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PRESTRESSED LOSSES FROM SHRINKAGE AND NONLINEAR CREEP OF CONCRETE OF REINFORCED CONCRETE ROD SYSTEMS

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ABSTRACT

The article under discussion presents the algorithm for calculating prestressed reinforced concrete rod systems taking into account prestressing loss from nonlinear operation of reinforced concrete over time. The authors of the article suggested a program which is intended for calculation of prestressed concrete trusses taking into account stiffness of knots, creep and shrinkage of concrete, and also for change of prestressed in time, being under the influence of external loads, using the method of consecutive approximations.

KEY WORDS: *pressure, pre-pressure, deformation, creep, shrinkage, armature, connection, stages, losses, external, size, deformation.*

INTRODUCTION

Prestressed reinforced concrete structures have a complex stress state, varying in time from the effects of external loads, the manifestation of inelastic deformations of concrete, relaxation of stresses in steel and other conditions. In this connection, at designing of prestressed designs it is necessary to know the basic reasons, influence on character and size of change of pressure in armature and concrete at various stages of their work.

MODELS OF SAMPLES AND RESEARCH METHODS

Precise account of factors influencing the value of losses, as a rule, is a complex and often difficult to solve [1, 2]. In this connection, for practical calculations it is necessary to accept less exact, but simplified methods of preliminary stress losses accounting.

Pre-voltage losses considered in calculations can be divided into the following types: shrinkage of concrete; creep of concrete; relaxation of stresses in reinforcement; deformation of anchors, washers and gaskets; deformation of joints between blocks of composite structures; deformation of forms for the manufacture of structures; friction of reinforcement in the wall of the channel or concrete surface of structures; concrete buckling under the loops of ring (spiral) reinforcement; temperature difference between the stretched reinforcement and the temperature of the devices that take the stress; multiple repeated load; difference between the coefficients of linear elongation of reinforcement and concrete during the operation of the structure in conditions of increased temperature.

The above factors affecting the prestressed losses from shrinkage and creep of concrete, the relaxation of steel stresses are manifested over a long period of time.

In the operational phase, the main shrinkage and creep of concrete acts on the pre-stressed losses.

Let us determine the pre-stress losses from concrete creep using the formula [3].

$$\sigma_n = \frac{\sigma_b}{\mu_s}\left(1 - e^{-\xi}\varphi_t\right) \qquad (1)$$

where:

$$\sigma_b = \sigma_{sk}\frac{\mu_H}{1 + n_s\mu} \qquad (2)$$ - initial voltage.

Taking into account the growth of the elastic deformation modulus of concrete in time, the experimental parameters are determined:

$$\xi = n_н\mu_s\left(1 - \frac{n_н\mu_s}{\delta\varphi_t} l_n \frac{1 + n_н\mu_s + \delta\varphi_t}{1 + n_н\mu_s}\right) \qquad (3)$$

$$\mu_s = \frac{A_{sp}}{A} + \frac{A_s}{A} \qquad (4)$$

$$\mu_s = \frac{A_s}{A}; \qquad \mu_н = \frac{A_{sp}}{A} \qquad (5)$$

$$n_s = \frac{E_s}{E_M^{(t)}}; \qquad n_н = \frac{E_н}{E_M^{(t)}}. \qquad (6)$$

$$\varphi_e = \varphi_\infty\left(1 - e^{-b_1 t}\right) \qquad (7)$$

$\varphi_\infty = \varphi_\infty^c\eta_1\eta_2\eta_3$ - creep limit characteristic;

φ_∞^c - creep limit characteristic value for average conditions;

η_1 - correction factor dependent on the humidity of the environment in which the element (construction) is located;

$\eta_2 = 1{,}926 - 0{,}738 l_{gb}$ - correction factor that takes into account scaling factors (element size);

η_3 - correction factor depending on the age of the concrete t_o d the moment the element is loaded;

$E_M^{(t)} = E_{M(\infty)}^o\left(1 - \beta e^{-\alpha t}\right)$ - the elastic-momentous deformations of concrete;

$E_{M(\infty)}^o \beta, \alpha$ - constants that depend on curing conditions and concrete composition [4].

Pre-stressed losses from concrete shrinkage are determined by a formula:

$$\sigma_{s,y} = \frac{\alpha_y E_M^{(t)}}{\mu_s\varphi_\infty}\left(1 - e^{-\xi\varphi t}\right) \qquad (8)$$

where:

$\alpha_y = \alpha_y^c\eta_1\eta_2\eta_4$ - the ultimate relative deformation of shrinkage;

α_y^c - the value of the ultimate relative deformation of shrinkage for average conditions;

α_y^c - the correction factor, depending on the time from which shrinkage and concrete accounting begins.

Determining the pre-stressed loss from creep and shrinkage in time, we find the value of "compressive force":

$$N_{sp} = \sigma_{sk} - \left(\sigma_n + \sigma_{sy}\right)A_{sp} \qquad (9)$$

The calculated N_{sp} load is treated as an external load and is applied to the end of the prestressed rods with a reverse sign.

THE RESULTS OF THE EXPERIMENTS AND THEIR ANALYSIS

According to the developed algorithms the program is compiled and examples are considered.

The program is intended for calculation of prestressed concrete trusses taking into account stiffness of knots, creep and shrinkage of concrete, and also for change of prestressed in time, being under the influence of external loads, using the method of consecutive approximations. The general structure of the program calculation process is shown in Figure (1).

The results of the considered examples (calculation of prestressed reinforced concrete trusses taking into account the stiffness of the nodes in the inelastic stage) show that the stresses from shrinkage and creep in most of the elements do not change significantly and only in the lower zones significantly decreases.

On the basis of graphs (Figures 2, 3, 4) the increase of Δσ at different reinforcement percentages obtained in accordance with Table 1 shows that from the action of constant operating loads the stress in the rods of the truss decreases in time in the upper zone and increases in the lower zone, slant and rack. As the percentage of reinforcement increases, the stress increment - Δσ changes within the following limits:
a) in the lower zone from 2 to 8%; b) in the upper zone from 0.5 to 3.5%; c) in the struts from 0.2 to 2.4%.

At the same load level, the process of redistribution of effort increases as the percentage of reinforcement increases. This is due to the fact that in the elements of the farm with a high percentage of reinforcement in compressed concrete and, consequently, the non-linearity of deformation increases. Non-linearity of deformation contributes to the redistribution of stresses between the rods of the farm.

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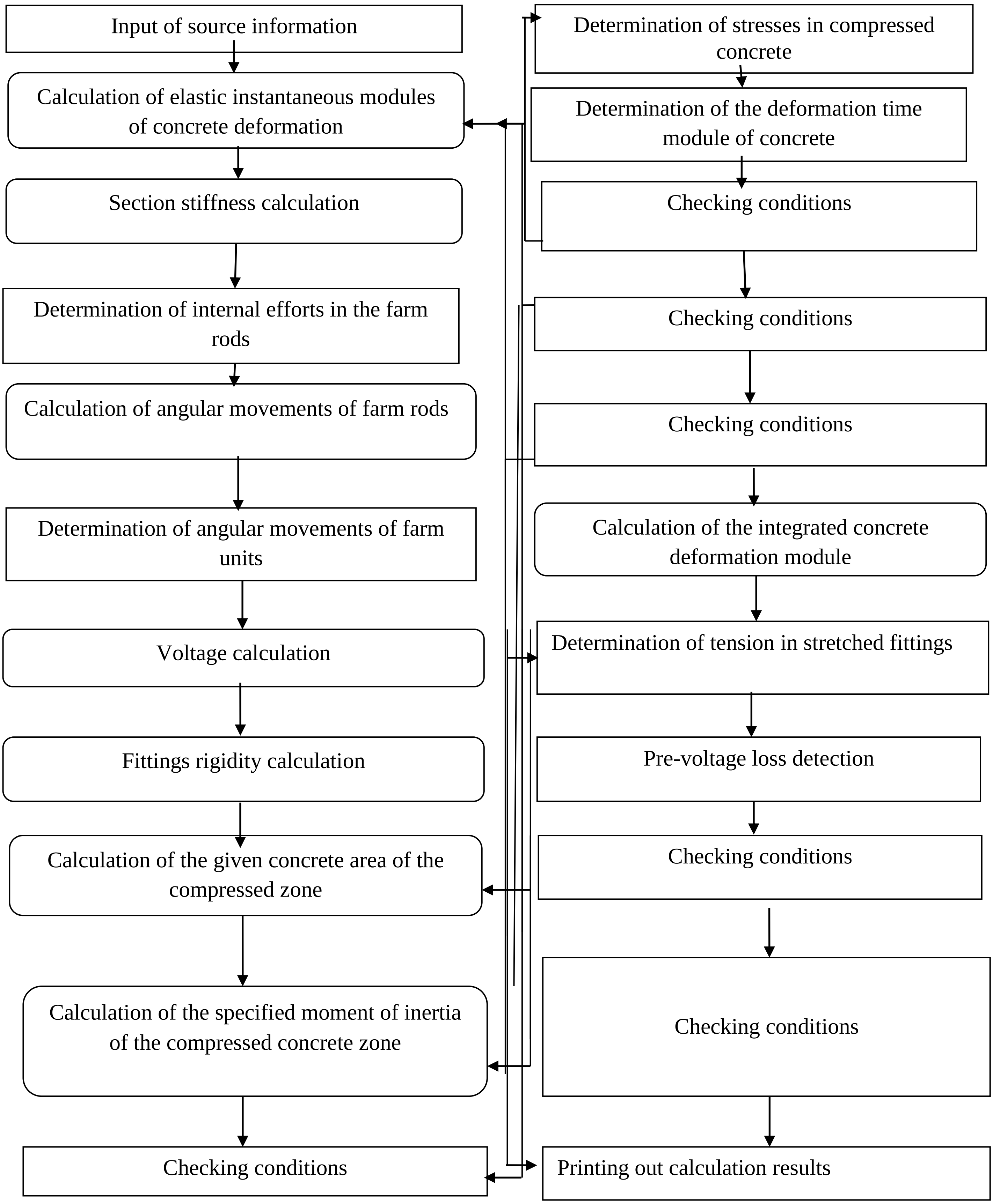

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Fig.1 General structure of the program calculation process

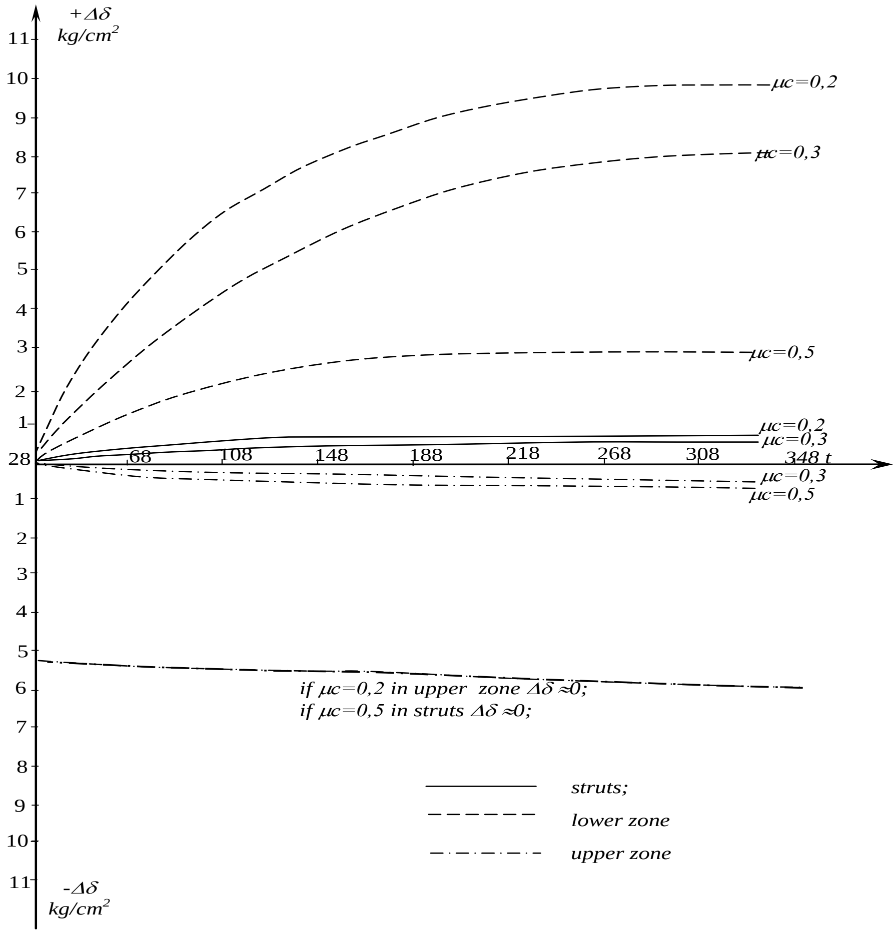

Fig.2. Stress increase at the increase from the compressed elements

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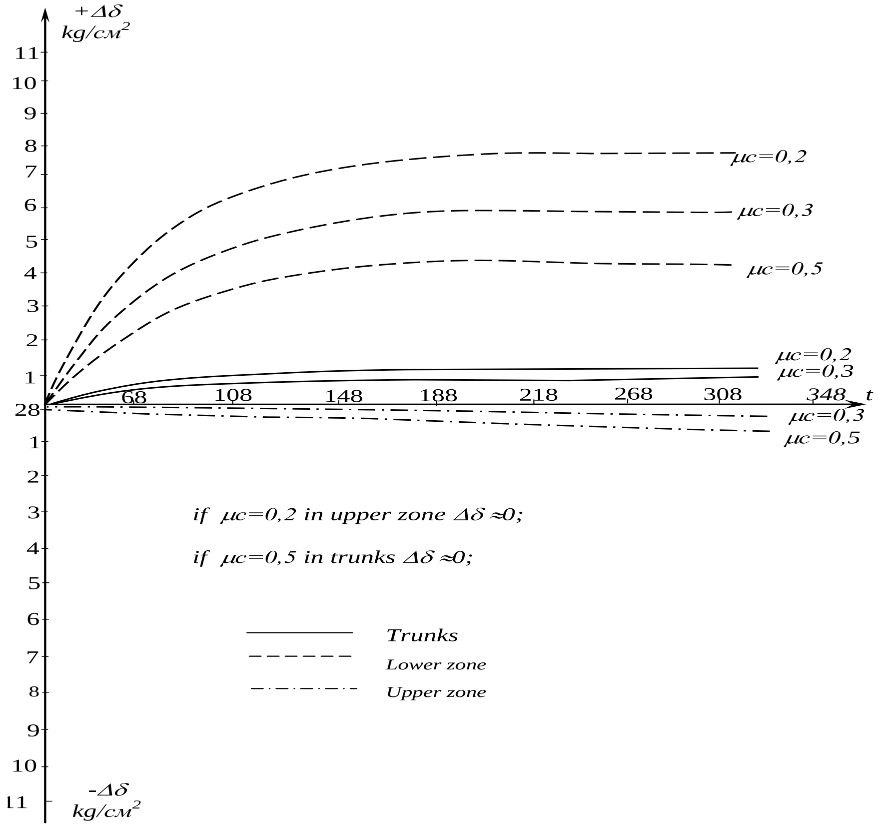

Fig.3. Stress increase at the increase in tension from the stretched elements

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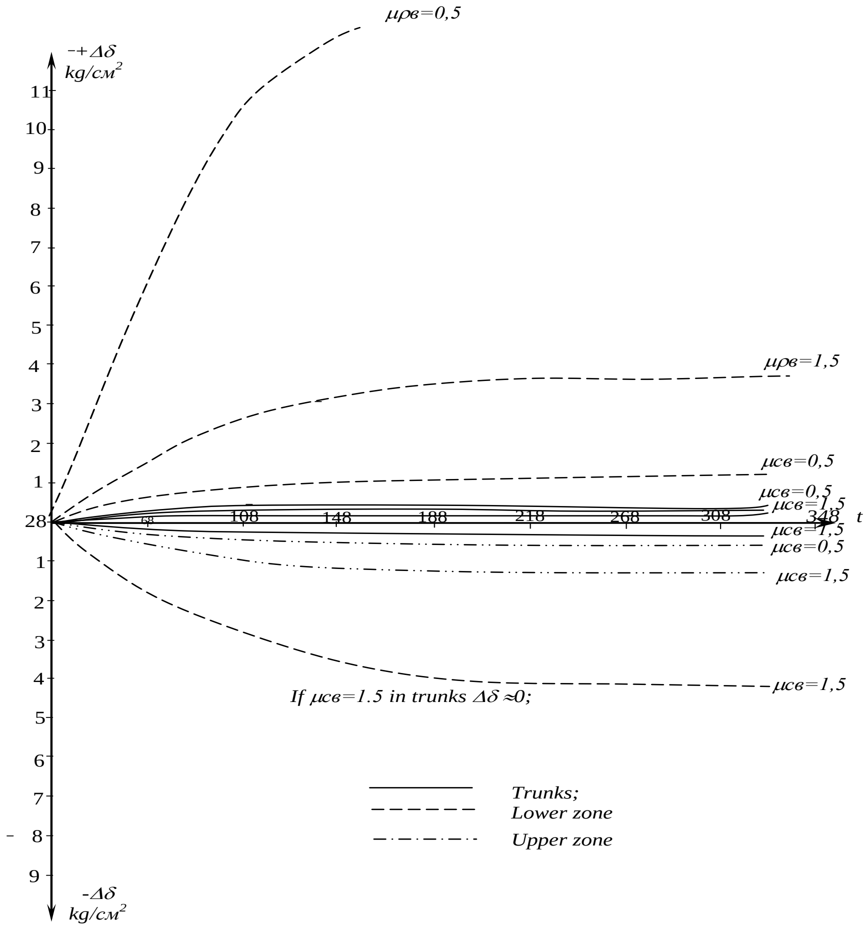

Fig.4. Stress increase at increase and consequently in all elements

Farm elements	Task Setting: t / day		% армирования							
			$0,2^{c}$	$0,5^{c}$	$0,5^{p}$	$2,5^{p}$	$0,5^{св}$	$1,5^{св}$	$0,5^{рв}$	$1,5^{рв}$
Upper zone	Elastic, non-linear disequilibrium	$t_o=28$ $t_o=28$ $t=112$	1,000 0,950 0,947	1,000 0,892 0,887	1,000 0,954 0,951	1,000 0,970 0,964	1,000 0,917 0,911	1,000 0,706 0,696	1,000 1,007 1,006	1,000 0,927 0,926
Lower zone	Elastic, non-linear disequilibrium	$t_o=28$ $t_o=28$ $t=112$	1,000 1,205 1,214	1,000 1,058 1,058	1,000 1,135 1,137	1,000 1,139 1,151	1,000 1,016 1,024	1,000 0,666 0,669	1,000 1,217 1,223	1,000 1,089 1,093
Slopes	Elastic, non-linear disequilibrium	$t_o=28$ $t_o=28$ $t=112$	1,000 0,658 0,660	1,000 0,418 0,420	1,000 0,667 0,670	1,000 0,649 0,650	1,000 0,409 0,410	1,000 0,152 0,152	1,000 1,328 1,386	1,000 0,493 0,494

Note: c, p, s, ditch means that reinforcement percentages change only in compressed, stretched and consequently in all elements of the farm.

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