# SUNLIGHT EXPOSURE: MINIMUM SOLAR ALTITUDE

## *PRESLNENIE: MINIMÁLNA VÝŠKA SLNKA*

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**Abstract:**

*Humans in building interiors are very sensitive to sufficient daylight and access to sunlight. There are a lot of research studies about influence of daylight on the human health, well-being and productivity in work places. Presence of sunlight in interiors is required mainly in residential buildings, in buildings for health care and seniors or in buildings occupied by children. In contrast, industrial indoor spaces are rather protected against direct sun light because of technology processes and undesirable high glare probability of occurrence. Generally, there are missing standard criteria for design and evaluation of insolation in building interiors in European countries. In order to properly design visual environment in building interiors, it is important to have information about changes of solar azimuths and solar altitudes during a year, specific requirements for evaluation of insolation and obstruction shading received sun beams.*

**Keywords:** *Building insolation, sun energy, interior orientation, building envelopes*

## 1 Introduction

Insolation on/in buildings can be evaluated in the aspect of sun energy utilisation or the positive influence of sun radiation on the human body. In the first case, insolated buildings façades should be oriented to receive the solar energy as much as possible, e.g. [1]. In the second case, building interiors should be sufficiently insolated to create healthy indoor environment [2 and 3]. There are published several methods for evaluation of insolation based on the sun-path geometry [2, 4 - 6] or based on processing annual sunshine duration data [7].
Standards are generally elaborated to determinate building design criteria. In the case of insolation, the minimum sun exposure of space and acceptance angle in which sunlight can be theoretically taken into account are prescribed. To evaluate insolation in buildings, the changes of sun height and solar azimuth as well as configuration and location of surrounding buildings are important to determine. Solar altitude is variously changed during a day and during a year depending on the locality with specific geographical latitude and climatic conditions. To verify architectural solutions the design criteria and rules should be based on the respecting human needs, technical and economic society potential [2, 3, 8].
Traditionally, the architects have intention to design family houses and flats in residential buildings with window orientation to sunny side as the best. Problems can occur in densely urban areas when parcels are shaded by surrounding buildings. Access to sunlight should be in existing building interiors as well as in new building interiors which will be constructed in future. In Slovakia and Czech Republic, it is applied so called Right to Sun [9], based on the regulation and standards, which is important not only for control of design of building interiors but also for urbanisation of cities. Orientation of parcels on the ground in cities is not regular and orientation of building façades follows street lines in prevailing cases. This creates limits for orientation of windows and insolation of interiors. Possible insolation is investigated in the range of acceptable angle $\alpha$, i.e. azimuthal angle limited by minimum solar altitude min $\gamma_s$ in the morning and minimum solar altitude min $\gamma_s$ in the afternoon. In

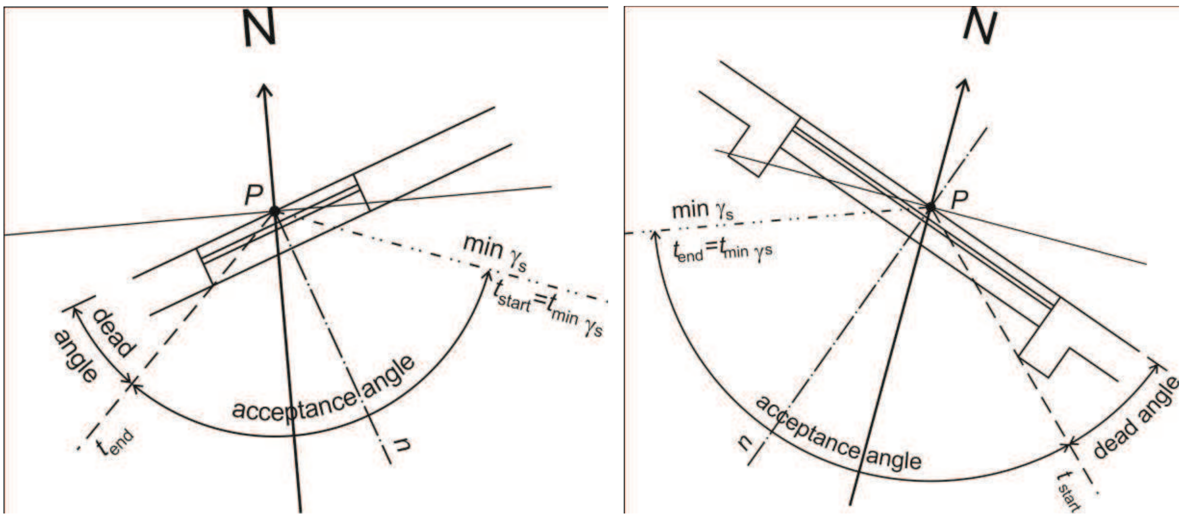
dependence on the window orientation the value of acceptance angle can be reduced by dead angle $\Delta$, [10].

## 2 Rules for sunlight exposure

The access to sunlight is required by regulation, standards or local rules only in several European countries [11] at present. The Slovak standard [6] determines minimum insolation time during reference day in the defined flat area. Generally, in the urban areas, vegetation, buildings or various constructions can screen sun beams in the front of relevant windows. Therefore, influence of sun rays with heights below 5° is excluded in the evaluation of insolation.

Building envelopes can have various wall thicknesses and window reveal can screen penetrated sun beams of high angle of incidence. To avoid this, received sun beams in the range of dead angle $\Delta$ = 25° are excluded from evaluation. Dead angle is measured from the reference point located on the inner surface of the window glazing at axis of its width.

Other conditions for dead angle determination are stated in the [12]. The reference point is located on the inner surface and at the centre of the aperture width. In this case, the values of dead angle depend on the wall thickness and window aperture width, as is shown in the plan in Figure 1.




A. B.

*Fig. 1* Scheme representing determination of dead angle according to the prEN 17037
A. In the morning. B. In the afternoon.

## 3 Determination of the minimum solar altitude

Free horizon in front of windows is not occuring in urban areas. There are distant obstructions and vegetation which can screen received sun rays when sun disk is close the horizon. Determination of vegetation dimensions and shape is difficult because of changing during a year. In practical calculation, shading obstructions, which are close the horizon can be substitute by shading angle /or so called minimum solar altitude $\gamma_s$ from which insolation is taken into account, Figure 2.

To allow insolation in rooms in building with corridor in the central part, several calculation studies of the minimum solar altitude $\gamma_s$ were accomplished, [13]. Results show that orientation of window normal $\alpha_{wn,s}$ between 90° and 120° measured from South to East or from South to North allows to insolate rooms in these buildings and allows to place buildings on the ground with declination of their axis from North – South direction, which is important architectural requirement.

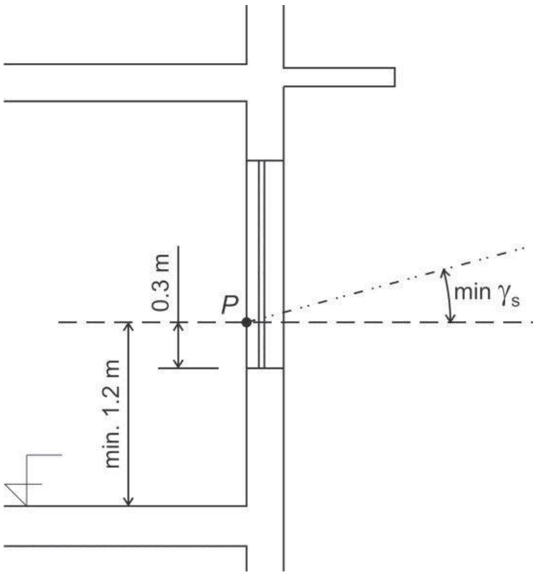



*Fig. 2* Scheme of the reference point position and minimum solar altitude $\gamma_s$ in the section

Value of the minimum solar altitude $\gamma_s$ can be calculated using input data: $\varphi$ - geographical latitude of the side, $\delta$ - declination of the reference day, $ET$ - equation of time, $\omega$ - hour angle, $\Delta$ - dead angle and $s$ - insolation.

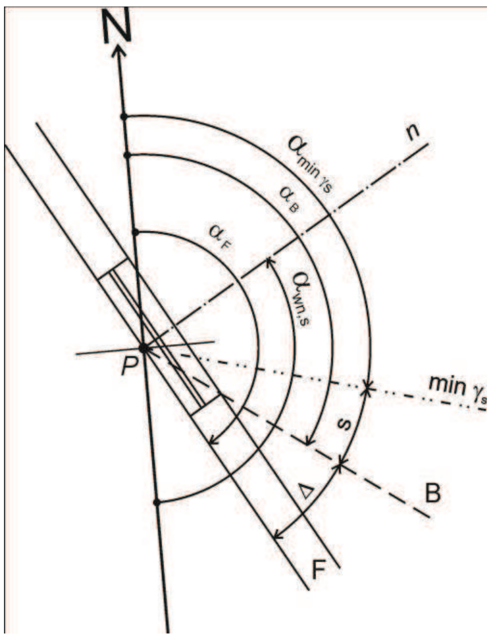



*Fig. 3* Calculation scheme for determination of min $\gamma_s$

If window normal $\alpha_{wn,s}$ is determined 120° from South, dead angle $\Delta$ = 25° and required insolation $s$ = 1.5 hour, then this situation is presented in Figure 3 and minimum solar altitude $\gamma_s$ is possible to determine applying common formulae for calculation of solar altitude $\gamma_s$ and solar azimuth $\alpha_s$. The procedure is simple and contains following steps:

a. Calculation of the façade azimuth $\alpha_F = 180° - \alpha_{wn,s} + 90° = 180° - 120° + 90° = 150°$.

b. Calculation of the azimuth limited by the dead angle $\alpha_B = \alpha_F - \Delta = 150° - 25° = 125°$. If min $\gamma_s$ is calculated for Bratislava and reference day 21st March, then for geographical latitude $\varphi = 48.2°$ is declination $\delta = -0.01797°$.
c. Determination of the time $t_B$ when sun is in the position with the azimuth $\alpha_B$. Sun has position in azimuth $\alpha_B = 125°$ at the time $t_B = 8{:}52$ hour.
d. Calculation of the time $t_{min,\gamma s}$ when sun is in the position with solar altitude min $\gamma_S$. In the morning is valid $t_{min,\gamma s} = t_B - 1{:}30 = 7{:}22$ hour. At this time, sun is in the position $\alpha_{min\ \gamma,s} = 105.73°$ and min $\gamma_s = 13{,}605°$.

By the similar way it is possible to determine min $\gamma_s$ for afternoon and for 1 hour insolation in densely urban areas. In Table 1 there are presented values of min $\gamma_s$ for selected European capital cities. Procedure allows determination of min $\gamma_s$ values for arbitrary city and reference day. Data in Table 1 indicate dependence of the access to sunlight on the geographical latitude. Logically, in southern countries min $\gamma_s$ values are higher and respect historical fact of shorter distances between buildings than it is in northern countries.

.*Tab. 1* Minimum sun height $\gamma_s$ on 21st March for selected European cities

| **Nation** | **Capital** | **Geographical latitude $\varphi$ [°]** | **Solar altitude, $\gamma_{s,min}$ [°]** | |
|---|---|---|---|---|
| | | | **Minimum exposure to sunlight 1 hour** | **Minimum exposure to sunlight 1.5 hour** |
| Cyprus | Nicosia | 34.88 | 29 | 23 |
| Greece | Athens | 37.90 | 26 | 20 |
| Spain | Madrid | 40.45 | 25 | 19 |
| Bulgaria | Sofia | 42.73 | 23 | 17 |
| Switzerland | Bern | 46.25 | 20 | 15 |
| Slovakia | Bratislava | 48.20 | 19 | 14 |
| Czech Republic | Prague | 50.10 | 18 | 13 |
| Poland | Warsaw | 52.17 | 16 | 12 |
| Germany | Berlin | 52.47 | 16 | 11 |
| Denmark | Copenhagen | 55.63 | 14 | 10 |
| Finland | Helsinki | 60.32 | 12 | 8 |
| Iceland | Reykjavik | 64.13 | 10 | 6 |

In practice, requirements for fix value of minimum solar altitude can occur. In this case, the window normal is variable quantity and influences limits for window orientation in the morning and in the afternoon. Requirements for lower values of minimum solar altitude $\gamma_s$ are legal in northern countries where solar altitudes are lower during a year than in southern countries or in the cases when insolation of interiors is preferred during winter months. Above described procedure with small modification can be used for solution of this task. Example in Table 2 presents limits for orientation window measured from South for reference day February 1st and tree categories of insolation when minimum solar altitude $\gamma_s = 3°$.
Highlighted cells in Table 2 show cases in what the buildings with central corridor can be designed. This is not possible in all localities. If orientation of parcel do not allow placement of building in the South – North direction and in the East or West direction exist shading buildings/obstructions, then possibilities for design of insolated interiors can be significantly reduced.

*Tab.* 2 Orientation of window on February 1st for selected cities when minimum solar altitude $\gamma_s = 3°$

| Country | City | Geographical latitude, $\varphi$, [°] | Window normal measured from South, $\alpha_{wn,s}$ [°] Minimum sunlight exposure category | | |
|---|---|---|---|---|---|
| | | | 1.5 hour | 3 hours | 4 hours |
| Cyprus | Nicosia | 34.88 | 117 | 97 | 81 |
| Greece | Athens | 37.90 | 115 | 95 | 79 |
| Spain | Madrid | 40.45 | 113 | 92 | 77 |
| Bulgaria | Sofia | 42.73 | 111 | 90 | 75 |
| Switzerland | Bern | 46.25 | 108 | 87 | 72 |
| Slovakia | Bratislava | 48.20 | 106 | 85 | 70 |
| Czech Republic | Prague | 50.10 | 104 | 83 | 68 |
| Poland | Warsaw | 52.17 | 102 | 81 | 66 |
| Germany | Berlin | 52.47 | 102 | 80 | 65 |
| Denmark | Copenhagen | 55.63 | 98 | 76 | 61 |
| Finland | Helsinki | 60.32 | 91 | 69 | 54 |
| Iceland | Reykjavik | 64.13 | 48 | 60 | 46 |

## 4 Conslusions

Theory and practice in lighting engineering are focused on design and construction of good healthy and visual building interiors. Insolation plays important role in the rating of building quality. Because urban areas are densely built-up, the rules for evaluation of insolation should respect good access to sunlight in existing buildings as well as in the new buildings designed on free parcels. This can be control by sunlight duration criteria and range of acceptance angle which limits can be determined by solar altitude.
Presented procedure allows calculation minimum solar altitude and allows determination of limits for orientation of interiors to sunlight in various localities.

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