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MODELING OF LARGE-SPAN SUSPENDED SHELLS OF UNIQUE BUILDINGS TAKING INTO ACCOUNT THE OPERATION OF THE SUPPORT CONTOUR

Annotation: The results of the study of the stress-strain state of hanging systems of support loops in the stages of pre-tension of shrouds in the installation and operational States are presented. The nature of the operation of the support rings depends on the type and level of loading, the momentless and bending state of the ring of mutual coupling of the cable-stayed belts. The structural safety of hanging systems from accidental beyond-design impacts is investigated, which leads to overload of individual sections, breakage of shrouds, failure of anchor fasteners, pliability of support rings, and changes in the initial geometric forms of the ring as a result of progressive destruction of hanging systems.

Key words: modeling, suspension system, stages of work, vant, failure of the anchor.

1.Introduction

Progress in the field of suspended systems largely depends on solving two problems: choosing the optimal structural scheme of the suspended roof and choosing the optimal support contour.

Our studies of suspended systems are devoted to these problems. Let us consider self-balanced suspended structures, the shape of their surface is obtained naturally or as a result of pre-stressing the structure. Compliance with these conditions determines the most important advantages of suspended roofs. Although we have separated the problems of choosing optimal solutions, in suspended systems they are especially closely related to each other, so no clear boundaries were drawn between them [1-4].

The stress-strain state of suspended systems, taking into account the operation of support contours, was studied with the aim of:

– identifying the features of the operation of external and internal support rings at the stages of pre-stressing of cable-stayed systems, the transition of the structure to the installation and operational state;

– to identify the nature of the work of external and internal support rings, from the mutual connection of cable belts under various loading schemes, from the breakage of cable belts and from the failure of cable anchorages to the roof rings;

When studying the contour ring of a suspended roof, the forces in the cables are considered an external load.

The main feature of support contours is the perception of chain forces from the roof, the horizontal components are 4-5 times greater than the vertical ones.

The design of the support contour, the specific weight by material consumption is always more than 50%, increases its material intensity and leads to a significant impact on technical and economic indicators.

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2. Research objectives.

In this case, the external load on the contour rings can be uniformly distributed, one-sided, local, concentrated, etc., having an arbitrary nature of the impact (Fig. 1).

The horizontal components of the force from the roof significantly complicate the work of the support contour.

With uneven loads on the roof, moments additionally appear in the ring. (Fig. 2).

In the technical literature, there is no clear definition for assessing the size of the rings for the work of a spatial hanging roof.

It should be noted here that with an increase in the size of the middle ring, its weight increases, which should be taken into account as a concentrated force (mass) [1, 3]. In the work of L.N. Pokrovsky [2], it is shown that the concentrated mass in dynamic calculations should be taken into account when the concentrated mass is comparable to the mass of the entire building roof.

The stress-strain state of the outer and inner (contours) rings largely depends on the nature of the loading from the mutual connectivity of the upper and lower chords of the cables (Fig. 2).

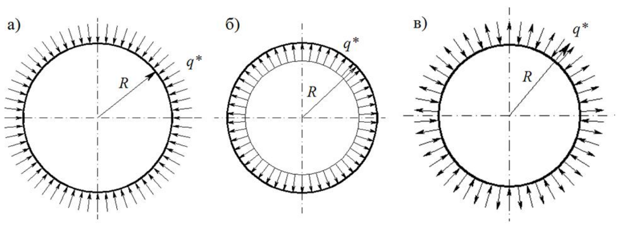

Figure 2 – Schematic diagram of the forces from the cable in single- and double-belt rings under uniformly distributed compressive (a), tensile (b), compressive and tensile (c) local (d) effects.

3. Research results

Let both cable-stayed system grids be fixed in a support contour of circular outline and have the same sag in the center (Fig. 2). In this case, the radial system thrust will be the same:

$$H = qsR^2 / 6f \quad (1)$$

(1)

where q – интенсивность нагрузки; s – шаг вант.

Taking this equality into account, we obtain the same value of the spacer for the cross mesh.

$$H = qa(2R)^2 / 16f = qaR^2 / 4f; \quad (2)$$

where a – step of the cable mesh.

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Let us now calculate, under individual conditions, the reduced material consumption for the radial and cross-section mesh. $2CqsR^3/6fsR = CqR^2/3f$; $2Cqa^2R^2/4fa^2 = CqR^2/2f$; (3)

In addition, from the production conditions, the fastening of radial cables to the contour rings requires a minimum number of anchor fastenings and reduces the cable forces transmitted to the ring by 1.5 times.

Let us consider the features of calculating the contour ring of a radial cable-stayed system, both plane and spatial deformation.

Having selected an infinitely small element of the ring of length ds, we will compose the equations of its equilibrium in a deformed state: $Q_1' + N/\rho_1 + q_n = 0; N' - Q_1/\rho_1 + q_t = 0; M' - Q_1 = 0;$ (4)

Here q_n, q_t, q_b – components of the external linear load of the contour ring; ρ_1, and ρ_2 – radii of curvature of the deformed axis, which are expressed through increments of curvatures, χ_1 и χ_2

The dependence of the internal forces of the ring on the deformations of the cables is: $M_1 = -EJ_1\chi_1 = -A\chi_1$; $M_2 = -EJ_2\chi_2 = -B\chi_2$; $M_{12} = -GJ_d\tau = -C\tau$, (5)

where $C = -GJ_d$ – torsional rigidity of the rod.

Let us consider the influence of stretched radial cables on the operation of the ring studied by introducing an elastic foundation of the Winkler type. The horizontal component of the load on the ring can be expressed by the dependence [1, 3, 8]

$$q_x = H + \partial H/\partial u, \quad (6)$$

где – H the value of the load from the spread of the cables to the deformation of the ring; u horizontal displacements of the ring. The load on the ring can be represented as the resistance of some elastic medium, characterized by the bedding coefficient. $k = \partial H/\partial u$

In this case, the bending moment acting in the plane of the ring can be determined by the formula

$$M_1 = R^2 \quad (n^2 - 1)a_n \cos n\varphi / G_k \quad (7)$$

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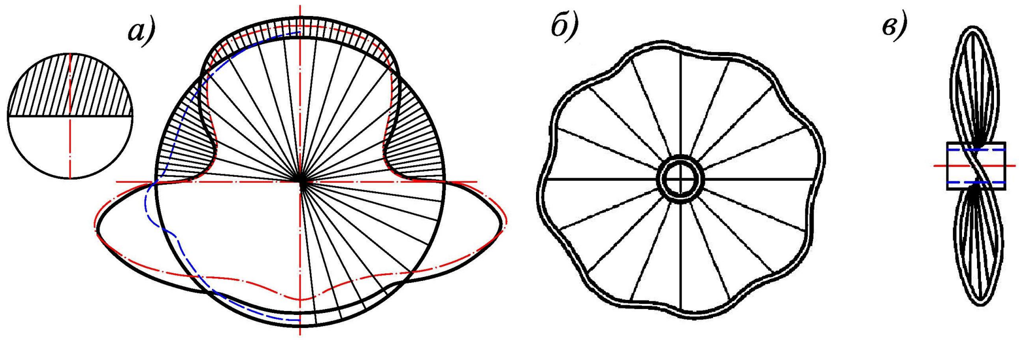

Figure 3 – Bending moment diagrams of the ring under loading. Forms of loss of stability of the ring under preliminary tension of the cables.

The equilibrium of an element of a circular ring in its plane without bending is expressed by the relation $q' = \tau$ or, since at the same time W = 0,

$$N_1 = N_2 . \tag{8}$$

Substituting (4), we obtain the relations between N1 and N2, in which the contour ring is momentless:

$$N_{10} = const, \quad N_{20} = 0;. N_{1n} - N_{2n} / n. \tag{9}$$

Case n = 0 corresponds to the compression of the ring under any asymmetric loading of the roof. Thus, under vertical loads on the hanging shell representing a linear combination of loads with different amplitudes at different points, the contour ring does not experience bending in its plane.

The structural safety of hanging systems depends on random external beyond-design impacts and internal quality factors directly related to the adopted design solutions. The study was conducted on pre-stressed single- and double-belt hanging roofs with a span of 120 m and an experimental model with a scale of 1:100 [3, 8]. The results of the study - the nature of the change in bending moments in the horizontal plane of the ring when loading the roof with a temporary load located on half the area (see Fig. 3a) and the loss of stability of the outer ring from the pre-stressing of the cables are shown in Fig. 3 b, c. Under these stress conditions for cables loaded with a transverse load, the failure of anchor fastenings from the support contours occurred at 1.15-1.2 times exceeding the design loads. Under such loading, cables broke at 1.2-1.3 times exceeding the design loads. In the outer support rings in the tested models of hanging shells, the beginning of the change in the geometric shapes of the support ring occurred at 1.25-1.4 times exceeding the design forces, and for the inner support rings, it occurred at 1.3-1.5 times exceeding the design forces.

Analysis of the behavior of the studied full-scale structures under various most unfavorable loading schemes showed that they can be recommended for use as roofs of unique public buildings, as one of the most effective solutions.

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