The Mesh of Shells of a Bionic Type to be Operated in Extreme Habitats

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Abstract. The authors of the article emphasized the structural efficiency and unique geometry of bionic shells which make it possible to implement the most extraordinary architectural solutions. The estimations of different options of geodetic shells are given. The conclusions on the mesh of shells of this type in extreme habitats are made. The mesh of shells of a bionic type has the criteria which are deterministic, for example, shape strength, resistance to aerodynamic, snow loads, minimum construction material and maximum usage of the volume.

1. Introduction

The existing base of construction and structural constructions production in the northern regions of the country is still primarily oriented towards application of reinforced concrete, stone and steel structures, while the abundant forest resources are not sufficiently used.

Since the ancient times, the wood has been the main construction material, and it has not lost its relevance, but vice versa, today the number of constructions of various purpose that are made of this material is growing with every passing day.

The main construction materials are made of the wood, such as: laminated veneer lumber, regularized round timber, dry profiled lumber, laminated plywood tubes. Although they are made of the same material, due to the production technology, they have different physical and technical parameters and properties.

The wooden structures have significant advantages: the steel intensity decreases by 3 times, mass of the building - by 2-3 times, installation labor capacity - up to 2.5 times, forest resources renewability, sustainability, high strength and rigidity parameters, excellent aesthetic and acoustic properties of the wood, perfect aesthetic properties, light and handling properties, minimum energy capacity in the construction product release.

The most popular all over the world is spatial and frame structures in the form of the mesh of shells of a bionic type which, in their turn, make it possible to make spans of more than 40 m.

2. Methods

Methods for assessing the degree of damage or the operational suitability of structures throughout in the northern districts are somewhat different, in some documents the area of damaged floor structures is limited; in others, the state of the structures that have not left work is assessed; as well as the economic benefits of building a new one or restoring an old building [7-8].
The main means of a building from progressive collapse is a method of reconstruction the strength of load-bearing structures, ensuring the bearing capacity of the elements of a framework of the building (structures of coatings and floors, structure nodes, creating continuity and continuity of floor reinforcement, etc.).

As mentioned above, redundancy is a method of increasing the reliability of an object by installing additional elements that exceed the minimum required for the normal execution by the object of its functional purpose. In this case, the system rejects only if the main and all reserving elements fail.

The system of reservation can be presented from a number of stages, at each of which certain functions of the system are performed. The task of reservation is to find such a number of reserve samples at each stage, which will ensure a given level of system reliability at the lowest cost [9-10].

3. Results and discussion
This is also confirmed by practical achievements of foreign partners, in particular, the successfully installed dome on the Amundsen-Scott South Pole station, the US intracontinental pole station located on the glacier in the Antarctic.

![Figure 1. US intracontinental pole station located on the glacier in the Antarctic.](image1)

The dome was mounted in 1975, its diameter is 50 m and height is 16 m. This structure has become a point of interest of the station; it even included a shop, post office, and pub.

![Figure 2. Mesh of shell of free configurations.](image2)
The design of mesh of shells is made in specialized software suites of the computer-assisted design systems (CAD).

The load-carrying structural systems represent the frame of the construction object. They determine not only the space-planning solutions of the designed object which are related to its designation but also the load-carrying capacity (strength, rigidity, stability).

From the point of view of the construction science, the load-carrying frames of the modern buildings or structures are the complex construction schemes consisting of a number of elements which parameters differ in essence.

This guide book offers to use algorithmic models in solving the tasks on calculation, regulation, and improvement of load-carrying structures of construction objects. In this case, it is possible not only to estimate the load-carrying capacity but also to find efficient structural solutions from the point of view of material and energy costs based on mathematical and software CAD tools [5,7].

4. Calculation of the proposed system
The model creation and strength estimation start with the analysis of the static operation of the 36 m diameter domes depending on their rise and grid configuration:

- Dome with 10 m rise (2 options)
- Dome with 15 m rise (2 options)
- Dome with 18 m rise (1 option)
- Dome with 20 m rise (2 options)

The load is taken as uniformly distributed (10 kN).

The laminated plywood tubes D150x15 mm are taken as frames.

The required weight of the laminated plywood tubes to ensure the load-carrying capacity of the structure:

\[ G = \frac{N^+ L^+}{R_y} l_i \rho_m + \frac{N^- L^-}{\varphi R_y} l_i \rho_m \]

Calculation results are given in tables 1.1 and 1.2.
Table 1

| Scheme | Effort in arch | Effort in support contour | Effort in 1 contour | Effort in 2 contour | Effort in 3 contour | Effort in 4 contour | Effort in 1 brace | Effort in 2 brace | Effort in 3 brace | Effort in 4 brace | Weight |
|--------|----------------|--------------------------|-------------------|-------------------|-------------------|-------------------|------------------|------------------|------------------|------------------|--------|
| 1. Diameter 36m Arrow 10m | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ |
| | 0 | 1600 | 1833 | 79 | 1085 | 66 | 0 | 0 | 406 | 84 | 249 | 38 | 175 | 7 | 1032 | 82 |
| Arrow 10m | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ |
| | -1704 | 4 | 0 | 0 | 0 | 433 | 7 | -2140 | 46 | -404 | 7 | -284 | 32 | -227 | 16 | -174 | 4 |
| 2. Diameter 36m Arrow 10m | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ |
| | 0 | 1390 | 78 | 1609 | 18 | 1003 | 84 | 0 | 0 | 510 | 42 | 471 | 57 | 108 | 2 | 928 | 7 |
| Arrow 10m | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ |
| | -1704 | 5 | 0 | 0 | 0 | 433 | 7 | -2140 | 46 | -404 | 7 | -284 | 32 | -227 | 16 | -174 | 4 |
| 3. Diameter 36m Arrow 10m | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ | $\sum N = 1250$ | $\sum T = 1250$ |
| | 0 | 1059 | 0 | 190 | 0 | 1348 | 5 | 30 | 68 | 0 | 287 | 5 | 140 | 9 | 550 | 33 | 579 | 02 |
Table 2

| Scheme  | Efforts in arches | Efforts in the support center | Effort in 1 contour | Effort in 2 contour | Effort in 3 contour | Effort in 4 contour | Efforts in 1 brace | Efforts in 2 brace | Efforts in 3 brace | Efforts in 4 brace | Weight |
|---------|-----------------|-------------------------------|-------------------|-------------------|-------------------|-------------------|------------------|-----------------|-----------------|-----------------|--------|
| 4 Diameter 36u |                  |                               |                   |                   |                   |                   |                  |                 |                 |                 |        |
| Arrow 1st | 0               | 100000.0                      | 170000.0          | 220000.0          | 300000.0          | 300000.0          | 300000.0         | 300000.0        | 300000.0        | 300000.0        |        |
| Arrow 2nd | 0               | 150000.0                      | 200000.0          | 250000.0          | 300000.0          | 300000.0          | 300000.0         | 300000.0        | 300000.0        | 300000.0        |        |
| Arrow 3rd | 0               | 200000.0                      | 250000.0          | 300000.0          | 350000.0          | 350000.0          | 350000.0         | 350000.0        | 350000.0        | 350000.0        |        |
| 4 Diameter 36u |                  |                               |                   |                   |                   |                   |                  |                 |                 |                 |        |
| Arrow 1st | 0               | 100000.0                      | 170000.0          | 220000.0          | 300000.0          | 300000.0          | 300000.0         | 300000.0        | 300000.0        | 300000.0        |        |
| Arrow 2nd | 0               | 150000.0                      | 200000.0          | 250000.0          | 300000.0          | 300000.0          | 300000.0         | 300000.0        | 300000.0        | 300000.0        |        |
| Arrow 3rd | 0               | 200000.0                      | 250000.0          | 300000.0          | 350000.0          | 350000.0          | 350000.0         | 350000.0        | 350000.0        | 350000.0        |        |

5. Conclusions
The infinite possibilities of architectural shapes that are characteristic for the mesh of shells, their use in severe and changing climatic conditions on the earth make them the structures of the future for sure. But to implement the potential, a lot of developments in material science, design automation, construction norms and rules are to be made.

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