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THE USING OF LIGHT FIELD'S INTEGRAL CHARACTERISTIC FOR ESTIMATION OF DAYLIGHT

Light field is a physical notion that more precisely describes the light environment. Light comes to the point of view from all the sides. The situation depends on the point location in the space. For an extremely small point located in space, it is the medium spherical illumination that describes best of all the conditions of light environment. The physical meaning of spherical illumination is the integral of illumination on the infinitesimal sphere surface. It has symbol $E_{4\pi}$ that's mean that light come to surface from all the sides.

Keywords: room lighting, illumination on a spherical surface

1. THE TERM "LIGHT FIELD"

The first scientists who had introduced the term "light field" were Arndt, Helwig, Krochmann. The Russian famous scientist A.A. Gershun had proposed the structured theory of light field. Later the scientific school of Moscow State University of Civil Engineering evolved this theory.

The spherical illumination can estimate good visibility of volume objects. Its visibility depends on its presence, intensity and arrangement of own and falling shadows on the object. In different area this object, that has to be make up, can be also different. For example in industry there are marks and screws, which workers have to wrap in the object to the marked depth. It is the wire diameter on the dark background for net weaving. For the manufacture of electrical lamp on the spiralization sector it can be tungsten spiral diameter in case of low contrast with background. All this optic works were investigated in the Moscow State University of Building. One of more interesting example is the improvement of lighting conditions of spiralization sector in the Maylee-Sai manufacture of electrical lamp in Kyrgyzstan. It is the biggest factory of electrical lamps in Asia. Workers were needs to detect the defects of automatic spiral winding and they used the loupes for this. It was very difficult and detecting of defects wasn't very good. As a decision of this problem the management increases the level of artificial lighting up to 3000 lx. The lighting system had turned into lighting ceiling and workers had received big heat, lighting and sound discomfort [1].

In fact it was necessary to create special magnitude shadows from the wires to achieve a distinct visibility. It was achieved with help of special correlation of spherical illumination and value of light vector ($\vec{\varepsilon}$), and also particular incidence angle of light vector (vertical β and horizontal α). At that the excellent condition of visibility were won at the horizontal luminance value 700 lx.

When the volumetric object is disposed on the horizontal surface, the light comes to the object from upper semi-sphere only. The light environment of such object can be describe by such light field integral characteristic as medium semi-spherical illumination - ($E_{2\pi}$.). The stitch on the material in the clothing industry can be an example of such object. The correlation $m\frac{E_{2\pi}}{|\varepsilon|}$ and angles β and θ are also very important there. Correlation $m\frac{E_{2\pi}}{|\varepsilon|}$ has name of illumination contrast. The researchers of Moscow State University of Civil Engineering were investigating the required value of $E_{2\pi}$ and $\overline{m}$, β, θ had received concrete data for clothing industry.

$E_{4\pi}$ and $E_{2\pi}$ are used for estimation of visual work like horizontal illumination that is traditional characteristic for many countries. Horizontal illumination is the particular case of light field characteristic. In this case the object is not volumetric. It is located on the surface, for example it is text written on the paper. The light comes to the paper from upper semi-sphere and at different angles in contrast of semi-spherical illumination where light comes at right angle to the surface. Illumination obeys the cosine low.

2. INTEGRAL CHARACTERISTICS OF LIGHT FIELD

Cylindrical illumination is also one of integral characteristics of light field. It is integral illumination of the infinitesimal cylinder's surface. The cylindrical illumination is the characteristic that doesn't depend on the vision direction. That's why it characterizes good the human impression from light saturation of the room. The semi-cylindrical illumination can also estimate the impression of the light saturation but only on the direction of the sight that's unacceptable for the rationing. Pr. M.M. Epaneshnikov offered to use the cylindrical illumination for estimating of the light saturation and now this characteristic is included to the Russian standard for such rooms as different halls and lobbies, other words, for the rooms where the impression of light saturation is important.

All of the integral characteristics of light field are measured in lux [lx], because they present themselves the illumination on the different types of receiver. Integral characteristic can be roughly measured with help of simple luxmeter with plane photocell. For example we can get the value of spherical illumination by measurement of the illumination on six cube surfaces. We need to divide the sum of values on six to receive the value of spherical illumination ($E_{4\pi}$). For definition of the cylindrical illumination we have to measure the illumination in 4 vertical surface of cube and divide the sum on 4.

Nevertheless for precise measurement the special device is required. For example the investigator of MGSU use RadioLux 111 by PRC Krochmann (Fig. 1) with special photometer heads.

Fig. 1. Photometer RadioLux 111

The daylight, which is a criterion for windows and different natural light system designing and choosing of room's size and material of wall finishing, depend on exterior illumination.

Exterior illumination is always changing and depends on light climate of the area (the altitude of sun rising, cloudiness, statistical probability of clear, overcast and semi-clear sky and other). That's why it is comparative value named daylight factor that is used for illumination measurement. For integral light field characteristics estimation earlier they supposed to use the ratio of this characteristic inside and outside of the room. But it was possible to use this ratio only for measurement and it was unable for the calculation because there were not any statistical data of integral light field characteristic for outdoor illumination in the world. In the same time according to the program of International Commission of Lighting the specialists of many countries carry out the statistical investigations and measurement of horizontal illumination in the different months of the year and for different time of the day. In Japan such measurement are made on the 24 weather station and in Russia we have only two stations with such purposes. Nevertheless Russia is covered by immense net of weather stations where the actinometric investigations are made. It's mean the data of solar radiation measurement for each month and the equivalent of solar radiation. In this way we have the information about changing of outdoor

horizontal diffusive and integral daylight illumination. That's why we proposed to introduce the ratio of summary light field characteristic to outdoor horizontal illumination as a comparative value of integral illumination.

$$E_{4\pi\,rel} = \frac{E_{4\pi ext}}{E_{hor}} \cdot 100\%,\ E_{2\pi\,rel} = \frac{E_{2\pi ext}}{E_{hor}} \cdot 100\%.\ E_{Cyl\,rel} = \frac{E_{cyl\,ext}}{E_{hor}} \cdot 100\%$$

The rationing of daylight in civil buildings in Russia is very significant. This rationing as a solar radiation rationing is an important instrument of build density and number of floors limitation. Moreover the disturbance of the norm has big financial significance for private flats. For example contrary buildings can lead the disturbance of daylight illumination norm to decrease of the flat price at 4÷5 times. The rationing value of daylight factor for living room is 0.5% on the floor, 1 m from the wall contrary to the window in one room of 1- or 2-room flat and in 2 rooms of 4- and more rooms flat. In other room the value of daylight factor 0.5% must be provided in the room center (Figs. 2, 3).

The Germany daylight standard (DIN-5034) requires to provide the value of daylight factor 0.5% on the height 0.8 m from the floor in the center of the room near the side wall. Unfortunately the information about the origin of all this data is not presented in the available sources.

In that time it's clear that the conditions of visual work in the residential building are on the second place and the daylight saturation has overriding significance. When we imagine the standard room model with vertical window, we can remark that the major part of daylight stream comes to the horizontal photocell from the window and from the ceiling and overhead part of the walls as a reflected light (Fig. 2). At the same time the viewing angle of comfortable vision amounts near 30° up and 40° low according to the conclusion of the scientists (Fig. 3). It's mean that the observer perceives first of all the light coming from the window and the light reflected from the walls. The possible variation of horizontal viewing angle can be 360°.

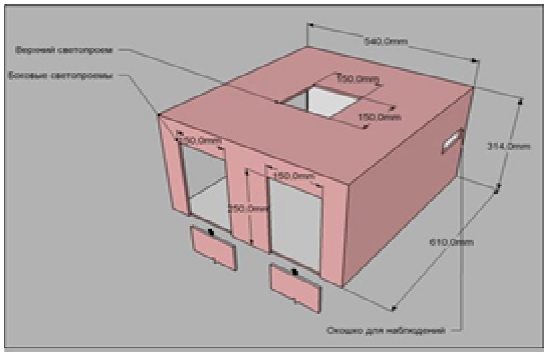

Fig. 2. The model standard room with a vertical window to evaluate the reflected light flowing into the horizontal photocell

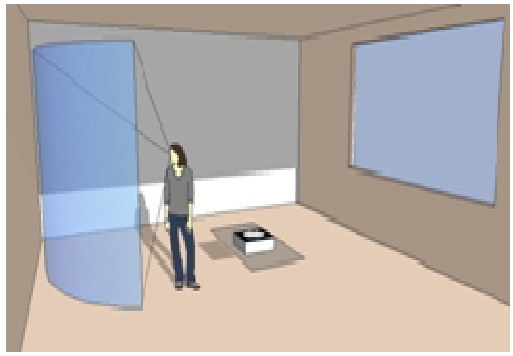

Fig. 3. The viewing angle of comfortable vision amounts near 30° up and 40°

Side light falls by sliding stream and create the low level of horizontal illumination, although it can saturate good the room by light. The light reflected from the interior surfaces serves to leveling of the light distribution in the room depth. This fact confirms the conclusion of T.N. Sydorova and Pr. M.M. Epaneshnikov about the ability of using the cylindrical illumination for light saturation of the room [2].

On Figure 4 the graphics of relative horizontal and cylindrical illuminations in the room with vertical windows are presented. We can see that the value of $E_{cyl\ rel}$ in the room's depth is higher that the value of Daylight factor. The measurement shows that the relation between horizontal and cylindrical illumination is possible. That's why such experiment was made in MGSU with help of room model with changing dimension of window's height. Due to this investigation the value of relative characteristics of spherical and cylindrical luminance for different points of the room and with different height of windowsill were received. The experiment was made in the room with black and white walls i.e. with high and low reflection factor.

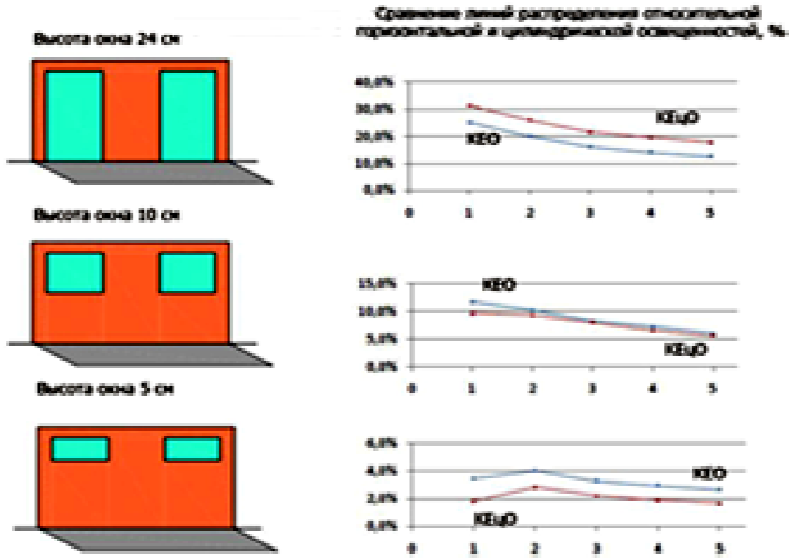

Fig. 4. The graphics of relative horizontal and cylindrical illuminations in the room with vertical windows

The result of the measurements had showed once again the importance of such characteristic of the room as the location and the dimension of the windows, the material and the color of the surfaces for the creation of the light environment in the room. The comparative analysis of the cylindrical and horizontal illumination dependence from the reflective ability of the room's surfaces allows making a supposition that the cylindrical illumination may be an instrument for light climate description in the room.

Nevertheless we plan to make some psycho-physical investigation for seriously propose the concrete value of daylight factor for the rationing of the daylight with help of the light saturation. It is necessary for the places where the visual work isn't the determinative parameter. The preferable value of the cylindrical illumination will be determined on the base of questioning of the different category of observers and with help of statistical adaptation of the data. After that we will get a possibility to determine the significance of the required value of the daylight factor and verify the accepted rationing value of the daylight factor.

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WYKORZYSTANIE PÓL ŚWIETLNYCH DO OCENY WARUNKÓW OŚWIETLENIA POMIESZCZEŃ ŚWIATŁEM DZIENNYM

Pola świetlne stwarzają możliwości bardziej precyzyjnego opisywania środowiska świetlnego we wnętrzach budynków. Światło do danego punktu dociera z różnych kierunków, w związku z tym warunki oświetlenia zależą od położenia punktu w przestrzeni. W celu precyzyjnej oceny warunków świetlnych należy stosować przestrzenne charakterystyki oświetlenia, które można badać za pomocą luksomierza kulistego. Fizyczny sens oświetlenia sferycznego polega na oświetleniu powierzchni nieskończenie małej kuli. Parametr o symbolu $E_{4\pi}$ oznacza, że światło dociera do powierzchni ze wszystkich stron.

Słowa kluczowe: oświetlenie pomieszczeń, natężenie światła na powierzchni kulistej