High tensile steel in reinforced concrete structures

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Objekttyp: **Article**

Zeitschrift: **IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht**

Band (Jahr): **2 (1936)**

PDF erstellt am: **21.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-3268

IIc3

High Tensile Steel in Reinforced Concrete Structures.

Verwendung des hochwertigen Stahls in Eisenbeton-Konstruktionen.

Les aciers à haute résistance dans les constructions de béton armé.

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According to the regulations in force in various countries the permissible stress of mild steel such as is ordinarily used in the reinforcement of concrete amounts to 1200 kg/cm², and that of high tensile steel to 1800 kg/cm². The cross section of the tensile reinforcement may, therefore, be reduced by one third if the "1800" or high tensile steel is adopted instead of the "1200" or ordinary mild steel, without altering the depth of the beam. This involves a slight increase in the compression of the concrete, but this is always permissible as *Saliger* has shown in his paper N° II c 3 before the present Congress. If, then, it is desired to replace n round bars of diameter d of mild steel by n_1 round bars of diameter d_1 of steel "1800" we obtain —

$$n\, d^2\, \pi \cdot 1200 = n_1\, d_1^2\, \pi \cdot 1800$$

It is desired that the adhesion stress should remain the same in both cases, therefore

$$n\, d\, \pi = n_1\, d_1\, \pi$$

The above equations give the condition

$$n : n_1 = d_1 : d = 1200 : 1800 = 2 : 3$$

It follows that we can, for instance, replace two bars of 9 mm diameter of steel "1200" by three bars of 6 mm diameter of steel "1800". This entails very thin bars, which are expensive and which are not stiff enough to retain their straightness.

These disadvantages may be avoided by giving the reinforcing bars a regular triangular section. Of all the possible regular polygons of equal area, the triangle is the one which has the largest perimeter and the circle is the one which has the smallest. If d is the diameter of the circle and a = 1.1 d is the side of an equilateral triangle, then the perimeter of the triangle is 3 a = 3.3 d and that of the circle is π d = 3.14 d, and the difference between them is $3a - 3d = 0 \cdot 16d$. Thus the perimeter of the triangle is 5% greater than that of the circle.

The area of the circle is $A_0 = \frac{d^2\pi}{4}$ and that of the triangle is $A_\Delta = a^2 \frac{\sqrt{3}}{4}$

Hence $$\frac{A_0}{A_\Delta} = \frac{d^2\pi}{a^2\sqrt{3}} = \frac{\pi}{1.21\sqrt{3}} = 1.5 = \frac{1800}{1200}$$

Thus a round bar of diameter d of steel "1200" may be replaced by a triangular bar of steel "1800" if the side of the triangle is 1.1 d. This gives a saving of 33% of steel without reducing the bond.

It would, therefore, be advantageous to adopt bars of steel "1800" of triangular section, and if the rolling of such sections were decided upon the following advantages would also accrue:

1) The danger of confusion between round bars of steel "1800" and those of steel "1200" would be eliminated.

2) Of all regular figures of equal area, the triangle has the largest moment of inertia and the circle has the smallest. (Figures bounded by perimeters containing re-entrant angles or concave curves, such as for instance a star, are here not considered. A bar of which the section is shaped like a star can be drawn out of the concrete within a cylindrical space which has no concavity, this cylinder being the smallest that can be circumscribed around the star in question.) The area of the circle being $A_0 = \frac{d^2\pi}{4}$ the corresponding moment of inertia will be $I_0 = A_0 \frac{d^2}{16}$. The area of the triangle being $A_\Delta = a^2 \frac{\sqrt{3}}{4}$ its corresponding moment of inertia will be $I_\Delta = A_\Delta \frac{a^2}{24}$.

From the equation $A_0 = A_\Delta$ we have $\frac{a^2}{d^2} = \frac{\pi}{\sqrt{3}}$

whence $$\frac{I_\Delta}{I_0} = \frac{2a^2}{3d^2} = \frac{2\pi}{3\sqrt{3}} = 1.21.$$

Thus the moment of inertia of the triangle is 21% greater than that of the circle having the same area. Triangular bars are therefore more rigid than round bars and are not as easy to curve and bend, but retain their straightness better in course of handling, both in the store and on the site. This is a matter of some importance, for curved bars must straighten themselves before they can begin to act in tension, and meanwhile those bars which are already straight are overworked. In the case of compression reinforcement the stiffness of the bars is still more important, and round bars not being very rigid tend to buckle easily. There is, therefore, no object in using round bars of steel "1800" in compression.

3) Triangular bars take up less room in the store than round bars because they fill the whole of any given space without wastage: six triangles form

a regular hexagon, and such hexagons may be stacked closely against one another without losing any space.

4) A triangular bar can easily be twisted so as to obtain a special shape as in Ransome's system. In this way the grip between the bar and the concrete may be still further improved, seeing that the circumference of the circle enclosing the regular triangle is 21 % greater than the perimeter of the triangle itself. A twisted bar cannot be pulled out of the concrete without first having to strip the latter from the cylindrical surface circumscribing the bar, or from a surface which is still larger. This has been shown by experiments on Isteg steel. In such experiments at Warsaw, carried out by *Bryla* and *Huber*, two round bars of 7 mm diameter twisted into a spiral around one another gave an adhesion 20 % greater than a single equivalent round bar of 12 mm diameter. The circle circumscribed around the two twisted bars each 7 mm in diameter is itself of 14 mm diameter, and its circumference is, therefore, 16.67 % greater than that of the round bars. The difference of 20—16.67 % is attributable to the fact that the imaginary tube enclosing the twisted Isteg is a little larger than twice 7 mm, and does not form a precisely regular cylinder.

Instead of rolling triangular bars of steel 1800 they might be rolled from steel 1200, and their quality subsequently improved by stretching and twisting as is done for Isteg steel.