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РОЗРАХУНОК МІЦНОСТІ МІЖКОЛОННИХ ПЛИТ НА ОСНОВІ МЕТОДУ ВІРТУАЛЬНИХ РОБІТ

***Анотація** . Розроблено методику розрахунку несучої здатності міжколонної плити перекриття безконсольно-безкапітельно-безбалкової каркасної конструктивної системи кінематичним способом за методом граничної рівноваги. Також приділяється увага встановленню місця розташування ліній пластичних шарнірів.*

***Ключові слова:** навантаження, зусилля, пластичний шарнір, розрахункова схема, розрахунок кінематичним методом.*

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CALCULATION OF INTER-COLUMN SLABS BEARING CAPACITY ON THE BASIS OF THE VIRTUAL WORKS METHOD

***Abstract.** The method of bearing capacity calculation of the inter-column slabs of flat slab frame system is developed by a kinematic way based on the ultimate equilibrium method. The basis of the study is the kinematic method of the limit equilibrium method and its application to calculate the load-bearing capacity of the inter-column slab in flat slab structural system, as well as to select the area of the working reinforcement. Attention is also paid to establishing the location of the lines of plastic hinges formation.*

***Keywords:** load, effort, plastic hinge, design scheme, kinematic method calculation.*

Introduction. The condition of the housing stock and providing citizens with housing is an urgent and, at the same time, the least regulated problem of the Ukrainian economy. The availability of housing for the general public and the provision of socially disadvantaged groups is one of the priority areas of public policy in the field of construction. Over the years, the housing queue and the low availability of population compared to European countries - testifies to the increasing relevance of affordable housing at the regional and national level. One of the solutions to this problem is the use of a flat slab structural system [1].

Kinematic method for bearing capacity calculation. Replacement frame calculation is provided in many sources. This method of calculation has its advantages and disadvantages,

but the main problem is that such a scheme does not correspond to the actual work of the frame under load. This is especially true for overlapping.

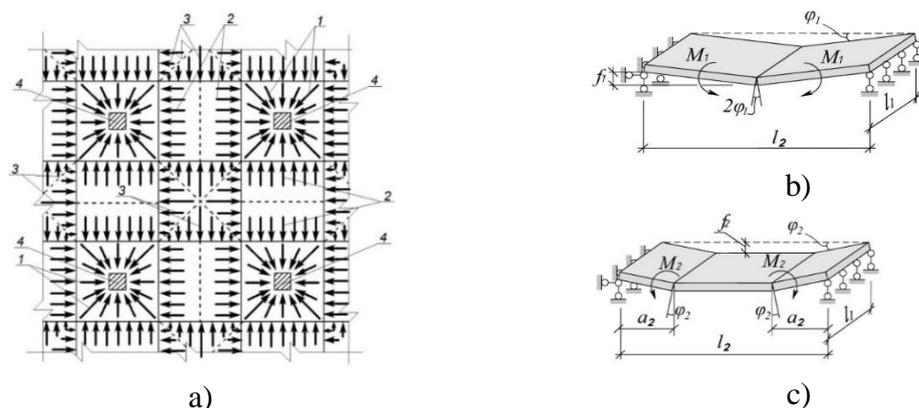


Figure 1 – a) the Load redistribution schemes between overlapping elements: 1 - loading the column; 2 - distribution of load from intercolumn slabs to overcolumned slabs; 3 - distribution of load from middle slabs to intercolumn slabs; 4 – columns

Two possible kinematic schemes for the destruction of the intercolumn slab: b) first scheme, c) second scheme

To determine the internal forces in the cross-section of the slab it is proposed to use the boundary equilibrium method implemented in the kinematic way. On the basis of this method the equation of virtual works equality from external q and internal M efforts on possible slab movements (Fig. 1) is presented in the form:

$$W_{Ed} = W_{Rd} \quad (1)$$

According to the applied kinematic scheme, the destruction of the intercolumn slab occurs because of the formation in it of a linear plastic hinge from the bottom in the middle of the slab [1]. In this case, it is loaded over the whole area by uniformly distributed loads q and triangular loading on both opposite sides with a maximum value of ordinate $q \cdot l / 2$ in the middle of the span (triangular loading on the slab is transferred (Fig. 1) from its two adjacent middle slabs at the moment of separation disks in the limit state) [1].

The following designations are introduced on the calculated kinematic scheme of the intercolumn slab fracture: l – slab spans in both directions (it is taken into account that in practice the slab has the same dimensions in two directions l); M_1 – bending moment in span; $M_2 = 50 \text{ kN}\cdot\text{m/m}$ – bending moment that arises at the joint of inter-columned and overcolumned slabs (value is obtained from experimental investigation); f – virtual deflection of the intercolumn slab in the stage of its destruction; φ – is the virtual rotation angle of the formed discs of the slab in the stage of its destruction.

According to the calculation scheme as a result of rotation of disks 1 and 2 (moments M_1 and M_2) virtual work is carried out (Fig. 1,b):

$$W_{Rd} = W_M = M_1 \cdot \delta_j + M_2 \cdot \delta_j \quad (2)$$

In equation (1) the moments M_1 and M_2 are distributed per meter, that is, their unit is $\text{kN}\cdot\text{m/m}$.

To facilitate the derivation of the formula for calculating W_q , the calculation scheme shown in Fig. 1 is represented by two schemes. In the first one, the inter-column slab is loaded only with a uniformly distributed load q (Fig. 2), and in the second one, the inter-column slab is loaded only with a triangular load with maximum load ordinates $q \cdot l / 2$ in the middle of the span (Fig. 2). Using the following diagrams we can write that in the stage of destruction of the intercolumn slab virtual work from the action of external load q :

$$W_{Ed} = W_q = W_{1q} + W_{2q}, \quad (3)$$

in which W_{1q} is a virtual work from a uniformly distributed load according to the first loading scheme (Fig. 2), and W_{2q} is a virtual work from a triangular load according to the second loading scheme (Fig. 2).

The equation to determine the first component of virtual work in equation (3):

$$W_{1q} = \int_A \delta y(x) \times q \times dA = q \times V = 0,25 \times l^3 \times q \times \delta j. \quad (4)$$

In the equation (4) V is the volume of the prism, formed by the turns of disks 1 and 2.

The expression to determine the second component of virtual work in equation (3) for the intercolumn slab loaded with only triangular load ($q(x) = q \cdot x$; $y(x) = x \cdot \text{tg} \varphi = x \cdot \varphi$):

$$W_{2q} = 2 \times 2 \times \int_0^{0,5l} \delta q(x) \times l \times y(x) = q \times \frac{l^3}{6} \times \delta j. \quad (5)$$

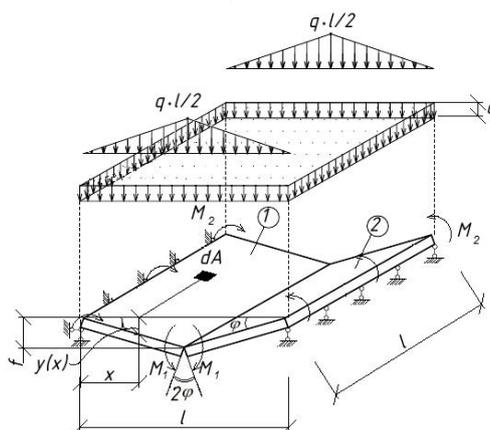


Figure 2 Design kinematic scheme of the intercolumn slab destruction in the limit equilibrium state: 1, 2 - disks of the slab

After substitution (4) and (5) in (3) we have that external forces perform virtual work

$$W_q = \frac{q \delta j l^3}{4} + \frac{q \delta j l^3}{6}. \quad (6)$$

After substitution (2) and (6) in (1) it is obtained that the equation of virtual works (1) is reduced to the following:

$$q = \frac{24 \times M_1 + 12 \times M_2}{5 l^2}, \quad (7)$$

Equation (7) gives the formula for calculating the load-bearing capacity of the intercolumn floor slab.

In a similar way, substituting expressions (5) and (4) into equation (1) for the second kinematic failure scheme (Fig. 1,c) we obtain the value of the limit load:

$$q = \frac{12 M_1 \times k_m \times l + 6 M_2}{a_2 (9 l^2 - 6 l \times a_2 - 4 a_2^2)} \quad (8)$$

Conclusions. In this scientific research, we have obtained the formulas of the intercolumn slab load-bearing capacity of the flat slab frame structural system, which take into account the deformation compatibility with adjacent slabs. This, in turn, allows you to more accurately determine the bearing capacity of the inter-column slabs, and accordingly to more accurately calculate the area of the main reinforcement in the considered slab.

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