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Research of the stress condition of the normal section of reinforced concrete elements using nonlinear deformation model

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Abstract

This article presents a technique to describe the stress-strain state of the normal section of reinforced concrete beams using nonlinear deformation model. An algorithm of describing the section operation built with the use of mathematical apparatus in the «MathCAD» environment. This algorithm allowed details to consider the state of stress of the normal section on the basis of stepper-iterative and integrated processes using real materials deformation diagrams. During algorithmization of section operation, we determined stresses, strains, nonlinear coefficients, the center of gravity of real diagrams of stresses and strains, the coordinates of the vertices of normal cracks, boundaries compressed, tensioned and damaged zones of section and other. Modern positions in the theory of concrete strength were applied and refined.

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Keywords: Reinforced concrete element; Normal section; The nonlinear deformation model; Stress; Strain; Diagram of deformation of the material.

1. Introduction

One of the directions of further development of the theory of reinforced concrete is the use of nonlinear deformation model (hereinafter - NDM) for the research of the works of reinforced concrete structures. A significant number of works [1-4] shows the relevance of this research trend. These works consider various aspects of the application of NDM for the analysis of stress-strain state of normal sections of reinforced concrete elements. The

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paper deals with the questions of the effective use of computer mathematical apparatus for improving NDM and major accomplishment, which are as follows:

- The introduction of the diagrams of real material deformation into the algorithm for calculating on NDM [5,6];
- The high degree of application of integrated and iterative processes in the section calculation;
- The use of mathematical programming for different combinations of elements of the equilibrium conditions;
- Finding a wider range of geometric parameters of the normal section as in the process of loading and in an extreme condition;
- Accounting for non-linear properties of the materials of the construction;
- The high degree of convergence of the results with the experimental data;
- Formation of the prerequisites for the creation of a full NDM for calculating the inclined section.

2. The implementation of NDM in the computer environment «MathCAD» to study the stress state of the normal section of a bending element.

Calculation algorithm is available in the format of programming blocks implemented in the working paper of the program:

- The first block describes the geometric characteristics of construction and the loads applied thereto with the output of internal forces acting for any section along the length of the element (or height in the case of calculating column [7,8]);
- The second block describes the state of physical and mechanical properties of materials used in the calculation are integrated into the calculation through a real stress-strain diagram, the specified function;
- The third block – calculation of creep of concrete, with the installation of timer to control every step of loading throughout the construction life cycle [9,10]. The possibility of taking into account the time set design concrete strength is fulfilled;
- The fourth block describes the characteristics of the algorithm of nonlinear deformation model, which includes: the number of sites of integration for the height / width of the cross-section and the number of cross-sections along the length (height) of the element and their geometrical characteristics;
- The fifth block – the main core of the algorithm, which is a block-simulation of infinite steps of the iterative cycle search section of the equilibrium state with the output of the normal section calculation results.

Fifth calculation block is based on the algorithm processing cyclic false condition «while», which arguments form the block execution condition and stop the cycle. Setting initial approximations and cycle line with the condition «while» are as follows:

$$Core(i,\ j,\ L_x)\ :=\|\ \nu_{bx(\mathrm{i})} \leftarrow 1, \nu_{by(\mathrm{j})} \leftarrow 1$$

$$\|\ \nu_s \leftarrow 1$$

$$\|\ \nu_{\mathrm{s}} \leftarrow 1$$

$$\|\ while\left(\left|M_x\left(L_x\right)\right|-\left|M_{xp}\right|\Big/\left|M_x\left(L_x\right)\right|\cdot 100\%\geq 0.1\%\right)\forall\left(\left|N_b\right|-\left|N_s\right|\Big/\left|N_b\right|\cdot 100\%\geq 0.1\%\right)$$

Search of equilibrium will be maintained as long as the condition is not violated false cycle, thus satisfied the required contact condition in this case – the observance of the calculation error.

Stress-strain state of the normal section is characterized by the total work of flexural stiffness of all elementary-sectional areas in different planes of the external load. Formulaic recording of the flexural stiffness of the elementary layers of the normal section described as follows:

$$D_{11b} \leftarrow \int_0^h E_{eff} A_{bi} z_{bi}^2(\mathrm{i}) \nu_{bx}(\mathrm{i})\,\mathrm{di},\ D_{22b} \leftarrow \int_0^b E_{eff} A_{bj} z_{bj}^2(\mathrm{j}) \nu_{by}(\mathrm{j})\,\mathrm{dj};$$