67% to 11.8%, for the short side "a" - from 43.3% to 24.7%, for the long side "b," - from 43.3% to 9.8%.

Conclusion

1. Prestressing is recommended to apply when the side of the slab is longer, than 7*m*, since with a shorter side length, the installation of prestressing reinforcement is less expedient and entails high economic costs.
2. The use of post-tensioned ropes on the shorter side of a rectangular cell is unreasonable since the deflection on the short side meets the normative value even before the prestressed reinforcement is introduced into the model.
3. It is expedient to install more ropes for longer cells. For example, according to the calculation, it is not reasonable to install less than 7 ropes for a 6×9*m* cell, and it is expedient to install 9 ropes or more for a 6×12*m* cell. However, the use of 9 or more ropes can create large flexures at the base of the column, which would require additional reinforcement and strength testing of the compressed concrete.
4. With an increase of the long side of the slab cell from 6 to 12*m*, the effect on the deflection of the installation along the contour of larger number of ropes decreases significantly: for the center of the cell, it reduced from 67% to 11.8%, for the short side "a" - from 43.3% to 24.7%, for the long side "b" - from 43.3% to 9.8%. This indicates that for cells with sides of 7*m* or more, it is more expedient to use a average number of ropes but with a higher prestressing force to reduce the financial cost of their installation.
5. The method of modeling prestressed ropes using rod reinforcement with the application of a temperature load is simple, accurate, and easy to use.

References

[1]. V.S. Kuznetsov, Yu.A. Shaposhnikova, K opredeleniyu progibov bezbalochnykh perekrytiy, armirovannykh prednapryazhennoy diagonal'noy armaturoy bez stsepleniya s betonom. Nauchnoye obozreniye, 21, 2015, 50-55 (in Russian).

[2]. A.T. Parinov, Predvaritel'no napryazhennyye zhelezobetonnyye konstruktsii, armirovannyye kanatami (eds. V.I. Gritsyk, I.A. Parinov). Nauka-Spektr, Rostov-on-Don, 2010 (in Russian).

[3]. I.O. Pogrebnoy, V.D. Kuznetsov, Bezrigel'nyy predvaritel'no napryazhennyy karkas s ploskim perekrytiyem. Inzhenerno-stroitel'nyy zhurnal, 3, 2010, 52-55 (in Russian).

[4]. Bijan O Aalami, Allan Bommer, Design fundamentals of post-tensioned concrete floors. Phoenix, 1999.

[5]. A.G. Tamrazyan, I.K. Manayenkov, K raschetu ploskikh zhelezobetonnykh perekrytiy s uchetom fakticheskoy zhestkosti secheniya. Nauchnoye obozreniye, 8, 2015, 87-92 (in Russian).

[6]. A.G. Tamrazyan, I.V. Dudina, Vliyaniye izmenchivosti kontroliruyemykh parametrov na nadezhnost' prednapryazhennykh balok na stadii izgotovleniya. Zhilishchnoye stroitel'stvo, 1, 2001, 16-17 (in Russian).

[7]. A.G. Tamrazyan Calculation of reinforced concrete plates with hole at long-term loading. IOP Conference Series Materials Science and Engineering, 365 (5), 2018, 052021. DOI:10.1088/1757-899X/365/5/052021

[8]. A.G. Tamrazyan, The Assessment of Reliability of Punching Reinforced Concrete Beamless Slabs under the Influence of a Concentrated Force at High Temperatures. Procedia Engineering, 153, 2016, 715-720. DOI:10.1016/J.PROENG.2016.08.231

[9]. D.V. Portayev, Raschet i konstruirovaniye monolitnykh prednapryazhennykh konstruktsiy grazhdanskikh zdaniy. ASV, Moscow, 2011(in Russian).

[10]. A.A. Askadskiy, T.A.Matseyevich, Komp'yuternyy sintez setchatykh polimerov. Doklady Rossiyskoy akademii nauk. Khimiya, nauki o materialakh, 494 (1), 2020, 77-84 (in Russian).

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