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Optimal Design of Prestressed Reinforced Concrete Strap Fram

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Annotation: The article provides the development of an algorithm for calculating and optimal design of prestressed concrete trusses taking into account the rigidity of the nodes, analysis of the results.

Keywords: knot stiffness, concrete shrinkage, creep, algorithm, optimal design, prestressing.

One of the advantages of prestressed reinforced concrete is its resistance to cracking. As a result of the use of high-quality durable materials (rebar and concrete), it is possible to spend 30-70% less reinforcement compared to an ordinary reinforced concrete element. In this case, the consumption of concrete decreases and the weight of the structure is lightened. In addition, it increases the resistance to cracks, the hardness of the iron (it allows you to cover large areas by making long beams), waterproofing, resistance to the effects of dynamic loads, and ensures long-term operation.

An increase in the percentage of reinforcement increases the earthquake resistance of prestressed (especially with a cross-section surface and made of lightweight concrete) structures. The fact is that due to the use of stronger and lighter materials, prestressed structures can be lighter and have a smaller surface than ordinary structures with the same load bearing capacity. Due to compression of some elements of buildings and structures with pre-stressed reinforcement, spatial performance and earthquake resistance can be increased. It distinguishes structural reinforcement by its extreme resistance to corrosion and by its high resistance and durability [1,2,3].

Natural compatibility in reinforcement and concrete work ($\varepsilon_s = \varepsilon_b$) does not have a significant effect on the elongation of concrete. The limit elongation of concrete before cracking is 0.15-0.2 mm/m ($\varepsilon_{bt,u} = (0,15 \cdots 0,20 \ x10^{-3})$ does not exceed Hence, the stress in the reinforcement when the concrete cracks:

$\sigma_s = \varepsilon_s \cdot E_s = \varepsilon_{bt,u} \cdot E_s = 20 \cdot 10^{-5} \cdot 2 \cdot 10^5 = 40 \ M\Pi a$ is equal to.

As the load increases, the crack widens. A-II, A- III 0.1...0.2 mm hair-thick cracks appear during the operation of simple elements equipped with class fittings due to the external load (in this case, the amount of tension in the fittings does not exceed the yield limit, (σ_s= 270-340 MPa). Usually, these cracks are not visible under normal conditions, and they can affect the working conditions and longevity of reinforced concrete to some extent. But the experience of using reinforced concrete shows that it is not necessary to be afraid of these cracks [4,5].

It turned out that it is impossible to use high-strength reinforcement in an ordinary reinforced concrete element. If the tension in the armature $\sigma_s \geq 500 \ MPa$ if there is, the opening of hair-thickness cracks reaches an unacceptable level. In this case, the concrete will not be able to protect the reinforcement, the dampness will increase, and the element cannot be used. There is no way to prevent this [6]. The engineer-builder is faced with the question of what kind of material it is, if it is not possible to improve it, increase its strength and reduce its weight.

During tensioning of the armature, the pre-excited stresses in it decrease over time due to irreversible losses. These losses occur as a result of concrete penetration and hardening, relaxation (reduction) of stresses in the reinforcement, deformation of anchors, friction of the reinforcement against the walls of the hole, and various other reasons. There are 11 types of losses in total.

It is these losses that must be taken into account when calculating prestressed structures, because they lead to a decrease in tension in the prestressed reinforcement [7,8].

Losses are divided into two groups. First losses σ_{los1} occurs during the preparation of the element and concrete compaction. Second losses σ_{los2} and it is formed after concrete is compacted.

If the reinforcements are tensioned by pulling on the supports, then the first group of losses is determined as follows:

$\sigma_{los1} = \sigma_1 + \sigma_2 + \sigma_3 + \sigma_4 + \sigma_5 + \sigma_6$ (1)

the second group of losses:

$\sigma_{los2} = \sigma_8 + \sigma_9$ (2)

If the reinforcements are tensioned by pulling into the concrete, then

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$\sigma_{los1}=\sigma_3+\sigma_4$ (3)

$\sigma_{los2}=\sigma_1+\sigma_8+\sigma_9+\sigma_{10}+\sigma_{11}$ will be equal.

the amount of losses is determined according to Appendix, in which the total amount:

$\sigma_{los}=\sigma_{los1}+\sigma_{los2}$ (4)

will be, but the amount of losses in the design of the structure according to the general norm 100 MPa should not be less than

Optimal design of constructions is the main issue, in which, taking into account its solid, long-term reliable operation, convenience of manufacturing technology - consumption of materials, cost and other indicators are determined [9,10].

Among the many issues discussed, we see that research has been conducted to reduce the weight and cost of the structure based on the strength conditions.

We present a calculation algorithm for optimizing the size of prestressed reinforced concrete truss truss nodes, taking into account the condition of uniformity, penetration and creep of concrete, and changes in prestressing over time.

It is required to reduce the theoretical size of the straw farm:

$$V=\sum_{(j)}F_j l_j=\sum_{(j)}K_1 h_j l_j \quad (5)$$

the following limitations should be taken into account:

a) for compressible elements:

$$R_b-\left|\sigma_{ijk}^{b}(t)\right|\geq 0 \quad (6)$$

b) for tensile elements:

$$R_s-\left|\sigma_{ijk}^{s}(t)\right|\geq 0 \quad (7)$$

here: l_j - the length of the stern;

V - the size of the structure;

F_j - Stergen cross-sectional surface.

To solve the given problem, we reduce the volume function (5) to the Logrange function, taking into account the constraints (6) and (7):

$$\varphi=V+\sum_{(i)}\sum_{(j)}\sum_{(k)}U_{ijk}g_{ijk} \quad (8)$$

or:

$$\varphi=\sum_{(j)}k_1 h_j l_j+\sum_{(i)}\sum_{(j)}\sum_{(k)}U_{ijk}g_{ijk} \quad (9)$$

here: φ - Logrange function; U_{ijk} - additional acceptable unknown.

h_j and U_{ijk} to find, we express (8) as follows:

$$\frac{\partial\varphi}{\partial h_j}=2K_1 h_j l_j+\sum_{(i)}\sum_{(j)}\sum_{(k)}U_{ijk}\left(-\frac{\partial\left|\sigma_{ijk}\right|}{\partial h_j}\right)=0$$

and (6) and (7) restrictions:

$$g_{ijk}=\frac{\partial\varphi}{\partial U_{ijk}}=R_b-\left|\sigma_{ijk}^{b}\right|=0;$$

$$g_{ijk} = \frac{\partial \varphi}{\partial U_{ijk}} = R_s - \left|\sigma^s_{ijk}\right| = 0,$$

here: $K_1 = \frac{b}{h}$ - the ratio of the width of the cross – sectional surface of the stern to its height;

h - stergen cross-sectional surface height;

b - cross-sectional width;

σ^b - stresses in concrete (in compressive elements);

σ^s - stresses in reinforcement (in tensile elements);

i - sections; j - sturgeons; k - time.

The optimal quantities of the unknowns are found by solving the Logrange formula by iteration:

$$h_j^{(t)} = \frac{1}{2K_1 l_j} \sum_{(i)} \sum_{(j)} \sum_{(k)} U_{ijk} \frac{\partial \left|\sigma^b_{ijk}\right|}{\partial h_j};$$

$$U^{(t)}_{ijk} = \max\left\{ 0U^{(t-1)}_{ijk} - \rho(R_b - \left|\sigma^b_{ijk}\right|)\right\}.$$

Convergence in the iteration method is considered terminated when the following conditions are met:

$$\left|h_j^{(t-1)}\right| - \left|h_j^{(t)}\right| \le \xi;$$

$$\left|U^{(t-1)}_{ijk}\right| - \left|U^{(t)}_{ijk}\right| \le h,$$

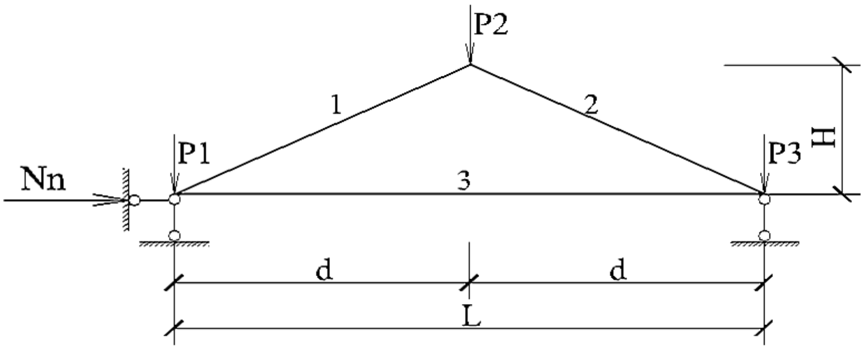
here: ξ and h - a measure of accuracy of calculation;

ρ - the minimization step of the function.

Based on the developed calculation algorithm, a number of examples were viewed and the obtained results were analyzed [11,12].

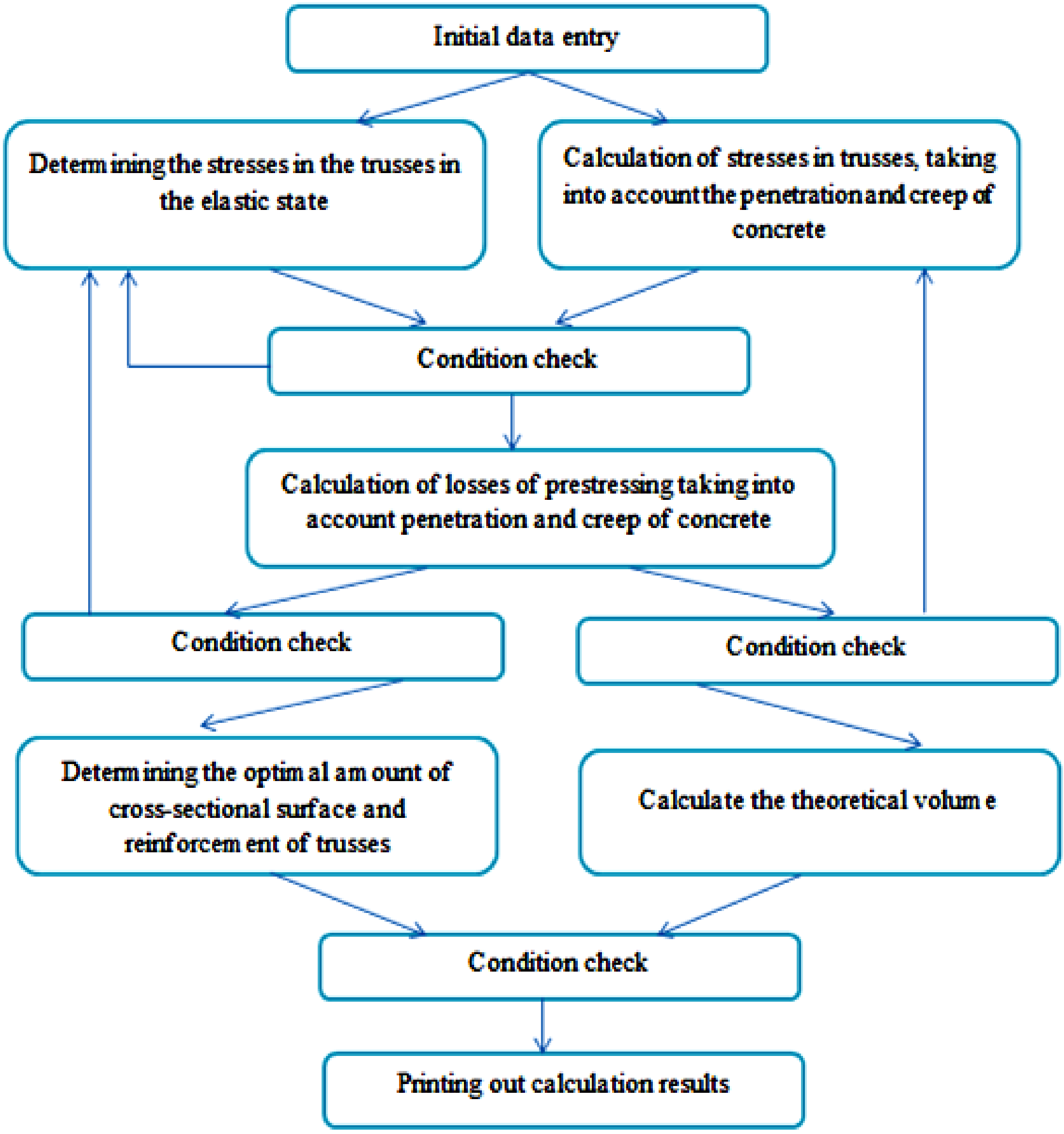
The problem is solved in a gradual approach. As a result, the optimal size of the cross-section of the farm struts - h, the volume of concrete, the cross-sectional surface of the reinforcement is found.

As an example, the farm shown in Fig. 1 is built, and its theoretical volume, cross-sectional surfaces of concrete and reinforcement in the struts are determined.



1 – picture. Calculation scheme of prestressed reinforced concrete truss truss.

The block diagram of the computer program is presented in Figure 2.



2 – picture. Block-scheme of the program for optimal design of cross-sectional surfaces of reinforced concrete trusses.

The analysis of the obtained results shows that it will be possible to design economically efficient constructions of prestressed reinforced concrete truss trusses, taking into account the creepage and creep of concrete and the change of prestress over time [13,14,15]:

1) When the nodes of the truss are taken as single, the redistribution of stresses among the elements leads to a decrease in the amount of concrete by 6-15%, depending on the type of the truss and its spacing.

2) In order to reduce the tensile stresses generated by bending in single-knot trusses, it is advisable to reinforce the top girders and columns with prestressed reinforcement.

3) An increase in the percentage of reinforcement in trusses working under the same load leads to a redistribution of stresses.

4) Due to the increase in the percentage of reinforcement, the changes in the tension in the rods as a function of time are as follows:

a) 2 - 8% in the lower belt;

b) 0.5 - 3.5% in the upper belt;

c) 0.2 - 2.4% in drawers;

5) In the case of the most undesirable stress-deformation, the optimal cross-section of the trusses and the amount of necessary reinforcements are determined.
6) The cross-section of the trusses satisfying the strength condition and the theoretical volume of concrete are found.
7) The redistribution of stresses in the trusses due to the uniformity of the nodes leads to the reduction of the cross-sectional areas of the elements and, as a result, to the economy of the volume of concrete.

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