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Features of Application of Spatial Metal Farms in the Production and Public Buildings

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Abstract. Latticed metal spatial cover designs have many advantages over traditional structures, for example, in front of flat farms. However, their mass application is hampered by the following factors: the complexity of the implementation of nodal connections, the laboriousness of manufacturing, the laboriousness of transportation and installation. Another factor that restrains the widespread use of spatial factors is their little study. This is especially reflected in the restriction of the use of new structures or on the attempt of non-standard use of known structures, etc. The author of this work in his project practice used a structural plate as an inclined covering in a production building. The task in hand does not have a known direct analog of the already developed structural coating plate for use under the specified conditions. The authors proposed a new technical solution of the structural plate. The authors proposed to collect spatial structures by combining flat inclined trusses. All elements of flat trusses are proposed to be made from metal corners, and the nodes of trusses are made of sheet parts. To achieve this goal, the authors solved a number of problems: the refinement of nodal loads acting on the inclined spatial structure; the search for the optimal distribution of material within the spatial lattice structure; ensuring compliance of the designed structure with the current construction standards.

1. Introduction

In the coatings of public and industrial buildings, it is often necessary to cover large spans. Various designs can be used for this purpose. Today, as the bearing structures of the coatings of these buildings, flat farms are the most common [1]. Plane farms have shortcomings that can be eliminated in the case of the application of spatial structures of coatings. Spatial structures are devoid of such drawbacks as: the need to provide a flat shape when bending a farm, ensuring the joint work of neighbouring farms, ensuring geometric invariability of the coating, and so on [2-20]. Latticed metal spatial cover designs have many advantages over traditional structures, for example, in front of flat farms. However, their mass application is hampered by the following factors: the complexity of the implementation of nodal connections, the laboriousness of manufacturing, the laboriousness of transportation and installation. Another factor that restrains the widespread use of spatial factors is their little study. This is especially reflected in the restriction of the use of new structures or on the attempt of non-standard use of known structures.

Well-known spatial metal coating designs, called "structural slabs" or simply "structures" (figure 1). They have proven themselves as reliable, safe, architecturally expressive, quickly constructed structures. Their reliability is proved by a lot of experimental and theoretical studies, a lot of experimental development. In different countries there are catalogs of manufacturers, standard albums of drawings, project documentation for serial production, as well as recommendations for calculation and design, regulatory documentation for this type of structure [21-23]. However, all these materials are applicable only to specific conditions for the use of structural boards. In particular, ensuring the guarantee of reliable operation of the structural plate when designing and manufacturing it on the basis of the listed documents is possible only for the horizontal arrangement of the structure (figure 2). In the case, for example, of tilting the structural plate, its reliability and safety requires a demonstrative justification.

The author of this work in his project practice used a structural plate as an inclined covering in a production building (figure 3). Next, the results of the calculated justification for the reliability of such a technical solution are presented.

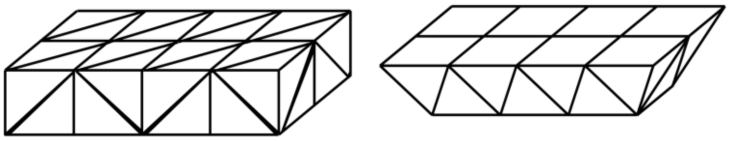

Figure 1. General view of structural plates.

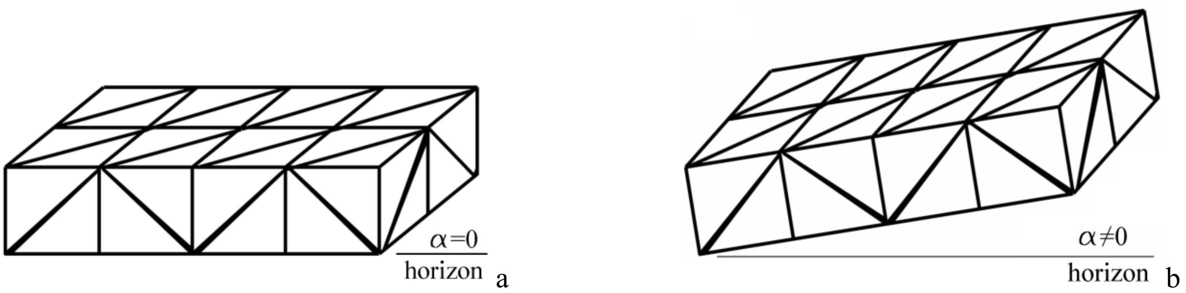

Figure 2. Design position of structural plates.
a - Correct position, according to RF norms;
b - Wrong position, according to RF norms.

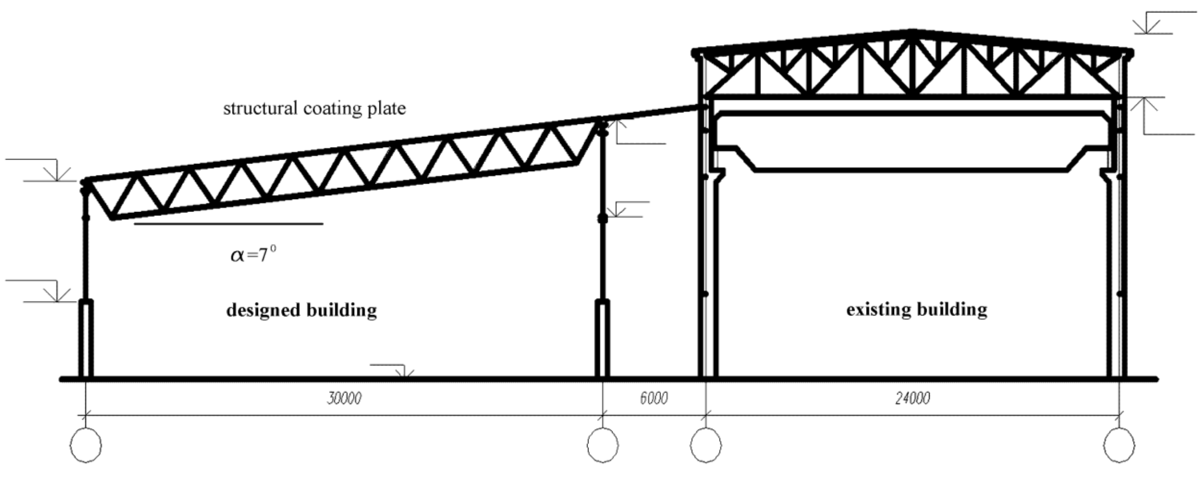

Figure 3. The building scheme with an inclined structural slab of the coating.

2. Materials and methods

According to the conditions of the task, the building with dimensions of 30x84 m^2 should be covered by a structural plate tilted at an angle of 7° to the horizontal. The building's design scheme is a nonfree spatial frame (figure 4). The overall stability of such a frame is provided a priori, since it is possible to attach it to a rigid object. A tough object for the task at hand is a nearby production building.

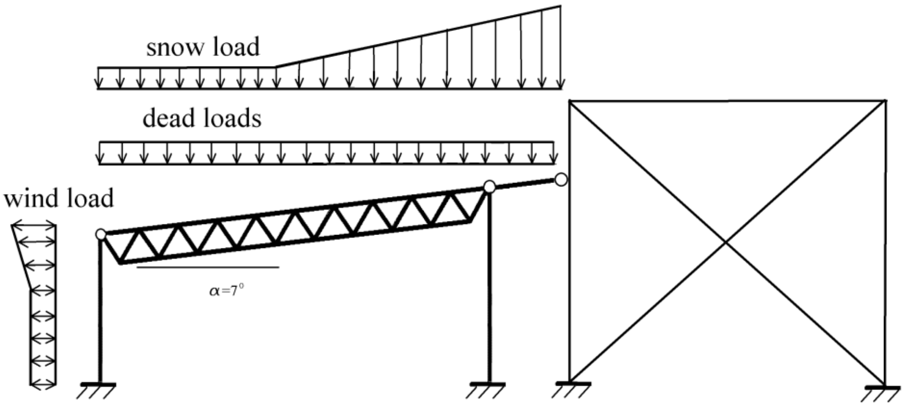

Figure 4. Building design scheme.

The task in hand does not have a known direct analog of the already developed structural coating plate for use under the specified conditions. In the building regulatory documents of Russia, the scheme depicted in figures 3, 4 requires taking into account asymmetric loads. Asymmetric loads arise from snow accumulations on the coverings of buildings having a step change in height. This kind of snow accumulation near the roof fractures is usually called a "snow bag". Recommended for consideration the shape of the snow bag for the problem in question is presented in figure 4. For the conditions of construction in Russia, snow load can often be the main load for structures of coatings of buildings and structures. The shape of the main load largely determines the distribution of the material within the spatial lattice metal structure. The presence of the roof slope and the presence of a load from the snow bag on the cover are the main differences that make it difficult to directly apply the known technical solutions of structural plates for the conditions under consideration [21, 23].

The authors proposed a new technical solution of the structural plate [24, 25]. The authors proposed to collect spatial structures by combining flat inclined trusses (figure 5). All elements of flat trusses are proposed to be made from metal corners, and the nodes of trusses are made of sheet parts (figure 6). The use of long flat trusses as the main building unit of the spatial structure has certain advantages [26]. The technical solution proposed by the authors has a novelty, protected by the Rus patent [24, 25]. A new technical solution for spatial construction required justification for reliability and safety. To achieve this goal, the authors solved a number of problems:

1. specification of the node loads acting on the oblique spatial structure, including the asymmetric snow load;
2. search for the optimal distribution of material within a spatial lattice structure;
3. Ensuring compliance of the designed construction with the current building standards.

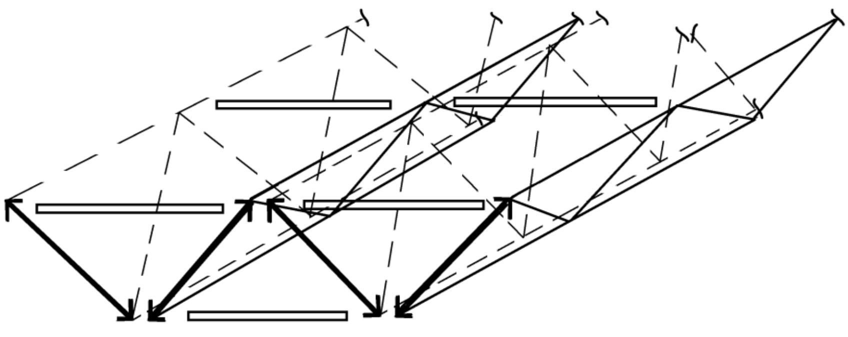

Figure 5. Assembly diagram of the spatial slabs of flat sloping farms.

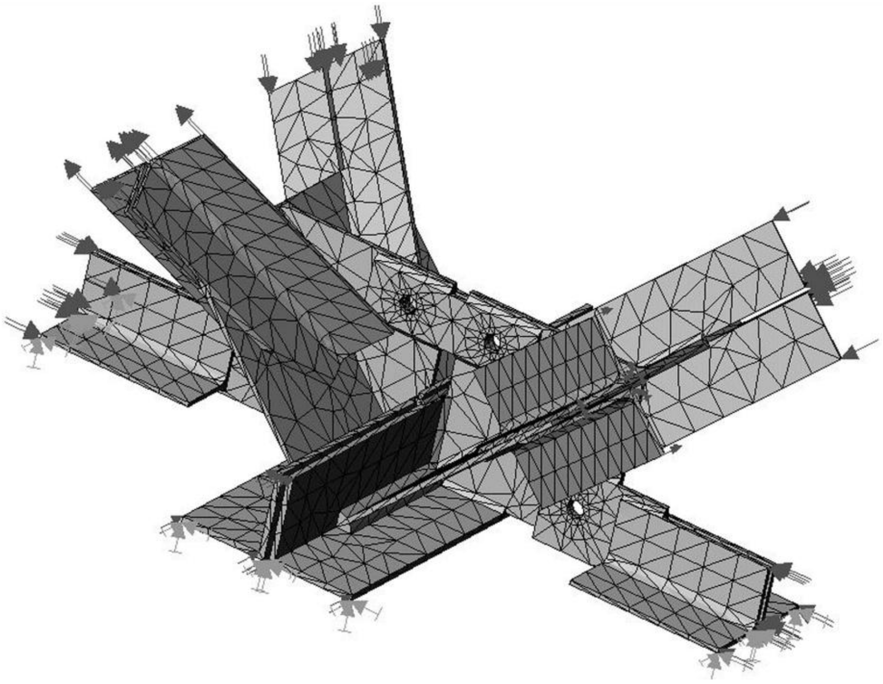

Figure 6. A node is made on the leaf elements.

3. Results

To achieve the feather goal, the authors analyzed the distribution of nodal loads with a variation in the angle of inclination of the upper belt net of the structure [27]. It is established that the nodal load can be calculated by a simplified procedure. The node load on the nodes of one waist cell of the upper mesh of the structural structure is inversely proportional to the distance from the node of the cell to the vector of the resultant force from the load collected from the cell in question. When these studies are performed, the magnitude of the load calculation error is determined. It is established that for angles less than 63° the error can be neglected [27].

Two other tasks were solved jointly. For this purpose, the authors developed a mathematical apparatus for parametric optimization of curvilinear structural structures [28-30]. The developed mathematical apparatus was the basis of the algorithm of the software complex for optimal design of structural structures [28-30]. A settlement complex was created that combined the work of its own production programs and the Mirage calculation program (NIIAS, Kiev).

One of the authors' programs completed the preparation of the initial data for the automated design calculation for the FEM in the “Mirage” program. Another program of the authors carried out work to determine the optimal distribution of material in the design, calculated in the “Mirage” program. The third program calculated the design quality criterion, ran iterative procedures to change the initial parameters and decided to continue or complete the calculations. As a result of operation of the described complex, the structural design optimal in steel consumption was obtained [31].

To solve the problem of reducing the complexity of nodal joints of the structure, the authors developed a node with sheet connecting elements (figure 6). The proposed unit is easy to manufacture and has a good compensation ability. The node was optimized by the authors using modern software tools. Analysis of the stress-strain state of the nodal connection was made with the help of well-known calculation complexes: Lira (NIIASS, Kiev), Cosmos/Works (Structural Research & Analysis Corp., Los Angeles), ANSYS Design Space 6.0.1 (ANSYS, USA). The design model of a node whose geometry is created by SolidWorks (SolidWorks Corp.). U. S.), presented in figure 6.

4. Conclusions:

At the moment, we can say with confidence that:

1. The use of spatial core systems to cover large-span buildings for industrial and public use has many advantages over traditional coating solutions. The spatial operation of such a coating, provided its rational (optimal) design allows to reduce the total consumption of material on the coating structure.
2. Installation of the spatial structure is much faster than the coating with the use of flat farms, which reduces the overall construction time of a building or structure.
3. The rigidity of the supporting frame of the building is provided by the spatial operation of the entire coating and does not require the installation of additional bonds in the coating.
4. Experience in the use of spatial structural designs as coatings of buildings of large spans suggests the rationality of their application.

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