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THE ATTAINMENT OF EQUAL DURABILITY OF LONGITUDINAL REINFORCEMENTS IN FERRO-CONCRETE ROD CONSTRUCTIONS AT THE STAGE OF PROJECT CONSTRUCTION

Key words

Reinforcement, longitudinal strain, ferro-concrete rod.

Abstract

In the given work, methods of mass transfer theory are used to solve problems of the reaction grout propagations in ferroconcrete rectangular rod cross-section elements and to suggest, on this basis, an original constructive solution for reinforcement cross-sections accounting for the equal reinforcement durability.

It is known that under the influence of an external aggressive medium of a natural or technogenic character, concrete passivizing properties suffer a loss with respect to the reinforcement that begins corroding. In rod elements, the process of corrosion begins in angular rods, and due to this, in angular zones there appear corrosive cracks [5] that degrade the bearing power of ferroconcrete elements and deface the aesthetic view.

A traditional location of longitudinal reinforcement rods in rectangular, T-shaped and I-beam cross-sections is shown in Fig. 1a, where

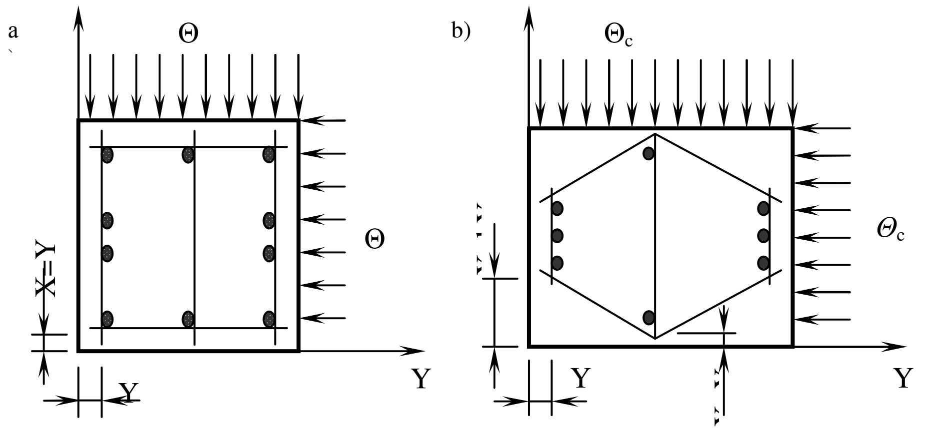

Fig. 1. a – is a traditional reinforcement location; b – is the reinforcement location for equal workable conditions of interstitial and angular rods due to a displacement of the angular rods

In this case, the thickness of protective concrete layers, considered as spans from reciprocally perpendicular surfaces of the element to the reinforcement rods, is taken to be equal (X = Y). Such a location implies, deliberately, unequal workable conditions for angular and interstitial rods in aggressive media.

Angular cross-section areas with angular reinforcement rods are subject to the influence of an aggressive medium on two reciprocally perpendicular surfaces. In the theory of mass potential transfer, angular cross-sections are idealized in the form of a two-sided angle. The cross-section parts, adjacent to interstitial reinforcement rods, are at a sufficient distance from angular zones and subject to the influence of the external medium in one direction only. They are idealized as a half-delimited body.

The differential equation for the mass potential transfer or potential conductivity is written analogously to Feek's second law [1, 3, 4] (with no account for thermal or baro-diffusion and in the absence of inner sources or off-flows of either heat or mass):

$$\frac{d\Theta}{d\tau} = a\Delta^2\Theta \tag{1}$$

Where, Θ is the potential transfer as a function of time and co-ordinates; τ is the time; a is the equivalent potential conductivity co-efficient.

The solution of equation (1) for boundary conditions of the first kind may be written as follows:

a) For the half-delimited body, in the form of a parameter of the relative potential conductivity Θ_{nm}:

$$\Theta_{nm} = \frac{\Theta_c - \Theta(y,\tau)}{\Theta_c - \Theta_0} = 1 - erfc\frac{1}{2\sqrt{Fo_y}} \tag{2}$$

b) For the two-sided angle in the form of a parameter of the relative potential conductivity Θ_{dy}:

$$\Theta_{dy} = \frac{\Theta_c - \Theta(x,y,\tau)}{\Theta_c - \Theta_0} = 1 - erfc\frac{1}{2\sqrt{Fo_x}} - erfc\frac{1}{2\sqrt{Fo_x}} + erfc\frac{1}{2\sqrt{Fo_x}} \times erfc\frac{1}{2\sqrt{Fo_y}} \tag{3}$$

Where Θ_0 is the initial potential transfer distribution in the body; Θ_c – potential transfer for the environmental medium; $Fo_x = \frac{a\tau}{X^2}$, $Fo_y = \frac{a\tau}{Y^2}$ – are the Fourier numbers (non-dimensional time) on coordinates X and Y, respectively; $erfc\frac{1}{2\sqrt{Fo_i}} = 1 - erf\frac{1}{2\sqrt{Fo_i}}$, $erf\frac{1}{2\sqrt{Fo_i}}$ is the function of Gaussian errors.

Let us write down the parts of equations (2) and (3) as follows:

$$\frac{\Theta(y,\tau)}{\Theta_0} = \Theta_{nm}(1 - \frac{\Theta_c}{\Theta_0}) + \frac{\Theta_c}{\Theta_0} \tag{4}$$

$$\frac{\Theta(x,y,\tau)}{\Theta_0} = \Theta_{dy}(1 - \frac{\Theta_c}{\Theta_0}) + \frac{\Theta_c}{\Theta_0} \tag{5}$$

It is practically very important to solve the problem of placing angular reinforcement rods so that the rods might be, approximately, in the same conditions as interstitial reinforcement rods from the standpoint of attaining, at the same time, equal relative concentrations of mass potential potentials. The fulfilment of this condition, based on the equality of the right parts of Equations (4) and (5) is the following:

$$\theta_{nm}\left(1 - \frac{\theta_c}{\theta_o}\right) + \frac{\theta_c}{\theta_o} = \theta_{\partial y}\left(1 - \frac{\theta_c}{\theta_o}\right) + \frac{\theta_c}{\theta_o} \tag{6}$$

This implies the equality of mass transfer parameters for the half-delimited body and for the two-sided angle $\theta_{nm} = \theta_{\partial y}$. By making the right parts of Equations (2) and (3) equal,

$$1-erfc\frac{1}{2\sqrt{Fo_y}}=1-erfc\frac{1}{2\sqrt{Fo_x}}-erfc\frac{1}{2\sqrt{Fo_x}}+erfc\frac{1}{2\sqrt{Fo_x}}\times erfc\frac{1}{2\sqrt{Fo_y}} \tag{7}$$

We may state that the simultaneous attainment of the equality in relative concentrations of mass transfer potentials for the half-delimited body and two-sided angle, having one common coordinate Y, is possible at the observance of the following condition:

$$1=1-erfc\frac{1}{2\sqrt{Fo_x}} \tag{8}$$

or

$$erfc\frac{1}{2\sqrt{Fo_x}}=0 \tag{9}$$

The solution, $\frac{1}{2\sqrt{Fo_x}}=\infty$, or $Fo_x=\frac{a\tau}{x^2}\to 0$ satisfies Equation (9). The solution obtained is obvious and is valid for the initial distribution at $F_{oi} = 0$, when both bodies are in the equilibrium condition with the environmental medium.

When affected by the environmental medium, at the time $\tau > 0$ and equivalently potential conductivity co-efficient a $\neq$ 0, the tendency to zero of the number $Fo_x=\frac{a\tau}{x^2}\to 0$ is possible only at x$\to\infty$. Thus, the angular rods in a rectangular cross-section will, theoretically, be in the same conditions as interstitial rods, if a two-sided angle is transformed into a non-limited body.

For a practical solution of this problem, one should know a permissible value of the divergence ε_o in the determination of relative parameters of mass transfer potentials for a half-delimited body θ_{nm} and for a two-sided angle $\theta_{\partial y}$. This permissible value should satisfy the inequality

$$\frac{\theta_{nm}-\theta_{\partial y}}{\theta_{nm}}<\varepsilon_o \tag{10}$$

The left part of the inequality (10) represents nothing else but

$$\frac{\theta_{nm}-\theta_{\partial y}}{\theta_{nm}}=\frac{\left(1-erfc\frac{1}{2\sqrt{Fo_y}}\right)-\left(1-erfc\frac{1}{2\sqrt{Fo_y}}-erfc\frac{1}{2\sqrt{Fo_x}}+erfc\frac{1}{2\sqrt{Fo_x}}\times erfc\frac{1}{2\sqrt{Fo_y}}\right)}{1-erfc\frac{1}{2\sqrt{Fo_y}}}=$$

$$=erfc\frac{1}{2\sqrt{Fo_x}} \tag{11}$$

Now, designate by ε_a the absolute deviation in the value of the mass transfer potential parameter of the half-delimited body θ_{nm} from the parameter of the two-sided angle $\theta_{\partial y}$ and write it as $\varepsilon_a = \theta_{пт}(Fo_y) - \theta_{ду}(Fo_y, Fo_x)$. Then, the absolute divergence ε_0 and absolute deviation ε_a will be linked by the following equation:

$$\varepsilon_o=\frac{\varepsilon_a}{\theta_{nm}(Fo_y)} \tag{12}$$

As seen from Formula (12), at a constant value of the relative divergence between the parameters of mass transfer potential ε_0, the value of the absolute deviation ε_a will decrease with a decrease in the mass transfer potential parameter $\theta_{nm}(Fo_y)$ for the half-delimited body and, naturally, becomes equal to zero at a balance state.

In practical projecting of ferroconcrete elements related to mass potential transfer in the process of exploitation, it is more correct to use not a relative permissible divergence E_0, but the absolute deviation between parameters of mass transfer potential E_a, which, proceeding from Formulas (11) and (12), will be equal to

$$\varepsilon_a=\varepsilon_o\theta_{nm}(Fo_y)=erfc\frac{1}{2\sqrt{Fo_x}}\left(1-erfc\frac{1}{2\sqrt{Fo_y}}\right) \tag{13}$$

Quantitatively, the value of error ε_a obtained from calculating, using Formula (2), the mass transfer potential parameter for the two-sided angle $\theta_{\partial y}$, as for a half-delimited body, should better be correlated with the value of a reliable probability accepted at the determination of a concrete normative strength [2]. In correspondence with the value of reliable probability 0.95, the value of absolute deviation between the parameters of mass transfer potentials of the half-delimited body and two-sided angle will be equal to $\varepsilon_a = 0.05$ or 5%.

Fig. 2 gives the diagram that affords, by the known value $Fo_y = a\tau/Y^2$ to determine the ratio k = X/Y between the coordinates X and Y for angular rods. As seen in the diagram, parameter K changes in time, ambiguously. At small Fourier numbers ($Fo_y < 2$), the parameter value does not exceed the value $K \approx 2.5 - 3.0$. For middle values of Fourier numbers within $Fo_y = 2 - 80$, the parameter K monotonously increases up to the maximum value $K = 5.5$ at $Fo_y = 30$, and then it begins monotonously decreasing to $K = 3$ at $Fo_y = 80$. At large values of Fourier numbers ($Fo_y > 80$), parameter K goes on decreasing.

The results of the experiments carried out show the angular and interstitial zones of rectangular cross-sections to react to the external medium influence ambiguously. Angular zones are in more severe conditions as compared to interstitial ones. his feature must be taken into account when locating longitudinal reinforcements when designing ferroconcrete rod constructions of a rectangular cross-section. The parameter value K is unambiguously determined by the diagram given in Fig. 1b, as a function of the number $Fo_y = a\tau/Y^2$.

A correct location of the longitudinal reinforcement, when angular and interstitial reinforcement rods are, approximately, in the same conditions, is shown in Fig. 1b.

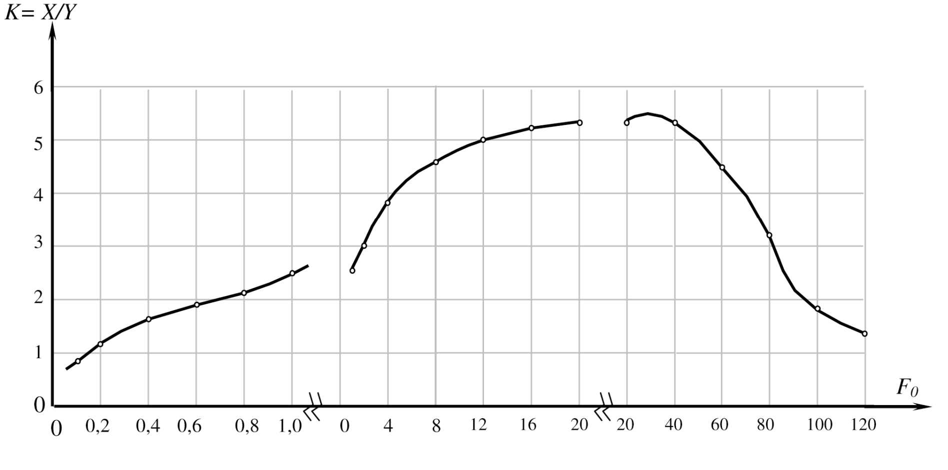

Fig. 2. The chart of ratio k = X/Y

References

1. Luikov A.V.: Heat and mass transfer in capillary-porous bodies, Advances in Heat Transfer. V.I. Academic Press, 1964.
2. СНиП 2.03.01-84. Concrete and ferro-concrete constructions/Gosstroy USSR. – M.: 1985. – 79 p.

3. Frank-Kamanetskiy D.A.: Diffusion and heat-transfer in chemical kinetics. – M.: 1967. 491 p.
4. Luikov A.V., Mikhailov Y.A.: Theory of energy and Mass Transfer, Prentice – Hall Inc., New York, 1961, Pergamon Press, London, 1965.
5. Schäden and Mängel an Baukonstruktiotien (Beurteilung, Sicherung, Sanierung). 2 Auflage. R. Rybichi, Werner – Verlag. – Düsseldorf 1974, pp. 432.

Ocena trwałości zbrojenia przy odkształceniu podłużnym w żelbetowych elementach konstrukcyjnych na etapie projektowania konstrukcji

Słowa kluczowe

Zbrojenie betou, odkształcenie podłużne, elementy żelbetowe.

Streszczenie

W artykule przedstawiono wykorzystanie metod teorii przenikania masy do rozwiązywania problemów odkształcenia podłużnego w żelbetowych prętach o przekroju prostokątnym. Opracowano oryginalne rozwiązania do obliczeń zbrojeń betou pozwalające na uzyskiwanie wymaganej trwałości.