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DESIGN STRENGTH OF REINFORCED CONCRETE FOR BIAXIALLY BENDED MEMBERS

It is confidently stated [1] that almost all structures undergo one or another type of complex deformation. At the same time, very often complexly deformed reinforced concrete structures analysis is carry out on plane types of deformations in orthogonal main planes of inertia. Designers are forced to resort to such a simplification, since the calculations of reinforced concrete structures for complex types of deformation are still quite complex. To solve this problem for the calculation of biaxially bended members with triangular form of the compressed area, the concept of design strength of reinforced concrete is used, which was introduced by D.V. Kochkarev [2].

When determining the strength of reinforced concrete cross-sections at biaxial bending, the following assumptions are used [3]:

– plane sections remain plane;

– the strain in reinforcement, whether in tension or in compression, is the same as that in the surrounding concrete;

– the tensile strength of the concrete is ignored;

– a rectangular stress distribution in compressed concrete is assumed.

In general, the design strength of reinforced concrete depends on the physical and mechanical parameters of concrete and reinforcement that make up the cross-section of the member. The general condition of reinforced concrete members bearing capacity at plane bending has the form

$$M_{Ed} \le M_{Rd} = f_{zM} W, \tag{1}$$

where M_{Ed} – the bending moment, which appear because of external loads; M_{Rd} – the bending moment, which may be perceived by the beam; $f_{zM} = f\,(C, \rho_l, f_{yd})$ – the design value of reinforced concrete strength for flexural members; $W = bd^2/6$ – elastic resistance moment of a section.

To transform (1) for biaxially bended members it's proposed using coefficient γ

$$M_{Ed} \le M_{Rd} = f_{zM} W \gamma\,, \tag{2}$$

where γ – coefficient, which takes into account the influence of biaxial bending.

According to the accepted prerequisites, the design scheme of the section of biaxially bended member with a triangular form of a compressed concrete area will have the form presented in Figure 1.

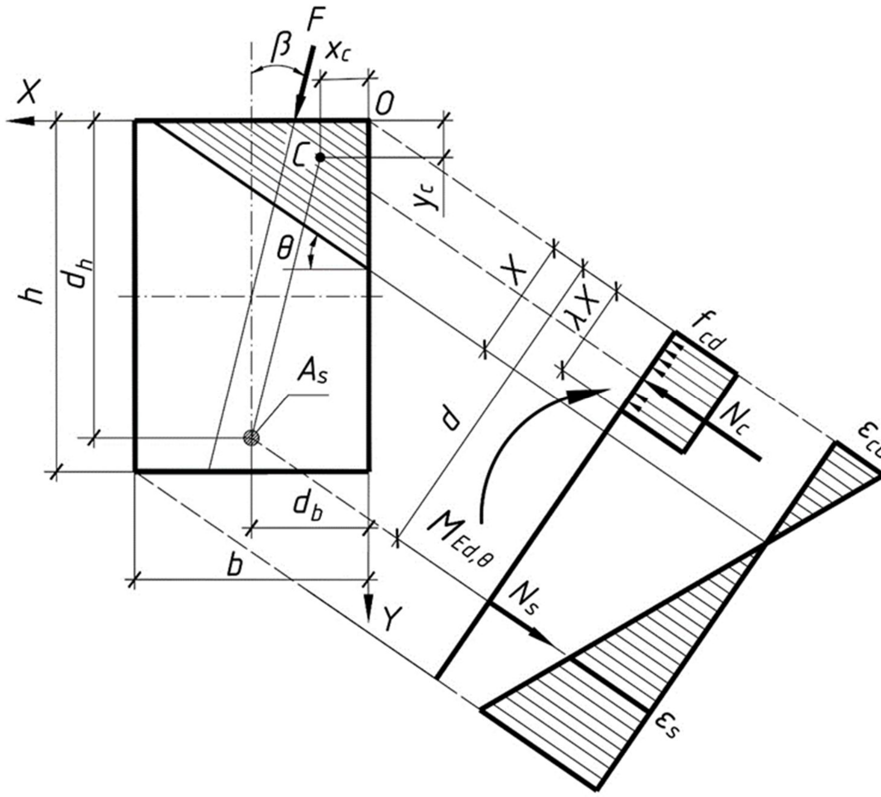

Fig. 1. Design diagram of the cross-section of the biaxially bended member with a triangular form of a compressed concrete area

The general equilibrium equations for the design scheme under consideration (Figure 1) will have the form:

$$\sum Z = N_s - N_c = 0; \tag{3}$$

$$\sum M_C = M_{Rd,Y} - M_{Ed,Y} = 0, \tag{4}$$

where

$$M_{Rd,Y} = N_s \left(d_h - y_c\right), \tag{5}$$

N_s, N_c – resultant forces in the tensile reinforcement and in the compressed concrete zone, respectively;

d_h – the distance from the most compressed concrete fiber of the cross-section to the point of application of resultant N_s;

y_c – the coordinate of the resultant N_c application in coordinate system XOY;

$M_{Rd,Y}$, $M_{Ed,Y}$ – values of bending moments from the action of internal and external forces, respectively, in the plane of the coordinate axis Y at the moment of exhaustion of the strength of the reinforced concrete member in the normal section.

Combining equation of equilibrium (3) and (4) to (2) it is received:

$$M_{Rd,Y} = f_{yd}\rho_l b d_h\left(d_h - \frac{1}{3}\sqrt{\frac{2f_{yd}\rho_l b d_h \tan\theta}{f_{cd}}}\right), \qquad (6)$$

where f_{yd} – design yield strength of reinforcement; $\rho_l = A_s / (bd_h)$ – longitudinal reinforcement ratio; θ – angle of inclination of the neutral axis; f_{cd} – design compressive strength of concrete.

By equating the right-hand side of inequality (2) and equation (6) the coefficient γ may be obtained for a rectangular cross-section with a triangular form of the compressed zone of concrete, i.e.

$$\gamma = \frac{2f_{cd}}{2f_{cd} - f_{yd}\rho_l} - \sqrt{\frac{8f_{cd}f_{yd}\rho_l\tan\theta}{9\left(2f_{cd} - f_{yd}\rho_l\right)^2}\frac{b}{d_h}}. \qquad (7)$$

To obtain the dependence $\theta = f(\beta)$, which can be used to calculate the angle θ of inclination of the neutral axis, the condition of parallelism of the planes of the internal $M_{Rd,\beta}$ and external $M_{Ed,\beta}$ bending moments action is applied. Those planes are inclined at an angle β to the vertical Y axis of symmetry of the section. Having singled out the ratio b / d_h as one that can be specified, the formula for determining the angle θ is written in the form:

$$\tan\theta = \frac{d_h}{b}\frac{f_{cd}l^2}{8f_{yd}\rho_l\tan^2\beta}\left(\sqrt{1 + \frac{8f_{yd}\rho_l}{f_{cd}l^2}\frac{b}{d_h}\tan\beta} - 1\right)^2, \qquad (8)$$

where $l = 3kb / d_h - 3\tan\beta$; $k = d_b / b$.

Thus, using dependencies (12) and (18), it is possible to tabulate the coefficient of decreasing of the strength of reinforced concrete at biaxial bending when the angle β of the external load plane inclination to the vertical axis of symmetry of the section is changed for a certain value of the b / d_h ratio.

Conclusions. The condition for determining the design strength of reinforced concrete for biaxially bended members with a triangular form of a compressed concrete area has been established. On the basis of the proposed condition, the ultimate values of the design strength of reinforced concrete may be determined for normally reinforced concrete member, that is, for those in which at the moment of failure, the stress of the tensile reinforcement reaches the yield point.

References

1. Павліков, А.М, Гарькава, О.В. (2018) Залізобетонні конструкції в умовах складного деформування та їх розрахунок. Полтава : ПолтНТУ.

2. Кочкарьов, Д.В. (2015) Нелінійний опір залізобетонних елементів і конструкцій. Рівне: О. Зень.

3. EN 1992-1-1. Eurocode 2: Design of reinforced concrete structures. Part 1-1. General rules and regulations.