Light & Engineering
Vol. 28, No. 1, pp. 58–62, 2020
https://doi.org/10.33383/2019-062
Svetotekhnika #1, 2020

MODELLING OF THE INSOLATION MODE OF URBAN DEVELOPMENT USING AN INSOPLANOGRAM

Adham I. Giyasov

Moscow State University of Civil Engineering (National Research University)
E-mail: adham52@mail.ru

ABSTRACT

A design of an insoplanogram of a tablet type that is aimed at simulating insolation and the degree of shadowing of the territory of different-height building system and buildings in southern geographic latitudes by determining the optimal gap between buildings through identifying shading and insolation, is described in action

Key words: insolation, insoplanogram, shading, radiation, light and shade, buildings, development

To regulate the light and microclimate of urban development and ensure sanitary and hygienic requirements, it is important to determine the optimal gap between buildings. Identification of the area of shading and insolation is one of the most important tasks in determining the density or percentage of development of residential areas, as well as urbanized areas in general. Architects, builders, hygienists, doctors, and other specialists pay great attention to this issue, since insolation is the most important natural factor of urban planning.

Determining the location of the building in the development system with the appropriate sanitary gaps and the choice of its orientation is one of the initial tasks of optimizing the insolation regime, which is solved taking into account the insolation, fire protection, and other requirements. Thus, it is necessary to consider purpose of a building, conditions of already developed city building and climatic features of the construction area.

To assess the mode of insolation and shading of urban areas, the author proposes an easy – to-use design of the insoplanogram of the tablet type (ITT), which allows modelling the impact of radiant energy of the sun on buildings and the building area.

Theoretical and experimental studies on insolation and natural light began more than half a century ago (in connection with the problems of architectural design) and are fully reflected, for example, in books [1–5]. They set out the methods of geometric and analytical calculations for insolation of buildings, the principles of sun protection. However, in all these and other similar works, the issues of insolation, natural lighting and UV irradiation of buildings are considered for conditions significantly different from the Central Asian and Asian countries located in the southern latitudes – from 30 to 45 degrees north latitude.

Solar-light conditions in Central Asia are very peculiar: they are characterized by a maximum in the CIS probability and duration of sunshine, the most direct, total and reflected radiation, negligible stray radiation, etc. In this regard, the regime of solar radiation in urban areas and buildings (with a significant contrast of natural lighting and great brightness of surfaces) exposed to the direct rays of the sun influences the character of light and shade.

The issues of insolation of residential premises and territories are regulated by different normative documents, in particular – [6–10].

In recent years, along with the analytical method for calculating insolation indicators, there have been works on methods of modelling the insolation regime and graphical constructions of shadows from buildings and structures in order to optimize their location and orientation on the ground [11–15].

Geometric methods of constructing the envelope of shadows from shading buildings in a given area and determining the duration of insolation in a given time interval are presented in [16,17].

Many programs have been created to calculate the duration of insolation of residential buildings and territories, see, for example, [18–20].

There are examples of underestimation or overestimation of such means of regulation as the impact of radiant energy of the sun on buildings and building areas simultaneously in both qualitative and quantitative terms. All this leads to errors that are difficult or impossible to correct after the construction of buildings and urban structures, especially in regions with hot climate. To get out of this situation, the architect-designer needs to have methods of accounting for local characteristics of insolation that are easy to use, sufficiently accurate and suitable for general practice, and have some additional data.

The analysis of the existing methods of evaluation of the insolation regime and methods of the corresponding calculation shows that the range of tasks solved by them is limited only to certain areas of design (depending on the set architectural, construction and urban planning problems). Today, there is almost no universal method that would allow a comprehensive assessment of both qualitative and quantitative indicators of insolation. The qualitative indicators of insolation include the duration of biological exposure to insolation, measured in hours, and its quantitative indicator, measured in W/m^2, is the irradiation on the surface, which is created by a parallel beam of sunlight entering the premises and on the territory of the building from the direction in which the disk of the sun is visible at the moment.

Currently, there are two ways to calculate the insolation time: with the help of an insolation – manually and with the help of specialized computer pro-

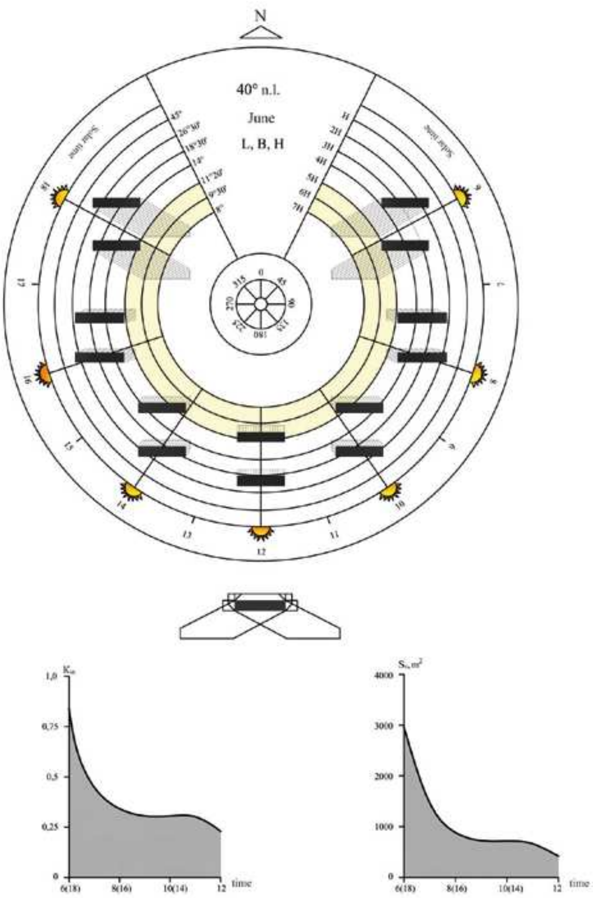

Fig. 1. ITT for evaluation of light and shade from buildings of latitudinal orientation (a) and graph of shading coefficient in the circuit of interbuilding territory K_{se} (b) [$K_{se} = K_s / K_i$, $K_s = S_s / S_g$, $K_i = S_i / S_g$, where S_i, S_s and S_g – areas of insolation, shading and general area]

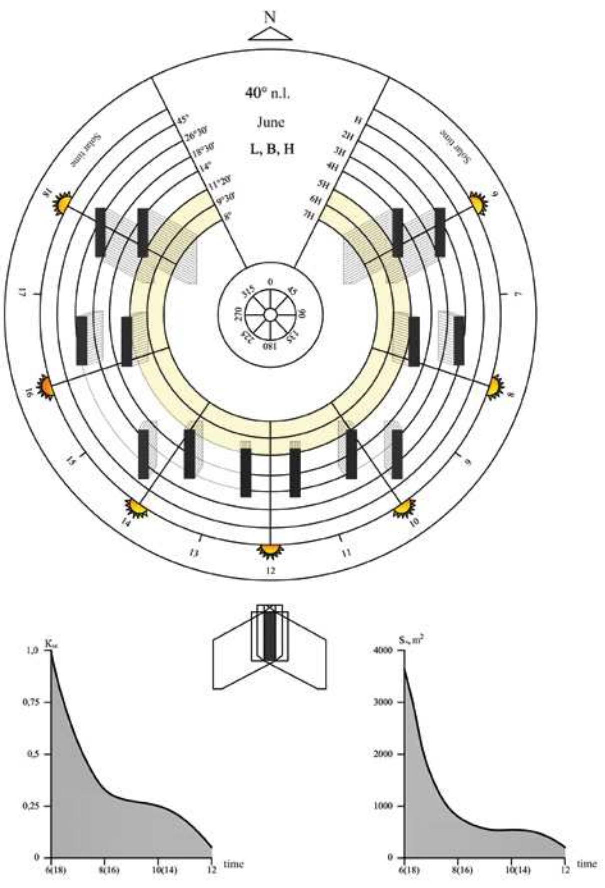

Fig. 2. ITT for evaluation of light and shade from buildings of meridional orientation (a) and graph of shading coefficient in the circuit of interbuilding territory K_{se} (b) [$K_{se} = K_s / K_i$, $K_s = S_s / S_g$, $K_i = S_i / S_g$, where S_i, S_s and S_g – areas of insolation, shading and general area]

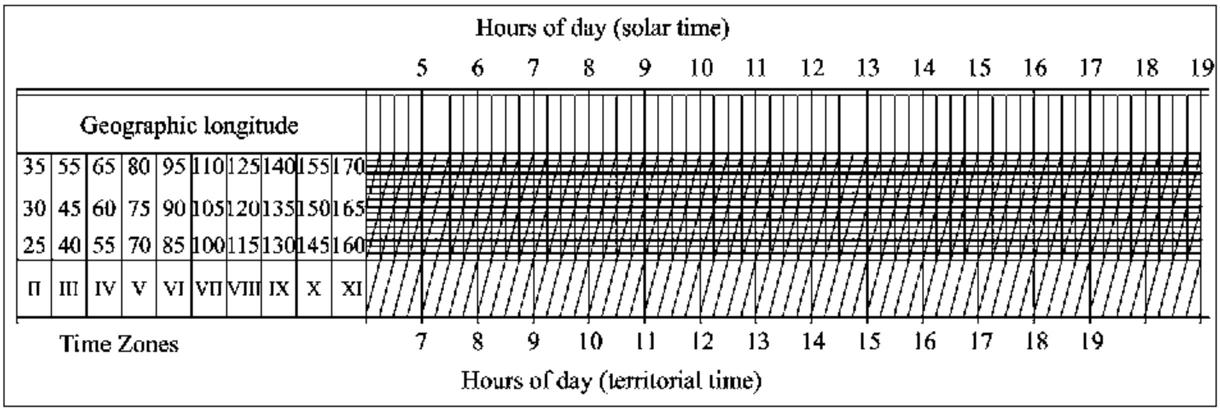

Fig. 3. Scale of solar-daylight savings time

grams. The computer method allows calculating qualitative index of insolation, which is very important for performance of expert works in cases of the compacted building. The manual method is simple, labour-intensive and rather exact way to assess not only this qualitative indicator (at architectural and construction design), but also quantitative insolation index of an object.

In this regard, the calculation methods that simulate the natural course of insolation on the building plan have practical application in urban planning to the present time. They allow using tablet type devices to determine both qualitative and quantitative insolation indicators directly on the scheme of the building plan made at the appropriate scale.

An easy-to-use device for determining the values of qualitative and quantitative indicators of insolation and shading zones is the proposed ITT built on the basis of astronomical data on the positions of the sun and nomogram standards of the Sternberg Astronomical Institute.

The ITT proposed for the practice of designing does not claim to be universal in application. The calculations made with ITT and the graph of solar radiation intensity attached to it do not contradict the existing methods of estimating the insolation regime – with the help of different graphs, tablets and computer calculations. (On the contrary, they make up for the lack of assessment of the “energy side” of insolation).

Difference between calculation of insolation indicators by means of ITT and other methods of calculation consists that ITT allows predicting the insolation mode concerning a chiaroscuro on the plan of different height building and making “energy” calculation.

The construction of gaps between buildings, their comparison and analysis of the conditions of insolation of the territory and buildings using the proposed ITT allow us to conclude that at any orientation of the building, the gaps are a function of the area of the envelope of shadows for the normative duration of insolation (Fig. 1 and Fig. 2).

The principle of construction and operation of ITT is caused by the interaction of the position of the insolated or shaded object on the earth’s surface and the course of the sun in the sky during the daylight hours from 6 to 18 hours solar time. The construction of the envelope of shadows from buildings is made in the period from sunrise to sunset for different geographical areas for the necessary warm and cold months of the year, as well as in the period provided for in the construction and sanitary standards.

ITT consists of a flat transparent base. The trajectory of the sun for the required month of the year within the azimuth from 0 to 360° and the position of the insolated object are given in a horizontal plane and expressed in a circular contour of the Central part of ITT for the period of daylight.

In the upper part of the device, the pointer of its direction to the North is applied when the device is superimposed on the building scheme. Under the direction indicator, there are the latitude and building parameters – length *L*, width *B* and height *H*.

Basis of ITT – circular grid formed by open circles applied at intervals *H* equal to the height of the shading building in the scale of the drawing. To the right of the direction indicator is the length of the radii of the incomplete circles that are multiples of the height of the shading object 1*H*, 2*H*, 3*H*, 4*H*, 5*H*, 6*H*, and 7*H*. To the left is the angular height of the sun (45°, 26°30’, 18°30’, 14°, 1 °30’ and 9°30’ and 8°) at the time of the beam passing through the top of the building with a height of *H* in the centre of the device.

On ITT, the insolation time is given by the average solar time. The conversion of solar time to territorial time or vice versa for the territory of the CIS according to the given solar-daylight scale is presented in Fig. 3.

Qualitative indicators of insolation of the building area, facades of buildings and premises, as well as the construction of the envelope of shadows and the shading area, are determined by applying a transparent planchette directly to the development plans.

The duration of the thermal effect of insolation with the establishment of the amount of incoming solar energy is determined in accordance with the schedule attached to ITT, Fig. 4.

ITT determines indicators of insolation and its impact on horizontal and vertical surfaces oriented to azimuths from 0 to 360° and shaded by buildings, canopies, balconies and loggias.

Parameters determined by ITT in assessing the insolation of buildings are the next:

– Direction, area, time and duration of insolation and shading;

– Direction, area, time and duration of UV exposure to insolation;

– Direction, area of irradiation and shading;

– Direction, area, time, duration of thermal exposure to insolation with the establishment of the amount of incoming solar energy;

– Areas for planting trees and various shading devices.

Using ITT and according to development plans made on a scale from 1:500 to 1:2000, the optimal orientation of buildings and the size of the gaps between them in the building are established in the residential area and the territory of cities according to the height of the shading object, and it is also planned to place sports and children’s playgrounds, driveways, walkways, green spaces, recreation areas, public utility sites, etc.

For insolation calculations in flat conditions, the height of a building is usually taken to be its size from ground level to the highest elevation of the building. The ground level under the shading building can be (by horizontal marks) above or below the point under study. In this case, it is necessary to take into account the terrain. The height of the shading object should be taken as the difference between the highest mark of the cornice of the shading object and the mark of the point under study.

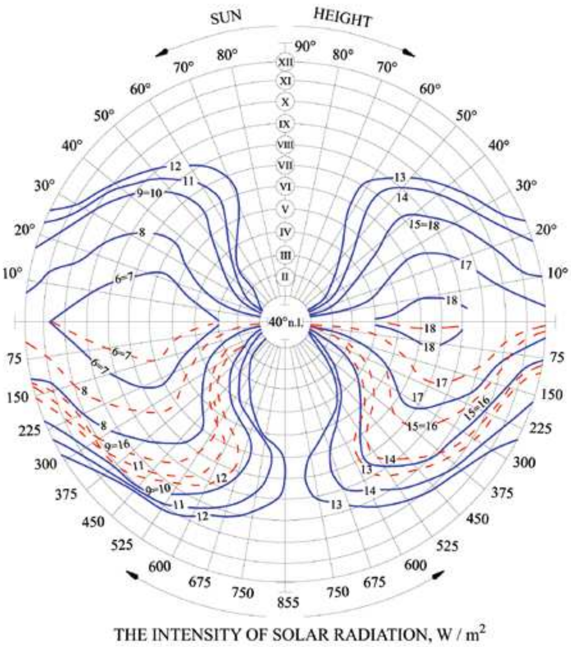

Fig. 4. Intensity of total (—) and direct (—) solar radiation for 40 degrees north latitude during the year from 8 to 18 hours solar time, W/m^2

The selection of the necessary device with the determination of the estimated height of the shading building is the first and mandatory condition that must be observed in all insolation calculations.

The accuracy of the assessment of insolation depends on the latitude, scale of the drawing, the size of the shading object, and the direction of the meridian of ITT.

The proposed ITT is designed to predict the mode of insolation and to identify the degree of shading of the territory of different-height buildings in order to optimize the volume-planning structure of buildings and urban areas, their improvement, landscaping and selection of sun protection devices.

The initial stage of design and survey work on the formation of a planning scheme of urban development with a comfortable environment is the assessment, analysis and regulation of the duration of insolation of the active layer of the building, which is the key climate-forming factor of the premises and the development areas.

Thus, the ecological situation of the territory of urban development and buildings erected in a hot climate depends on the prediction and assessment of the insolation regime in qualitative and quantitative terms at the design stage.

The developed ITT is recommended for use in design and survey works in architectural and construction design of buildings and in urban planning in the development of general plans of settlements, cities, scheme of planning, organization of land plots and in solving a certain range of tasks to assess the insolation regime.

This design of ITT with the schedule of solar radiation intensity attached to it and a technique of using the device were tested in a number of design and survey works and in educational practice of students of architectural and construction universities, having received a positive assessment.

REFERENCES

1. Gusev N.M., Klimov P.P. Construction physics (Gusev N.M., Klimov P.P. Stroitel'naya fizika). Moscow: Gosstroiizdat, 1965, 386 p.
2. Dashkevich L.L. Methods of calculation of insolation in the design of industrial buildings (Dashkevich L.L. Metody rascheta insolyatsii pri proyektirovanii promyshlennykh zdaniy).. Moscow: Gosstroiizdat, 1963, 526 p.
3. Dunaev B.A. Insolation of housing (Dunayev B.A. Insolyatsiya zhil'ya). Moscow: Stroizdat, 1979, 102 p.
4. Olgyay V, Olgyay A. Solar control and shading devices. Princeton, New Jersey: Princeton University Press, 1957, 325 p.
5. Twardowski, M. The Sun in architecture (Tvardovskiy M. Solntse v arkhitekture). Translated from Polish. Moscow: Stroizdat, 1977, 288 p.
6. Russian State Standard SanPiN2.2.1/2.1.1.1076–01 "Hygienic requirements for insolation and sun protection of premises of residential and public buildings and territories".
7. Russian State Standard SanPiN2.1.2.2645–10 "Sanitary and epidemiological requirements for living conditions in residential buildings and premises".
8. Russian State Standard SP 54.13330.2016 "Residential multi-apartment buildings".
9. DIN5034–1:2005–02–16 "Daylight in interiors –Part 1: General requirements".
10. BS8206–2:2008 "Lighting for buildings. Code of practice for daylighting".
11.Bakharev D. V., Orlova L.N. On regulation and calculation of nsolation (Bakharev D.V., Orlova L.N. O regulirovanii i raschete izolyatsii) //Svetotekhnika 2006, No. 1, pp. 18–27.
12. V.A. Karataev et al. Insolation of premises and building areas: textbook (V.A. Karatayev i dr. Insolyatsiya pomeshcheniy i stroitel'nykh ploshchadok: uchebnik) / Novosibirsk State University of Architecture and Civil Engineering (Sibstrin). Novosibirsk, 2013, 64 p.
13. Letsius E.P. Building shadows and perspectives of a number of architectural forms (Letsius Ye.P. Postroyeniye teney i perspektiv ryada arkhitekturnykh form): textbook -Moscow: Architecture, 2005, 144 p.
14. Obolensky N.V. Architecture and the sun (Obolenskiy N.V. Arkhitektura i solntse). Moscow: Stroizdat, 1988. 207 p.
15. Giyasov A. The Role of the Solar Irradiation Plate for Estimation of the Insolation Regime of Urban Territories and Buildings// Light & Engineering Journal, 2019, # 2. pp. 111–116.
16. Pritykin F.N. Virtual modeling of robot movements having different structure of kinematic chains (Pritykin F.N. Virtual'noye modelirovaniye dvizheniy robotov, imeyushchikh razlichnuyu strukturu kinematicheskikh tsepey): Monograph-Omsk: OmSTU Publishing house, 2014, 172 p.
17. Pritykin F.N., Shkuro E. Yu. Analytical method of setting the shadow areas of buildings and structures in order to determine their optimal location in the given area// Vestnik of SUSU. Series "Construction and architecture".2017, Vol. 17, No. 2.
18. Kheifets A.L. Calculation of insolation duration by means of 3D-modeling of Autocad package: collection of scientific works (Kheyfets A.L. Raschet dlitel'nosti insolyatsii s pomoshch'yu 3D-modelirovaniya paketa Autocad: sbornik nauchnykh trudov), Vol. 7, Yekaterinburg, 2004, 367 p.
19. Lyubimov A. BIM – new features of the Revit platform (Lyubimov A. BIM – novyye vozmozhnosti platformy Revit)/ / CAD and graphics. 2007, #10, 7 p.
20. CITYS: Solaris 5.20. Calculation of insolation, KEO and noise vibrations. The user's guide. URL: http://www.sitis.ru/ documentation/sitis-solaris.pdf (date accessed: 10.08.2019).

Adham I. Giyasov,
Doctor of Technical Science, Professor. He graduated from the Tajik Polytechnic Institute in 1975. At present, he is Professor of department "Design of buildings and structures" of National Research Moscow State University of Civil Engineering. His research interests: energy efficient buildings, architectural and construction physics, insolation, aerodynamics, urban ecology