The Application of Evolutional Algorithm Optimization of Sprengel Systems of Transport Buildings and Structures for Northern Districts

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Abstract. One of the most effective types of modern building structures are combined systems sprengel type for cold areas and aggressive environments. Structurally, they consist of a stiffening beam reinforced with one or several pre-stressed flexible elements - ties. The practice of designing such systems has shown that the greatest efforts in a stiffening beam arise under the action of non-equilibrium, including one-sided loads. To solve this problem, a technique based on the use of heuristic optimization methods has been developed: a genetic algorithm and an annealing simulation algorithm.

1. Introduction

Comparison of modern achievements in the field of construction has shown that traditional constructions from mono-material (concrete, metal, wood, engineering plastics, etc.) do not allow full use of the strength and heat engineering properties of these materials, while at present, there is a need for more economical designs that are efficient at low temperature conditions [1, 2].

An analysis of the evolution of load-bearing building systems shows that one of a perspective and promising directions for their further development is the use as flat, spatial and spatial stand-alone structures of prestressed combined harness-type systems.

The main advantage of trussed girders (trusses, beams) is the rational distribution of material, since the outline of the bearing inhaling is similar to the shape of the envelope of the bending moment diagram in the stiffness beam from the set of active loads [3, 4].

Economic efficiency, low weight, reducing the cost of transportation, the possibility of manufacturing at a construction site or at assembly bases prove the effectiveness of their use for transport buildings and structures, the construction of which, as a rule, is carried out in areas remote from the construction industry complexes [5, 6].

In addition, truss structures in comparison with traditional trusses and other end-to-end bearing systems have fewer nodes, joints, etc., which provides improved cold resistance of structures during operation in the northern regions of Russia.

Optimization of the design of frame structures, including metal prestressed trusses, with a variation of their outlines, is a multiparameter problem of nonlinear programming, often requiring combined algorithms that combine various methods and modern approach of organizing of optimization
calculations by a computer. Methods for solving problems of this type are extremely complex, their general solutions have not yet been fully developed [7, 8].

A rational geometric shape of the trussed systems as a whole is determined by the shape of the steel cables of trussed girders. Thus, the search for optimal geometrical forms of the truss structure is largely a search for optimal outlines of cables.

2. Methods

Analysis of the distribution of bending moments in stiffness beams of trussed systems from various types of loadings showed that the most dangerous loads for the stability of structures of this type can be one-sided loading.

There are some effective solutions for taking an effort from a one-sided load, which, nevertheless, have a number of disadvantages.

The direction of improvement of the truss system is the reduction of material consumption under the action of distributed one-sided loads [9, 10].

The authors of the article have developed a technical solution for stabilizing a trussed girder (Figure 1.), including a stiffness beam, a main trussed girder consisting of a main tie beam and racks with slideways for its free passage, additional trussed girders, including a stabilizing tightening beams, freely missed through the slideways in the racks of main trussed girder, on one part of the span of the truss attached to the beam-strut in its bearing areas, and on the other to the bearing draw, and having the form of broken lines inscribed in the curves of variable cree outlines, whose outlines are directed in the area of attachment to the bearing tie beam convexity down with the smallest radius of curvature at the points of greatest transverse deformations of the beam struts, and in the area of attachment to the beam struts - convex upward within the outer dimension of the main trussed girder [11, 12].

![Figure 1. A general view of a trussed girder according to the patent of the Russian Federation for invention No. 2668624.](image)

The proposed technical solution for stabilization of trussed girders increase rigidity, bearing capacity and live participation.

3. Results and discussion

The effectiveness of this design is achieved due to the elastic resistance of the racks of the trussed girder, which is formed due to the curvilinearity of the shape of the stabilizing tightening and is adjustable to the design of the truss.

The proposed truss structure is distinguished by the simplicity of the implementation of elements and components, a small number of nodes and, consequently, low costs for the fabrication of the structure [13, 14].

The effectiveness of stabilization depends on many factors: the distribution of stiffness between the components of the trussed beam elements (beam strut, main and stabilizing tie beams), the construction height of the truss and boom sagging main and stabilizing cables, the shape of the stabilizing cables and their prestressing.

The determination of the optimal parameters of the truss beam is proposed to be carried out on the basis of an evolutionary (genetic) algorithm.
Genetic (evolutionary) algorithms are adaptive search methods that can solve optimization problems. They use an analogue of the mechanism of genetic (evolutionary) inheritance and an analogue of natural selection, while preserving biological terminology and the basic concepts of linear algebra [19, 20].

An evolutionary algorithm was used for optimizing the topology of stabilizing cables of the trussed girder, and it was adapted by the authors to optimize the parameters of the truss structure (Figure 2).

Figure 2. The flowchart of the algorithm of genetic (evolutionary) optimization applied to the structures under consideration.

For this problem, the authors of the article used the following provisions:

- Using the node algorithms, a single basic parametric model of a truss beam was created - a genome, including a set of optimized parameters - genes with their own limits of changeability; on the basis of the base model, a population is randomly generated - a set of design schemes of truss beams;
- On the basis of FEM, internal forces and movements in elements of truss girders of the entire population are determined; the efficiency of each genome — a calculation model of a truss beam — was determined in accordance with the objective function;
- Verification of the optimization criterion - the optimization criterion recommended by the software developer is adopted: optimization is considered completed if the current result of the objective function is not improved for 50 generations (optimization cycles);
- Proportional selection and linkage of genomes with a relative genomic distation of 25%;
- Combining and changing the system parameters randomly, forming a new design scheme.
To create a parametric model, a software complex was used, including:

- Rhinoceros to visualize the model;
- Grasshopper to create a parametric model;
- Karamba as a finite element solver;
- Galapagos for the implementation of optimization algorithms.

The finite element model has the following assumptions:

- the supporting nodes of the trussed beam are articulated; free longitudinal displacements are provided in one unit;
- the joints of the racks to the stiffness beam are rigid;
- the junction points of the cables to the racks are rigid, while the bending moments in the strings do not occur due to their low flexural rigidity; slippage of stabilizing cables relatively to the racks in the design model is not implemented, which, however, does not have a significant impact on the distribution of forces in the beam-strut;
- the load is applied in the nodes of the upper chord;
- the calculation was made in a linear formulation;
- stabilizing cables are without prestressing.

Baseline data for the calculation:
- span of truss beam is 36m;
- the rigidity of the elements of the spire-gel farm: the stiffness of the beam-struts - I-beam 30B2 according to the STO ASCM 20-93; stiffness racks - continuous square section with a side of 5 cm; rigidity of the main and stabilizing puffs - a continuous square section with a side of 2.5 cm; - 3m racks pitch, construction hoist beam struts 0.6m and boom sagging main tie beam 2.5m relative to the supports of the trussed truss; - the height of the farm in the middle of the span of 3.1m (1/10 of the span); - the value of the load 34 kN [14, 16].

As a result of optimization, a new topology of stabilizing cables was obtained. The calculation was carried out by the “SCAD” (Figure 3).

From the presented materials it is clear that for the change in the geometry of the stabilizing puffs, a reduction in the forces (bending moments in the stiffening beam) by 13.4% was achieved without changing the weight of the structure.
Figure 3. Optimization results of the trussed beam based on the evolutionary algorithm.
4. Conclusions
1. Based on the analysis of existing solutions to increase the bearing capacity of the trussed beams under conditions of one-sided loadings, a new technical solution was proposed to stabilize the truss girders, protected by the RF patent No. 2182208.
2. A method was developed for adapting a genetic (evolutionary) optimization algorithm with reference to building systems, and specifically, to structures of a truss-like type.
3. On the basis of the developed methodology, a series of numerical experiments to determine the optimal topology of a trussed beam with stabilizing tie beams was carried out. The effect of reducing of a maximum effort for the considered option was 13.4%.

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