Variant Design of Metal Dome Frame

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Abstract. There are proposals for a reasonable choice of a cost-effective version of the metal frame of the dome. The selection is made from a limited number of alternative designs. Variants of designs differing from each other in the framework scheme. Evaluation of the economic efficiency of the options is made according to the cost of construction. Total cost is defined as the sum of the cost of manufacturing the structure and the cost of the materials from which the structure is made. The cost of manufacturing the design has been proposed to be determined according to the method of Professor Ya.M Likhtarnikov’s. The results of the calculation of the labour-consumption and cost of manufacture for the three variants of metal domes are presented. The definition of cost for three options of projects is presented and their comparison is made. A method for choosing the most effective option is presented.

1. Introduction

One of the ways to increase the efficiency of construction is the use of light spatial structures [1] - [7], for example, domes.

The effectiveness of these structures compared to traditional structures due to the reduction of material consumption for the manufacture of the supporting frame. This occurs as a result of a more accurate research and analysis of structures, taking into account their spatial work [8]. According to [8], the mass of structures is a characteristic of their economic efficiency. Mass determines the number of operations associated with the manufacture of metal construction. The cost of its movement depends on the mass of structures and its details. Therefore, the mass can be used as an indicator of the complexity of manufacturing and installation. The mass of the metal structure is an indirect characteristic of the overall dimensions of the structure. The labour-consumption of each production operation to make the metal construction depends on the mass of its parts. Reducing the mass of the structure leads to a decrease in the labour-consumption of its manufacture. The number of parts in the design is an indicator that determines the labour-consumption of its manufacture. It depends on the volume of such technological operations as: measurements, marking, metal cutting, assembly of individual parts, etc. The presence of holes and welds has a significant impact on the labour-consumption of manufacturing structures. Even a small number of them has a significant impact on the labour-consumption of manufacturing the structure.

The technology of processing the part depends on the geometric shape of metal. Sheet detail is usually close to rectangle. The labour-consumption of the assembly and welding of products from sheet parts depends mainly on the perimeter of the part. The details of the shaped profile (angle, I-beam, channel, pipe) have one main size – length. The assembly and welding of structures from
shaped parts is different from the assembly and welding of sheet structures. Hence, the difference in
the labour-consumption of the manufacture of the construction of sheet or profile parts. This means
that there is a dependence of the labour-consumption of manufacturing the structure on the shape of
the profile of its parts. For example, it is known that for parts having the shape of an elongated
rectangle, the labour-consumption is higher than for parts that are close in shape to a square [6].

2. Materials and methods
The labour-consumption of assembling structures made of shape parts consists of time to move the
part, its installation in place and fixing. All the listed time depends on the size of the part (main
dimensions and shape of the profile), and, therefore, is proportional to the mass. The labour-
consumption of welding metal parts depends on the type of cross-section of the weld, its size and
method of welding. The labour-consumption of manufacturing a metal structure can be defined as the
sum of the labour-consumption of the operations of processing, assembly and welding its parts.

To calculate economic efficiency of the designed metal structures the authors used
Ya.M. Likhtarnikov's methodology [9, 10]. According to this methodology to determine the cost of the
construction one has to calculate the construction weight and its elements and units weight $T^{prod}$, labour hours, transport operation $T^{transp}$ and construction assembling $T^{inst}$:

$$T = T^{prod} + T^{transp} + T^{inst}$$

3. Results and discussions
The authors applied the method of variant design for designing a dome roof presents in the figure 1.

Figure 1. Projected building dome

While designing this roof the authors chose three variants of frame structures for comparative
analysis. Projects were developed for Ribbed ring-shaped dome (figure 2), Grid dome (figure 3),
Webbed geodesic dome (figure 4). Geometrical arrangement of the dome design was made while
using AutoCAD and SolidWorks software systems. Static analysis of the dome design structures was
made while using LIRA software system. The model of the construction node connector was made by
SolidWorks CAD system [11]. The weight Dome, its labour-consumption of manufacturing and its
The cost was calculated in Excel application (table 1). Calculated by the formula (1) cost indicators are presented in the form of graphs in figures 8-10.

![Figure 2. Ribbed ring-shaped dome](image1)

![Figure 3. Ribbed ring-shaped dome](image2)

![Figure 4. Webbed geodesic dome](image3)

Models for installing dome structures on the walls of a building are shown in figure 5. The geometric dimensions of the ribbed ring-shaped dome are shown in figures 6, 7. Other options for dome structures have similar overall dimensions. All design options had the same initial conditions for design. For all design options, steel with the same characteristics was adopted, loads of the same magnitude, conditions of bearing on the walls are the same for everyone. The differences between the design options were in the geometric characteristics elements, the construction of the joint connections of the elements, the methods of the connection of the elements to each other.

These differences affect the volume of material for the manufacture of the structure, the number of hardware and welding operations in joints, the total weight of the construction, the complexity of working with it, etc. The number and quality of operations for the manufacture of parts of a dome structure also significantly changes depending on the variant design. To take into account all the listed differences and evaluate the total cost of creating a dome structure allows the methodology [9]. The specified methodology is universal in nature. It’s can be applied to any metal structures. With its help, it is possible to determine the labor intensity and cost of manufacturing the structure at the plant, the cost of transporting the structure from the place of manufacture to the installation site, the cost of installing the structure in the design position. The authors used it to assess the cost of structures shown in figures 4-7. The calculated costs of the options for dome structures are presented in table 1. A visually comparison of the cost indicators of structures is shown in figures 8-10.
Figure 5. Some models of installing dome on walls of building

Figure 6. Geometric dimensions of ribbed ring-shaped dome
Figure 7. Characteristics of ribbed ring-shaped dome

Table 1. Calculation results

| N  | Variants of the construction         | Labor intensity, man-hours | Metal weight, tons | Manufacturing cost, U.S. dollars | Cost of basic materials, U.S. dollars | Total cost, U.S. dollars |
|----|-------------------------------------|-----------------------------|-------------------|---------------------------------|---------------------------------------|-------------------------|
| 1  | Ribbed ring-shaped dome             | 258.70                      | 3.49              | 1 990                           | 1 691                                 | 3 681                   |
| 2  | Grid dome                           | 315.36                      | 2.40              | 2 426                           | 1 162                                 | 3 587                   |
| 3  | Webbed geodesic dome                | 416.00                      | 2.53              | 3 200                           | 1 228                                 | 4 428                   |

Figure 8. Cost of basic materials

Figure 9. Manufacturing cost
4. Conclusions
1. Comparison of three variants of metal frames of the dome roof allowed to establish the most efficient design.
2. In the presented task, the best cost has Grid dome variant.
3. Alternative design of structures allows you to make an informed choice of the best of the considered structures.
4. The presented study made it possible to quickly select the most interesting design option. For a more accurate and global assessment of the cost-effectiveness of structures, the alternative design method is not acceptable. To achieve a global solution, methods for optimal structural design should be used.

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