

Deflections of slabs of monolithic flat ceilings with high-strength reinforcement without adhesion to concrete

Vitaliy Kuznetsov¹ and Yulia Shaposhnikova²

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

E-mail: ¹vitalik.kuznetsov2016@yandex.ru ²yuliatalyzova@yandex.ru

Abstract. The article deals with the effect of prestressed reinforcement without adhesion to concrete on the deflections of a slab of monolithic flat overlapping. One of the drawbacks that prevent the wide spread of beams, is the development of excessive deflections in the center of the slab. The aim of the study is to determine the level of influence of prestressed reinforcement without adhesion to concrete on the deflections of a slab of monolithic slabs, and also to compare the results on the deflection of plates with the contour and diagonal arrangement of the prestressed reinforcement. The shape of the rope is represented by the part of the parabola passing through the points of the rope support. On the support, the vertical and horizontal components of the reaction are determined by the longitudinal force in the rope and the exit angle of the rope. Plates of monolithic flat overlap 9x9m with diagonal and contour pre-stressed reinforcement were investigated. The influence of the arrangement of prestressed reinforcement on the deflections was evaluated in the Scad Office program. The deflection of the guy was simulated in the form of nodal forces, the number of which depends on the accepted grid, and the magnitude of the coordinate of the node point and the value of the resistance force on the support. According to the results of the study, the use of high-strength reinforcement without adhesion to concrete reduces the deflections in the center of the plate to 14.5% compared to the plate without prestressing. The difference in deflections in the center of the plate, with contour and diagonal ropes, is 16.33%. Analysis of the results allows a positive assessment of the use of high-strength reinforcement without adhesion to concrete to reduce the deflections of slabs without beams.

Key words. Monolithic flat overlap, monostrend, tensioning armature, deflection, rope, diagonal arrangement of prestressed reinforcement.

1. Introduction

One of the drawbacks preventing the wide spreading of flat ceilings is the development of excessive deflections in the center of the slab. Thus, at spans of more than 7 meters, Russian standards recommend that capital be built up to reduce deflections or additionally use a high-strength prestressed reinforcement without adhesion to concrete, without providing information about the calculation [1].

The aim of the study is to determine the level of influence of prestressed reinforcement without adhesion to concrete on the deflections of a monolithic flat overlap plate, and also to compare the results on the deflection of plates with the contour and diagonal arrangement of prestressed reinforcement.

The object of the study were slabs of monolithic flat roofing 9x9 m with a diagonal and contour prestressed reinforcement. The thickness of the plates is $h = 200$ mm, the protective layer $a=a'=30$



mm. Class of concrete B30. Section of the column 300×300 mm. Prefabricated reinforcement is used - three ropes of class K7O monostrend in each direction [14]. The area of one rope is $A_{sp}=1.54 \text{ cm}^2$, $R_{s,n}=1860 \text{ MPa}$, $E_{sp}=195000 \text{ MPa}$. The level of prestressing taking into account the elastic compression and all losses $\sigma_{sp0}=0.7 \cdot 1860=1302 \text{ MPa}$. The prestressing force is $N_{sp0}=n \cdot \sigma_{sp0} \cdot A_{sp}=3 \cdot 1.54 \cdot 10^{-4} \cdot 1302 \cdot 10^3=601.52 \text{ kN}$. The initial deflection of the ropes during fabrication $f_0=h-a-a'=200-30-30=140 \text{ mm}$, the relative deflection at the center of the plate $l/200$, absolute - $(900-30)/200=4.35 \text{ cm}$.

In European [2 - 4] and in American [5] norms systems with cohesion with concrete and without it are separated, but for the latter they are limited by the coefficients of pre-stress level limitation. The detailed justification of the introduced coefficients in the norms is not indicated.

Several modern works on this direction, taking into account the work of prestressed reinforcement without adhesion to concrete, are devoted to a monolithic overlap only with the orthogonal arrangement of prestressed reinforcement [6 - 13].

The methods and conditions for fixing ropes in monolithic slabs can be chosen in accordance with [15-19].

Some questions of the use of prestressed diagonal reinforcement without adhesion to concrete in non-beam ceilings and its effect on the strength of the slab of such an overlap were considered by the authors in the previously published works [20 - 26].

2. Methods

The tensile reinforcement in the form of several ropes (1-5 pieces) can be laid between the columns along the contour or diagonally. The position of the ropes along the height of the cross-section, as a rule, corresponds to the expected moment diagram and, with a uniformly distributed load, can be represented as part of a parabola or circle.

In work, the form of the rope position is represented by a part of the parabola passing through the supports A and B, and the height by the deflection f (Figure 1).

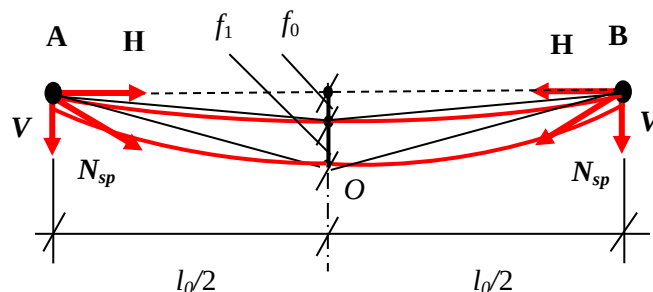


Figure 1. To determine the deflections of the slab

The initial parabola equation

$$y = -\frac{4f}{l^2} x(x-l). \quad (1)$$

The area of a parabola is determined by integrating equation (1)

$$S_1 = \frac{4f}{l^2} \int_0^x x(l-x)dx. \quad (2)$$

For limits from 0 to l , the area of the parabola is

$$S_1 = \frac{4f}{l^2} x^2 \left(\frac{x}{3} - \frac{l}{2} \right) = \frac{2fl}{3}, \quad (3)$$

f – deflection;

x, y – coordinates;

l – distance between the column axes diagonally or along the contour, is adopted depending on the type of calculation.

The vertical component (deflection) of ropes depends on the angle of inclination of rope α and at any point i the repulsion is equal to

$$P_i = N_{sp} \sin \alpha_i. \quad (4)$$

N_{sp} – prestressing force.

On the support, the vertical reaction V and the horizontal H are determined by the longitudinal force in the rope and the exit angle α . The angle α is differentiated by equation (1)

$$y' = \operatorname{tg} \alpha = -\frac{4f}{l^2} (2x - l) \quad (5)$$

For $x=0$ $\operatorname{tg} \alpha = 4f/l$. The angle α is calculated.

The rebound can be represented as the total area of two half-parabolas (Figure 2)

$$S_2 = p_{\max} l / 3 \quad (6)$$

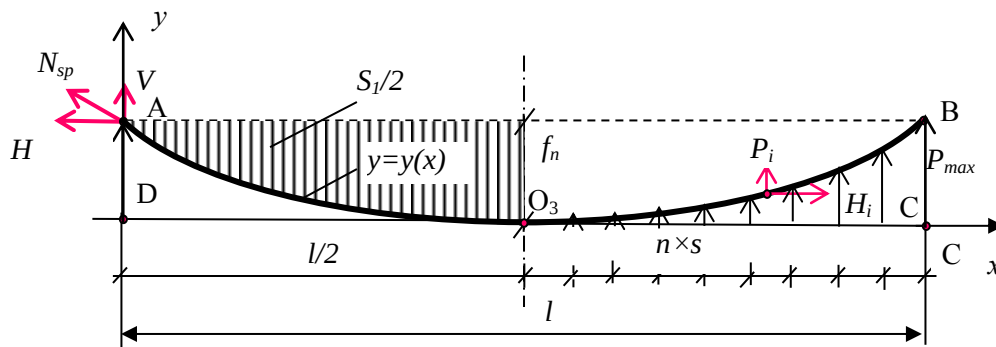


Figure 2. Calculation of rope rebound

The maximum value of the support $p_{\max}$ is determined from the condition that the sum of the projections of all forces on the ordinate axis is zero. On the vertical reaction on the support V , the maximum value of the support $p_{\max}$.

$$2V = p_{\max} l / 3, \quad (7)$$

Consequently

$$p_{\max} = 6V / l. \quad (8)$$

The distribution of the resistance along the length at the origin of coordinates at the point A is expressed by the formula (9)

$$P_i = -p_{\max} - \frac{4p_{\max}}{l^2} x(x - l) \quad (9)$$

or

$$P_i = -p_{\max} \left(\frac{4}{l^2} x(x - l) \right). \quad (10)$$

In accordance with formula (6), the angle of exit of the guy on the support and the vertical reaction of the support V were determined. The maximum p_{max} and current p_i values of the parabolic load intensity were calculated from formulas (8 and 10).

3. Results

When comparing deflections, it was taken into account that the ratio of the maximum deflection of the over-column strip to the deflection at the center of the span, in accordance with [22], is equal to $(0,6\div 7)f$. This circumstance is important when assessing the effectiveness of prestressing in non-beam ceilings.

The values of node loads for a finite element of 0.5×0.5 m up to the axis of symmetry are shown in Figure 3.

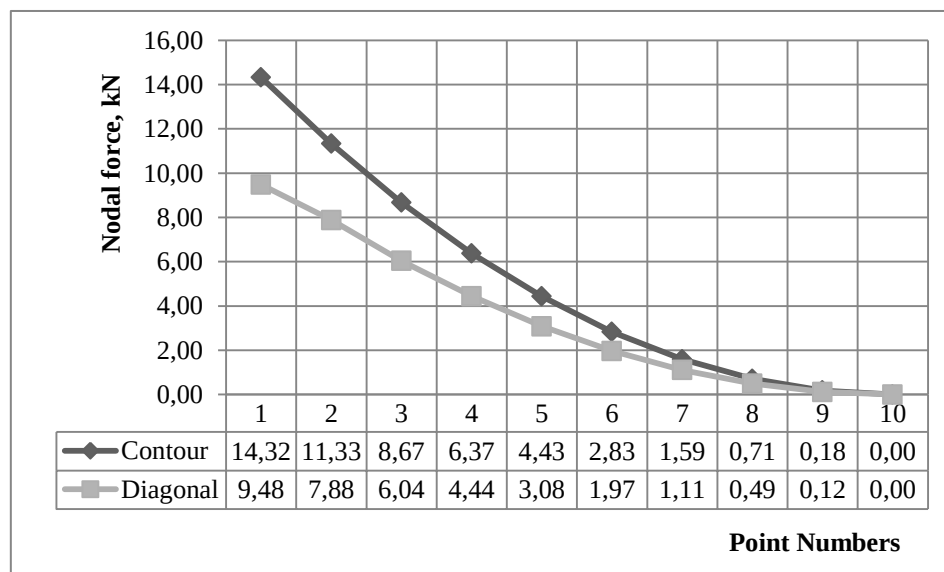


Figure 3. Distribution of nodal forces along the length of the rope

The influence of the arrangement of prestressed reinforcement on deflections was evaluated in the Scad Office program [27]. The grid was taken at 0.5×0.5 m, the anchoring in the corners is rigid. The load is evenly distributed $q=5$ kN/m². The rebound was represented in the form of nodal forces, the number of which depends on the accepted grid, and the magnitude of the node's coordinate and the value of the support on the support. The results of calculations of plate deflections for diagonal and contour positioning of ropes, as well as without ropes are presented in Figures 4, 5 and 6.

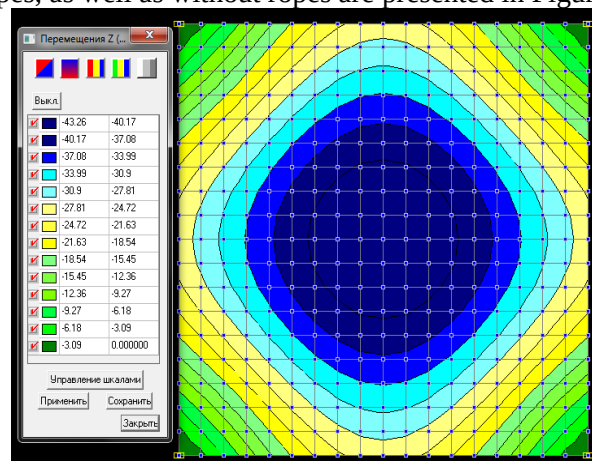


Figure 4. Distribution of plate deformation without prestressing

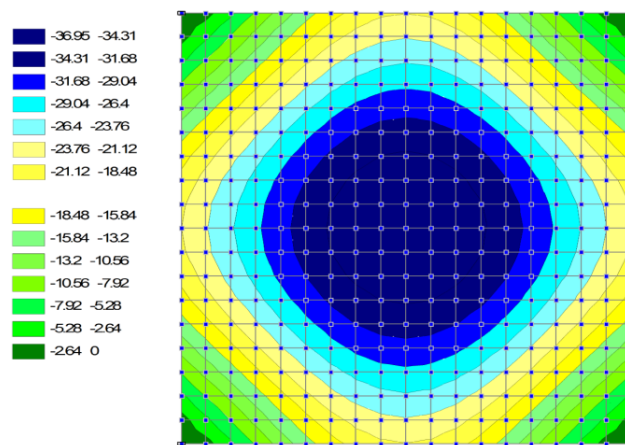


Figure 5. Distribution of deformations of a plate with a diagonal prestressed reinforcement

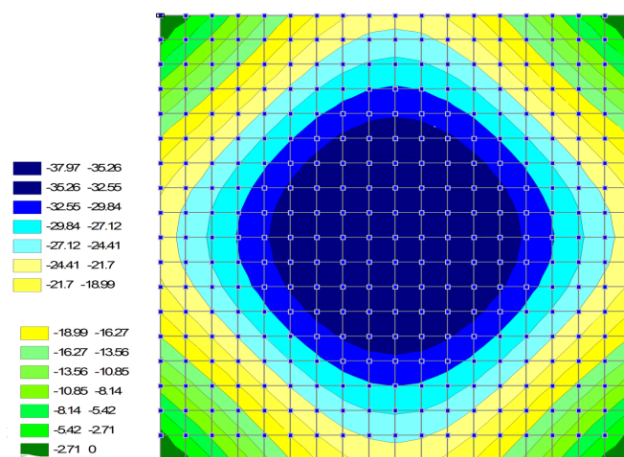


Figure 6. Distribution of deformations of a plate with a contour pre-stressed reinforcement

Comparative results of the maximum deflections in the center of the plate for different rope locations are shown in Table 1.

Table 1. The deflections in the center of the plate with different ropes

The level of prestressing	Deflections in the center of the plate f , mm				
	Without prestressing	With contour ropes		With diagonal ropes	
σ_{sp0} , MPa		Absolute, mm	Reduction of deflection, %	Absolute, mm	Reduction of deflection, %
1302	43.26	36.96	14.56	37.97	12.23

4. Discussion

In recent years, more attention has been paid to monolithic ceilings. Frame-monolithic is now one of the most popular types of construction. Since the development of excessive deflections in the center of the slab is one of the drawbacks preventing the wide distribution of beams, therefore to expand the range of spans and loads for buildings of this type, a fuller study of the work of monolithic ceilings is needed.

As a result of the study, the authors established the levels of influence of prestressed reinforcement without adhesion to concrete on the deflections of a monolithic bezel, and a comparison was made between the results of deflection of plates with the contour and diagonal arrangement of the prestressed reinforcement.

Knowing the values of deflections is necessary when calculating the strength of monolithic beams without overlapping with simultaneous use of conventional and high-strength reinforcement in order to prevent constriction of the reinforcement and maximum use of its strength characteristics.

5. Conclusions

1. Analysis of the results allows a positive assessment of the use of high-strength reinforcement without adhesion to concrete to reduce the deflections of slabs without beams.

2. The use of stressed reinforcement without adhesion to concrete reduces the deflections in the center of the plate to 14.5% in comparison with the plate without prestressing.

3. The difference in deflections in the center of the plate, with contour and diagonal ropes, is 16.33%. However, with the diagonal arrangement, the total length of the ropes (between the column axes) is 25.46 m, and for the contour 36 m, i.e., more than 1.4 times, and for tensioning the diagonal reinforcement on both sides only 4 working points are required, and the contour line - 8, Which is important from the point of view of economy of a design.

4. The effect of prestress on the movement of the plate is regulated by the number of ropes and the initial level of stress. An increase in the height of the plate leads to an increase in the initial deflection, an increase in the forces of repulsion, and a reduction in deflections. However, in order to satisfy the requirements of the first group of ultimate strength states, the establishment of the pre-stress level of the ropes should be made taking into account the possible achievement of design stress in the high strength reinforcement.

References

- [1] 2007 SP 52-103-2007 Concrete monolithic construction of buildings
- [2] 1998 La norme NBN EN 1992-1-1. Eurocode 2
- [3] 2006 Manual for the Design of Concrete Building Structures to Eurocode 2 *Institution of Structural Engineers* (London)
- [4] 2010 BS8110. British Standard. Structural use of concrete
- [5] 2004 ACI 318-05. Building Code Requirements for Structural Concrete and Commentary
- [6] Dzjuba I S, Vatin N I and Kuznecov V D 2008 Solid-span ribbed slab with aftertension *Civil Engineering Journal* **1** pp 5 - 12
- [7] Kishinevskaja E V, Vatin N I and Kuznecov V D 2009 Reinforcement of building constructions with aftertension concrete *Civil Engineering Journal* **3** pp 29-32
- [8] Muttoni A 2012 *Conception et dimensionnement de la precontrainte* (Lausanne: Ecole polytechnique federale)
- [9] Paille G M 2013 *Calcul des structures en beton arme* (Paris: AFNOR)
- [10] Seinturiere R 2006 *Etat Limite de service* (IUT, Génie: Civil de Grenoble)
- [11] Morozov A BIM in Russia: prestressed concrete - two approaches for modeling in Revit-Robot Available at: <http://bim-fea.blogspot.ru/2012/09/bim-revit-robot.html>. Accessed: Dec. 10, 2016
- [12] Portaev D V 2011 *Calculation and design of monolithic prestressed structures of civil buildings* (Moscow: ASV) p 248

- [13] Portaev D V Experience the calculation of monolithic prestressed structures in SCAD software complex using the method of equivalent loadings. Available at: <http://scadsoft.com/download/Portaev2012.pdf>. Accessed: Dec. 10, 2016
- [14] Citnikov S L and Mirjushenko E F 2011 *Method for manufacturing prestressed concrete structures and monostrend* (Moscow: Patent for the invention № 2427686) Available at: <http://www.freepatent.ru/patents/2427686>. Accessed: Dec. 10, 2016
- [15] Methods for fixing the valve by pulling Available at: <http://msd.com.ua/tehnologiya-betonnyx-i-zhelezobetonnyx-izdelii/sposoby-zakrepleniya-armatury-pri-natyazhenii/>. Accessed: Dec. 10, 2016
- [16] 2010 TKP 45-5.03-135-2009 (02250) Reinforced concrete prestressed structures without coupling reinforcement with concrete. Design Rules (Minsk: Ministry of Architecture and Construction of Belarus)
- [17] Information Sheet CPM Builder. Elements of prestressing systems. Coupler type M / ME. Available at: <http://psk-stroitel.ru/oborudovanie/elementy-sistem-prednapryazheniya/kupler-tipa-m-me.html>. Accessed: Dec. 10, 2016
- [18] 2005 ETA-06/0022. Dywidag bonded post-tensioning system for 3 to 37 strands (140 and 150 mm²)
- [19] 2004 ETA-03/0036. Post-tensioning kit for prestressing of structures with unbonded monostrands for concrete
- [20] Bardysheva Yu A, Kuznecov V S and Talyzova Yu A 2014 Constructive solutions beamless floors without capitals with prestressed reinforcement *Vestnik MGSU* **6** pp 44-51
- [21] Kremnev V A, Kuznecov V S and Talyzova Yu A 2014 Features of distribution of stresses in the slab beamless floors of prestressing force *Vestnik MGSU* **9** pp 48-53
- [22] Kuznecov V S and Shaposhnikova Yu A 2015 By definition, the stress in the reinforcement without adhesion to concrete slabs in beamless *Industrial and civil engineering* **3** pp 50-53
- [23] Kuznecov V S and Shaposhnikova Yu A 2016 Determination of stress-strain state beamless floors with mixed reinforcement *Industrial and civil engineering* **2** pp 54-57
- [24] Kuznecov V S and Shaposhnikova Yu A 2016 The strength of prestressed reinforced beamless floors in the stages of production and destruction *System technologies* **1/18** pp 85-92
- [25] Kuznecov V S and Shaposhnikova Yu A 2015 Determination of deflections beamless floors reinforced with prestressed diagonal reinforcement without adhesion to concrete *Scientific Review* **21** pp 50-55
- [26] Kuznecov V S and Shaposhnikova Yu A 2016 On the definition deflections of monolithic slabs with the mixed reinforcing at the stage of limit equilibrium *MATEC Web of Conferences* (Web of Science) Available at: <http://www.matec-conferences.org/>, 2016g. Accessed: Dec. 10, 2016
- [27] Karpilovskij V S 2011 *SCAD OFFICE. Computer complex Scad* (Moscow: ASV) pp 274-283