INCREASE OF THE LOAD-BEARING CAPACITY OF STRUCTURAL COMPONENTS OF THIN BARS

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The main cause of plane bending instability of thin bars of open profile in Timoshenko's investigations [1] is their small torsional rigidity C in comparison with the maximum and minimum flexural rigidities $B_1$ and $B_2$. In the case when $B_1$ and $B_2$ are quantities of the same order, instability of plane strain is possible only if the value of C is small in comparison with $B_1$ and $B_2$.

This circumstance gives grounds to assume that, with appropriate reinforcement of a bar by plates or inclined ribs increasing its torsional rigidity, we can provide stability of plane strain within the limits of elasticity. This article is devoted to an experimental check of this assumption.

On the basis of the condition of instability of plane strain in the elastic region, we manufactured four No. 16 406 cm long H-beams rolled according to GOST 8239-56. Attachment of the ends enabled them to rotate freely relative to the principal axes of inertia and eliminated torsion relative to the longitudinal axis of the bar. A point load was applied in the middle of the span to the compressed chord in the plane of maximum rigidity of the section. Below are given the values of the mechanical characteristics of the steel of the investigated bars, determined as a result of tensile testing plane specimens according to GOST 1497-61, which were made from the material of the flange and web:

<table>
<thead>
<tr>
<th>$q_0$</th>
<th>10$^4$, kg/mm $^2$</th>
<th>$E$</th>
<th>10$^4$, kg/mm $^2$</th>
<th>$\varepsilon$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.2 (flange)</td>
<td>34.2 (web)</td>
<td>2.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

The limiting load was determined from the conditions of development of a complete plastic hinge in the dangerous section by Strel'bitskaya's method [2]:

$$P_\text{lim} = \frac{4}{h_0^2} \left( \frac{h_0}{h_0} + \frac{\sigma_y}{E} \frac{h_0^4}{h_0^4} \right) = 3270 \text{ kg.}$$

Table 1 gives all the necessary dimensions and geometric characteristics of the sections determined from measurement results.

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<table>
<thead>
<tr>
<th>Beams</th>
<th>$l$, cm</th>
<th>$h$, cm</th>
<th>$b$, cm</th>
<th>$t_0$, cm</th>
<th>$t_y$, cm</th>
<th>$t_w$, cm</th>
<th>$I_x$, cm$^4$</th>
<th>$I_y$, cm$^4$</th>
<th>$I_w$, cm$^4$</th>
<th>$C$</th>
<th>10$^4$, kg/mm $^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unreinforced</td>
<td>406,0</td>
<td>15,14</td>
<td>8,25</td>
<td>0,76</td>
<td>0,52</td>
<td>835,9</td>
<td>59,96</td>
<td>3294,4</td>
<td>3,88</td>
<td>3,85</td>
<td></td>
</tr>
<tr>
<td>Reinforced</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23,8</td>
<td>23,7</td>
<td></td>
</tr>
</tbody>
</table>


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Two of the four bars were reinforced by inclined ribs "crosswise" (Fig. 1), in which case the value of the reduced torsional rigidity \( C_{\text{red}} \) is determined by Reut's formula [3]:

\[
C_{\text{red}} = a C.
\]

Here \( a \) is the coefficient of increase of torsional rigidity,

\[
a = \frac{1}{1 + \frac{C_t}{C}}.
\]

where

\[
C_t = \frac{\beta}{\delta^2 + \eta \sigma + \nu};
\]

\[
\beta = \frac{6EI_t h_0^2}{P_f};
\]

\[
\eta = a \left( \frac{2}{t \cos^4 \alpha_t} - 2 \right) + \frac{30/l_f}{a} \left( \frac{\mu_f}{F_f} + \frac{\mu_r}{F_r \cos \alpha_t} \right);
\]

\[
u = a^2 - \frac{30/l_f}{F_f}.
\]

where \( l_f, F_f, I_f, F_r \) are, respectively, the maximum moment of inertia and cross sectional area of the flange and rib; \( \mu_f = 1.1, \mu_r = 1.2 \) are coefficients taking into account the nonuniform distribution of tangential stresses over the flange and rib sections. The other notations are shown in Fig. 1. In the given case the coefficient \( a = 0.6 \).

The critical load for reinforced bars was also determined by formula (1) in which, in place of the torsional rigidity \( C \), its new value \( C_{\text{red}} \) was introduced:

\[
P_{C, \lim} = \frac{m V E_{\text{red}}}{l_f^2} = \sqrt{a} P_c = 5050 \text{ kg}.
\]

Then the ratio of \( P_{C, \lim} \) to \( P_{\lim} \) was 1.54.

The tests were carried out on the machine designed by Chernov [4]. The beams were installed in multicomponent dynamometric supports which permitted measuring the vertical and horizontal components of the reactions acting in the support sections. The loading device during deformation of the bar provided the prescribed direction of the force. The torsional rigidity of the bars \( C \) was determined experimentally, in addition to being calculated. The deviation of the calculated values of \( C \) from the experimental was less than 2%.

In testing the bars we measured the longitudinal deformations of the fibers, deflections of the flanges in a horizontal direction and of the web in the vertical direction, and elongation of the fibers by four mechanical strain gages located 0.1 m from the site of load applications on the extreme fibers of the flanges. The deflections of the flanges and web were measured by the LISI PAO-6 system of deflectometers. The angle of twist of the middle section was calculated on the basis of the displacements of the flanges.

The inaccuracy of the installation and certain initial imperfections of the bar had a substantial effect when testing beams without reinforcement. For them the smallest loads caused flexural-torsional strains...