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CONTENTS

BUILDING STRUCTURES

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RATIONAL GEOMETRICAL CHARACTERS OF SADDLE SHAPE CABLE ROOF SUPPORTED BY TENSIONED CABLES

Keywords. Saddle shape cable roof, cable net, geometrical characters

Abstract. The saddle shape cable roof, which is supported by tension cables, is considered in the paper. The roof is kinematics invariable because of prestressing of rectangular (orthogonal) cable net. The correlation between the main geometrical characters of the cable roof and weight of the cable net, which is divided by the area covered by the cable roof, was ascertained by a numeral experiment. The main geometrical characters are the initial curvatures of stressing, suspension and tension cables and step of stressing and suspension cables.

1.Introduction.

Saddle shape cable roofs may be divided into the following groups depending on the construction of supporting contour. [1]:

- Roofs with transference of the horizontal cable forces on inclined or vertical arches.
- Roofs with transference of the horizontal cable forces on contour beams of different shapes.
- Roofs with transference of the horizontal cable forces on tension cables, which may be fixed in the anchors.

Supporting contour in the form of massive arches, beams or girders made of steel, ferroconcrete or glued wood is a peculiarity of the two first groups of the roofs.

In accordance with the data published in [2-4], the rational values of the initial curvatures of suspension cables of the structures are 0,067-0,125 from their span. Rational values of the initial curvatures of stressing cables are 0,04 - 0,1 from their span. Rational step of suspension and stressing cables changes from 1 to 4 meters.

Supporting contour in the form of tension cables made of steel is a peculiarity of third group of the roofs [5]. Information about the structures is a complicated one. So, the aim of the paper is the estimation of rational main geometrical characters of a square in plane saddle shape cable roof, which is supported by tension cables. Geometrical characters of the structure, which have influence on the expenditure of material, are considered as the main. The characters are the initial curvatures of stressing, suspension and tension cables and step of stressing and suspension cables. (Fig. 1)

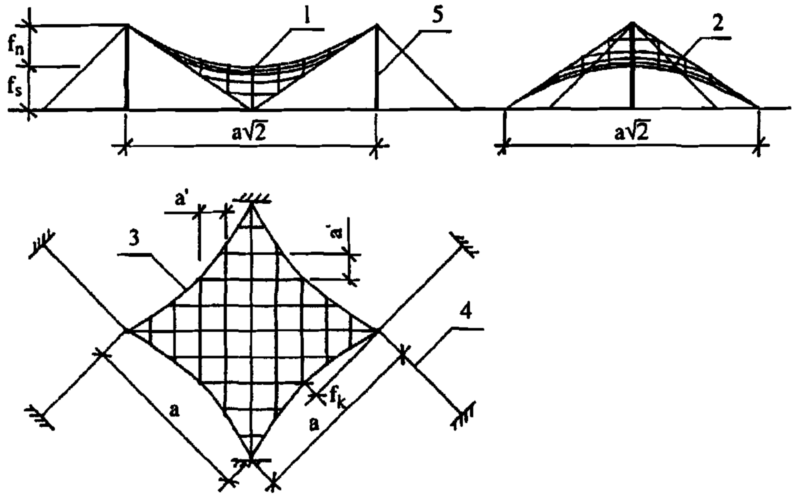

Fig. 1 Scheme of Cable Net

1 - suspension cables; 2 - stressing cables; 3 - tension cables; 4 - anchor supports; 5 - columns; f_n - initial curvature of suspension cable; f_s - initial curvature of stressing cable; f_k - initial curvature of tension cable; a - length of one side of the structure; a' - step of stressing and suspension cables.

2. Approach to the solution of the problem

Correlation between the main geometrical characters of the structure and expenditure of cable nets material is determined in the form of nonlinear equation by the method of experiment planning. Coefficients of the equation are determined by using of numeral experiments results. The experiment was conducted with such values of the main geometrical characters of the structure, which were chosen according to the rules of experiments planning. Numeral experiment is connected with calculation of forces in the cables of the net. The forces are necessary for calculations of cables cross sections [2] and expenditure of cable nets material.

Cable net (Fig.1.) which is loaded by prestressing and loads which are applied to the cable nets nodes is considered as an analyze scheme.

The numeral experiment is conducted both by the NISA family of programs V 8.0 and by the approximate step method which is based on the succession [5].
The NISA family of programs V 8.0 by the analyze of the cable net is based on the total Lagrangian formulation and full Newton-Rapson iterative method. The cable net is modeled by a finite element mesh. A finite element type is 3-D two-node cable. All the nodes of support of the cable net are completely fixed.
The approximate step method is based on the eq. (1) for calculation of the cable by taking into account elastic elongation's and points of joints displacements.

$$n_1^3 + \left[\frac{EA\int_\ell q_0^2 dx}{2\ell n_0} - n_0 + \frac{\delta}{\ell}EA\right]n_1^2 - \frac{EA\int_\ell q_1^2 dx}{2\ell} = 0 \qquad (1)$$

Where: q_0 - load to the cable from the prestressing; q1 - load to the cable from the prestressing and loads; n_0 - force in the cable from the prestressing; n_1 - force in the cable from the prestressing and loads; ? - displacements of points of joints under the action of prestressing and loads.
Rational values of the main geometrical characters of the structure are determined by the system of eq. (2)

$$\partial y/\partial x_1 = 0 \qquad (2)$$
$$\partial y/\partial x_2 = 0$$
$$\partial y/\partial x_3 = 0$$

Where: y - correlation between the main geometrical characters of the structure and expenditure of cable nets material; x_1 - initial curvatures of suspension and stressing cables; x_2 - initial curvatures of tension cables; x_3 - step of suspension and stressing cables.

3. Numeral result.

Values of the main geometrical characters of the structure change in the following way: initial curvatures of suspension and stressing cables from 4 to 10 m, initial curvatures of tension cables from 3 to 5 m, step of suspension and stressing cables from 0,707 to 1,414 m.
The structure with the size in plan 20 x 20 m is calculated to the action of main load combination [5]. The main load combination is dead weight of the structure and snow. The calculated value of snow load is 1,12 kPa. The calculated value of load is 1,39 kPa.
Thickness of layers of the roof cross section is shown in Fig.2.
Wire rope with modulus of elasticity in $1{,}3.10^5$ mPa is considered as cable nets material.

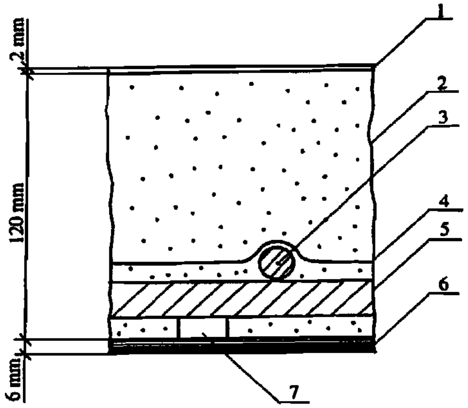

Fig.2. Cross Section of the Roof
1- glass fabric which is covered by polymer resin; 2 - foamplastic; 3 - stressing cable; 4 - glass net; 5 - suspension cable; 6 - saddle shape plywood sheets; 7 - a detail of tension and distancing of strengthening elements of plywood sheets.

The dependence of Fig.3. was obtained when the initial curvatures of suspension and stressing cables were constant and equal to 8,262 m.

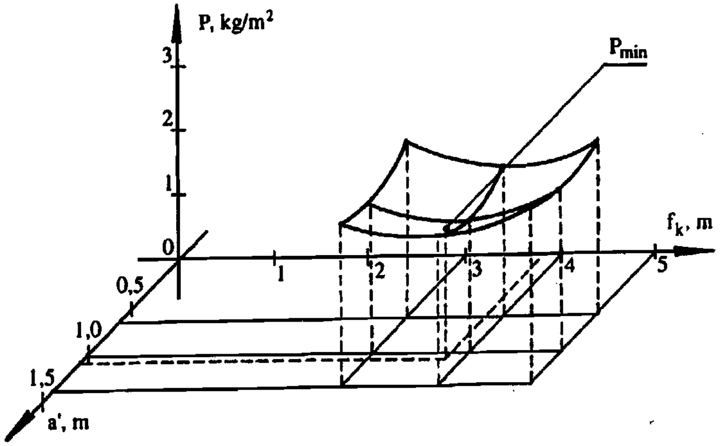

Fig.3. Dependence of Cable Net Materials Expenditure from Initial Curvature of Tension Cables and Step of Stressing and Suspension Cables
P - cable net materials expenditure at m^2 of covered area; P_{min} - minimal value of P;
a', f_k - means as in Fig.1

The dependence of Fig.4 was obtained when the step of suspension and stressing cables was equal to 1,13 m.

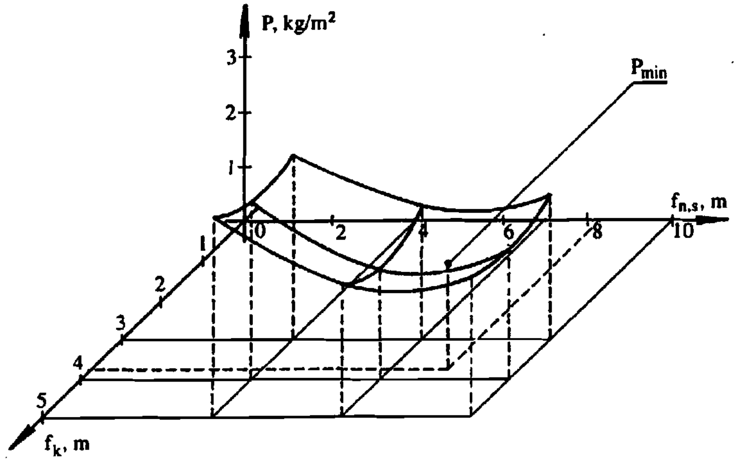

Fig.4. Dependence of Cable Net Material Expenditure from the Initial Curvatures of Tension, Suspension and Stressing Cables
P, P_{min} - means as in Fig.3, f_k, $f_{n,s}$ - means as in fig 1.

The dependence of Fig.5. was obtained when the initial curvatures of tension cables were constant and equal to 3,86 m.

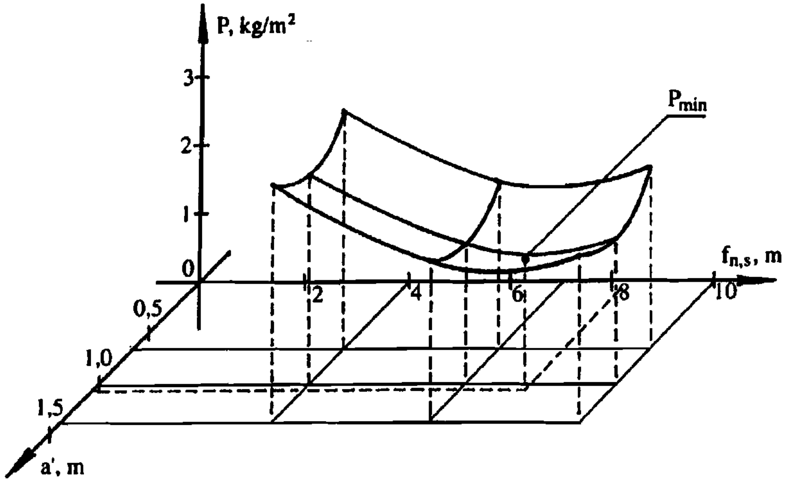

Fig.5. Dependence of Cable Net Materials Expenditure from the Initial Curvatures and Step of Suspension and Stabilization Cables
P, P_{min} - means as in Fig.3, a', $f_{n,s}$ - means as in fig 1.

The dependence of Fig.6 was obtained when the main geometrical characters of the structure were the following: initial curvatures of suspension, stressing and tension cables, and step of suspension and stressing cables are 0,41; 0,193; 0,057 from the length of one side of structure accordingly.

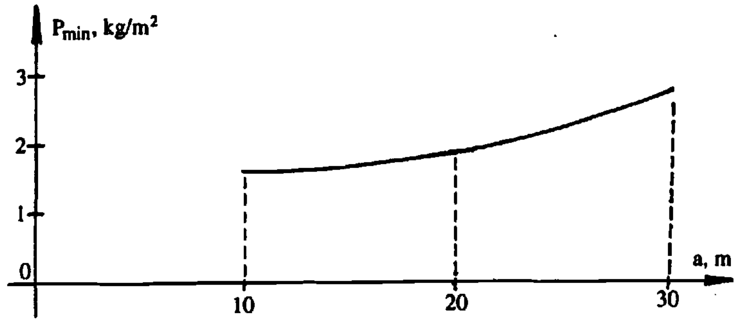

Fig.6. Dependence of Cable Net Materials Expenditure from the Length of One Side of the Structure

4. Conclusions

A simple method for estimation of rational main geometrical characters of a square in plane saddle shape cable roof, which is supported by tension cables, is offered. By the numeral solution it is shown, that rational initial curvatures of suspension, stressing, tension cables and rational step of suspension and stressing cables are 0,41; 0,193; 0,057 from the length of one side of the structure accordingly.

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