Insolation factor in the design of energy-efficient buildings

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Abstract. This article discusses the importance of taking into account the insolation factor in the design of energy-efficient residential buildings. The existing and fixed in the regulatory literature method of calculating insolation is analyzed, its strengths and weaknesses are revealed. As a way to further develop energy-efficient design, a variant of the automated calculation of insolation on the basis of the Autodesk Revit software package and the Dynamo visual programming platform was considered. The creation of an algorithm is demonstrated step by step, the advantages of using this method are clearly shown. Conclusions are drawn about the applicability of the obtained model in the design of buildings and structures.

1. Introduction

The twentieth century is characterized by incredible rates of growth in industry and production. This period is called the scientific and technological revolution. Due to the rapid development of technology, the widespread electrification of cities, an increase in the population, the amount of energy consumed has grown significantly. After the middle of the twentieth century, humanity first encountered an awareness of the problem of the exhaustibility of natural resources, such as oil, coal and gas.

Since that time, people began to think about saving natural energy sources. One of the ways to do this was to use alternative energy sources, such as wind, water flows in rivers, solar radiation and others.

In this regard, the approach to the design of buildings and structures has changed. Now one of the main trends is the creation of buildings that, in addition to classical energy sources, use alternative ones. With this approach, it is very important to effectively save energy inside the building so that as little as possible of it is uselessly released into the environment. It is this idea that has become the basis for the principle of design and construction of buildings that is very important in our time - energy efficiency.

There are many areas in the field of energy-efficient construction. Here are the most significant of them:

- Increasing regulatory requirements for energy efficiency in buildings;
- Use of building materials with low thermal conductivity;
- Introduction of building energy efficiency classes to improve metering quality;
- Design of buildings and structures, taking into account all significant factors affecting their energy efficiency.

All the above directions are aimed at the most efficient use of available energy sources, taking into account the influence of natural factors. Such factors include, for example, air humidity, its temperature, wind speed and direction, and, of course, insolation.

In this article, the achievement of energy efficiency of a building will be considered, first of all, precisely in the context of its insolation, as one of the most important factors affecting the energy efficiency of a building and the comfort of people in it.
Insolation is called direct solar irradiation of surfaces and spaces. This process is nothing more than the transmission of electromagnetic waves of different lengths from the Sun to the Earth, followed by irradiation by these waves of the entire surface of the planet.

Speaking about the energy efficiency of buildings, it is first necessary to take into account electromagnetic waves of the infrared range, which when absorbed by the surfaces of buildings cause an increase in the temperature of the materials of which these buildings are made. An important feature of this radiation is that it freely penetrates through the windows of buildings, heating air and surfaces, especially intensively in the summer.

Sunlight is also an important component of the environment, necessary for the normal life of any living organism and directly affecting human comfort and health.

With a lack of lighting, a person can develop many diseases, some of which are difficult to treat:

- tuberculosis;
- rickets;
- osteoporosis;
- scurvy.

However, excess sunlight also negatively affects the human body due to excessive exposure to the body with the same electromagnetic waves, which leads to poor health, increased fatigue and can even provoke the development of cancerous tumors.

Based on the above reasons, when designing energy-efficient and safe modern residential buildings, it is necessary to pay special attention to the degree of insolation of the building and take into account the comprehensive effect of lighting on the projected object.

2. Overview of existing methods for calculating insolation

In the Russian Federation, issues of energy-efficient construction and, in particular, insolation of buildings began to be regulated relatively recently.

In Russia, on November 23, 2009, Federal Law No. 261-ФЗ On Energy Saving and Improving Energy Efficiency, and on Amending Certain Legislative Acts of the Russian Federation was adopted, which should regulate the rules and requirements for the process of designing buildings and structures.

Also, from August 21, 2016, Order No. 399 of the Ministry of Construction and Housing and Communal Services of the Russian Federation (Ministry of Construction of the Russian Federation) “On Approving the Rules for Determining the Energy Efficiency Class of Multi-Apartment Buildings” came into force, according to which each residential house must be assigned an energy efficiency class.

In 2017, GOST R 57795-2017 “Buildings and Structures. Methods for calculating the duration of insolation”, according to which it is necessary to calculate the insolation of buildings and structures. And although at the moment this calculation is not mandatory in the preparation of project documentation, it is necessary to solve a number of practical problems related to the lighting regimes of territories and premises. These tasks are provided for by current documents, such as SP 42.13330, SP 54.13330, SP 160.1325800, and are aimed at fulfilling the requirements of SanPiN 2.2.1 / 2.1.1.1076, which in fact makes the requirements for insolation mandatory.

The analytical calculation of insolation given in the aforementioned GOST R 57795-2017 is the only officially approved method in Russia. This calculation is based on the use of insolation graphs and solar maps, which makes it quite convenient, but lowers accuracy, especially when calculating large objects of complex shapes or entire groups of objects.

3. Creating an algorithm for automatic calculation of insolation

The above limitations of the analytical calculation method inevitably imply the need to create a more accurate method for calculating the insolation of buildings and structures. The most rational way to create this method is to use BIM - technologies (Building Information Model).

The advantage of calculations performed using information models is their accuracy and speed. The disadvantages include the relative complexity of mastering software systems that calculate information
models, as well as the need for a large number of diverse source data, which is directly related to the
cost of design work.

The most technically advanced examples of software systems that calculate building information
models are Nemetschek Allplan, mACT – ARCHICAD и Autodesk Revit.

The algorithm performed in the framework of this article was created for the Autodesk Revit software
package using the Dynamo visual programming platform. Step by step we will analyze the process of
creating an algorithm for the analysis of insolation.

For an example of calculation in Revit, forms of several adjacent buildings were created, the
calculation of which must be done together (which is impossible for the analytical method from GOST
R 57795-2017).

![Figure 1. Spatial model of a group of buildings.](image)

The next step is to create a family of facade panels called “Stained Glass Panel”. To accelerate this
process, the southern facades in front of the standing buildings were not divided into separate elements,
since their insolation will be the same.

Now you need to set the “Solar” parameter, which is responsible for the duration of insolation, as
well as a filter for sorting stained glass panels.

![Figure 2. Insolation time parameter.](image)
Panels with insolation of 1 hour or less are highlighted in black; dark gray - up to 1.5 hours; light gray - up to 2 hours; white - from 4 hours or more.

Next, go to the Dynamo visual programming platform. For the script to work correctly, you will need to install the following plugins: LunchBox for Dynamo, Ladybug, Ampersand.

In the Dynamo program, we set the shading geometry (the plane onto which the sun's rays will fall) by selecting all the facade panels of the building.

![Diagram of shading geometry](image)

**Figure 3.** Shading geometry.

Now you need to set the location of the buildings (we will choose the city of Moscow) and the period of data analysis (March 22 from 7 to 17 hours), as shown in the figures.

![Diagram of geographical parameters](image)

**Figure 4.** Geographical parameters of the object.
Then the so-called “solar path” with the necessary density is built. By density here is meant the number of positions of the sun taken into account in this calculation in one hour. This number should not be too small, as this will negatively affect the accuracy of the calculation, however, setting it too large is also irrational, as the computer hardware will be overloaded. For this calculation, we take the density of the "solar path" 4 times per hour.

Figure 5. Time parameters for an object.
After that, all panels are divided into planes, divided into faces, and an outer face is selected for each plane. In this calculation, each panel is divided into 6 planes.

Figure 6. The construction of the "solar path".

Figure 7. Dividing a panel on the edge.
Then, at each face, there is a central point from which the normal to the face is drawn. This is necessary for the correct modeling of the surface of the panel relative to the sunlight.

Next, you need to calculate the amount of insolation time for each panel and translate it into hours.

![Image of Sunlight Analysis Diagram]

**Figure 8.** Counting insolation time for each panel.

Now the Solar parameter created earlier must be set for all panels in accordance with the calculated time of their insolation.

As a result of all the above actions, we obtain an information model of a group of buildings with the calculated insolation time for each section of the illuminated surface.

The graphical result of this algorithm is a three-dimensional model of a group of buildings with a color display of the insolation time of the plots. Data on insolation time can also be automatically entered into the specification for the automated creation of reporting documentation.
Figure 9. Panel surface options.

Figure 10. Setting a time parameter for panels.
4. Conclusions
The model considered in this article is simple, does not have a large number of elements and is rather a demonstration. However, it clearly demonstrates all the benefits of calculating insolation using BIM.

The algorithm for calculating the insolation time created once can be used in the design of any buildings and structures, as well as groups of buildings and structures. For repeated use, it will be necessary to change the model of the structure, geographical and temporal parameters (if necessary). This algorithm can significantly speed up the process of building design, as well as improve its quality, since the architect will no longer need to spend time evaluating the illumination of the building.

Using parametric design methods using BIM can qualitatively improve and speed up the design of buildings and structures. The implementation of these methods is laborious at the initial stages, but having mastered them, construction companies will be able to more quickly and efficiently create projects for energy-efficient and comfortable buildings, which the entire world construction industry is now striving for. Based on this, it can be argued that the future of building design is closely related to the introduction of new technologies based on information models of buildings and structures.

References
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