

To the problem of the use of forming principles in the residential buildings architecture with regard to the energy efficiency

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Abstract. The aim of this study was to determine the role of the formation process in the architecture of residential buildings to improve their energy efficiency. The analysis of various types of national dwellings has been carried out, in which the criterion for evaluating the architectural form of the building was the volume compactness index associated with its form. The ratio of the area of the outer building structure to the heated volume is accepted for the index of compactness. The dwellings of the peoples in the North Russia and Siberia, Armenia, South India and Central Asia have been studied. It is shown that the morphogenesis of residential buildings could be the determining factor for a low consumption of thermal energy used for heating of buildings. The author concluded that, in addition to the use of advanced modern energy-saving technologies, the work with the architectural form is also important for energy consumption savings.

1 Introduction

Currently, the problem of energy efficiency of buildings is related primarily to the increasing energy consumption in the process of buildings maintenance for the following creation of a favorable microclimate in rooms and premises [1]. The depletion of natural resources and the increase in human population causes the problem of the need in saving energy. That is why the architecture and building techniques in many respects should be based on natural and climatic needs of the region and meet the comfort requirements to the inner environment [2, 3].

In accordance with the modern requirements of the sustainable development in the process of design and construction of buildings the renewable energy sources are actively used. The reduction in the heat loss of the building is achieved in different ways. One of them is the construction of mass brick walls, the use of high-quality thermal insulation of building envelopes and energy-efficient window systems. Today the most effective direction is the use of solar panels, ground thermal installations, wind power station, tidal power stations. At the same time, we have some experience in creating favorable microclimate in rooms and premises and a comfortable environment with the use of appropriate architectural forms. The analysis proved that the buildings of the same size, but different forms have

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different compactness indices. The hemispherical shape has a lower compactness (1.01), and thus the least heat loss compared with the buildings of conic, cylindrical or cubic forms. These traditional types of dwellings as yurts and igloos, how the studies have shown, the standards for the energy efficiency

It is noteworthy that the concept of humanity autotrophy (suggested by V.I. Vernadsky as early as 1937 to refer to the process of obtaining food and energy for the humanity due to the solar energy) becomes a methodological basis for the solution of the problem of energy production in the process of development of new design and construction methods for the energy-efficient architecture projects [4].

2 Experimental section

The reduction in the building heat loss of is achieved in different ways. One of them is the use of massive accumulating elements (such as solid brick walls), the creation of the high-quality thermal insulation of exterior building envelopes (walls, windows, roofing structures), the use of energy-efficient filling of window frames, the sealing of the outer shells of buildings [5, 6]. The use of alternative energy sources for heating and lighting of buildings is the most effective way.

Nowadays the renewable energy sources are discussed in the use of ground thermal energy plants, wind power plants, solar panels and tidal power stations. In modern architectural and building practice, the trend ensuring the creation of a favorable indoor climate, including: air conditioning and ventilation with heat recovery, the use of energy-efficient windows and LED lighting has been developed [7, 8].

An example of that may be the "first active house in Russia". It was built in the Moscow region. Inside this apartment house a healthy microclimate was created with the maximum level of natural light and regular circulation of fresh air. This is achieved by the introduction of a special indoor climate control system (Window Master), regulating the sun protection systems, the temperature of the underfloor and the ventilation. From the example of "the first active house in Russia" we can conclude that the whole system of energy efficiency of buildings has been already developed. However, these systems affect mainly the technological aspects of the design process.

At the same time, during the evolution of buildings the vast experience is accumulated in creating favorable microclimate with the help of shaping techniques [9]. Many theoretical works from Vitruvius to Le Corbusier, F.L. Wright and I.V. Zholtovskiy were devoted to the problems of architectural formation of buildings. Let us consider some special features of the morphogenesis of buildings on the basis of the analysis of developments of various types of the residential buildings. Most clearly these methods can be traced at the example of the history of development of national types of residential buildings. The study examined more than 70 specific space-and-planning decisions. The residential buildings of every nation are the result of a complex process of change and improvement of life conditions associated with various aspects of human life and the environment. These are the climatic conditions, the economy special features, the technology development, the national customs, traditions and beliefs.

In our study, the analysis of different types of national dwellings was carried out considering the period of construction of buildings, their location and the materials used. As a criterion of the architectural-and-spatial organization of the building we took the volume compactness index of the building related to its shape. The compactness index is the ratio of the area of the outer structural shell of the building to its heated volume [10]. It is shown that for the same building volumes the greater the area of the building envelope structure, the more volume compactness index is which causes an increase in the building heat loss.

The architectural shape and the building envelope are considered as the elements forming the microclimate and regulating the heat loss. The studies have shown that with the increase value of the compactness volume index equal to 0.01, the energy consumption for heating is increased by 2.5 % [11]. According to the data obtained by German experts in energy consumption in buildings of various shapes, with an increase in the total area of the exterior building envelope the energy consumption for some comfort microclimate characteristics of rooms and premises also correspondingly increases [12]. Therefore, in the process of the development of volumetric-and-planning solutions it is important to find a rational form of the building, providing minimal heat loss through the building envelope structure.

3 Result section

The results of this study are based on the analysis of the most characteristic space-and-planning decisions for national dwellings. Let us follow the changes in the rate of compactness of the building at the example of selected types of buildings with certain forms (tent - conical shape; hut - a cubic form; Tods housing - cylindrical shape, the dwellings of the Eskimos and the peoples of the Turkic language group - the spherical shape) with relatively the same heated volume values.

One of the common types of dwellings of the North-East European peoples (Saami, Nenets) and Siberian peoples (Evenki, Mansi, Northern Yakutian, Orok, Mganasany, Tozhu Tuvans et al.) is a cone-shaped tent. The conic frame of the dwelling consists of 30-50 sloping poles, covered in winter with the cloth made of deer, red deer, moose skins. In summer the structure is covered by the boiled birch bark, the bark or the burlap. The entrance is in winter halted by the skins and in summer by the coarse cloth. In the center of the tent there is a plague, there are sleeping places on both sides with respect to the entrance. The floor has a multi-layer coating: the first layer is the birch bark, then it contains wicker mats and dry grass, and the reindeer skins are on the top of it. This type of dwellings is mobile and it is caused by a nomadic way of life [13]. The climatic conditions of these areas: the annual average temperature in winter is $-20\text{ }^{\circ}\text{C}$, in summer it is $+18\text{ }^{\circ}\text{C}$. The building materials are the wood and the deer skins. The estimate compactness volume index is 2.10.

To the cubic form of the dwellings the huts in Armenia, Afghanistan, Georgia and Ossetia belong. Usually, there are monumental stone buildings. In the mountainous areas of the Crimea it may be a small house made of wood, clay, ceramic stone or mud bricks. This type of dwellings is located on the mountain slopes (the terraces). The flat roof of the building is the underlying floor or the yard for a superior building. The climatic characteristics of these areas: the annual average temperature in winter is $-10\text{ }^{\circ}\text{C}$, in summer it is $+20\text{ }^{\circ}\text{C}$. The applicable building materials are the stone and the wood. The estimate compactness volume is 1.63. In addition to that, a hut on the slope has a complex configuration plan with lots of the corridors and open galleries and transitions within the planning structure, mainly due to a difficult mountainous terrain and the way of life of the people living in these territories.

The most typical traditional dwelling with cylindrical shape is the dwelling of the peoples Toda in South India. Traditionally, the dwellings are built of bamboo in a barrel-shaped form and resemble a barrel cut in half (with the cut to the ground). The height of the dwellings is up to three meters. The arched building envelope of side walls and roofs are reinforced by the rattan wood; the covering of the dwellings is made from the straw. The end walls are made of the polished stone. Today, the traditional Tod's dwelling can be found in a small number of settlements in the mountains of Nilgiri (Blue Mountains) in

India. In the dwelling it is warm in winter and cool in summer. The climatic characteristics of the area of residence: the annual average temperature in winter is +15 °C, in summer it is +30 °C [14]. The used building materials are the wood and the leaves of different plants. The estimate compactness volume index is 1.35.

The spherical shape of the national dwelling is presented by the igloo (snow huts of Escimos and the yurt of the Mongolian and Turkic language group peoples). Igloo is a dome-shaped construction of wind compacted snow or ice blocks. The entrance is the hole in the floor, which leads to a corridor dug in the snow below the floor level. The light penetrates through the thickness of the walls or windows made of the lake ice. In order to protect the entrance from the wind, a done shape vestibule is fixed to the main volume. According to the publications, the temperature in an unheated igloo is duce to the human body heat loss within +2...+6 °C. The highest temperature that can be achieved in heated snow igloos (at the distance of 25...30 cm from the roof) with a shield fabric dome is + 30 °C. In this case the outdoor winter temperature may be -30...-45 °C, and the compactness index is 1.0.

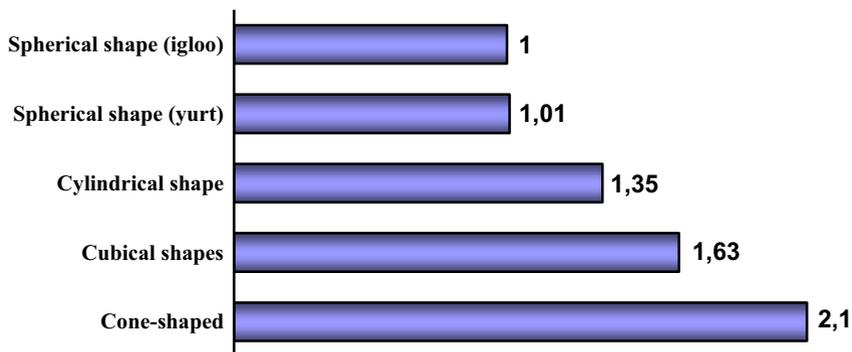


Fig. 1. The volume compactness index of the architectural-and-spatial organization of the residential buildings

The climate parameters of regions inhabited by ethnic groups of the Turkic language group: the annual average temperature in winter is -10 °C, in summer it is +25 °C, the most commonly used building materials in the construction of yurt is the wood and the felt mats. The compactness index for the buildings of the Turkic language group peoples is 1.01, and it is not surprising, as the yurt is closest in its form to a sphere or a hemisphere, which is a perfect and energy-efficient form. The main purpose of these dwellings is to minimize the heat losses. In the process of development, the yurt has reached the maximum ease and convenience of transportation; fast assembly and disassembly within a few hours. All this is in turn determined its exquisite compositional simplicity and mobility.

4 Discussion section

The reduction in the compactness index causes the reduction in the heat loss (Fig. 1). The existence and survival of the human beings in harsh natural conditions determined the development of dwellings of various ethnic groups (first from the tent to the lodge and the tipi, then from plague and yaranga to the igloo and yurt). The development of the forms of dwelling from cubic to spherical has been largely determined by the climatic conditions. The optimal form of the nomad house is a yurt with hemispherical shape. "When the people lived and developed in round dwellings: yurts, tents, teepees, tents – they understood the

nature and were inseparable from it in their minds. Turning to the cubic forms of the housing, we started to fight the nature. In the spherical structures, the human consciousness begins to transform itself into creative and generating sources. Human beings in all the ages and up to the present time subconsciously linked the divine energy with spherical surfaces, reflecting their consciousness in religious buildings: churches, minarets, mosques. We need the quick-to-erect, better transparent, flexible and subsequently solidifying spherical shapes" [15]. This is connected, among other things, with the substantial performance of the content and the organization of the architectural space, for example, the establishment of so-called "spiritual centers" of residential buildings in the form of shop windows or small museums and galleries with the family achievements, which promote the education of the younger generation and the transmission of the accumulated wealth of cultural and family traditions to future generations [16].

The technology of building of the dome (spherical) buildings can be traced as the example of the project of a country spa hotel, designed by the team of the dome construction technology center iDome. The dome hotel construction, as the authors of the project say, can reduce energy consumption by 70% compared with the usual "square" architecture. In the construction the eco-friendly and fire-safe materials were used. The project opens up the broad prospects for the creation of architectural complexes with the most complete set of services and at the same time with the energy consumption saving.

5 Conclusions

Thus, examining the special features of the national dwelling morphogenesis and the typology of residential buildings, we conclude that, in addition to the use of advanced modern technologies, aimed at improving the energy efficiency of the building, a great potential has the work with the architectural form. Most of the considered optimal shape of the building is a spherical shape or a hemispherical shape with the lowest compactness volume index of 1.01 compared to a cone-shaped or cubical shapes with compactness volume index indices respectively of 2.10 and 1.63. The shape of the building as it is can be an important parameter of the energy consumption savings for buildings and facilities that undoubtedly will enrich the research in the field of the sustainable architecture.

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