https://doi.org/10.52340/building.2024.01.69.09

SCIENTIFIC-TECHNICAL JOURNAL,"BUILDING" #1(69), 2024

A RECTANGLE SUPPORTED ON ALL FOUR SIDES DETERMINATION OF THE MAXIMUM NORMAL STRESSES IN THE SLAB ONE OF THE SIMPLIFIED METHODS

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Abstract: The article presents the etermination of maximum bending, bending moments and normal stresses in rectangular slabs supported by four lateral hinges by one of the simplified methods, which is called the method of intersecting rods.

Key words: calculation scheme of the plate, set of sub-schemes, maximum deflection of the slab, bending moments and normal stresses.

Introduction

One of the most common elements in buildings is a slab, which is calculated using the theory of plates. If a continuous body (continuum) is meant in the geometric model of the calculation scheme of the plate, then its calculation by the theory of classical elasticity will be reduced to solving a system of differential equations of complex structure, which is associated with great (often insurmountable) mathematical difficulties [1,2,3]. Because of this, a technical theory has been developed for plates in engineering practice, the basis of which is the hypothesis of a rigid normal (Kirchhoff's hypothesis. Using this hypothesis, a private differential equation is derived in the technical theory of plates. The solution of this equation in a direct way (i.e. by integrating it) is possible only for some simple cases (in particular, for circular and ring plates). Therefore, they resort to indirect solution methods, for example, the representation of the bending function in the form of trigonometric rows (the methods of Navier, Levy and others), which are also quite time-consuming [6]. Therefore, it was necessary to create such methods that would reduce within the framework of the technical theory Computational operations. One of these methods is based on the representation of the calculation scheme of a slab with intersecting rods. The representation of the calculation scheme as sub-schemes according to the boundary conditions transforms a two-variable problem into two one-variable problems, which are combined by constructing the equation of compatibility of deformations representing the condition of body continuity in the form of canonical equations of the method of known forces. The latter can be built only for a specific accounting scheme [7,8].

The construction of compatibility equations considering only bending deformations gives results of insufficient accuracy with the traditional method. compared to the results obtained. A way to overcome this inaccuracy is to consider twisting deformations along with bending deformations.

Main part

Option I

Fig. 1 presents the so-called The given system, i.e., a rectangular plate hinged at all four edges, is subjected to a uniformly distributed load of intensity q. Our objective is to determine the maximum deflections, bending moments, and normal stresses along the major axis passing through the center of gravity of the slab.

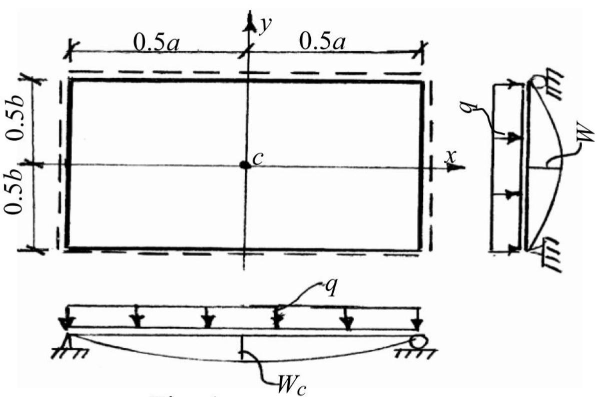

Fig. 1

Fig.To do this, let's present the given system (slab) with a combination of ψ and ω stone schemes (Fig. 2). ψ According to the diagrams, the tile is attached only by the right and left edges, and we mean that it has turned into a rod,

which is loaded as With an external (operating) uniformly distributed load with a given q intensity, as well as with an equally distributed interaction load with an intensity q*, which are actual parameters and act on the rods presented in the sub-diagrams as external force factors. ω In the sub-scheme, only the actual load with intensity q* acts on the rod. We can put a load with a real intensity q on the rod of the ω subcircuit, and then a fictitious load with an intensity of q* will act on the rod of the ψ subcircuit.q A load with an intensity of q=1 causes a displacement; a load with an intensity of q=1 causes a displacement, and the same q=1 load causes a displacement in the rod of the sub-circuit. All these displacements are defined only considering bending deformations. in factBy the scheme ω, the bending of the rod causes ω *By the scheme, the stem is twisted into the stem of the scheme and vice versa. Therefore, it is necessary to determine the vertical displacements caused by the twisting moment in both the ψ, and ω subframe rods. These are , and .The deflection causes* $\Delta^{\psi m}(x)$,

The vertical displacements, taking into account the joint action of the bending moment and the twisting moment, will be:

$\Delta(x) = \Delta^{\psi q}(x) - \Delta^{\psi m}(x)$;

$\Delta(x) = \Delta^{\psi q}(x) - \Delta^{\psi m}(x)$;

$$\delta(y) = \delta^{\omega q}(y) - \delta^{\omega m}(y). \qquad (1)$$

Since these displacements reach a maximum at the point c where the x and y axes intersect, therefore

$\Delta^{\psi}_{\max} = \Delta^{\psi q}_{c} - \Delta^{\psi m}_{c}$; $\qquad \delta^{\psi}_{c} = \delta^{\psi q}_{c} - \delta^{\psi m}_{c}$;

$$\delta^{\omega}_{c} = \delta^{\omega q}_{c} - \delta^{\omega m}_{c}. \qquad (2)$$

The compatibility condition of vertical displacements (maximum bending of rods) at point c will have the form:

$$\Delta^{\psi}_{c} - \delta^{\psi}_{c} q^* = \delta^{\omega}_{c} q^*, \qquad (3)$$

from where $$q^* = \frac{\Delta^{\psi}_{c}}{\delta^{\psi}_{c} + \delta^{\omega}_{c}}. \qquad (4)$$

The right-hand side of (3) represents the vertical displacement of point c in the scheme ω, which is the maximum displacement in the slab, since both sides of equation (3) reflect the equality of the displacements at point c, both ψ, and ω in the rods of the scheme, which means the maximum displacement of the slab. Thus

$$\delta^{\omega}_{c} q^* = W_c \qquad (5)$$

where W_c -th The vertical bending of the slab is noted.

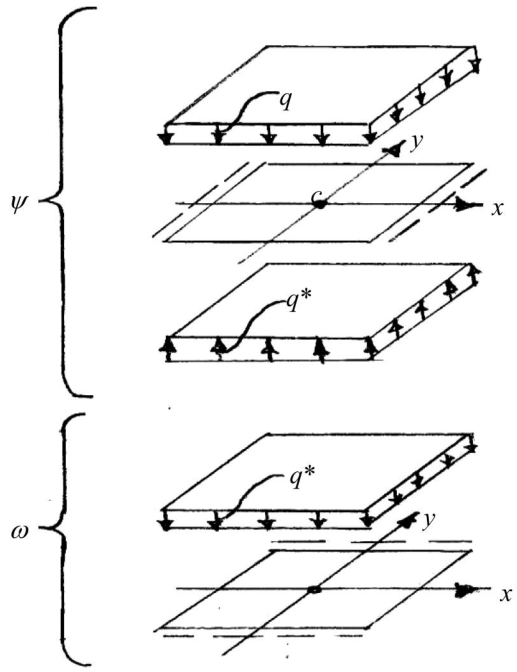

fig. 2

Let's define it first $\Delta_c^{\psi q}$, $\delta_c^{\psi q}$ and $\delta_c^{\omega q}$ displacements. For this, we use the calculation scheme of the rod presented in Fig. 3, according to which

$$\Delta^q(x) = \frac{q \cdot b}{23EI_x}(2ax^3 - x^4 - a^3x), \qquad (6)$$

where **b** is the width of the rod

Since the cross section of the rod is rectangular. Hence its moment of inertia $I_x = bh^3/12$. i.e.

$$\frac{qb}{23E\frac{bh^3}{12}} = \frac{q}{2Eh^3}. \qquad (7)$$

considering this

$$\Delta_{\max}^q = \Delta^q(x = 0,5a) = -0,1563\frac{qa^4}{EI^3};$$

$$\Delta_{\max}^q = -1563\frac{a^4}{EI^3}. \qquad (8)$$

turning angle

$$\Phi^q(x) = \frac{d\Delta^q(x)}{dx} = \frac{q}{2Eh^3}(6ax^2 - 4x^3 - a^3), \ (9)$$

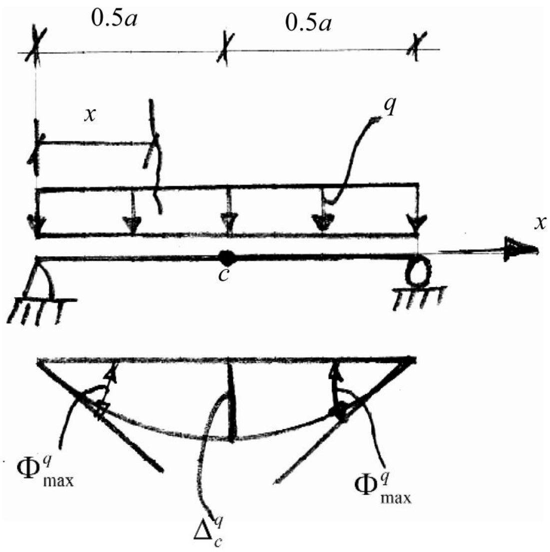

Fig. 3

$$\Phi_{\max}^q = \Phi^q(x = 0) = -0,5\frac{qa^3}{Eh^3}.(10)$$

Thus

$$\Delta_{\max}^{\psi q} = \Delta_c^{\psi q} = -0,1563\frac{qa^4}{EI^3};\ \delta_c^{\psi q} = -\frac{0,1563a^4}{Eh^3};$$

$$\delta_c^{\omega q} = -\frac{0,1563b^4}{Eh^3}. \qquad (11)$$

$\Delta_c^{\psi m}$, $\delta_c^{\psi m}$ and $\delta_c^{\omega m}$ To determine the displacements, we use the scheme presented in Fig. 4, according to which

$$\Delta^m(x) = \frac{mb}{2EI}(ax - x^2), \qquad (12)$$

$$\Delta_{\max}^m = \Delta^m(x = 0,5a) = 1,5\frac{ma^2}{Eh^3}, \qquad (13)$$

$$\Phi^m(x) = \frac{d\Delta^m(x)}{dx} = \frac{mb}{2EI}(a - 2x),$$

$$\Phi_{\max}^m = \Phi^m(x = 0) = \frac{mba}{EI_x} = \frac{mab}{2E\frac{bh^3}{12}} = 6\frac{a}{Eh^3}$$

m.(14)

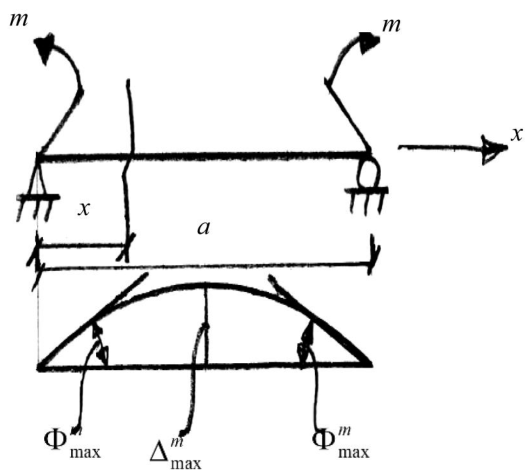

fig. 4

$$\Phi_{gr} = m_{gr}\frac{\frac{ab}{\ell}}{GI_{gr}}. \qquad (15)$$

Since (see [4] p. 221, Fig. 23.6), (14) will take the form since

$$\Phi_{gr} = m_{gr}\frac{0,25\ell}{GI_{gr}}. \qquad (16)$$

As is known, the shear modulus

$$G = \frac{E}{2(1+\nu)}, \qquad (17)$$

where v is Poisson 's $I_{გრ}$ ratio, and [see [4], p. 218, formula 35,6) is the torsion moment of inertia and is determined by the formula

$$I_{გრ} = \alpha h^2, \quad (18)$$

fig.5 according to the scheme presented in Figure 5 (see [4] p. 222

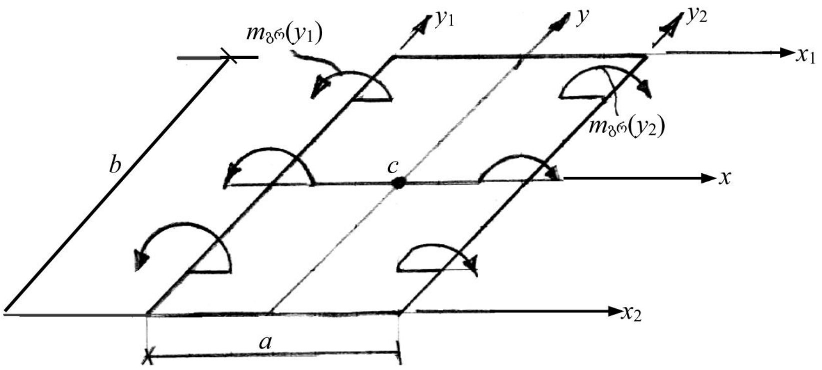

fig. 5

where **h i**s the thickness of the plate, and the coefficient α is taken from the table (see [4], p. 219, table 1.6) according to 0.5a/b (because according to Fig. 5 $m_{გრ}(y_1) = m_{გრ}(y_2)$ and each will affect half of the page a

Insert (17) and (18) into (16)

$$\Phi_{gr} = m_{gr} \frac{0,5(1+v)\ell}{E\alpha h^4}. \quad (19)$$

Based on (10).

$$\Phi^q_{y_1} = \frac{-0,5qa^3}{Eh^3}; \Phi^q_{x_1} = 0,5\frac{qb^3}{Eh^3}. \quad (20)$$

Based on (14), we will have

$$I^m_{y_1} = 6\frac{a}{Eh^3}; \quad I^m_x = 6\frac{b}{Eh^3}. \quad (21)$$

According to (19).

$$I_{y_1} = \frac{0,5(1+v)b}{E\alpha_a h^4}; \; I_{x_1} = \frac{0,5(1+v)b}{E\alpha_b h^4}. \quad (22)$$

the condition of compatibility of deformations (in this case, the equality of rotation angles y_1 around the axis, for example

$$I^{\psi q}_{y_1} \cdot m^q_{y_1} + \Phi^{\psi q}_{y_1} = I^{\omega q}_{y_1} \cdot m^q_{y_1}. \quad (23)$$

from where

$$m^q_{y_1} = \frac{\Phi^{\psi q}_{y_1}}{I^{\psi q}_{y_1} + I^{\omega q}_{y_1}}. \quad (24)$$

By entering the corresponding parameters of (20), (21) and (22) into (24), we get

$$m^q_{y_1} = \frac{0,25\dfrac{qa^3}{Eh^3}}{6\dfrac{a}{Eh^3} + 0,5\dfrac{(1+v)}{E\alpha_b \cdot h^4}} = \frac{qa^2}{12 + \dfrac{b(1+v)}{\alpha_a \cdot a \cdot h}}.$$

(25)

We will take it in a completely similar way

$$m^q_{x_1} = \frac{qa^2}{12 + \dfrac{a(1+v)}{\alpha_b \cdot b \cdot h}}. \quad (26)$$

Based on (8).

$$\Delta^{\psi m}_c = 1,5\frac{a^2}{Eh^3} m^q_{y_1}; \quad \delta^{\psi m}_c = 1,5\frac{a^2}{Eh^3};$$

$$\delta^{\omega m}_c = 1,5\frac{b^2}{Eh^3}. \quad (27)$$

Bending values considering interaction moments Δ^{ψ}_c, δ^{ψ}_c and δ^{ω}_c are calculated by means of (2) and by entering them into (4) q* is determined, and by means of (5) W_c .

W_c -s - After the definitionan $W(y)$ and $W(x)$, it can be expressed using the 6-th formula:

$$W(x) = W_c \frac{2ax^3 - x^4 - a^3x}{0,3125a^4}, \quad (28)$$

$$W(y) = W_c \frac{2by^3 - y^4 - b^3y}{0,3125b^4}. \quad (29)$$

If we assume that the maximum deflection of the rod is equal to the maximum deflection of the plate, we have

$$\Delta^{\psi q}_c = W_c. \quad (30)$$

We can determine the uniformly distributed load q' for the rod, which will cause the maximum load in the rod, which would be caused by the uniformly distributed load q in the plate.

According to (8

$$\Delta_c^{\psi} = \frac{0{,}1563 q' a^4}{Eh^3}. \qquad (31)$$

Let's insert (30) into (31).

$$W_c = \frac{0{,}1563 q' a^4}{Eh^3} = W_c. \qquad (32)$$

from where

$$q' = \frac{Eh^3 \cdot W_c}{0{,}1563 a^4}. \qquad (33)$$

Based on 3

$$M_y(x) = \frac{q'}{2}(ax - x^2), \qquad (34)$$

then

$$M_{y\max}^x = M_c^x = M_y(x = 0{,}5a) = \frac{q'}{2} 0{,}25a^2 = 0{,}125 q' a^2 =$$

$$= 0{,}125 \frac{Eh^3 W_c a^2}{0{,}1563 a^4} = \frac{0{,}8 \cdot W_c Eh^3}{a^2}. \qquad (35)$$

Similarly

$$M_c^y = \frac{0{,}8 \cdot W_c Eh^3}{b^2}. \qquad (36)$$

moments of resistance

$$W^x = \frac{bh^2}{6}; \ W^y = \frac{ah^2}{6}. \qquad (37)$$

Maximum voltages

$$\sigma_{\max}^x = \sigma_c^x = \frac{M_c^x}{W^x}; \qquad (38)$$

$$\sigma_{\max}^y = \sigma_c^y = \frac{M_c^y}{W^y}. \qquad (39)$$

Numerical example: a = 1 m; b = 2 m; h = 0.2 m; q = 2 kN/cm2; $E = 3000$ kn/cm2; $\nu = 0{,}3$.

solution. α_a and α_b we determine the coefficients from the table, see ([4] p. 219, Table 1.6) using interpolation according to 0.5a/h and 0.5b/h):

$$\alpha_a = 0{,}457 + \frac{0{,}790 - 0{,}456}{2} = 0{,}6235,$$

$$\alpha_b = 1{,}123 + \frac{1{,}789 - 1{,}123}{2} = 1{,}456.$$

according to(24).

$$M_{y_1} = \frac{qa^2}{12 + \frac{b(1+\nu)}{a\alpha_a h}} = \frac{q}{12 + \frac{4 \cdot 13}{0{,}6235 \cdot 0{,}2}} = 0{,}0186q$$

.according to (26)

$$M_{x_1} = \frac{qb^2}{12 + \frac{a(1+\nu)}{b\alpha_b h}} = \frac{q \cdot 4}{12 + \frac{13}{2 \cdot 1{,}456 \cdot 0{,}2}} = 0{,}2811q$$

.according to(8).

$$\Delta_c^{\psi q} = 0{,}1563 \frac{qa^4}{Eh^3} =$$

$$0{,}1563 \frac{q}{E \cdot 0{,}008} = 19{,}53 \frac{q}{E}, \ \delta_c^{\psi q} = \frac{19{,}53}{E}.$$

according to(27).

$$\Delta_c^{\psi m} = \frac{1{,}5a^2}{Eh^3} m_{y_1} = \frac{1{,}5}{E \cdot 0{,}008} \cdot 0{,}0186 \frac{1}{E} =$$

$$3{,}49 \frac{q}{E}; \ \delta_c^{\psi m} = \frac{3{,}49}{E}.$$

according to(2).

$$\Delta_c^{\psi} = (19{,}53 - 3{,}49) \frac{q}{E} = 16{,}04 \frac{q}{E};$$

$$\delta_c^{\psi} = 16{,}04;$$

according to(26).

$$\Delta_c^{\omega q} = 0{,}1563 \frac{qa^4}{Eh^3} =$$

$$0{,}1363 \frac{q \cdot 16}{E \cdot 0{,}008} = 312{,}6 \frac{q}{E};$$

according to(27).

$$\Delta_c^{\omega m} = \frac{1{,}5b^2}{Eh^3} m_{x_1} = \frac{1{,}5 \cdot 4}{E \cdot 0{,}008} \cdot 0{,}2811 = 210{,}8 \frac{q}{E}$$

;according to(2).

$$\Delta_c^{\omega} = (312{,}6 - 210{,}8) \frac{q}{E} = 101{,}8 \frac{q}{E};$$

$$\delta_c^{\omega} = \frac{101{,}8}{E}.$$

according to(4).

$$q^* = \frac{\Delta_c^{\psi}}{\delta_c^{\psi} + \delta_c^{\omega}} = \frac{16{,}04 \frac{q}{E}}{\frac{16{,}04}{E} + \frac{101{,}8}{E}} = 0{,}1361q.$$

according to(28).

$$W_c = \delta_c^{\psi} \cdot q^* = \frac{101{,}8 \cdot 10^2}{3000} \cdot 0{,}1361 \cdot 2 = 0{,}92 \text{ sm.}$$

according to(24).

$$M_c^y = \frac{0{,}8 W_c Eh^3}{b^2} = \frac{0{,}8 \cdot 0{,}92 \cdot 3 \cdot 10^3 \cdot 8 \cdot 10^3}{4 \cdot 10^2} = 442$$

kn.cm,

$M_c^x = \frac{0,8W_c Eh^3}{a^2} = \frac{0,8 \cdot 0,92 \cdot 3 \cdot 10^3 \cdot 8 \cdot 10^3}{10^2} = 1766$ kn.cmБ.

according to(37).

$W_x = \frac{bh^2}{6} = \frac{4 \cdot 10^2 \cdot 1 \cdot 10^2}{6} = 6667$ cm^3;

$W_y = \frac{4 \cdot 10^2 \cdot 4 \cdot 10^2}{6} = 26667$ cm^3;

$\sigma_c^x = \frac{M_c^x}{W^x} = \frac{1766}{6667} = 0,26$ kn/cm^2= 26 kg/cm^2;

$\sigma_c^y = \frac{M_y^x}{W^y} = \frac{442}{26667} = 0,017$ kn/cm^2= 1,7 kg/cm^2;

The calculation results are presented in fig.6

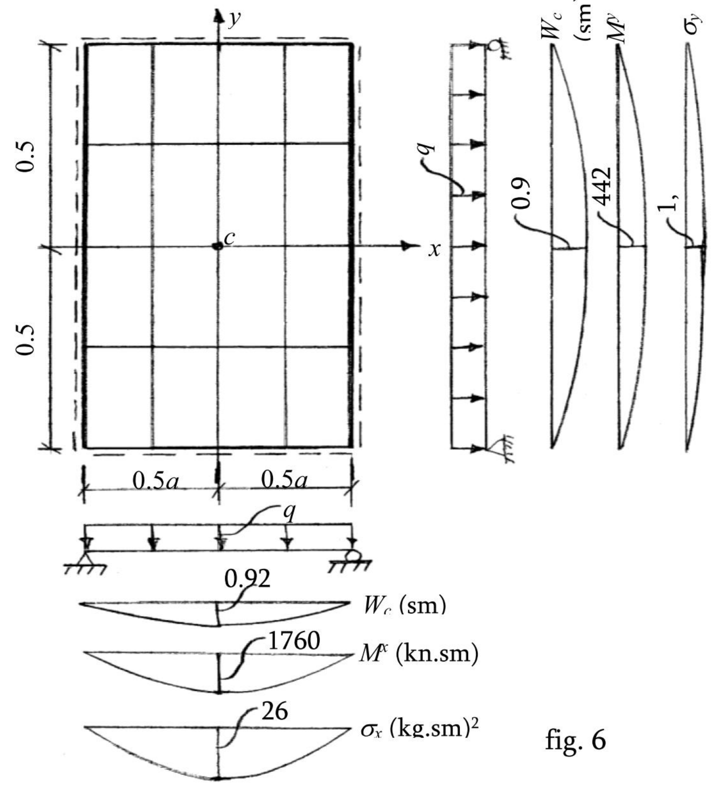

fig. 6

Option II

Fig. 7 shows a rectangular slab hinged at all four edges, the bending force **F** acts at the point **C** of the intersection of the main axes. In this option, the maximum bending, bending moments and normal stresses on the main axes passing through the center of gravity of the slab should be determined

In this case as well, let's imagine the given system (plate) as a combination of ψ and ω sub-schemes (Fig. 8). ψ According to the sub-scheme, at the point **C** of the plate, an external bending force F* is modeled as shown in the scheme. This is the actual force parameter and acts on the rods represented in the sub-diagrams as external force factors. ω In the sub-scheme, only the F* force acts on the rod. The force F causes $\Delta^{\psi q}(x)$ displacement in the ψ subcircuit; . F = 1 force - $\delta^{\psi q}(x)$ causes displacement in the same scheme, and F=1 force ω causes displacement in sub-scheme $\delta^{\omega q}(y)$. These displacements are determined by considering bending deformations only. In fact, the bending of the rod in the ψ scheme causes a twist in the ω scheme rod and vice versa. Therefore, it is necessary to determine the vertical displacements caused by the twisting moments in both the $\Delta^{\psi m}(x)$, $\delta^{\psi m}(x)$ and $\delta^{\omega m}(x)$ subframe members. These are, and Vertical of x and y, equations (1) take the form (2).

displacements of moments caused by bending and twisting are represented by equations (1). Since these equations reach a maximum at the point C of the intersection

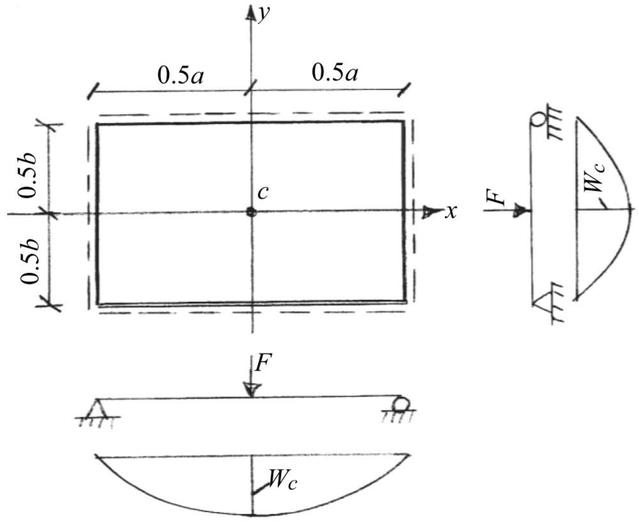

fig. 7

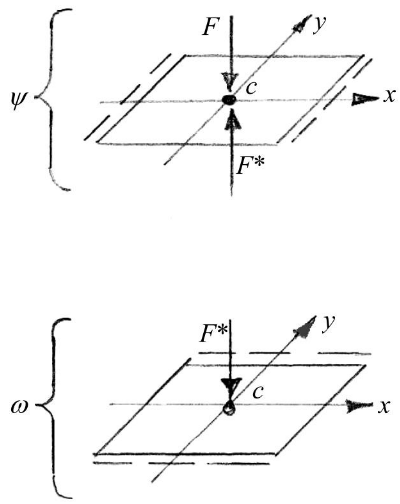

fig. 8

It will be a condition of compatibility of movements

$$\Delta_c^{\psi} - \delta_c^{\psi} \cdot F^* = \delta_c^{\omega} \cdot F^* . \quad (40)$$

from where $F^* = \dfrac{\Delta_c^{\psi}}{\delta_c^{\psi} + \delta_c^{\omega}}$. (41)

In this case, too, the right part of (40) reflects the vertical displacement of point C in the tile, and therefore

$$\delta_c^{\omega} \cdot F^* = W_c . \quad (42)$$

First we are bordering $\Delta_c^{\psi F}$, $\delta_c^{\psi F}$ and $\delta_c^{\omega F}$ displacements. $\Delta_c^{\psi F}$-s and $\delta_c^{\psi F}$-s For determination, we use the well-known calculation scheme (see Fig. 9), according to which

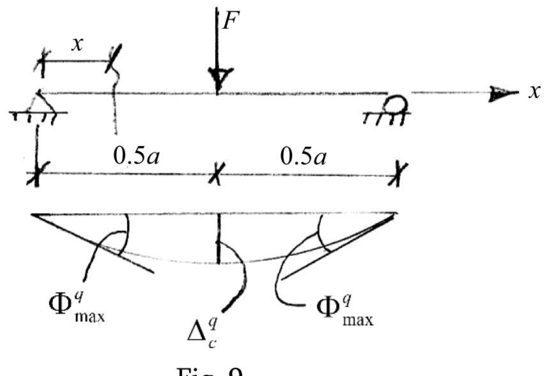

Fig. 9

$$\Delta^F(x) = \frac{F \cdot b}{12EI_x}\left(x^3 + \frac{a^2}{4}x\right); \left[0 \le x \le \frac{a}{2}\right], \quad (43)$$

where b is the width of the rod.

When x = 0.5a, then

$$\Delta^F(x = 0,5a) = \Delta^F_{\max} = 3\frac{Fa^3}{Ebh^3} .$$

therefore

$$\Delta_c^{\psi F} = 3\frac{Fa^3}{Ebh^3}; \quad \delta_c^{\psi F} = \frac{a^3}{Ebh^3}; \quad \delta_c^{\omega F} = 3\frac{b^3}{Eah^3} .$$

(44)

turning angle

$$\Phi^F(x) = \frac{\alpha\Delta^F(x)}{dx} = \frac{F}{Eh^3}\left(3x^2 + \frac{a^2}{4}\right). \quad (45)$$

since

$$\Phi^F_{\max} = \Phi^F(0) = \frac{Fa}{Eh^3 \cdot 4}. \quad (46)$$

Taking into account the sub-schemes presented in Fig. 8, we will have:

$$\Phi_c^{\psi F} = 0,25\frac{Fa^2}{Eh^3}; \quad I_c^{\psi F} = 0,25\frac{a^2}{Eh^3};$$

$$I_c^{\omega F} = 0,25\frac{b^2}{Eh^3}. \quad (47)$$

$\Delta^m(x)$ -we use the calculation scheme of the first option (Fig. 4) to determine, because in the first and second options the slab is supported in the same way (on all four edges).

$$\Delta_c^{\psi m} = 1,5\frac{Fa^3}{Eh^3}\cdot m_{y_1}^F; \quad \delta_c^{\psi m} = 1,5\frac{a^2}{Eh^3};$$

$$\delta_c^{\omega m} = 1,5\frac{b^2}{Eh^3}. \quad (48)$$

$m_{y_1}^F$ To determine the moment, we use the condition of compatibility of deformations (compatibility of rotation angles) around y_1 axes (see Fig. 5):

$$-I_c^{\psi F}\cdot m_{y_1}^F + \Phi_c^{\psi F} = I_c^{\omega F}\cdot m_{y_1}^F, \quad (49)$$

from where

$$m_{y_1}^F = \frac{\Phi_c^{\psi F}}{I_c^{\psi F} + I_c^{\omega F}} = \frac{F}{1+\frac{b^3}{a^3}}. \quad (50)$$

from where It is obtained in a completely similar way $m_{x_1}^F = \frac{F}{1+\frac{a^3}{b^3}}$. (51)

Δ_c^{ψ}, δ_c^{ψ} and δ_c^{ω} are calculated by means of (2), then by means of (4) -q* and finally by means of (5) Wc. After all, we can express W(x) and W(y)(43) using the function in (43)

$$W(x) = W_c\frac{x^3 + 0,25a^2x}{0,25a^3};$$

$$W(y) = W_c\frac{y^3 + 0,25b^2y}{0,25b^3}. \quad (52)$$

If we assume that the maximum deflection of the rod is equal to the deflection of the plate, we have: $\Delta_c^{\psi F} = W_c$. (53)

so we are given the opportunity to determine the magnitude of the bending force F ' which will cause the maximum load in the rod that was caused by the bending force F in the plate.

According to (44).

$$\Delta_c^{\psi F} = \frac{F'a^3}{Ebh^3}. \quad (54)$$

Let's insert (53) into (54).

$$W_c = \frac{F'a^3}{Ebh^3}, \quad (55)$$

from where

$$F' = \frac{Ebh^3W_c}{a^3}. (56)$$

Based on Fig. 3

$$M(x) = \frac{F'}{2}x = 0,5\frac{Ebh^3W_cx}{a^3}. \quad (57)$$

When $x = 0,5a$, thena:

$$M(x) = M_c^x = 0,25\frac{Ebh^3}{a^2}. (58)$$

similarly obtained

$$M_c^y = 0,25W_c\frac{Ebh^3}{a^2}. \quad (59)$$

According to (37) resistance moments

$$W^x = \frac{bh^3}{6}; W^y = \frac{ah^3}{6}. \quad (60)$$

Maximum stresses according to (38) and (39).

$$\sigma_c^x = \frac{M_c^x}{W^x}; \ \sigma_c^y = \frac{M_c^y}{W^y}. \quad (61)$$

A numerical example.a=1, b= –2m; h=0,2m; F=100kn; $E = 3000$ kn/sm^2, $v = 0,3$.

ion. As in the first option $\alpha_a = 0,6235$; $\alpha_b = 1,456$.

According to (50)-.

$$m_{y_1}^F = \frac{F}{1+\frac{b^2}{a^2}} = \frac{F}{1+\frac{8}{1}} = \frac{F}{9} = 0,11F;$$

$$m_{x_1}^F = \frac{F}{1+\frac{a^2}{b^2}} = \frac{F}{1+\frac{1}{8}} = \frac{F}{1,125} = 0,9F.$$

According to (44)

$$\Delta_c^{\psi F} = 3\frac{Fa^3}{Ebh^3} = 3\frac{F\cdot 1}{E\cdot 2\cdot 0,008} = 187,5\frac{F}{E};$$

$$\Delta_c^{\psi m} = 1,5\frac{a^2}{Eh^3}\cdot m_{y_1}^F = 1,5\frac{1\cdot 0,11F}{E\cdot 0,008} = 10,625\frac{F}{E}.$$

According to (2)-

$$\Delta_c^{\psi} = (187,5 - 20,625)\frac{F}{E} = 167\frac{F}{E};$$ so

$$\delta_c^{\psi} = \frac{167}{E}.$$

According to (44)

$$\Delta_c^{\omega F} = 3\frac{Fb^3}{Eah^3} = 3\frac{F \cdot 8}{E \cdot 1 \cdot 0,008} = 3000\frac{F}{E}.$$

According to (27)

$$\Delta_c^{\omega m} = \frac{1,5b^2}{Eh^3} \cdot m_{x_1} = \frac{1,5 \cdot 4}{E \cdot 0,008} \cdot 0,9F = 675\frac{F}{E}.$$

According to (2)

$$\Delta_c^{\omega} = (3000 - 675)\frac{F}{E} = 2325\frac{F}{E};$$ i.e.

$$\delta_c^{\omega} = \frac{2325}{E}.$$

According to (4)

$$F^* = \frac{\Delta^{\psi}}{\delta_c^{\psi} + \delta_c^{\omega}} = \frac{167\frac{F}{E}}{\frac{167}{E} + \frac{2325}{E}} = 0,067F.$$

According to (42)- According to it

$$W_c = \delta_c^{\omega} \cdot F^* = \frac{2325}{3 \cdot 10^3} \cdot 0,067 \cdot 10^2 = 5,2 \text{ cm}.$$

According to (35)

$$M_c^x = \frac{0,8 \cdot W_c E h^3}{a^2} =$$

$$\frac{0,8 \cdot 5,2 \cdot 3 \cdot 10^3 \cdot 8 \cdot 10^3}{10^2} = 998400 \text{ kn. sm}$$

$$M_c^? = \frac{0,8 \cdot W_c E h^3}{b^2} =$$

$$\frac{0,8 \cdot 5,2 \cdot 3 \cdot 10^3 \cdot 8 \cdot 10^3}{4 \cdot 10^2} = 249600 \text{ kn. sm.}$$

moments of resistance

$$W^x = \frac{bh^3}{6} = \frac{2 \cdot 10^2 \cdot 8 \cdot 10^3}{6} = 267 \cdot 10^3 \text{ cm}^3;$$

$$W^y = \frac{ah^3}{6} = \frac{1 \cdot 10^2 \cdot 8 \cdot 10^3}{6} = 133 \cdot 10^3 \text{ cm}^3.$$

Maximum voltages

$$\sigma_{\max}^x = \frac{M_c^x}{W^x} = \frac{998400}{133 \cdot 10^3} = 7,51 \text{kn/cm}^2;$$

$$\sigma_{\max}^y = \frac{M_c^y}{W^y} = \frac{249600}{133 \cdot 10^3} = 1,81 \text{kn/sm}^2.$$

The calculation results are presented in fig.

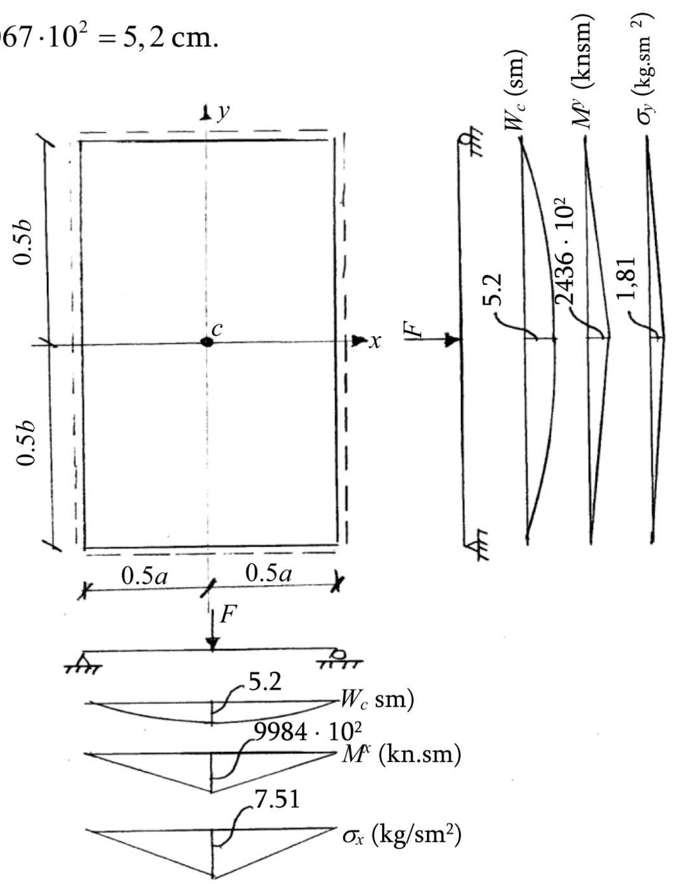

Fig. 10

Conclusion

Since in the discussed examples, the joint consideration of bending and twisting deformations brought the maximum bending with great accuracy to the results obtained by the traditional method, i.e. the representation of the bending function by trigonometric rows.

The method of determining the voltages presented in the article, which is based on the representation of the calculation circuit as a set of sub-circuits, is quite convenient for solving practical problems.

Reference

1.Chiras A.A. Structural mechanics. Theory and algorithms. "Stroyizdat", M., 1989.

2. Filin A.P. Modern problems of using electronic computers in the mechanics of solid deformable bodies. "Stroyizdat", L., 1974.32. Birger I.A., Mavlyutov R.R. Strength of materials. "Science", M., 1986.

3. Darkov A.V., Shpiro G.S. Strength of materials. "Higher School", M., 1965.

4. Kalmanok A.S. Structural mechanics of plates. "Mashstroyizdat", M., 1950.

5. Timoshenko M.P., Voinovsky-Krieger S. Plates and shells. M, 1963.6. D. Danelia, Z. 6.Madzaghua, D. Tabatadze, R. Tsvedadze. A practical method for determining maximum deflections and bending moments in rectangular plates under uniformly distributed loads. Building materials and products, Tbilisi, 2000.

7. D. Danelia, Z. Madzaghua, D. Tabatadze, R. Tskedadze. A practical method of calculations of a rectangular plate supported by a contour with a l oad in the form of a triangular prism. "Science and Technologies, No. 4-6, Tbilisi, 2001.