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INFLUENCE OF SNOW LOADING CHARACTER ON OPTIMAL LATTICE`S GEOMETRIC SHAPE OF THE COMBINED ARCH SYSTEM

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Abstract. In the article, the authors investigate the question of determining of the lattice made from flexible elements geometric share in a combined arch system proceeding from the condition of its operability and the minimum of the structure material consumption. This question is supposed to be solved with the help of the lattice geometric shape, without using the elements preliminary tension at this stage of the study. Evenly distributed load throughout the span (constant load with the snow load distributed along two triangles with peaks on the supports and zero values in the middle, because this combination of loads can cause a compression force in some elements of the flexible grating) is accepted as a load for determining the lattice geometry. The investigations carried out by the authors have shown that the optimal lattice shape depends not only on the ratio of the constant and snow loads, but also on the upper belt panels number. At what, the snow load according to the scheme of two triangles has determining value, in comparison with the snow load evenly distributed in half of the span. The obtained results of the investigation make possible to designate the combined arch system's lattice geometric share, taking into account the given ratio of constant and time loads in such a way that all flexible lattice's elements will work on tension and the material consumption of the structure will be the smallest.

Keywords: combined arch system, lattice, flexible elements, span, constant load, snow load, shape.

ВЛИЯНИЕ ХАРАКТЕРА СНЕГОВОЙ НАГРУЗКИ НА ОПТИМАЛЬНУЮ ГЕОМЕТРИЧЕСКУЮ ФОРМУ РЕШЕТКИ В КОМБИНИРОВАННОЙ АРОЧНОЙ СИСТЕМЕ

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Аннотация. В статье авторы исследуют вопрос определения геометрической формы решетки из гибких элементов в комбинированной арочной системе из условия работоспособности всех ее элементов и минимального расхода материала конструкции. Вопрос работоспособности всех элементов гибкой решетки на данном этапе предполагается решить геометрической формой самой решетки, не используя предварительного напряжения ее элементов. В качестве нагрузки для определения геометрии решетки рассмотрена равномерно-распределенная по всему пролету (собственный вес) в соотношении с распределенной снеговой по схеме из двух треугольников с вершинами на опорах и нулевым значением в середине пролета.

Ключевые слова: арочная система, решётка, гибкие элементы, нагрузка, пролет, форма.

ВПЛИВ ХАРАКТЕРУ СНІГОВОГО НАВАНТАЖЕННЯ НА ОПТИМАЛЬНУ ГЕОМЕТРИЧНУ ФОРМУ РЕШІТКИ У КОМБІНОВАНІЙ АРКОВІЙ СИСТЕМІ

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Анотація. У статті автори досліджують питання визначення геометричної форми решітки з гнучких елементів у комбінованій арковій системі за умови працездатності усіх її елементів та мінімальної витрати матеріалу конструкції. Питання працездатності усіх елементів гнучкої решітки на даному етапі передбачається вирішити геометричною формою самої решітки, не використовуючи попереднього напруження її елементів. В якості навантаження для визначення геометрії решітки розглянута рівномірно-розподілена на усьому прольоті (постійна) у співвідношенні з розподіленою сніговою по схемі з двох трикутників з вершинами на опорах та нульовим значенням посередині прольоту.

Ключові слова: аркова система, решітка, гнучкі елементи, навантаження, проліт, форма.

Introduction. An important state task, one of the main problems of scientific and technical progress in the field of steel structures, is the all-round steel economy. One of the ways to save metal is to improve the engineering calculations of structures bearing capacity that provide high reliability and economy of structures. Scientific research is always aimed at creating even more effective structural forms of structures. In State Building Norms В.2.6-198: 2014 «Steel structures. Norms of designing» in clause 5.2.1 it is recommended «to choose the optimal technical and economic indicators of structural schemes of buildings; apply advanced designs ... cable-stayed structures ... combined; to provide technological and minimal manufacturing complexity of structures; to apply constructions, providing manufacturability and minimal installation complexity». Therefore, the question of the flexible elements lattice (in a combined arch system without the use of prestressing) effective geometric shape determining is actual. The idea of creating such constructions, their features are set forth in [1].

Analysis of recent research and publications. The method of static calculation of such structures and the choice of the basic systems in the calculation of repeatedly statically indeterminate combined arched systems are justified in [2-5]. Some assumptions about actual work have been experimentally confirmed. The geometric shape of a flexible lattice, at which in there are no compression forces in its elements even without the use of prestressing [6] for a snowy one-sided load in a different (having an engineering sense) distribution with a uniformly distributed throughout the span constant load is defined in [1].

Objective is to determine the flexible lattice geometric shape, guided by the condition of its operability and the minimum material consumption of the arch structure with a parabolic upper belt.

Results of the research. The optimality conditions, assumptions, terms, load relations q/p and the methodology for solving the problem in this study are taken the same as in [1]. The number of panels of the upper belt n taken equal to 4, 6, ..., 12.

The studies carried out for the load relations q/p when loading the structure with a temporary snow load according to the scheme shown in Fig. 1 according to [7], showed that the lattice rod $Д_2$ also was control. However, under the considered loading the ordinates of the convergence point of the rays M depend not only on the load relation q/p, but also on the number of panels of the upper belt n.

As in [1], the optimal geometric scheme of the lattice can be previously assigned guided by the condition of the upper belt node (to which the control rod $Д_2$ belongs) equilibrium (the designation of the quantities β_0, t, t_1, $c_1 \ldots c_4$, F_1, F_2, P_1, P_2, a_1, a_2, α_1, α_2, see Fig. 1, and the values γ_1, γ_2, γ_3, c, k, k_x, k_y, see Fig. 2 in [1]).

Let us determine the concentrated forces at the nodes.

Supporting reaction of support A:

$$V_A = \frac{q \cdot L}{2} + \frac{11 \cdot p \cdot L}{24} \tag{1}$$

$$P_1 = F_1 \cdot \frac{c_2}{a_1} \tag{2}$$

where:

$$c_1 = \frac{a_1}{3} \cdot \left(\frac{2 \cdot p + q + 2 \cdot t}{2 \cdot p + q + t} \right) \tag{3}$$

$$c_2 = a_1 - c_1 \tag{4}$$

$$F_1 = \frac{2 \cdot p + q + t}{2} \cdot a_1 \tag{5}$$

$$t = \frac{4 \cdot p \cdot (0.5 \cdot L - a_1)}{L} + q \tag{6}$$

$$F_2 = \left(\frac{t + t_1}{2} \right) \cdot a_2 \tag{7}$$

$$t_1 = \frac{4 \cdot p}{L} \cdot a_3 + q \tag{8}$$

$$P_2 = F_1 \cdot \frac{c_1}{a_1} + F_2 \cdot \frac{c_4}{a_2} \tag{9}$$

$$c_4 = \frac{a_2}{3} \cdot \left(\frac{t_1 + 2 \cdot t}{t + t_1} \right) \tag{10}$$

The angle of inclination of the «root» of the lattice β_0, at which the control rod will have zero force, i.e. both optimality conditions are satisfied:

$$tg\beta_0 = \frac{P_2 \cdot \frac{\sin\gamma_3}{\sin\gamma_1} \cdot \sin\alpha_1 - (V_A - P_1)}{P_2 \cdot \frac{\sin\gamma_3}{\sin\gamma_1} \cdot \cos\alpha_1} =$$

$$= \frac{\left(F_1 \cdot \frac{c_1}{a_1} + F_2 \cdot \frac{c_4}{a_2} \right) \cdot \frac{\sin\gamma_3}{\sin\gamma_1} \cdot \sin\alpha_1 - \left(\frac{q \cdot L}{2} + \frac{11 \cdot p \cdot L}{24} - F_1 \cdot \frac{c_2}{a_1} \right)}{\left(F_1 \cdot \frac{c_1}{a_1} + F_2 \frac{c_4}{a_2} \right) \cdot \frac{\sin\gamma_3}{\sin\gamma_1} \cdot \cos\alpha_1} . \tag{11}$$

The results of the study of the dependence of the co-ordinates H_M of the rays M convergence point on the constant and snow loads ratio and the number of the upper belt panels are obtained in fractions of the rise of f:

$$H_M = \alpha \cdot f \tag{12}$$

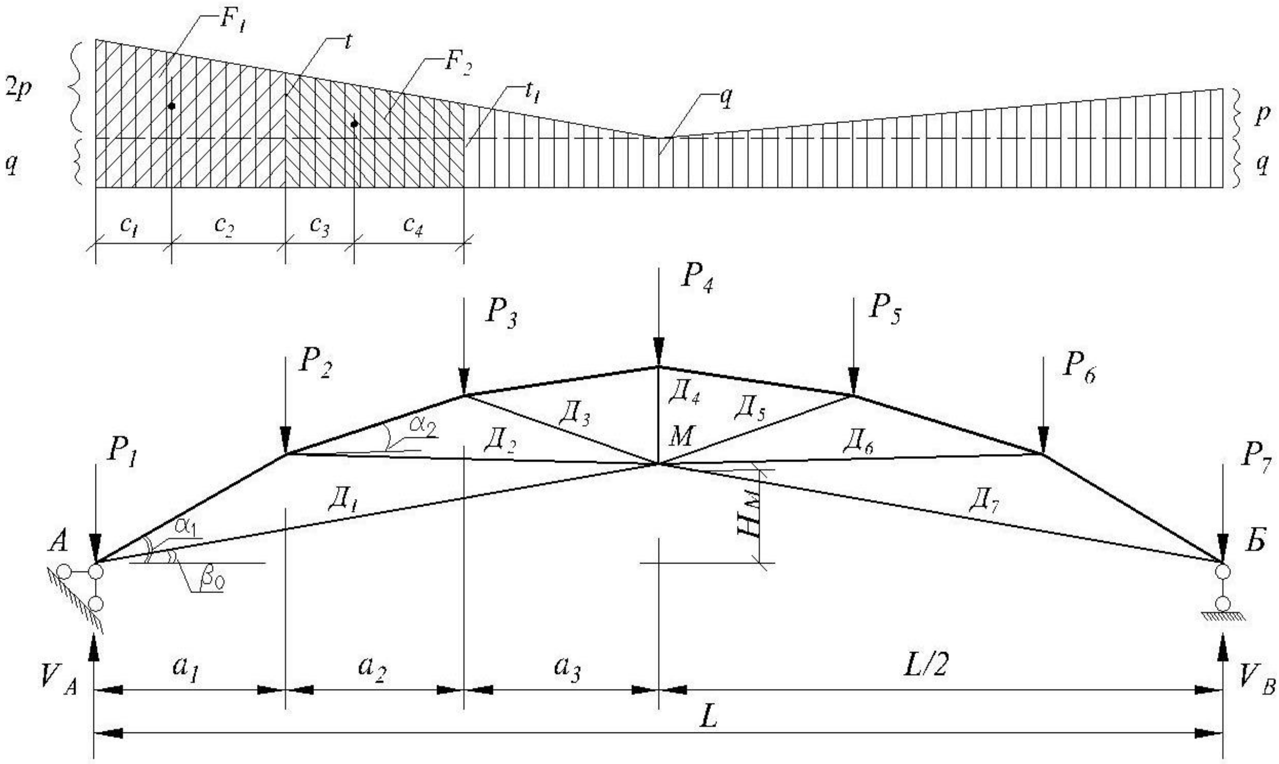

Fig. 1. The scheme of loading the structure at *q/p* = 1

The values of the coefficient *α* as a function of *q/p* and *n* are shown in Table 1. Based on the data in Table 1, graphs of the indicated dependences on the studied parameters are plotted (Fig. 2).

Table 1 – The values of the coefficient *α* as a function of *q/p* and *n*

Panels number *n*	Coefficient *α* as a function of *q/p*						
	1/10	1/5	1/2	1	2	5	10
4	0.4620	0.4243	0.3403	0.2573	0.1709	0.0854	0.0400
6	0.6969	0.6220	0.5459	0.4598	0.2995	0.1553	0.0842
8	0.7968	0.7510	0.6042	0.5436	0.3684	0.1920	0.1050
10	0.8509	0.8045	0.6914	0.5600	0.4066	0.2239	0.1287
12	0.8884	0.8420	0.7283	0.5695	0.4369	0.2460	0.1456

Analysis of the results in the presented study and performed in [1] showed that the nature of the two triangles snow load (in according to the scheme in Fig. 1), with vertices on the supports and zero in the middle of the span, is the determining load scheme in terms of non-removal flexible lattice elements.

Conclusions and prospects for further research:

1. In determining the maximum efforts the estimated load for such structures will be the total (own weight and snow) uniformly distributed over the span load.
2. The determining load scheme, in terms of non-removal of flexible lattice elements, is a two triangles snow load in combination with a uniformly distributed throughout the span constant load.
3. The results of these studies allow us to assign the flexible lattice geometric shape taking into account a given ratio of constant and time loads and the number of the upper belt panels satisfying both optimality conditions.

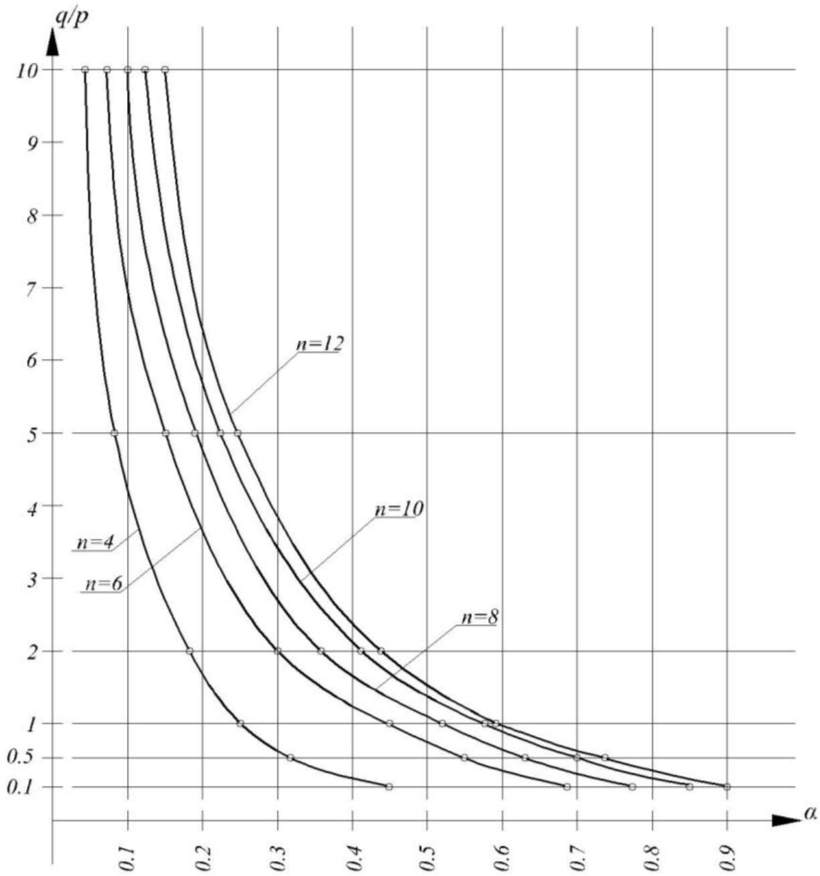

Fig. 2. Graphs of the dependence of the coefficient *α* on *q/p* and *n* for the optimal shape of the lattice

4. It is necessary to investigate possible loading schemes (that have an engineering sense) of such structures in terms of the flexible lattice elements operability and the minimum material consumption.

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