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UDK 624.012.43

STRENTH PROBLEMS OFINDIRECTLY REINFORCED COMRESSED ELEMENTS OF SPATIAL STRUCTURES

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Annotation: *The paper proposes a universal method for calculating the strength of diaphragms eccentrically compressed spatial elements with conventual and indirect reinforcement.*

Аннотация: *Анъанавий ва зич арматураланган номарказий қисилувччи фазовий эементлар диафрагмасининг универсал мустаҳкамлик усули таклиф қилинган. Усул деформацияланувчи қаттиқ жисмлар механикасининг асосий боғлланишларига асосланади. У "2П" хилидаги қобиқ диафрагмалар ўзагини тўрсимон ёки спирал арматуралаш усули билан мустаҳкамланган элементларини кучланиш деформацияланиш ҳолатини хусусиятларини ҳисобга олиш имконини беради.*

Аннотация: *В работе предлагается универсальный метод расчета прочности диафрагм внецентренно сжатых пространственных элементов с обычным и косвенным армированием. Метод базируется на основных зависимостях механики деформируемого твердого тела. Он позволяет учесть особенности напряженно-деформированного состояния бетона, обоймами которого служат сетчатые или спирально армированные элементы диафрагм оболочек типа "2П".*

Key words: *Spatial structures, indirect reinforcement, strength problems, 2P elements, optimal solutions.*

Калит сўзлар: *Фазовий конструкциялар, зич арматуралаш, мустаҳкамлик муаммоси, "2П" элементлар, оптимал ечим.*

Ключевые слова: *Пространственные конструкции, косвенное армирование, проблемы прочности, элементы «2П», оптимальное решение.*

The analysis of the method proposed by building codes for calculating the strength of compressed elements with indirect reinforcement indicates that it is based on experimental data on the tests of plane deformed states and therefore has a limited field of application. With the advent of new design solutions for the diaphragms of shells, in each café, additional experimental verification is required, associated with the setting of experimental on numerous laboratory samples.

Therefore, it is urgent to develop a universal method for calculating the strength of compressed elements of shell diaphragms with indirect reinforcement, which adequately takes into account the main features of their stress-strain state and deformation characteristics of concrete and steel [1,2].

Let us consider the theoretical aspects of determining the breaking load for eccentrically compressed rod elements of shell diaphragms with mesh or spiral reinforcement. The peculiarities of their reinforcement in accordance with the current standards design of reinforced concrete structures involve performing a strength calculation of normal sections on the basis of a nonlinear deformation model [3]. In this case, it is necessary to take into account the increase in the strength and deformability of the volumetric-stressed concrete core, as well as, its joint work with longitudinal and indirect reinforcement.

For more complex deformations (the oblique bending and oblique eccentric compressed), the compressed zone of the diaphragms of the shell structures has a shape that differs from a rectangle. This is naturally reflected in the stress-strain state of the zone and at its boundary height [2], and not only due to the variable section width, but also in connection with the different limiting deformability of the edge compressed fiber.

Since the height is inextricably linked with the ultimate elongation of the stretched reinforcement ε_{su} and with the maximum shortening of the concrete farthest from the neutral fiber line at the edge of the section ε_{su}, then its mathematical expression can be written as:

$$\xi_R = \frac{x_R}{h_0} = \frac{\varepsilon_{bu}}{\varepsilon_{bu} + \varepsilon_{su}} = \frac{1}{1 + \frac{\varepsilon_{su}}{\varepsilon_{bu}}} \qquad (1)$$

The main difficulty in using this formula lies in determining the ultimate deformations of materials, especially ε_{su}.

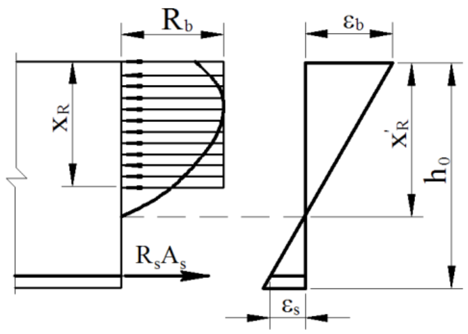

Fig. 1. Boundary height of the compressed zone of the diaphragm of shells and ribbed plates.

Since all stages of destruction give similar results, the modulus of concrete deformation in this state can be taken in accordance with the expression [1,4].

$$E_b^{'} = E_b(0{,}03 + 0{,}0047B). \qquad (2)$$

Then,

$$\xi_R^{'} = \frac{1}{1 + \frac{R_s}{\alpha R_b(0{,}03 + 0{,}0047B)}} \qquad (3)$$

Where: α is the ratio of the moduli of elasticity of reinforcement and concrete; *B* - class of concrete.

Here, attention should be paid to the need to take into account the change in the coefficients of transverse deformation of materials with an increase in the stress level of elements with indirect reinforcement. In this case, it becomes possible to give an accurate analytical assessment of the joint work of concrete and steel, since the value of the lateral pressure of the volumetric-compressed concrete core depends on the ratio of the values of v_b and $v_s$this creates the so-called cage effect. Parametric coordinates of the points of the diagram can be taken according to the recommendation [4]. For the diagram of a concrete core these coordinates are unknown at the beginning of the calculation. They largely depend on the ratio of the main compressive stresses. In centrally compressed concrete elements with indirect reinforcement at any point, the ultimate stress σ_{bzu} can be calculated by the formula obtained theoretically [4]:

$$\sigma_{bzu} = R_{bu} + k\sigma_{bxu} \qquad (4)$$

Where: R_{bu} is the strength of concrete; *k* – is the coefficient of lateral pressure depending on the level of lateral compression $m = \sigma_{bxu}/\sigma_{bzu}$and determined by the formula (5):

$$k = \frac{1+a-am}{b+(1-b)m} \qquad (5)$$

a and b – coefficients of the material established from experiments.

The value of the relative deformation of concrete ε_{bz0} for, elements with indirect reinforcement is proposed to be determined by the following formula:

$$\varepsilon_{bz0} = \varepsilon_{b0\left(\frac{\sigma_{bzu}}{R_{bu}}\right)} \qquad (6)$$

in which the exponent γ is calculated by the formula:

$$\gamma = 2 - \mu_{sz}\frac{E_s}{E_b} \qquad (7)$$

Where: ε_{bo} – is the value of the relative deformation of concrete at the top of the $\sigma_b - \varepsilon_b$diagram under axial compression (taken according to the current design standards); μ_{sz}- is a coefficient of longitudinal reinforcement; E_s and E_b are the initial moduli of elasticity of steel and concrete.

The resolving equation, relating the acting stresses and deformations of materials will be obtained by using the generalized Hooke's law for the elastic and elastoplastic stages of work. Let us consider the proposed method for calculating the strength of a compressed element, using the example of a P-shaped section with spiral reinforcement. When loading by a centrally applied compressive force of a reinforced concrete element of a P-shaped cross-section, reinforced with longitudinal reinforcement (reinforcement coefficient μ_{sz}) and a spiral diameter $d_{s,c}$ (Fig. 2.). compressive stresses $\sigma_{s,c}$ appear in the concrete core and longitudinal reinforcement, and tensile forces arise in the spiral bars with a cross-sectional area $A_{s,c}$. From the equilibrium condition of the considered fragment of height s, taking into account the uneven compression, we obtain the equations:

$$\frac{\sigma_{br}}{\psi_b} d_{eff}\frac{s}{2} - 2\sigma_{s,c}A_{s,c} = 0, \qquad (8)$$

Where: $\mu_{s,c}$- coefficient of indirect reinforcement with spirals; $\psi_b$is a coefficient taking into account the unevenness of the lateral compression of the concrete core (for a P-shaped section it usually takes ψ_b = 0,7, for a rectangular – ψ_b= 0,75), for a box-shaped and I-section$\psi_b = 0{,}8$.

Taking into account the known dependence $\sigma_{s,c} = \varepsilon_s \nu_s E_s$ for spiral reinforcement, equations (8) can be written in the following form:

$$\sigma_{br} = 0{,}9\mu_{s,c}\varepsilon_{s,c}\nu_s E_s \qquad (9)$$

Where: E_s is the modulus of elasticity of steel; $\varepsilon_{s,c}$- relative elongation strains of spiral reinforcement.

The practical implementation of the proposed calculation method is based on the step-iterative method in two stages. At the first stage, a centrally compressed element with indirect reinforcement is considered. For this stage of the optimal section of the element, a diagram of the volumetric stressed concrete core is constructed by calculation. In the calculations, it is recommended to increase gradually the axial deformation of the concrete. Further the stresses are determined (Fig. 2). as, well as the relative deformations of the elongation of the spiral reinforcement, after which the coefficients of elasticity and transverse deformations of the concrete and steel are calculated for a given level of loading. Then, the iterative process is repeated, until the specified computational accuracy is achieved.

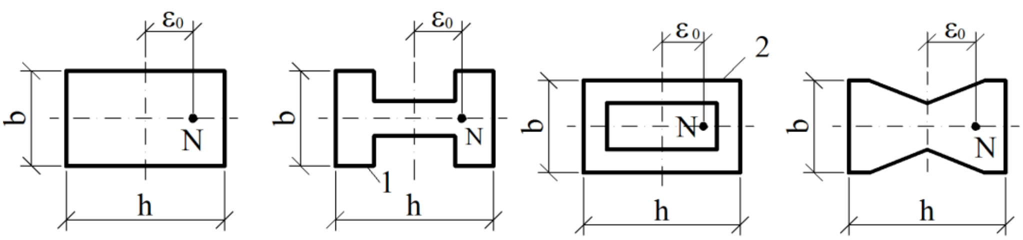

Fig. 2. Indirectly reinforced optimal sections of compressed reinforced concrete diaphragms of shells made of "P" elements at eccentricities $e_o > e_a$ - I-beams and box sections made of "P" elements.

At the second stage, the strength of the eccentrically compressed element is directly calculated using the known dependences of the norms.

Moreover, the calculated eccentricity is assumed to be no less than random, and the design flexibility is taken into account according to the deformed scheme.

Thus, a universal method for calculating the strength of compressed elements with indirect reinforcement of various kinds of optimal transverse of two "P" shaped sections has been obtained. Within the framework of this method on the basis of a nonlinear deformation model, an algorithm for calculating the strength was developed and estimates of the stress-strain state of eccentrically compressed elements were made.

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УДК 624.04+07

АКТИВ СЕЙСМИК ҲИМОЯ ҚУРИЛМАЛАРИНИНГ КЎП ҚАВАТЛИ БИНОЛАРДА ҚЎЛЛАНИЛАДИГАНЛИК ТАҲЛИЛИ ВА УЛАРНИ ҚЎЛЛАШНИНГ МАҚБУЛ ЕЧИМЛАРИ

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***Аннотация**: Ушбу мақолада бино ва иншоотларнинг сейсмик мустаҳкамлигини таъминлаш имконини берувчи мавжуд актив сейсмик ҳимоя қурилмалари ҳамда уларнинг қўлланилиши бўйича дунё миқёсидаги мавжуд манбалар таҳлили келтирилган бўлиб, уларни бино ва иншоотлара қўллаш учун математик моделлари келтирилган.*

***Аннотация**: В данной статье проведен анализ существующих устройств активной сейсмозащиты и их применения, обеспечивающих сейсмостойкость зданий и сооружений, также приведены математические модели их применения к зданиям и сооружениям.*