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 subjected to artificial 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 in 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 we chose 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 suitable calculation method and available calculation models.

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 up 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) m and side clear has 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. Diffusors 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 rectangular.

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 731 058-1. 

\[ L = \text{brightness of sky to the zenith} \]
\[ b = \text{average brightness of the sky} \]
\[ b = \text{brightness of sky at the angle} \gamma \text{above the horizon} \]

Outdoor terrain is considered dark if the object is not located at a height of more than 600 m. mm, 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. The same plane was at the height 850 mm above the floor.

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.

\[ AR = \frac{\text{length}}{\text{diameter}} = \frac{0.80}{0.40} = 2.0 \]

Calculation of the luminous flux \( \Phi \) entering the light guide depends on cross-sectional area of the lightguide \( \left( A = 0.196 \text{m}^2 \right) \) and the total external illuminance \( I \) = 2500 lux.

\[ \Phi = \frac{A x E}{0.196 \times 25000 \times 4900 \text{ lm}} \]

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 light guide. We can obtain approximate results of illuminance in the room by lightguide using this method.

Aspect Ratio affects transmission of light through light guide TTE:

\[ TTE = \frac{1 - \tan 30^\circ}{0.95} \]

It represents the segment of zenith of the sky with the most effective brightness of sky, this angle is objectively considered 30°. If it is the reflection coefficient of light on the internal surface of the lightguide, for the calculation was estimated 95%. Efficiency for transmission of light is affected not only the efficiency of transmission of light through light guide TTE, but also loss of light. It is recommended by the CIE equal to 0.63 and outdoor air pollution typical for urban areas and the use of the roof given value MF = 0.76. Therefore, the transmission factor of light EG is determined as follows:

\[ EG = TTE \times 0.63 \times 0.76 \times 0.428 \]

The flux of light leaving from light guide \( \Phi \) is given transmission factor of light guide EG and the flux of light entering into light guide \( \Phi = \Phi x \Phi \times EG = 4900 \times 0.426 \times 2087 \text{ lm} \)

Calculation of the illuminance \( E \), at a distance \( V = 0.50 \text{m} \) under the light guide in its axis is equal:

\[ E = \frac{4944 \times 0.494 \times 2087}{0.5 \times 2500} = 4124 \text{ lum} \]

2) LUXPOINT PACKAGE MODEL:

The authors of this model are Munier 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. It is based on loss of light through roof dome and diffuser and for this case is equal 0.82 x 0.55 x 0.428 = 0.068 x 0.428 = 0.0658

The flux of light leaving from light guide is equal to:

\[ \Phi = \Phi \times \Phi \times 0.68 \times 4900 \times 3244 \text{ lm} \]

The resulting illuminance \( E \) at the floor is:

\[ E = \frac{0.82 \times 0.428 \times 0.68 \times 4900 \times 3244 \text{ lm}}{0.5 \times 2500} = 2269 \text{ lum} \]

3) TSANG/GRASSOULT METHOD:

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

\[ L = \frac{2500 \times 4900 \times 0.68 \times 4900 \times 3244 \text{ lm}}{0.5 \times 2500} = 2269 \text{ lum} \]

MEASURING INSTRUMENTS:

For measuring internal and external illuminations used two separate calibrated luxmeters. It is important to ensure that the results are expressed accurately at the same time for this reason, we have the following internal and external conditions:

Luminance Uniformly, uniformly overcast 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. It’s length is placed parallel to and in close vicinity to the internal diameter light guide.

CONCLUSION: Computational models describe the transmission of light using light guide and aim to stimulate the level of daylight in the room where it is subjected to artificial 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 results. Alternatively, we most probably need to describe the behavior of light guides in the Czech Republic.

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