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STABILITY OF RECTANGULAR PLATES UNDER PURE BENDING

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The article investigates the problem stability of plates as part of I-steel beams reinforced by transverse ribs. The comparison of calculation results with the recommendations of EN 1993-1-5 [1] and СНиП II-23-81 [2]. As described by one of the ways to implement such calculations using the software package ANSYS.*

Buckling of thin-walled components has a great influence on the general state of the structure as a whole. This is due to the fact that the loss of local stability leads to a distortion of the shape, the bending displacement of the center, which in turn may cause torsion rod and premature its failure.

The study of this issue was first raised in the construction of bridges Britain and B. Conway Fëyrebërnom. Experiments on models of one-sixth size of the linear dimensions the designed bridges showed that the bearing capacity of the beam lost due to the buckling of thin walls, who handed shear and bending stresses. At the beginning of the XX century it was derived exact solutions to determine the critical stress of rectangular plates [3] when operated in three typical situations for bending rods: in pure shear, bending and combined effect.

Plates resistance under bending according to EN 1993-1-5

To check the bent elements used condition

$$\eta_1 = \frac{M_{Ed}}{\frac{f_y W_{eff}}{\gamma_{MO}}} \le 1,0\,,$$

where γ_{MO} – partial safety factor; M_{Ed} – design value of the bending moment.

Elastic resistance of the effective cross section in the case of uniaxial bending should be determined as the moment of inertia of the effective cross-sectional area divided by the distance from the gravity center to edge of the plate. The geometrical parameters are determined based on the diagram in Fig. 1.

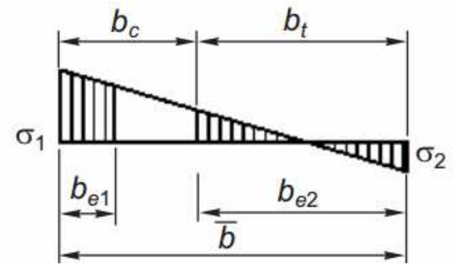

Fig. 1. To determine the effective cross section of the bent plate with double fixing

where ρ – plate buckling coefficient:

$\rho = 1$ when $\bar{\lambda}_p \le 0.5 + \sqrt{0.085 - 0.055\psi}$;

$\rho = \dfrac{\bar{\lambda}_p - 0.055 \cdot (3+\psi)}{\bar{\lambda}_p^{\,2}} \le 1$, when $\bar{\lambda}_p > 0.5 + \sqrt{0.085 - 0.055\psi}$,

where $\bar{\lambda}_p = \sqrt{\dfrac{f_y}{\sigma_{cr}}} = \dfrac{\bar{b}/t}{28.4\varepsilon \cdot \sqrt{k_\sigma}}$,

there k_σ – coefficient taking into account the effect of the stress ratio at the edges of the plate and the conditions of their attachment to the stability of the plate; $t = t_w$ – plate thickness; σ_{cr} – the elastic critical buckling stress.

$$\varepsilon = \sqrt{\frac{235}{f_y\left[\text{Н}/\text{мм}^2\right]}}\,.$$

Plates resistance under bending according to СНИП II-23-81*

The critical normal stress at conventional flexibility of the wall $\overline{\lambda}_w \leq 6\sqrt{R_y/\sigma}$ executed by the formula

$$\sigma_{cr} = \frac{c_{cr} R_y}{\overline{\lambda}_w^2}.$$

The coefficient for welded beams should be at Table 1, depending on the coefficient δ:

$$\delta = \beta \frac{b_f}{h_{ef}} \left(\frac{t_f}{t} \right)^3.$$

The coefficient depends on the operating conditions of the compressed zone.

Table 1

δ	≤0,8	1,0	2,0	4,0	6,0	10,0	≥30
c_{cr}	30,0	31,5	33,3	34,6	34,6	35,1	35,5

Simulation using FEM

It was chosen for calculation complex ANSYS 16.1 ACADEMIC.

The geometrical parameters of the plates were set parametrically so that their values could easily change. As the final element made SHELL281.

There were two options selected fixing: all edges of a freely supported (insufficient stiffness of the belt); all edges clamped (belts and ribs have sufficient rigidity). The load in the form of two bending moments applied to the right and left faces. As a result of the static analysis and calculation were obtained for stability factors critical load.

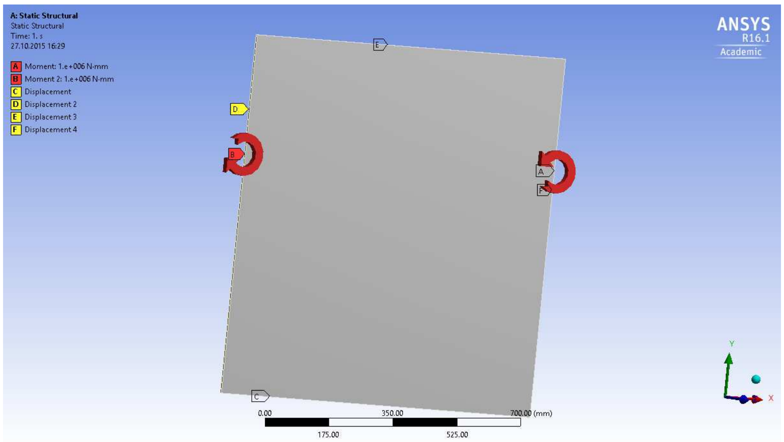

Fig. 2. A general view of investigated models

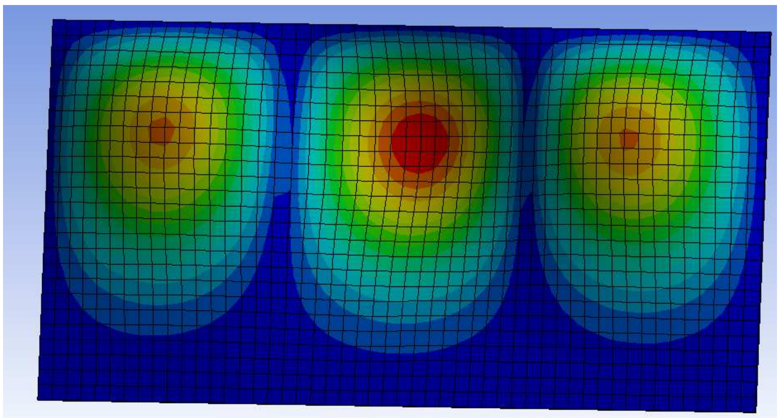

Fig. 3. Deformed model

Comparison of the critical normal stress bending plates/

Numerical experiments have been made on the calculation of the critical stress bending plates with different aspect ratio, thickness, and support conditions. The critical buckling stresses were also counted by current standards (see [1], [2]), and the formulas proposed by Timoshenko [3]. Data are presented in Table 2.

Table 2 – Comparison of the results of the critical normal stress for rectangular plates from the bending moment

Geom. Parameters of plates (B×Ш×T) mm	EN 1993-1-5 MPa	СНИП II-23-81* MPa	Analytical solution MPa	FEM (free support) MPa	FEM (rigidly fixed edges) MPa
1000×500×6	166.6	216	166.95	161,3	351.6
1000×670×6	166.6	216	155.87	152,1	332.1
1000×800×6	166.6	216	159.1	157,2	326.8
1000×1000×6	166.6	216	166.95	163,4	298.2
1000×1500×6	166.6	216	156.66	155,5	277.4
1000×2000×6	166.6	216	155.87	154,1	269.0
800×500×6	184.9	337.5	244.16	239.2	511.6
800×670×6	184.9	337.5	252.198	251.0	500.4
800×800×6	184.9	337.5	260.852	256.5	466.9
800×1000×6	184.9	337.5	252.816	241.3	447,8
800×1500×6	184.9	337.5	244.162	241.9	423,6
1200×670×6	150.6	150	112.4	107,2	247,1
1200×800×6	150.6	150	108.2	105,3	231,7
1200×1000×6	150.6	150	112.4	110,2	222,4
1200×1500×6	150.6	150	112.4	106,7	199,0
1200×2000×6	150.6	150	113.7	109,8	190,2

Analyzing the results, one can draw the following conclusions:

1) Stability of the plates under the action of the bending moment is practically independent of the presence and the distance between the ribs. This fact is taken into account not only the existing standards but also confirmed by analytical solutions. This is due to the fact that the plate with a large ratio of h / d curve for several half-waves and the energy of deformation increases slightly.

2) The greatest influence on the resistance to buckling of plates has a ratio of height to thickness (t / h).

A large range of values using different methods can be explained by the difference in the expected conditions of consolidation. If belts and fins considered stiff enough, the area in which the possible buckling of the plate is reduced and it behaves like a smaller plate. Also, the area adjacent to the upper belt compressive stresses which are maximized, is excluded from the deformed region, increasing the resistance to buckling.

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INVESTIGATING THE BEHAVIOR OF AXIALLY LOADED BORED PILES EMBEDDED IN SOIL USEDING FINITE ELEMENTS METHOD

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This comparative study is performed on bored piles by varying the basic problem parameters that are expected to affect pile carrying capacity and comparing the obtained results with those of the original basic problems, in order to get more knowledge about the behavior of bored piles under compressive load, and to include the best design for future pile construction.

The advancement of digital computers makes possible the development of sophisticated numerical solution techniques such as (F.E.M) for solving boundary value problems in geotechnical engineering. The advantages of the (F.E.M**)** is that it can be systematically programmed to accommodate such complex and