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Моделирование взаимодействия бетона и арматуры в задаче о простом растяжении

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Аннотация
Предлагается простая зависимость приложенных к арматурному стержню сил от его смещения в процессе выдергивании стержня из бетонного блока. За основу для формы кривой и ее характерных точек принимаются известные экспериментальные данные. Выписаны уравнения для получения коэффициентов кривой. Соответствующая кривая сравнивается с аналогичными, полученными по известным критериям. Отмечаются преимущества предложенного описания явления.
Ключевые слова: арматура, бетон, разрушение, композит, проскальзывание

Simulation of the interaction of concrete and reinforcement in the problem of simple tension

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Abstract
A simple dependence of the forces applied to the reinforcing bar on its displacement in the process of pulling the rod out of the concrete block is proposed. The basis for the shape of the curve and its characteristic points are taken known experimental data. Equations are written to obtain the coefficients of the curve. The corresponding curve is compared with similar, obtained according to known criteria. The advantages of the proposed description of the phenomenon are noted.
Keywords: reinforcement, concrete, destruction, composite, slippage

One of the most practically valuable for the construction with the use of reinforced concrete is the problem of destruction of slabs due to the loss of connection of reinforcement and concrete. As a particular problem, this problem is included in a more General problem of reliability of matrix-fiber compounds in composite media, including creep [1-3]. Most often it occurs at a bend of plates. That part of the slab that is subject to stretching (for example, the lower side of the slab in the ceiling slabs) can be destroyed not only because the concrete does not work well for stretching, but also because the incorrectly installed reinforcement or reinforcement of insufficient tensile strength will break or stretch out of the slab before or after the break. Numerous experimental data often give only the limiting characteristics of this problem – for example, the ultimate force or the ultimate deformation. It is much more important to know the functional dependence of the destructive force on the deformation of the valve displacement. Figure 1 shows a diagram of the concrete-reinforcement facility.

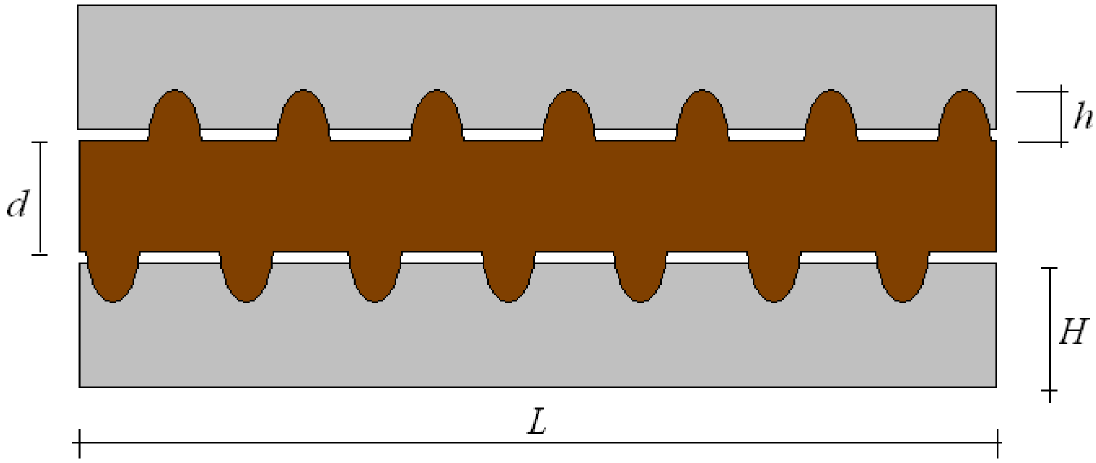

Figure 1-diagram of reinforcement in concrete

It is assumed that the values of the ribbed coating of the reinforcement bars are known-the step of the ribs, the height and even the shape. The problem of "pulling out" can be solved by the finite element method with a fine mesh on concrete and even smaller reinforcement with thickening at angular points. In this article, we construct a semi-empirical dependence of shear stresses τ in the contact zone on the displacement s of the valve. Such dependencies are already known. In the work of Balázs G. L [4] on the basis of own and known experiments with respect to new types of concrete and prestressed structures, the formula is derived and analyzed

$$\tau = 2\tau_{\max} s_{\max} s / (s_{\max}^2 + s^2), \tag{1}$$

where $\tau_{\max}$ — is the maximum shear stress, which can withstand a bunch of rebar-concrete under tension, $s_{\max}$ — the longitudinal displacement of the rebar at which begins the irreversible destruction (the analogue of the limit of elasticity in the curve tension - deformation).

In [5] in relation to the calculation of laminated strips with surface mounting (NSM) of polymer reinforced with carbon fiber (CFRP), used to increase the Flexural and shear strength of defective concrete elements , a two-link symmetric model was developed

$$\begin{aligned} &\tau = \tau_{\max}(s / s_{\max})^{\alpha},\ s < s_{\max}, \\ &\tau = \tau_{\max}(s / s_{\max})^{-\alpha},\ s > s_{\max}, \end{aligned} \tag{2}$$

where parameter α depends on the characteristics of the valve and in most cases can be taken to be 0.5. The developed numerical model made it possible to predict all the essential aspects registered experimentally and was recommended for the evaluation of numerical solutions in the design of concrete structures reinforced with NSM technology.

These and other well-known analytical models have one drawback. When exceeding the maximum force, the corresponding forces do not fall as quickly as it is often observed in experiments. We propose the following dependence, which to some extent is analogous to (1):

$$\tau = s\tau_{\max} / ((s-a)^2 + b). \tag{3}$$

Parameters a, b are determined from the condition of the curve passing through the maximum point $\tau = \tau_{\max}$, $s = s_{\max}$. For these parameters we have obvious equations

$$a = s_{\max} - 1/2,$$
$$b = s^2{}_{\max} - a^2 = s_{\max} - 1/4.$$

The curves (1), (2) and (3) in figure 2 are numbered 1, 2 and 3.

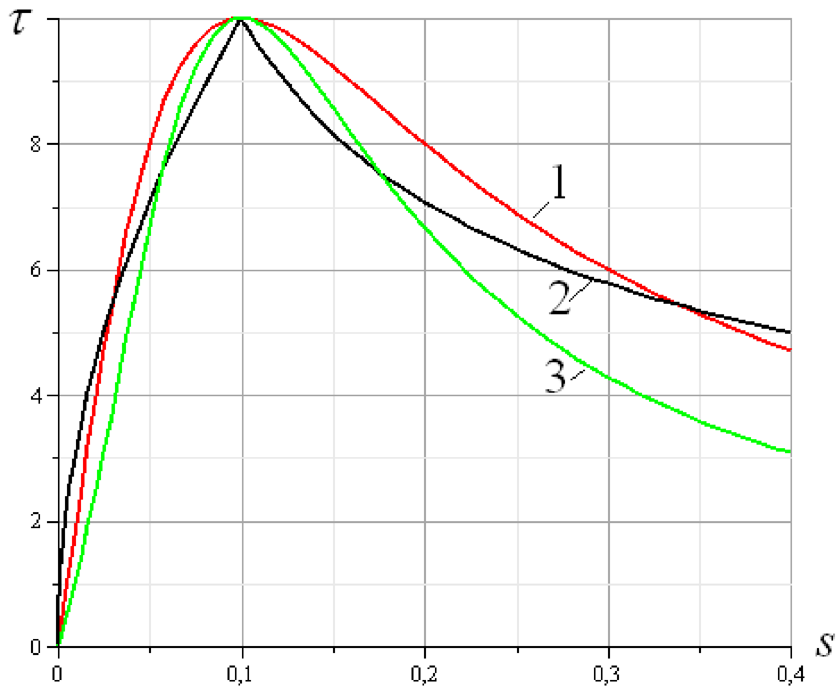

Figure 2— dependence of shear stress τ, MPa, on displacement s, mm, reinforcement relative to concrete

As expected, curve 3 has a larger fall after reaching the maximum. It should also be noted that in curve (3) there is no scale factor in the numerator. Scaling of the curve is obtained naturally, only from the condition of passing through a given point and does not have additional parameters that need to be determined from additional experiments.

The task of comparison of curves of shear stress against displacement in the reinforcement was considered in [6].

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