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ON THE DESIGN OF STRUCTURAL ELEMENTS BASED ON THE CONDITIONS OF STRENGTH AND RIGIDITY

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Анотація. *Розглядається задача проектування виходячи з умов міцності та жорсткості. Сформульовано вимоги для простих видів опору; запропоновано сучасне рішення цієї задачі .*

Ключові слова: теорія пружності, задача проектування за виконання умов міцності, умови жорсткості, види деформації, напруження.

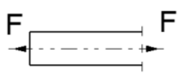
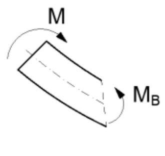
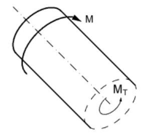
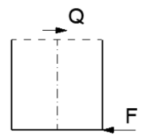
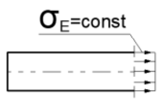
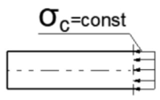
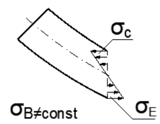
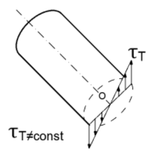
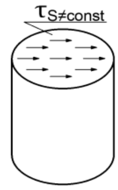
Abstract. *The problem of design based on the conditions of strength and stiffness is considered. The requirements for simple types of resistance are formulated; a modern solution to this problem is proposed.*

Keywords: theory of elasticity, the problem of designing for the fulfillment of strength conditions, stiffness conditions, types of deformation, stress.

Conditions of strength and stiffness, as well as criteria of strength and plasticity, are key concepts in the theory of elasticity that determine the behavior of materials under the influence of external loads. The process of studying these aspects reflects significant interest both among the scientific community and among industrial manufacturers, as they are important for the development and improvement of structural solutions in various fields of engineering.

The main task of the engineering calculation is to estimate the strength of the elements of machines and structures according to the known stress state [1-2]. This problem is most easily solved for simple types of deformation: tension-compression, bending, torsion, shear (Table 1). In these cases, stresses dangerous to the structure can be determined directly from experiments, taking into account the stress graphs. Stresses at which the destruction begins or residual deformations appear are considered dangerous. The values of the temporary resistance to destruction or the tensile strength limit (σ_b) are taken as dangerous stresses.

Table 1 – Types of deformation and corresponding internal forces

Type of deformation	**Extension**	**Compression**	**Bending**	**Twisting**	**Shear**
Internal power Factors					
Stress diagrams					

In order for the structure to meet the requirements of strength, rigidity and stability, and therefore to be reliable in operation, it is necessary to give its elements a rational shape and, in accordance with the mechanical properties of the materials from which this structure is made. The task of the designer and technologist is to propose optimal cross-sectional dimensions of the structure depending on the load and the nature of its application [3].

A strength condition is a condition that defines the maximum loads or stresses that a material can withstand without it beginning to deform or fail. It is key to assessing the stability and reliability of structural elements. Strength conditions are usually expressed in the form of maximum values of stresses or deformations to which the material can be subjected without its destructive deformation occurring.

Rigidity condition is a condition that determines the ability of a material or structure to withstand deformations under the influence of external loads without significant changes in its shape. More specifically, this means that the material or structure has a difference in the response to the applied force, providing minimum deformations under a given load. The condition of stiffness is key in mechanics of materials and engineering, as it determines the stability of structures and their ability to maintain shape and functionality under various operating conditions (Table 2).

Table 2 – Conditions of rigidity and strength for simple types of loading

Types of loading	Stress	Deformation	Rigidity condition	Strength condition
Elongation/ Compression	$\sigma = \frac{N_x}{A}$	$\Delta l = \frac{Nl}{E * A}$	$\Delta l = \frac{N_x * l}{E * A} \leq [\Delta l]$	$\sigma^{max} = \frac{N_x^{max}}{A} \leq [\sigma]$
Bending (pure)	$\sigma = \frac{M_z}{J_z} y$	$EJ_z * y = -M_z$	$f = \frac{M_z * l^2}{2E * J_z} \leq [f]$	$\sigma^{max} = \frac{M_z^{max}}{W_z} \leq [\sigma]$
Twisting	$\tau = \frac{M_x}{J_\rho}$	$\varphi = \frac{M_x * l}{G * J_\rho}$	$\varphi = \frac{M_x * l}{G * J_\rho} \leq [\varphi]$	$\tau^{max} = \frac{M_x^{max}}{W\rho} \leq [\tau]$
Pure shear	$\tau = \frac{Q}{A}$	$\gamma = \frac{Q}{G * A}$	$\gamma = \frac{Q}{G * A} \leq [\gamma]$	$\tau^{max} = \frac{Q^{max}}{A} \leq [\tau]$

When designing a curved beam, the required cross-sectional dimensions are selected using the sampling method, followed by strength tests as for a straight beam.

Conclusion

Conditions of strength and rigidity are the basis for solving problems of design calculations of structural elements. In the proposed form, these conditions are applicable for calculations of rod structures.

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