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ACCOUNTING OF CLIMATIC FEATURES IN DESIGNING SOLAR SHADING DEVICES

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ABSTRACT

Zoning maps of the territory of the Russian Federation on solar radiation and outdoor temperature are given. It should provide for shading of fenestration during the cooling period of buildings, depending on the total amount of solar radiation and the temperature of the outside air. Depending on the amount of solar radiation, five zones are proposed in the territory of the Russian Federation. For each of the five zones, the cooling period of the building is proposed, on which the choice of the parameters of the solar ray daily cone depends on the shape of a solar shading device. A map of isolines of solar radiation for July in the North Caucasus and Southern Federal Districts of the Russian Federation is proposed, which can be used to calculate heat input through fenestration.

Keywords: solar shading device, map of isolines of solar radiation, parameters of insolation, zoning of the territory

INTRODUCTION

In 2016, by assignment of the Federal Autonomous Institution "Federal Centre for Standardization in Construction" (FAI "FCS"), NIISF RAASN together with the Crimean Federal University named after V.I. Vernadsky developed a draft code of rules "Solar shading devices of buildings: Rules for Design", [1].

The effectiveness of the use of solar shading devices in buildings for various purposes has been repeatedly proven by domestic and foreign research [2–6]. It is also obvious that the economic efficiency of their use depends largely on the climatic conditions of the construction site.

Unlike the most European countries, where the climatic conditions are fairly homogeneous, in such states as Russia, the United States, China, Ukraine they differ radically in different regions. So, for example, in construction guide of Ukraine [7, 8] the territory of the country is divided into 5 main zones.

Prior to the development of the above mentioned draft Building Regulations [1], there were no documents in the Russian Federation that would regulate the use of various modern solar shading devices depending on the site of building construction and their destination, as well as actual climatic conditions.

Design of solar shading devices should be carried out taking into account the climatic conditions of the construction region in accordance with Building Regulation (BR) СП 131.13330.2012 [9].

In accordance with BR СП 50.13330 [10] in areas with an average monthly temperature of July 21 °C and above for windows of residential buildings, hospital facilities (clinics and hospitals), dispensaries, outpatient clinics, maternity homes, children's homes, houses-individuals for the elderly and disabled, kindergartens, day nurseries, and orphanages, as well as industrial buildings, in which the

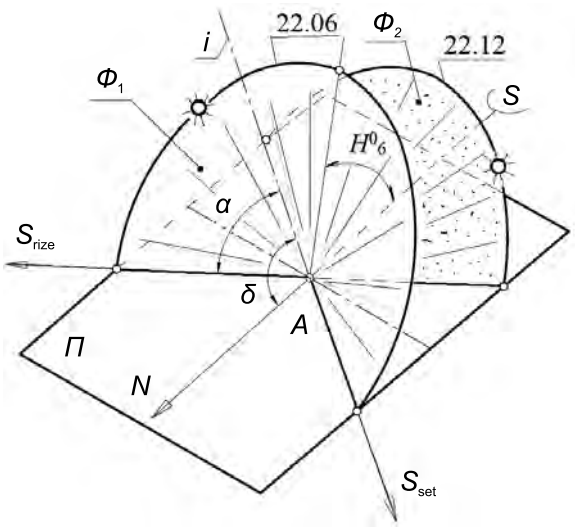

Fig. 1. Geometrical model of the solar ray daily cone: *A* – insolated point; *Φ* – solar ray daily cone; *α* – angle between the generator of the cone and its axis; *П* – horizontal plane; *δ* – latitude; *i* – axis of the Earth rotation; *S*, *N* – directions to the South and North; S_{rise} – sunrise direction; S_{set} – sunset direction; $H°_6$ – the angular height of the Sun at noon in June

optimum standards of temperature and relative humidity in the work area, or in which constant temperature or temperature and the relative humidity of the air must be maintained, should include solar shading devices.

Solar shading devices should be provided in the premises of public and industrial buildings, where in accordance with BR СП 52.13330 [11] it is supposed to perform visual works of high, very high and the highest accuracy.

In accordance with Sanitary Requirements (SR) 2.2.1 / 2.1.1.1076–01 [12] in the arrangement of windows of the western and south-western orientation in the buildings under construction and reconstruction in residential premises of apartments, dormitories, the main functional premises of children's educational organizations, educational organizations, general education organizations, having boarding schools and other specialized secondary educational institutions, medical and preventive, sanatorium and health institutions, social security institutions solar shading means should be provided.

GEOMETRICAL MODEL OF INSOLATION PROCESS

When designing solar shading devices to account for both: passive cooling in the warm period of the year and passive heating in the cold period of the year, it is necessary to take into account the total solar radiation with actual cloudiness in the construction site and the orientation of the building facades.

Differences in the positions of the Sun for different orientations and time of year are determined by the solar ray daily cone (SRDC) (Fig. 1).

The basis of all methods of forming stationary solar shading devices is the geometry of the apparent movement of the Sun across the sky, namely the geometric model of the insolation process in a point on the Earth during the day. This model is a one-parameter set of solar rays coming in one point on the Earth's surface during the day and is a solar ray daily cone (SRDC) [5]. Using the solar ray daily cone is the basis of all methods of forming solar shading devices (SSD), as well as the majority of methods of determining the duration of insolation.

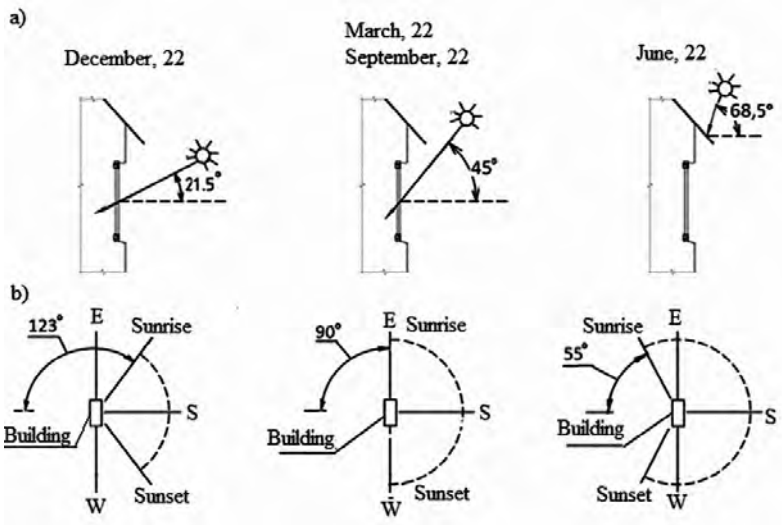

Fig. 2. Solar angles for the facade of southern orientation in the city of Krasnodar (45^0N) a) angular heights of the Sun; b) azimuths of sunrise and sunset

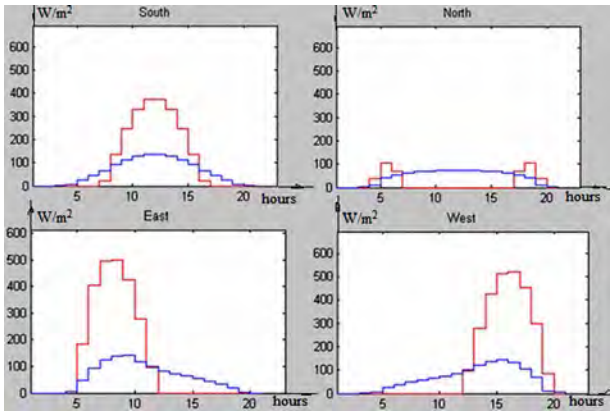

Fig. 3. Average monthly solar radiation (direct and scattered, W/m^2) for four orientations of the facade in July in Belgorod depending on the time of a day (50^0 N): red line – direct solar radiation, blue line – scattered solar radiation

The methodology for designing a SSD with the use of a solar ray daily cone is described in [5].

With the solar ray daily cone (SRDC):

- The angular height of the Sun at noon $H°_{12}$ for the selected day of the year – is used in calculating the parameters of the position of solar collectors and photovoltaic panels;
- Azimuths of the sunrise S_{rise} and sunset S_{set} for the selected date – used when determining the duration of insolation;
- Time of sunrise τ_{rise} and sunset τ_{set} of the Sun.

The horizontal plane Π cuts the cone on two generators, which indicates the directions of the sunrise and sunset in horizontal projection. S_{rise} is the azimuth of sunrise. S_{set} is the azimuth of sunset. The values of the azimuths of the sunrise and sunset for the city of Krasnodar are shown in Fig. 2.

When designing the solar shading device (SSD), it is necessary to take into account the differences in the amount of solar radiation on the building facades of different orientations during the winter and summer periods of the year. Average monthly solar radiation (direct and scattered) for four orientations of the facade in July [7] in Belgorod is shown in Fig. 3.

ZONING OF THE TERRITORY OF THE RUSSIAN FEDERATION ON SOLAR RADIATION AND OUTDOOR TEMPERATURE

Fig. 4 shows a map of the territory zoning of the Russian Federation on total solar radiation on a horizontal surface under real cloud conditions, constructed in accordance with the procedure [13] and data [14].

Five main zones were identified according to the conditions of total annual solar radiation on a horizontal surface under the actual cloud conditions:

– The first zone – 900 kWh / m^2 or less;
– The second zone – over 900 to 1000 kWh / m^2;
– The third zone – over 1000 to 1100 kWh / m^2;
– The fourth zone – over 1100 to 1200 kWh / m^2;
– The fifth zone – over 1200 kWh / m^2.

It is necessary to provide shading of fenestration during the overheating period (cooling period of buildings) depending on the total amount of solar radiation:

– In the first zone – it is not regulated;
– In the second zone – from May 22 to July 22;

Fig. 4. Schematic map of total annual solar radiation on a horizontal surface in conditions of actual cloudiness, kWh / m^2

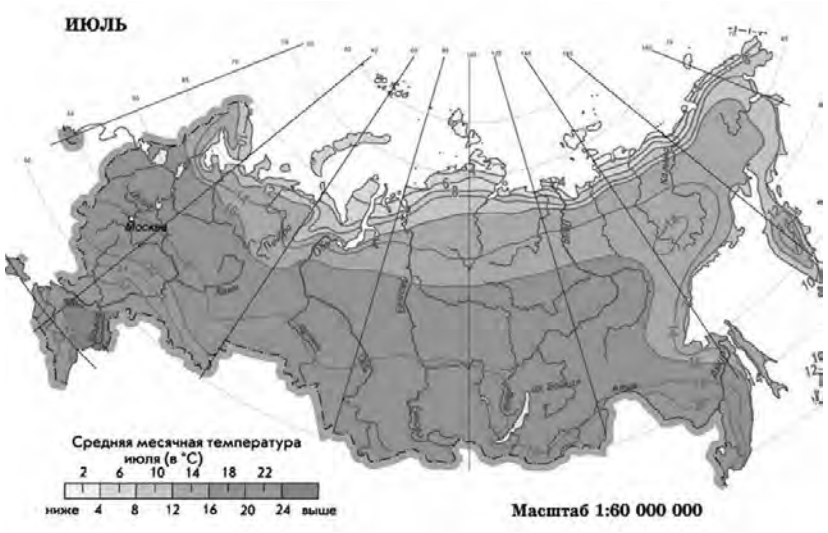

Fig. 5. Schematic map of the average temperature in July

– In the third and fourth zones – from April 22 to August 22;

– In the fifth zone – from March 22 to September 22.

For each of the five zones, periods of cooling and overheating affect the choice of the parameters of the solar ray daily cone [5].

To ensure visual comfort in the premises and privacy at night, solar shading devices should be provided for all orientations of the facades of buildings, including northern, in climatic regions where the polar day is observed in the summer.

In climatic regions with a predominance of sunny weather in the cold period of the year, it is necessary to ensure the possibility of providing passive solar heating of premises to reduce the energy costs for the operation of the heating systems of buildings.

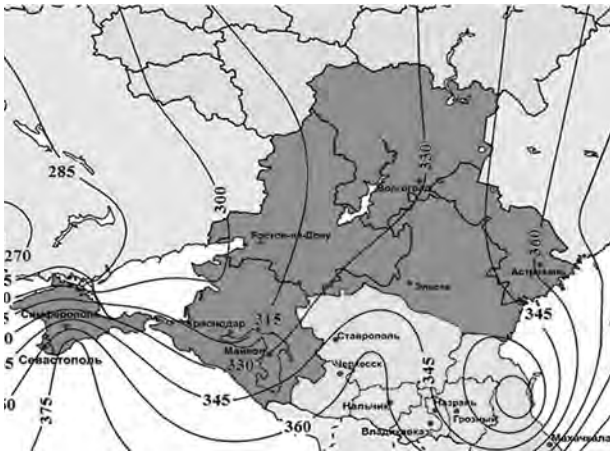

Fig. 6. Total solar radiation on a horizontal surface in July, W/m^2

Fig. 5 shows the zoning of the Russian Federation territory by the average monthly temperature of July, which should be used to determine the location of the SSD relatively to fenestration.

In the Crimean Federal University named after V.I. Vernadsky monthly maps of solar radiation isolines on a horizontal surface under conditions of actual cloudiness in W h/m^2 are developed, which is necessary for the calculation of heat input through fenestration. As an example, this article presents the results for the North Caucasus and Southern Federal Districts (Fig. 6).

CONCLUSIONS

To reduce the impact of harmful factors of direct solar radiation on the microclimate of premises, including overheating, during the cooling period of buildings it is necessary to use the solar protection of buildings. As a solar protection various measures can be considered:

– The rational orientation of the facades;

– The rational planning of the premises (loggias, visors on the facades, blinds, roller blinds, etc.);

– Planting green plantations near the facades of buildings;

– The equipment of fenestration with solar shading devices.

In all cases it is necessary to use solar geometry, the values of solar radiation and the temperature of the outside air.

In more detail, the basic principles of designing modern solar shading devices will be considered in subsequent publications.

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