# Buildings and constructions on the base of timber for the Arctic regions

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**Abstract.** Economic efficiency of development of high-latitude territories directly depends on the construction technologies applied here. Traditional materials such as reinforced concrete and steel cause unacceptably high resource consumption throughout the entire technological chain of construction production in the Northern regions, and the mechanical transfer of construction technologies to high-latitude construction are ineffective. Analysis of environmental effects on buildings and structures has shown that the most effective for the Extreme North is the dome shape, namely: the building of the lenticular shape; dome building; the building in the form of a sphere; in the form of a cone formed by rotating the Reuleaux triangle around the vertical axis of symmetry; the building of tetrahedron type, and various shapes formed by the combination of buildings of dome shapes. The rationality of constructions made of wood and wood materials is emphasized, which determines the necessity of creating an industry of glued elements. It has been widely used in high-latitude construction and has proved to be the best in terms of frost resistance, low resistance to corrosion from blizzards, high specific strength and low thermal conductivity for a long time.

## 1 Introduction

The earth's climate is getting warmer every year, and the Arctic’s warming is two to three times faster than the rest of the planet: over the last hundred years, the temperature there has increased by 4-5°C. The boundaries of solid sea ice are shifting further and further to the North. Warming in the Arctic mainland-Alaska, North-West Canada and the Asian coast of the Arctic Ocean are especially noticeable. As a result, the unique flora and fauna of the Arctic and the way of life of its indigenous inhabitants are on the verge of extinction [1].

As the main reason, scientists call the sharp temperature jumps caused by climate change in the Northern hemisphere, as well as the influence of warm winds. As a rule, the sea off the Northern coast of Greenland freezes so much that until recently it was called the "last ice region", which was supposed to be a deterrent to global warming.

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## 2 Materials and Methods

According to the latest data, the Arctic ice cover in the Spitsbergen region at the end of August was 40% lower than the average for this time of year since 1981. A record low was reached in July 2018. According to experts, at some stage between 2030 and 2050, ice in the Arctic Ocean may completely disappear in summer [1].

Abnormal temperatures in February and August 2018 led to the ice retreating from the coast at a record distance. "Almost all the ice to the North of Greenland is significantly destroyed and damaged, and therefore more mobile. Open water off the Northern coast of the island is an unusual phenomenon," emphasizes Ruth Mottram of the Danish Meteorological Institute [2].

The extreme North can be attributed to a kind of world in which you can select certain difficulties for design, such as:

-The severity of the climate, namely: permafrost, long winters, hurricanes and blizzards;

-weather contrast: changes in air temperature from minus 60 degrees in winter to plus 40 degrees in summer;

-the rapid transition from long winters to short summers;

-vastness: a quarter of the earth's land, where forty-seven percent of the territory of Russia with the most valuable raw materials and energy resources are swamped, snow-covered and frozen;

-lack of roads and deserted areas;

-shift and expeditionary nature of work, which generate the psychology of a temporary worker.

The main difficulty in solving the problem of forming a comfortable settlement environment in the extreme conditions of the North is that it is difficult to determine the boundary between the temporary and permanent character [3].

Significant flows of workers, affecting the quantity of population, structural and temporal features of extractive industries should also be taken into account.

In the opinion of the architect Yu. F. Ysov [4], the features of the northern dwelling architecture include the following factors:

1. Compactness - a property of the capacity of a spatial form, which is determined by the ratio of volume to the surface;

2. Orientation is a property of flexibility of the spatial form, its ability to reflect the conditions of the outside world. If the compactness of the shape stems from the need of isolation of the dwelling from the external environment, the orientation of the shape, on the contrary, is caused by the necessity of its connection with the external environment;

3. Integrity is a property of the spatial form that characterizes the organic unity of all its parts and details. If compactness is a special measure of volume, if the orientation establishes a connection of this volume with its environment, then the integrity of the spatial form expresses the unity of internal spatial organization.

The scale of structures, requiring enormous material, technical and labor resources, set the task of finding rational design schemes while maintaining the uniqueness and aesthetics of the architectural appearance [5]. In addition to this, the above complicating factors for construction in the Northern regions are to be superimposed.

Best described as a microarea—a Soviet planning concept that originated in the late 1950s—that has been adapted and transformed to accommodate environmental and social conditions in the extreme north, these two projects share many similarities despite their vastly different scales, and social, political, and economic contexts [7].

The analysis of environmental impacts on buildings and structures has shown that the most effective for the Extreme North is dome forms, namely: the building of a lenticular shape; dome building; building in the form of a sphere; in the form of a cone formed by the rotation of the Reuleaux triangle around the vertical axis of symmetry; buildings of aerostatic and tetrahedral type, as well as various forms formed by a combination of dome forms.

## 3 Results

According to the authors, of particular interest is the building having the shape of a ellipsoid truncated at the base (Fig. 1). Its technical idea is to create a compact and ergonomic architectural and expressive structure for a comfortable stay in the harsh conditions of the polar region, including the private space and a zone for public life (work, rest). Such a building can serve as a unit of a modular system for expeditionary bases (scientific, prospecting, geological exploration), as well as for permanent residence.

**Fig. 1.** Building of the ellipsoid shape truncated at the base.

The adopted rounded shape of the buildings has a minimum contact surface with the environment at a given volume, which ensures minimal heat loss through the walls of the premises. One of the proposed new solutions, taking into account both wind protection and insolation of the premises, is the horizontal development of the plan with an average number of stores. The building being designed is located in Norilsk (VI snow area 3 kPa with IV wind area – 0,48kPa). Only 146 days a year the city experiences the normal change of days and nights. The polar day lasts for 68 days while polar night for 45 days [8]. Land cover changes in three areas representative of natural and anthropogenic landscapes in the vicinity of Norilsk were examined over a 30 year period of documented warming focusing on three time periods corresponding to distinct socio-economic conditions: the mid- to late 1980s, the early 2000s, and the 2010s. Temperature increases resulted in consistent and significant greening and a slight increase in surface water extent in the nearby area unaffected by human activities [9].

The proposed structure is one-storey, with 40 × 88 m dimensions in the axes and a minimum +12,500 height within the area of the arena The dimensions of blocks of residential and public premises have a certain modular step, which allows them to be transported by all modes of transport, which in turn provides a rational relationship between the total area of the building and the labor costs for its construction on the construction site. The planning solution provides for the separation of the main premises. The selected building has one central entrance for both the athletes and spectators of the sports center. The length of the building can vary by adding modules. The timber glued elements are designed with a rectangular cross-section. The plan at +0.000 is shown in Fig. 2.

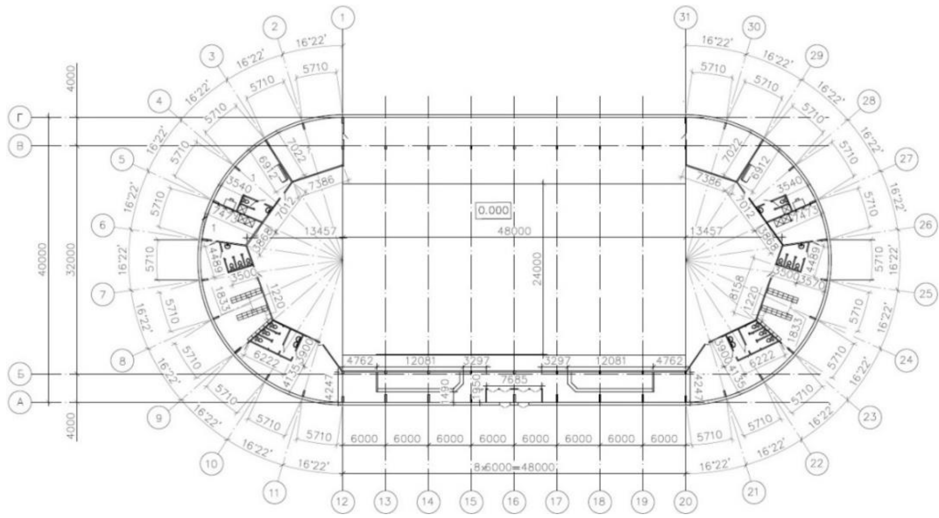

**Fig. 2**. Plan at + 0.000.

Structurally the building is divided into 3 parts: two end parts are made in the form of ribbed domes with a diameter of 40 meters and the central part is designed in the form of a vault with a width of 40 meters and a block length of 48 meters.

The diameter of the dome is formed of two timber columns with a 216 × 448 mm cross section and a 12.5 m height. At the top of the columns there is a three-hinged arch with a cross section of 216 × 1,056 mm with a radius of curvature of 20 meters. The arch step, as well as the step of the columns is 6 meters. Number of frames formed is 9. The curved beams of rectangular 216 × 1,056 mm section are installed on the edges. Horizontal steel straps with 80 × 5 mm cross-section are made at the junctions of columns with the arch. Cross-section of the structure is shown in Fig. 3.

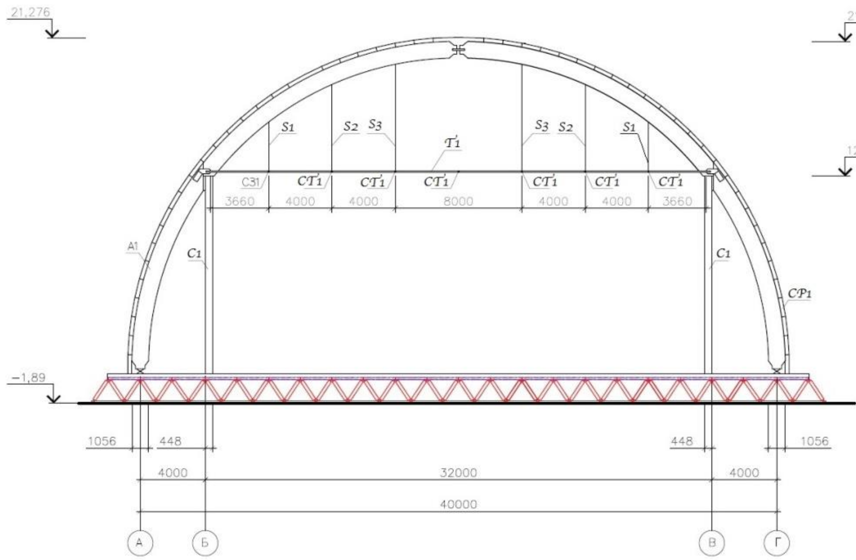


**Fig. 3**. The Diameter of the ellipsoid building form truncated at the base.

End halls represent a half ribbed dome. Frame is a timber foundation - supported semi - arch, at the top – metal semi – ring supported. Sections of semi – arches are 191 × 864 × 31,580 mm. The arrangement scheme of major structures is shown in Fig.4.

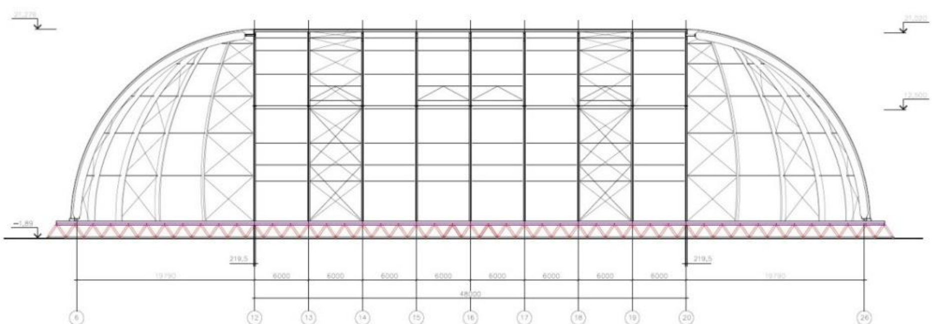

**Fig. 4.** The arrangement scheme of major structures (longitudinal section).

To ensure the geometric immutability and rigidity of the spatial frame system made of timber structures, vertical and horizontal connections are provided. Transverse steel braced farm (pitched ties), with cross-bars are installed in the second from the end sections at the upper edge of the cross section of the arch. Spacers are installed along the entire length of the structure and along the arc of the arch. Vertical links are timber trusses. Horizontal connections are also installed inside the building on the tie-beams.

In the dome parts, vertical cross ties are established in the extreme segments of the dome and through one along the entire length of the rib. Vertical cross connections between the columns are located in the second sections from the end.

The enclosing element of the proposed building is a curved panel with the upper and lower cladding, the frame of which is made in the form of a cross-beam system. The frame of the panel is made of transverse and longitudinal ribs, with 40 × 242 mm sections. The upper and lower cladding is plywood, 8 mm and 6 mm thick, respectively. Insulation is made of extruded polystyrene with a thickness of 160 mm.

For construction in the Northern regions another solution of building enclosure in the form of false facades made of glass and additional bearing structures is of interest. Glass with photo effect for summer time is proposed to be used, and in the darkness - to use the internal illumination of the false facade. This solution will improve both the thermal protection functions of the building and the energy efficiency of the building as a whole.

# 4 Discussion

The use of structures made of laminated and engineered timber in the construction of settlements in high latitudes with the implementation of the proposed forms will for certain provide high economic efficiency, guaranteed durability and safety of operation, and most importantly - a comfortable living environment for people in extreme conditions of the North.

The existing regulatory framework for high-latitude construction does not reflect all aspects of the safe development of natural resources in the Arctic zone. This is not because the regulatory framework is imperfect, but because a huge number of aspects cannot be built into the law; there appear new principles of management, technology, international requirements. Territorial dissociation of high-latitude objects imposes additional requirements for the safety of buildings and duplication of basic vital functions. Moreover, it is necessary to develop reliable technologies for rescue operations and fire fighting in low temperatures, to improve the efficiency of rescue operations-to create additional storage facilities for fire equipment and rescue equipment in key points of the Northern regions.

# 5 Conclusions

The proposed structure is competitive against the background of known solutions due to the principles analyzed by the authors for construction in the Far North. The rationality of structures made of timber and timber materials is emphasized, which determines the need to create an industry of glued elements. It is necessary to point to an underestimation of timber as a very effective construction material in high-latitude construction. It has been widely used in high-latitude construction and has proven to be the best in terms of frost resistance, low susceptibility to corrosion from snowstorms, high specific strength and low thermal conductivity for a long time.

Norilsk represents an archetypal model of mobility flows managed by a ‘big business’ firm. Indeed, between the 1960s and 1980s, the city's metallurgical complex promoted massive in-migration, followed by massive out-migration in the post-Soviet decades, with several projects of ‘managed decline’ [10].

This project is planned to be developed in the future, which will allow further implementation of structures in construction in the Northern regions, improve the accuracy of the design of buildings and structures of nonlinear energy-efficient aerodynamic forms. The adopted rounded shape of the buildings has a minimum contact surface with the environment at a given volume, which ensures minimal heat loss through the walls of the premises. The proposed concept looks ideal for the design of housing settlements.

Analysis of technical and economic indicators shows that the designing building is cheaper on 19% percent with compared to traditional construction solutions.

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