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SIMULATION OF THE STRESS-STRAIN STATE OF CONCRETE COLUMNS WITH PRE-COMPRESS HIGH-STRENGTH REINFORCEMENT

This article discusses the method of determining the stress-strain state of concrete columns with pre-compress high-strength reinforcement based on discrete representation of designs using real charts of the s-e **concrete and reinforcement using a computer. This technique allowed us to simulate the work of columns at all stages of loading up to the destruction. Herewith at each stage of loading we get the deformation and stress in the concrete and reinforcement throughout the all height of the section. This technique allows us to take into account prestressing in the reinforcement which takes place at the stage of manufacturing. In addition, it provides an opportunity to simulate the destruction of columns and determine their bearing capacity. Calculations of the experimental models of columns, that were made using this technique shown in most cases good coincidence of results.**

Key words: concrete column, the stress-strain state, the hypothesis of plane sections.

Розглянуто методику визначення напружено-деформованого стану залізобетонних колон з попередньо стиснутою високоміцною арматурою на базі дискретного представлення конструкцій з використанням реальних діаграм s-e **бетону та арматури за допомогою ЕОМ. Запропонована методика дала змогу промоделювати роботу колон на всіх стадіях завантаження включно з руйнуванням. На кожній стадії завантаження виникають деформації та напруження в бетоні та арматурі по всій висоті перерізу. Методика також дає змогу врахувати попередні напруження в арматурі, які існують на стадії виготовлення. Крім цього, вона дає можливість промоделювати руйнування колон та визначити їх несучу здатність. Виконані за допомогою запропонованої методики розрахунки експериментальних зразків колон показали переважно достатньо добрий збіг результатів.**

Ключові слова: залізобетонна колона, напружено-деформований стан, гіпотеза плоских перерізів.

Introduction

Research of concrete columns with pre-compressed high-strength reinforcement showed that the calculation methodology of existing regulations provides satisfactory matches of the value of durability, deformation, crack resistance with the experimental data. This technique does not give complete information about the stress-strain state of concrete columns at all stages of the work , not always accurately reflect the physical nature of the processes.

For the determination of the *bearing capacity*, deformation and crack resistance, a method of the determining of the stress-strain state of structures in concrete columns has been developed by a computer from the time of prestressing reinforcement to the destruction of the outer column load.

Experiment and assessment

The basis of the calculation model assigned a discrete representation of concrete core and the hypothesis of plane sections (Fig. 1). It is assumed that the core is made along the axis of the individual and elementary sites ***i*** and in the height - from individual single layers of concrete ***k*** and reinforcing steel ***n***.

The internal force and deformation of stresses within the areas of single layers are made permanent. Their value is determined by the values at the level of the median surface.

Since the deformations and stresses in materials - concrete and reinforcement, make up section, mutually determined, then the task is solved by a method of successive approximations.

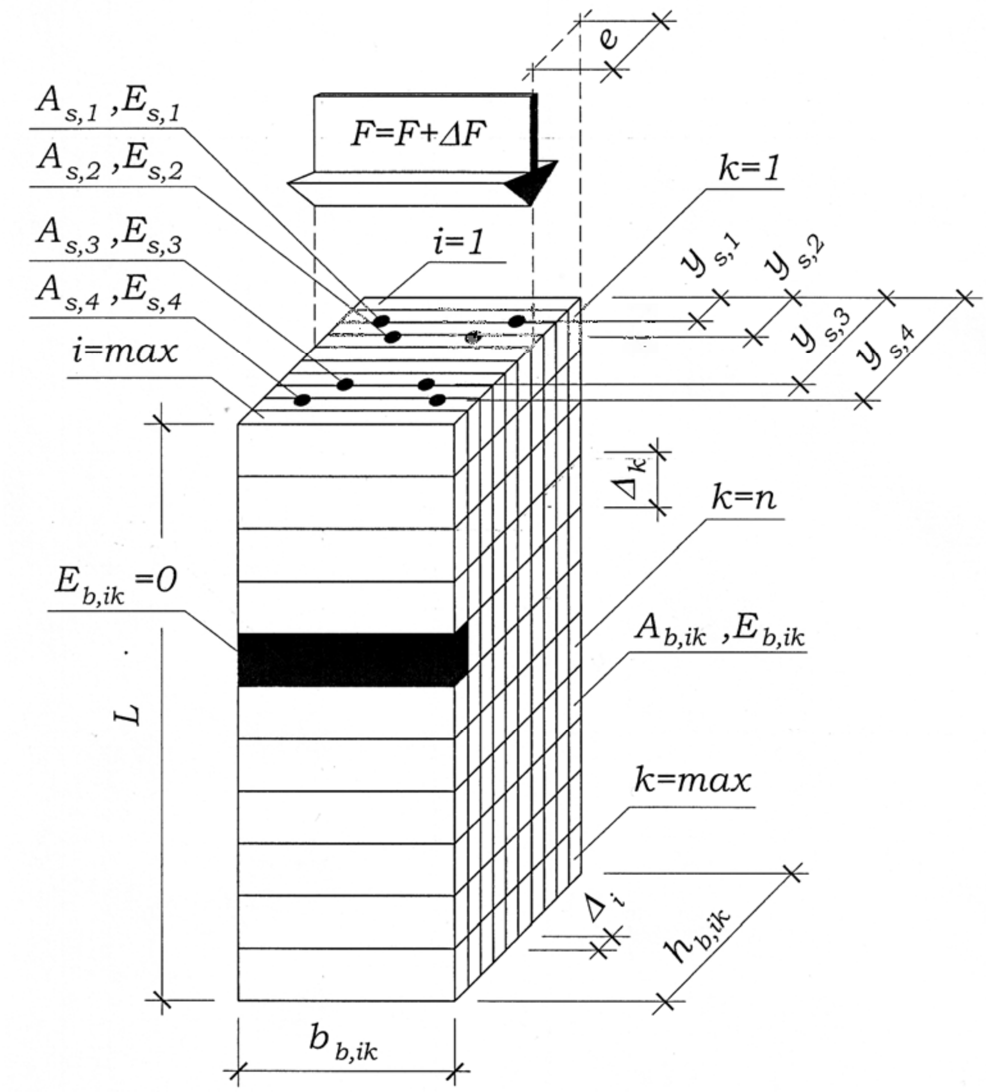

Fig. 1. Discrete representation of noncentral-compressed reinforced concrete core

Implementation of the computer calculations performed by the following algorithm (Fig. 2) with a load of core levels consistent application of external load *DF*:

1. Enter the necessary information on the size of the input shaft, its reinforcement (placing rods in cross section), the strength and deformation characteristics of materials, which are building real strain diagrams of materials.

2. At the beginning of the calculation of the value of cutting concrete and reinforcement modules equate to the initial elastic modulus:

$$E_{b,ik} = E_{b,o}\,;\; E_{s,in} = E_{s,o}\,. \tag{1}$$

The initial movement's sections are equal to *0*.

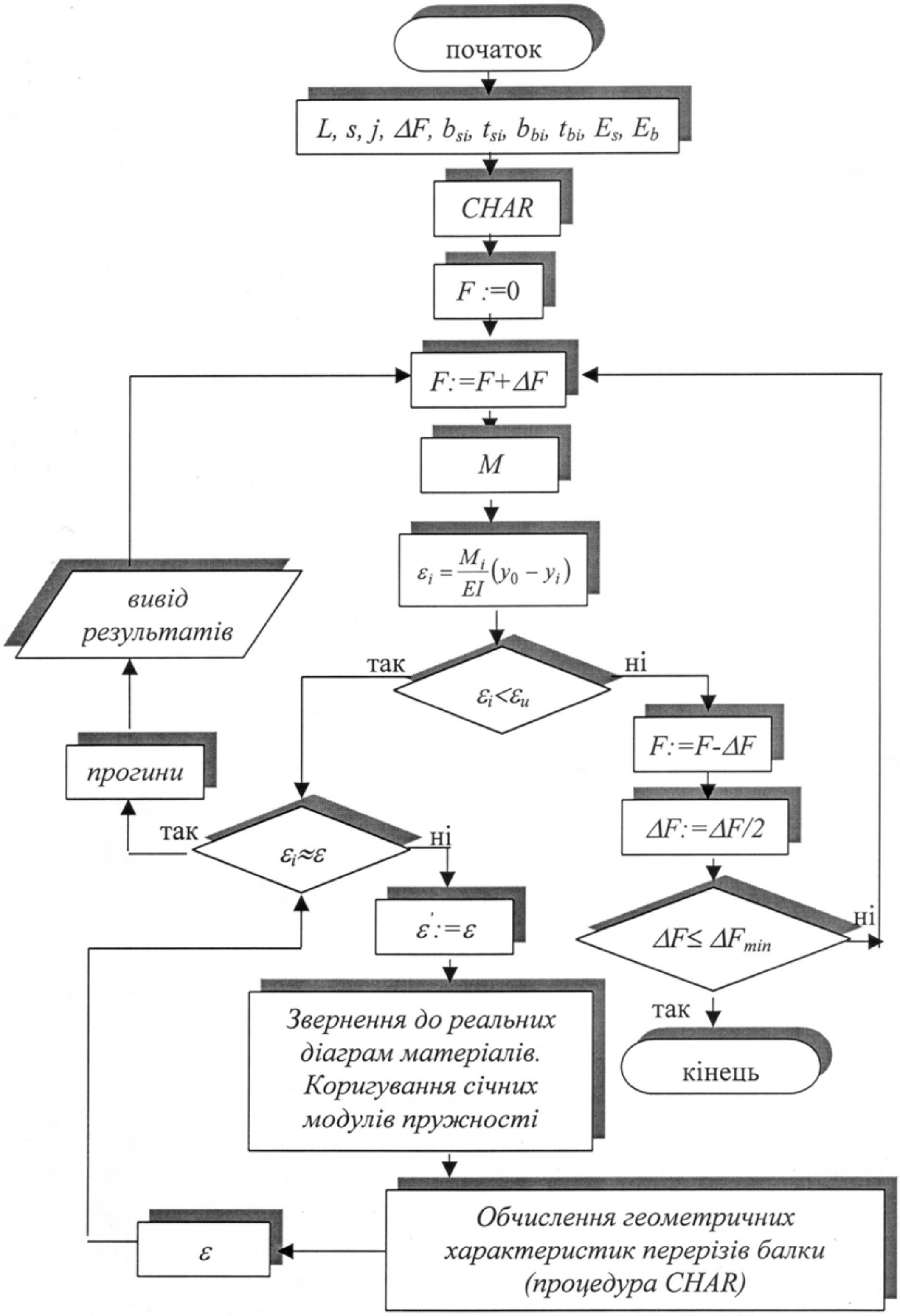

Fig. 2. Flowchart of calculating noncentral-compressed elements.

Relative deformations of materials are made zero. Only in the case of tension or compression reinforcement it assigned some initial value. Efforts to concrete while not transmitted (due to the constructive scheme intense reinforcement cages). Relative deformation of the concrete are zero.

3. Determine reduced to a single value of strain cross-sectional area of the module:

$$A_{red,i} = \sum_{k=1}^{k_{\max}} E_{b,ik} A_{b,ik} + \sum_{n=1}^{n_{\max}} E_{s,in} A_{s,in} ; \qquad (2)$$

Static moments of sections:

$$S_{red,i} = \sum_{k=1}^{k_{\max}} E_{b,ik} A_{b,ik} y_{1,ik} + \sum_{n=1}^{n_{\max}} E_{s,in} A_{s,in} y_{1,in} \, ; \tag{3}$$

The position of the center of mass *i* sections:

$$y_i = \frac{S_{red,i}}{A_{red,i}} \, ; \tag{4}$$

Moments of inertia sections:

$$I_{red,i} = \sum_{k=1}^{k_{\max}} E_{b,ik} A_{b,ik} y_{1,ik}^2 + \sum_{n=1}^{n_{\max}} E_{s,in} A_{s,in} y_{1,in}^2 \, . \tag{5}$$

4. Apply an external point load *F* and calculate internal stress N_i and M_i in sections and along the noncentral-compressed core.

5. For existing values summary sections and geometric characteristics ($A_{red,i}$, $S_{red,i}$, y, $I_{red,i}$) of internal efforts at them N_i and M_i and determine the relative deformation layers:

- concrete:

$$e_{b,ik} = \frac{N_i}{A_{red,i}} + \frac{M_i}{I_{red,i}} y_{ik} \, ; \tag{6}$$

- reinforcement:

$$e_{s,in} = \frac{N_i}{A_{red,i}} + \frac{M_i}{I_{red,i}} y_{in} \, . \tag{7}$$

6. According to the obtained relative deformation e_{bik} and e_{sin} based on the description of the actual strain diagrams «*s*-*e*» of concrete and steel reinforcement calculate the actual stresses, that operates in each element and corrects the value of intersecting modules in each elementary area of concrete and reinforcement.

Taking into account the physical nonlinearity of starting materials for the evaluation of the actual stress-strain state in cross sections of noncentral-compressed core we have used the method of successive approximations. In the first step of computing the value of intersecting modules are equal to the initial elastic modulus related materials. Calculating stresses and strains in each layer of all sections, we perform the correction of values intersecting elastic module:

- concrete:

$$E_{b,ik} = \frac{s_{b,ik}}{e_{b,ik}} \, ; \tag{8}$$

- reinforcement:

$$E_{s,in} = \frac{s_{s,in}}{e_{s,in}} \, ; \tag{9}$$

and continue calculation from point *3*, scilicet we calculate the geometric characteristics of reduced cross sections , taking into account the revised values of intersecting modules deformation of materials. Cycles of calculating are repeated to the time before the results are not close enough to two adjacent iterations. It should be noted that the application of the proposed mathematical model, requires a sufficiently accurate description of material deformation diagrams.

The load at which the concrete cracks, or destructs, set up according to the criteria of the concrete strength according to the second theory of the strength. Concrete is considered to be destroyed when the following conditions are fulfilled:

- for compression:

$$\left| e_{b,ik} \right| > e_{bf} \, ; \tag{10}$$

- for stretching:

$$\left|e_{b,ik}\right| > e_{btf}\,. \qquad (11)$$

Concrete elements, which in the process of calculation have cracked from tensile with further calculation excluded by resetting the values of these modules intersecting layers:

$$E_{b,ik} = 0\,. \qquad (12)$$

The experience of the calculations obtains sufficiently accurate results when the difference in adjacent repetitions decrease up to 0.1 ... 0.01%. Further improve of accuracy only increases the number of cycles and the time of computation without actually affecting the outcome.

The value of an external failure load for compressed-bending core set according with criteria for strength of concrete.

7. Calculation of the displacement axis of the rod is determined according to the famous expression of the Mora, replacing the summation of the integration:

$$f_i = \sum_{i=1}^{i_{\max}} \frac{M_i M_{i,1}}{I_{red,i}} + \sum_{i=1}^{i_{\max}} \frac{N_i N_{i,1}}{A_{red,i}}\,, \qquad (13)$$

where $M_{i,1}$ - the value of bending moment in the section of the unit *i* *from* unit load and strength. Then gradually increased external compressive stress on the value of *DF* (*F=F+DF*) and the calculation repeated from the step 3. Increasing the external load carried until one of the materials was less destructive boundary deformations. To improve the accuracy of calculating the failure load is applied consistently crushing stages. For this purpose we restored the values of $A_{red,i}$, $S_{red,i}$, y, $I_{red,i}$, E_{in}, E_{ik}, obtained at a stage prior to the destruction.

Growth *DF* was reduced by half (*DF=DF/2*) and the calculation was repeated. Crushing *DF was* repeated until the desired value was achieved DF_{min}.

At all stages the calculate program allowed to obtain graphs of relative deformations and stresses in any of the sections of the rod and bends in random intersection noncentral - compressed core, as well as their movements.

Conclusion

In the proposed method of determining the stress-strain state of concrete columns with high-strength pre-compressed reinforcement was simulated working prototypes at all stages of loading up to the destruction. As a result, we have received, distributions of stresses and strains in height typical section of the column.

In order to determine the optimal boundaries of the usage of proposed method of reinforcement of columns under different loading schemes a numerical experiment was carried out , using the developed mathematical model. In the numerical experiment considered the value of eccentricity from 0 to 210 mm, with varied class of concrete from C16/20 to C35/45. Optimum were columns with pre-compress high-strength reinforcement with small eccentricities that do not go beyond the kernel section.

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