# Stability of Long Plates with Non-Symmetric Reinforcement of the Edges with Thin-Walled Rods

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## ABSTRACT

*In this work, to study the effect of compressive forces on the stability of elongated plates, the long edges of which are reinforced with thin-walled rods of different torsional stiffness are considered. The short sides, to which compressive forces are applied, are considered pivotally supported on rigid supports.*

**KEYWORDS:** *Compressed, stretched, stability, elongated, plates, resilient pinching, hinged, torsional, bending, reinforced, unsecured, edges, stiffness, asymmetric.*

## 1. PROBLEM STATEMENT AND LITERATURE REVIEW

As far as we know, the stability of elongated reinforced plates, taking into account the torsion of the reinforcing ribs, is still insufficiently studied. Taking into account the specificity of the constrained torsion of thin-walled ribs, as will be shown below, significantly affects the parameters of the rigidity of the system, as a consequence, the stability of elongated reinforced plates.

Traditional in the literature [2, 3, 4, 6] is the following method of drawing up boundary conditions for reinforced plates. The loads transferred by the plate to the reinforcing bar are considered equal, but opposite in direction to the conditions in the corresponding sections of the plate. Then, the kinematic conditions of equality of displacements in the rod and plate along the line of their contact are introduced into these force conditions.

In publications [1, 5], a method is proposed for drawing up refined boundary conditions on the line of conjugation of the plate with the rod, which makes it possible to take into account the constraint in the warping of the end sections of the ribs. In this case, the degree of constraint of warping is taken into account by some parameter. This parameter is included in the expression for the generalized coefficient of elastic pinching of the edges of the plate and depends not only on the geometric and mechanical characteristics of the bar and the plate.

Solution method. As is known, a closed solution to the problem of the stability of an elongated rectangular plate can be obtained in single trigonometric series only when two parallel edges are hinged, while the other two edges can be fixed in an arbitrary way (M. Levy's solution).

Consider the problem of the stability of an elongated plate, the long edges of which are reinforced by thin-walled rods of different torsional stiffness. The short sides, to which compressive forces are applied, are considered pivotally supported on rigid supports (Fig. 1).

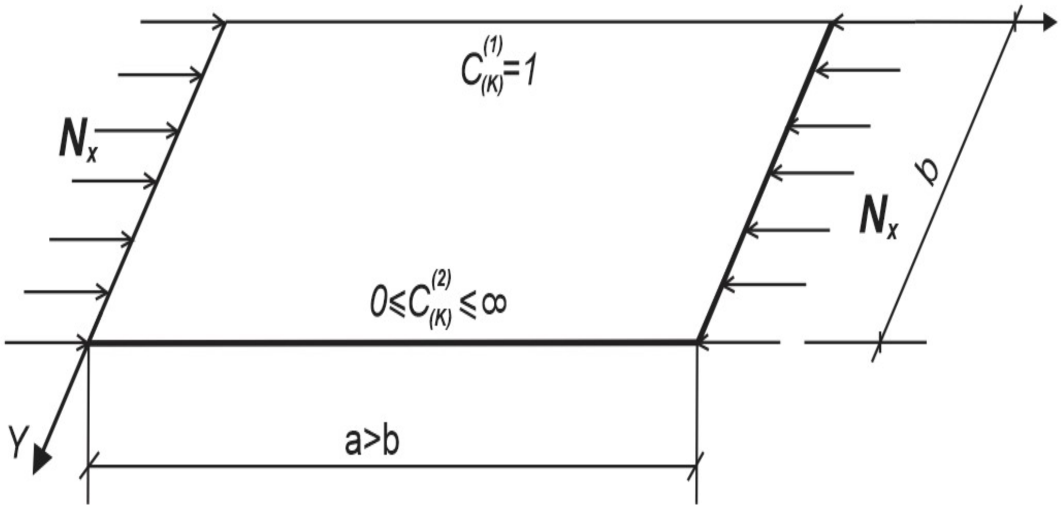

Fig. 1. Plates, the long edges of which are reinforced by thin-walled rods of different torsional rigidity and short sides, hingedly supported on rigid supports

Empty, uniformly distributed intensity load is applied to the hinged edges (at the level of the median plane)

$N_x$ = σδ = const, where δ is the thickness of the plate.

Let us write down the well-known differential equation of the problem

$$D\nabla^2\nabla^2 w + N_x\frac{\partial^2 w}{\partial x^2} = 0, \quad D = \frac{E\delta^3}{12(1-\mu^2)}\ , \qquad (1)$$

the solution of which is presented in the traditional form

$$w(x,y) = \sum_{n=1.2}^{\infty} f_n(y)\sin\lambda_n x, \lambda_n = \frac{n\pi}{a}\ , \qquad (2)$$

satisfying the boundary conditions of hinge support at the edges x = 0, a [2, 3, 4,6].

Substituting (2) into (1), we obtain the equation for determining the desired function $f_n(y)$

$$f_n^{IV} - 2\lambda_n^2 f_n^{II} + \lambda_n^2\left(\lambda_n^2 - \frac{N_x}{D}\right)f_n = 0, \qquad (3)$$

the solution of equation (3) is presented in the form

$$f_n = C_1 ch\alpha_n y + C_2 sh\alpha_n y + C_3\cos\beta_n y + C_4\sin\beta_n y \qquad (4)$$

where $\alpha_n = \sqrt{\lambda_n\left(\sqrt{\frac{N_x}{D}} + \lambda_n\right)}, \qquad \beta_n = \sqrt{\lambda_n\left(\sqrt{\frac{N_x}{D}} - \lambda_n\right)}, \qquad (5)$

The boundary conditions are as follows:

$$f_n(0) = 0, f_n(b) = 0,$$

$$f_n^I(0) = \frac{f_n^{II}(0) - \mu\lambda_n^2 f_n(0)}{t_k^{(1)} b\lambda_n^2}, \qquad f_n^I(b) = \frac{\mu\lambda_n^2 f_n(b) - f_n^{II}(b)}{t_k^{(2)} b\lambda_n^2}, \tag{6}$$

Let us subordinate the function $f_n$ (y) according to (4) to the following boundary conditions (6). As a result, we arrive at the following equation.

$$\left[2(\xi^2+\eta^2)+t_k^{(1)}\psi^2\mathrm{L}_1\right]\left[2(\xi^2+\eta^2)+t_k^{(2)}\psi^2\mathrm{L}_2\right]+$$

$$+\left[2(\xi^2+\eta^2)+t_k^{(2)}\psi^2\mathrm{L}_1\right]\left[2(\xi^2+\eta^2)+t_k^{(1)}\psi^2\mathrm{L}_2\right] \tag{7}$$

where $\mathrm{L}_1 = \xi th\xi + \eta tg\eta$ , $\mathrm{L}_2 = \xi cth\xi - \eta ctg\eta$

$$\xi = \frac{\alpha_n b}{2}, \quad \eta = \frac{\beta_n b}{2}, \quad \psi = \lambda_n b \tag{8}$$

The relationship between ξ and η, as well as the formula for the critical load intensity $N_x^*$ follow from (5)

$$\xi^2 - \eta^2 = \frac{\psi^2}{2}, N_x^* = 4D\frac{(\xi^2+\eta^2)^2}{(\psi b)^2}. \tag{9}$$

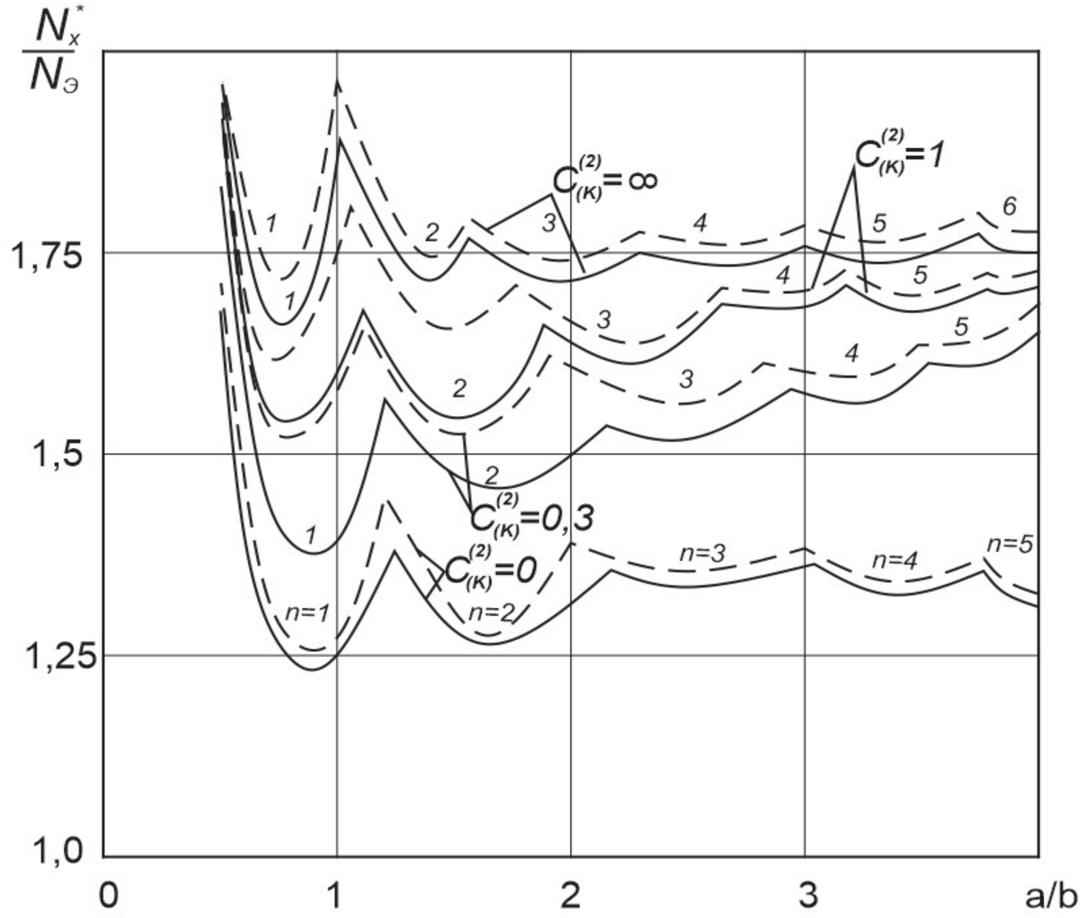

Fig. 2 - Graph of the dependence of the critical load parameter on the ratio a / b,

Equation (7) allows us to consider the case of asymmetric fastening of long sides by varying the coefficients of elastic restraint at each edge in the range from zero to infinity. The coefficients of elastic pinching at the edges $y = \pm\frac{b}{2}$ will be denoted, respectively: $t_k^{(1)}, t_k^{(2)}$.

As an example, particular cases are considered below. Figure 2 shows the dependence of the critical load parameter on the ratio a / b, constructed according to equations (7) and (9). Taken at the edge y = 0, the value of the parameter $C_k^{(1)} = 1$, and at the edge $y = b$: $0 \leq C_k^{(2)} \leq \infty$. The solid line corresponds to the free warping of the ends of the reinforcing rods, the dashed line - to the complete constraint of the warping.

With an increase in the ratio a / b, the critical load intensity increases and in the limit as $\frac{a}{b} \to \infty$, $N_x^*$ tends to a value corresponding to the complete pinching of the long edges.

**Conclusion.**

Used in solving problems of the stability of elongated reinforced plates, the dimensionless coefficient reflecting the degree of elastic pinching of the edges, take into account the mechanical and geometric characteristics of the plate and ribs, constructive methods of restraining the warping and attachment of ribs to the plate. An essential feature of these coefficients is their dependence on the number of bending half-waves of the plate formed in the course of stability.

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