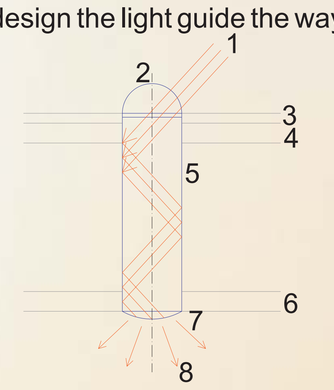
FACULTY OF CIVIL ENGINEERING CZECH TECHNICAL UNIVERSITY IN PRAGUE
DEPARTMENT OF BUILDING STRUCTURES

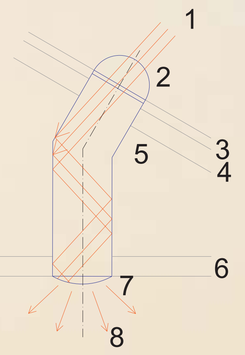
OPTIMIZING THE DESIGN LIGHT GUIDES INCLUDING METHODS OF MEASURING

ABSTRACT: Daylight is important for the human body primarily from the physiological and psychological aspects. Today is not inconsiderable economic aspect, too. In the absence of daylight leads to visual fatigue, which can lead to injury to the eyesight and various illnesses, as discussed by many experts. Rooms that are not in contact with the external environment are suitable for illumination light guides that can transmit light over long distances. The purchase of those is not the cheapest investment, therefore we should pay attention to optimize the design, to make installation bring the most efficient use. At the same time we should design the light guide the way that it wouldn´t form a thermal bridge and prevent the surface of condensation.

THE RESEARCH PLAN:

The first half of this research project, focused on research and definition of boundary conditions that will lead to the universal use of light guides to optimize the design. Following these conditions were selected several suitable interior, where as the main source of daylighting are just light guides. These rooms will be used as a reference room for defined boundary conditions and measurement. Furthermore, were chosen and described proper and the calibration verified measuring device. Selected rooms and different types of light guides have been simulated in computer models for the above mentioned boundary conditions. At present we measuring and processing the results. The methods are compared and evaluated. The outcome will define the boundary conditions for measurement, but also the most accurate measurement methodology based on the available calculation models.



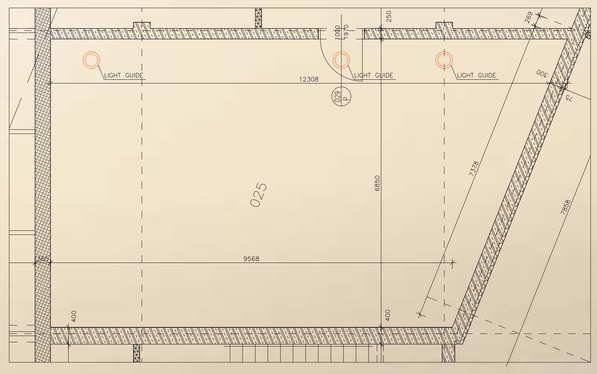


The principle function of light guide and its basic components:

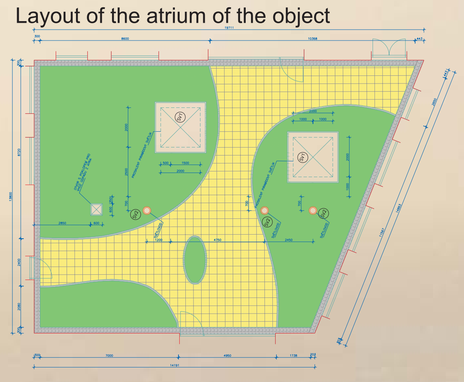
1 solar radiation
2 roof dome
3 roofing
4 bearing part of the roof
5 reflective tube
6 bearing part of the ceiling
7 light diffuser
8 diffused light

DESCRIPTION ONE OF THE SELECTED ROOM: Because this is a method of lighting, which is not quite common and is relatively economic demanding, it was necessary to visit many rooms where light guides were used. Suitable use of light guide was selected so that were the most universal in terms of chosen boundary conditions and used different types of light guides. For this presentation was chosen from selected and measured rooms just one in premises of the Institute of Geology AS CR, v. v. i., Prague 6 Lysolaje. The selected room is situated on the first basement floor and is used as a library. The room has a shape of rectangular trapezoid 12,3 (9,57) x 6,85 m and clear height 3,08 m. Daily light of this room is provide with only three light guides with diameter 400 mm and length 800 mm. Polycarbonate roof domes of the light guides are placed on a flat green roof in the atrium of the object and are partially shaded from whole object. Diffusers of light guide that worked as a source of day light for interior, are located at the level of ceiling of the room and they are circular.

Layout of the room



Layout of the atrium of the object



BOUNDARY CONDITIONS AND CONTROL POINTS: One of the most important conditions for the processing of results is uniformly overcast sky for the measurement and calculation method, which should correspond to the brightness distribution according to Czech standard 73 0580-1.

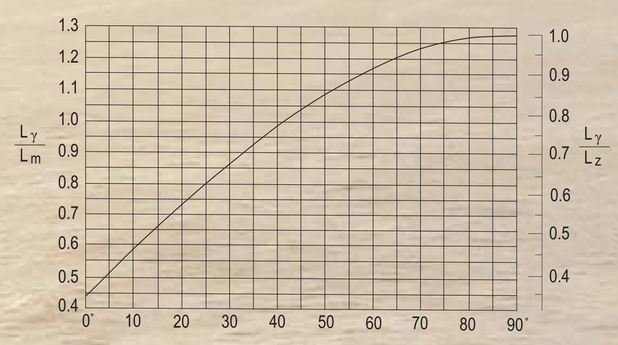
L_z = brightness of sky to the zenith

L_m = average brightness of the sky

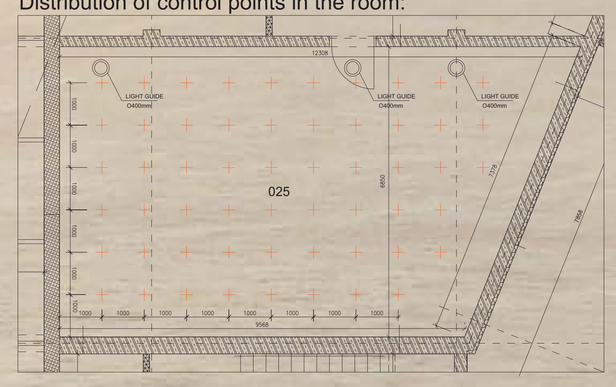
L_γ = brightness of sky at the angle γ(°) above the horizon

Outdoor terrain is considered dark if the object is not located at a height of more than 600m.nm, his average reflection of light is from 0.05 to 0.2.Illuminance and its distribution was determined in control points placed 1 m from side walls, in a regular rectangular network of 1m from each other across the reference plane.Comparative reference plane was at the height 850 mm above the floor.

Distribution of brightness uniformly overcloud sky and dark terrain from horizon (0 °) to the zenith (90 °)



Distribution of control points in the room:



DAYLIGHT IN THE ROOM:

The level of daylight in the room is described by means of daylight factor D. It is the ratio of internal to the external illuminance, expressed as a percentage.

$$D = \frac{E_i}{E_e} 100 = [\%]$$

CALCULATION METHODS: To calculate is important to define an Aspect Ratio AR, that is given to direct light guide as the ratio of length (l = 0.80 m) and diameter (d = 0.40 m) light guide.

AR = l/d = 0,80/0,40 = 2,0

Calculation of the luminous flux Φ_e entering the light guide depends on cross-sectional area the lightguide ($A = 0{,}196 m^2$) and and the total external illuminance E_e = 25000 lux.

$\Phi_e = A \times E_e = 0{,}196 \times 25000 = 4900$ lm

1) CALCULATION METHOD ACCORDING TO CIE:

The group of international experts specialized in the tubular light guides issued document CIE 173 -2006 (Tubular Daylight Guidance Systems) that include calculation method for the lead of light through lightguide. We can obtain approximate results of illuminance in the room lit lightguide using this method.

Aspect Ratio affects transmission of light through light guide TTE: $TTE = \frac{e^{\frac{l}{d}\tan\Theta \ln\rho}}{1-\frac{l}{d}\tan\Theta\ln\rho} = \frac{e^{\frac{0,8}{0,4}\tan 30 \ln 95}}{1-\frac{0,8}{0,4}\tan 30 \ln 0,95} = 0,89$

Θ... It represents the segment of zenith of the sky with the most effective brightness of sky, this angle is objectively considered 30 °

ρ ... It is the reflection coefficient of light on the internal surface of the lightguide, for the calculation was estimated 95%

Efficiency ofl ight transmission EG is affected not only the efficiency of transmission of light through light guide TTE, but also loss of diffuser and roof dome, that is recommended by the CIE equal to 0.63 and outdoor air pollution, typical for urban areas and the use of the room given value MF = 0,76. Therefore, the transmission factor of light EG is determined as follows:

EG = TTE x 0,63 x MF = 0,89 x 0,63 x 0,76 = 0,426.

The flux of light leaving from light guide Φ_i is given transmission factor of light through light guide EG and the flux of light entering into light guide: $\Phi_i = \Phi_e \times EG = 4900 \times 0{,}426 = 2087$ lm

Calculation of the illuminance E_i at a distance V = 0,50 m under the the light guide in its axis is equal:

$$E_i = 0{,}494 \times \frac{\Phi_i}{V^2} = 0{,}494 \times \frac{2087}{0{,}5^2} = 4124 \text{ lm}$$

2) LUXPLOT PACKAGE MODEL:

The authors of this model are Muneera and Jenkins, who described the difference between the light that enters the light guide and light that leaves from the light guide using transmission factor of light τ_t. It is based on loss of light through roof dome and diffusor and for this case is equal 0,82 : $\tau_t = 0{,}82 \times e^{-0{,}11 AR} = 0{,}82 \times e^{-0{,}11 \times 2{,}0} = 0{,}658$

The flux of light leaving from light guide is equal to: $\Phi_i = \tau_t \times \Phi_e = 0{,}658 \times 4900 = 3224$ lm

The resulting illuminance E_i at a distance V = 0,50 m under the the light guide in its axis, which was again modeled using measurements and calculations performed in the UK, includes coefficient 0, 494: $E_i = 0{,}494 \times \frac{\Phi_i}{V^2} = 0{,}494 \times \frac{3224}{0{,}5^2} = 6371$ lux

Jenkins and Muneer stated in their method also Daylight penetration factor DPF, that we can compare with Daylight factor D in Czech Republic $DPF = 0{,}406 \frac{e^{-0{,}11 AR}}{V^2}\pi r^2 = 0{,}406 \frac{e^{-0{,}11 \times 2}}{0{,}5^2}\pi 0{,}2^2 = 0{,}163$

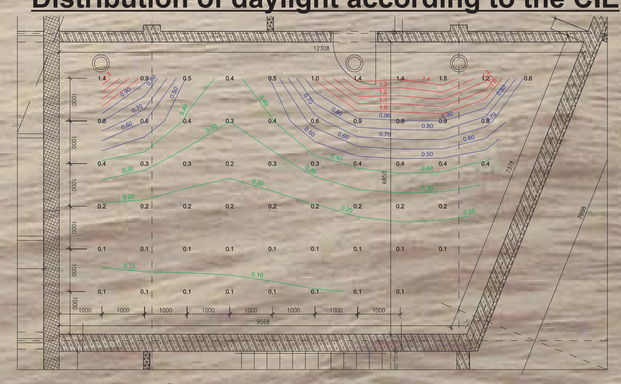
3) TSANGRASSOULISOVA METHOD:

The last of the evaluated methods was again published by Meneer and Jenkins in 2004, when it is supposed perfect scattering of light from the diffuser into the interior. To determine the brightness of the diffuser L is based method from the value of flux as follows:

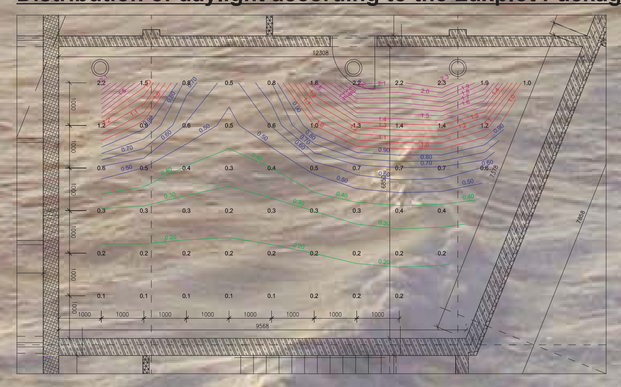
$$L = \frac{E_e \tau_T}{\pi} = \frac{25000 \times 0{,}658}{\pi} = 5236 \text{ cd/m}^2$$

The illuminance E_i at a distance V = 0,50 m under the the light guide in its axis is equal: $E_i = \frac{\pi L r^2}{V^2 + r^2} = \frac{\pi \times 5236 \times 0{,}2^2}{0{,}5^2 + 0{,}2^2} = 2269$ lux

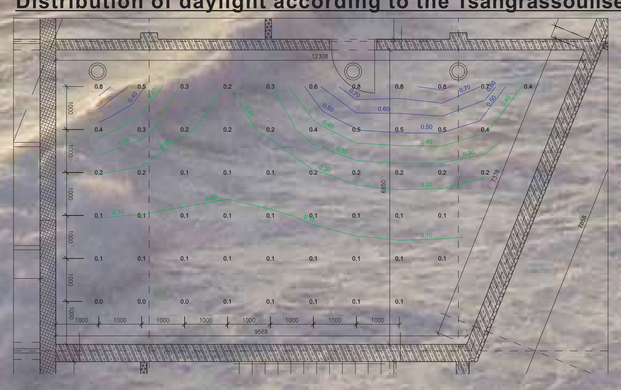
Distribution of daylight according to the CIE



Distribution of daylight according to the Luxplot Package



Distribution of daylight according to the Tsangrassoulise



MEASURING INSTRUMENTS:

Luxmeter:For measuring internal and external illumination are used two separate calibrated luxmeters. It is important to exterior and interior illuminance was measured at the same time for this reason that we have the variability of the external lighting conditions.

Luminance meter: Uniformly overcloud sky is controlled by measuring brightness using the luminance meter.If we have not luminance meter, we can use attachment for luxmeter with black matt surface inside. Its length is equal to a minimum of twenty times its internal diameter..

Luxmeter:

Attachment for luxmeter:

CONCLUSION: Computational models describe the transmission of light using light guide and allow us to outline the level of daylight in the room where is just a source of daylighting light guide. Now the rooms are examined by measuring and the final solution of our research plan will to specify the method that will be best to copy the actual measured values. Alternatively, we modify the method to describe the behavior of light guides in the Czech Republic.

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