Correction of the Uneven Brightness Coefficient for the Tropical Sky Conditions

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Abstract. In the design of buildings and structures, the calculation of natural lighting plays an important role in providing visual comfort, rational use of the daylight resource and achieving energy efficiency. Calculation methods and parameters are improved in the research process to imitate/simulate as much reality as possible. Until now, the overcast sky CIE is mainly used in the daylight calculations as the most unfavourable condition. This sky condition is characteristic of a long winter period of temperate climate and is not typical of the tropical sky, where diffuse horizontal illuminance values are very high. For these reasons, an update of theoretical studies in the daylighting calculations and design the daylighting systems must be completed. Accordingly, this study proposes modern methods of analysing the firmament luminance distributions to determine the coefficient of uneven brightness when calculating the Daylight Factor for more realistic sky conditions in the tropical climate of Vietnam. For this, the sky types have to be defined according to the locations. Fifteen international standard types of the firmament with their descriptors are provided by Kittler et al. and a technique using a relation of diffuse and total solar illuminance levels named the cloudiness coefficient Ko are considered to confirm the sky type for Hanoi and Ho Chi Minh City. Parameters were found to computing the sky luminance distributions and the coefficient of uneven brightness for Hanoi and Hochiminh City. A comparison of the results shows the differences of using classical Overcast sky condition and the proposed sky conditions. The method offered and verified in this study showed that, it has potential to be used for difference climate area.

1. Introduction

1.1. State of the art approach:

Daylight is the sustainable source of lighting for buildings. Research has proven that it could provide energy saving, good colour rendering, high work productivity, good visual comfort as well as human physiological and psychological needs. That natural light has always played a dominant role in human life [1-5]. In addition, daylighting calculations with the opening design are also considered to ensure durability and safety of buildings [6]. To correctly calculate daylighting and accomplish energy simulations it is necessary to study daylight conditions during the whole year.

There are several methods for defining daylight conditions in different climates and locations. The illuminance availability approach provides a direct view on illuminance changes, their levels and
difference, it is important to define luminance distribution and coefficient of uneven brightness under different sky conditions.

In the daylighting calculations in the document CI 367.1325800.2017- Residential and public buildings, Daylighting design, the Daylight Factor at a point in the room is defined:

with side lighting:

\[ e_p = C_N \left( \sum_{i=1}^{L} \varepsilon_{bi} q(\gamma)_{i} + \sum_{j=1}^{M} \varepsilon_{m_j} b_{fj} k_{tnj} r_{o} \tau_{o} MF \right) \]  \hspace{1cm} (1)

with overhead lighting:

\[ e'_p = C_N \left( \sum_{i=1}^{T} \varepsilon_{bi} q(\gamma)_{i} + \varepsilon_{eb}(r_{2} k_{f} - 1) \right) \tau_{o} MF \] \hspace{1cm} (2)

where:

\( C_N \) - light climate coefficient;
\( L \) - the number of sections of the sky visible through the light opening from the calculated point;
\( M \) - the number of sections of the facades of buildings of opposing buildings visible through the light opening from the calculated point;
\( \varepsilon_{bi} \) - geometrical DF at the calculated point inside lighting, taking into account direct light from the \( i \)-th part of the sky;
\( q_{bi} \) - coefficient of uneven brightness of the \( i \)-th area of the cloudy sky CIE;
\( \varepsilon_{m_j} \) - geometrical DF in the design point with side lighting, taking into account the light reflected from the \( j \)-th part of the building facades of the opposing building;
\( b_{fj} \) - average relative brightness of the \( j \)-th section of the facades of opposite buildings;
\( r_{o} \) - coefficient taking into account the increase of DF due to the light reflected from the surfaces of the room and the underlying layer adjacent to the building;
\( k_{tnj} \) - coefficient taking into account changes in the internal reflected component of the DF in the premises in the presence of opposing buildings;
\( \tau_{o} \) - total light transmittance;
\( MF \) - operating coefficient;
\( T \) - the number of light openings of the overhead lighting system;
\( \varepsilon_{eb} \) - geometric DF at the design point from the \( i \)-th opening;
\( \varepsilon_{eb} \) - average value of geometrical DF on the line of intersection of the working surface and the plane of the characteristic vertical section of the room;
\( r_{2} \) - coefficient taking into account the increase of DF due to the light reflected from the surfaces of the room by overhead lighting system;
\( k_{f} \) - coefficient taking into account the type of overhead lighting system;

The luminance distributions of the intermediate sky are represented as a superposition of two standard CIE skies [7]: The Clear Skies luminance distributions has the form (Kittler, 1965, CIE, 1973) and The Overcast Sky luminance distribution has the form (Moon & Spencer, 1942).

The Clear Skies luminance distributions:

\[ \beta_{cs} = \frac{L_{r}(a,\gamma)}{L_{z}} = \frac{0.12}{X} = \frac{(1 - e^{M Y})}{0.91 + 10e^{-3X} + 0.45 \cos^{2} X} \]  \hspace{1cm} (3)

\[ X = \arccos(cosZ_{y} \cosZ_{z} \sinZ_{y} \sinZ_{z} \cosA_{z}) \] \hspace{1cm} (4)

The Overcast Sky luminance distribution has the form (Moon & Spencer, 1942):

\[ \beta_{os} = \frac{L_{r}}{L_{z}} = \frac{1 + 2 \sin Y}{3} \]  \hspace{1cm} (5)
Unlike the clear sky case, the overcast sky distribution does not depend on the solar azimuth or the sky azimuth. Note that at fixed solar altitude the zenith ($\gamma = \pi/2$) is three times brighter than the horizon ($\gamma = 0$).

where:
- $\beta_{cs}$ - clear sky luminance distributions (cd.m$^{-2}$).
- $\beta_{os}$ - overcast sky luminance distributions (cd.m$^{-2}$).
- $\gamma$ - altitude angles of a point in the sky (radians).
- $L_z$ - sky zenith luminance (cd.m$^{-2}$).
- $\gamma_s$ - altitude angle of the Sun (radians).
- $L_z$ - the zenith luminance (cd.m$^{-2}$).
- $Z$ - the angular distance between a sky element and the zenith, $Z = 90^\circ - \gamma$.
- $L_{\gamma\alpha}$ - luminance in any arbitrary sky element (cd.m$^{-2}$).
- $X$ - the angular distance of the sky element from the Sun, defined by equation (4) (radians).
- $Z_s$ - the zenith distance of the Sun (radians).
- $A_{\alpha}$ - the azimuth difference between the element and the solar meridian (radians) with $A_{\alpha} = |\alpha - \alpha_s|$.

\( \alpha \) and \( \alpha_s \) are azimuthal angel of the vertical plane of the sky element and Sun position respectively (radians).

The definition sky type based on the concepts justifies the task to develop the new set of sky standards of Kittler et al. [8], which uses the ratio of diffuse sky illuminance to extra-terrestrial horizontal illuminance \( D_v/E_v \) and the luminous turbidity factor \( T_v \) as the descriptors of sky types. A comparison with method assessment the luminance distribution for a particular location based on the cloudiness calculation proposed by Aleksey K. Solovyov was conducted.

Figure 1. Angles defining the position of the Sun and sky element

1.2. Aim and objectives:

The aim of this research is to estimate the luminance distributions in real sky condition tropical Vietnam. Accordingly, this research is based on three main objectives:
- Define the sky types with two methods calculation: the first one using parameters of diffuse horizontal illuminance \( D_v \) to extra-terrestrial horizontal illuminance \( E_v \) and the luminous turbidity factor \( T_v \) as descriptors of the sky types; the second one using the cloudiness coefficient \( K_0 \) to define real sky condition by statistic of cloudiness.
- Obtain the value illuminance distributions \( \beta \) from the real sky condition.
- Define the uneven brightness coefficient \( q \) for tropical sky condition of Vietnam.
2. Methods

Based on the two extreme CIE standard skies of Kittler and Moon spencer, the intermediated sky conditions could be found with their descriptors of each sky types, which were proposed by Kittler et al and with the cloudiness coefficient $K_0$. The descriptors of sky types and the cloudiness coefficient $K_0$ were confirmed based on the weather data of the region’s climate. After that, the calculation of the illuminance distributions $\beta$ and the coefficient of uneven brightness $q$ of the defined sky type will be defined.

2.1. A set of standard skies characterizing daylight conditions by Kittler et al.

To make a measurement ruler of relative luminance distributions in different sky types, a set of standard skies characterizing daylight conditions identified [9]. Considering these concepts, fifteen sky types of relative luminance distributions by Kittler et al (1998) based on scan measured luminance data at Tokyo, Berkeley and Sydney were proposed at the same time. Five overcast, five clear and five transitional skies are modelled by the combination of graduation and indicatrix functions and the solution is proposed as a CIE code draft CIE (2001) [10]. This determination of daylighting conditions is more detail and covers the whole occurrence spectrum considering different diffuse scattering by the atmosphere and effects of direct Sunlight [11, 12].

To identify the sky type at least two of the descriptors have to obtain: the relative of diffuse horizontal illuminance $D_v$ to extra-terrestrial horizontal illuminance $E_v$ and the luminous turbidity factor $T_v$ which approximates the number of ideally clean atmospheres representing an actual case [4, 13].

$$T_v = -\ln\left(\frac{P_v}{E_v}\right)$$  
(6)

$$P_v = \frac{G_v}{E_v}$$  
(7)

$$E_v = 133.8 \sin \gamma_s \text{ lux}$$  
(8)

$$m = \frac{1}{\sin \gamma_s + 0.50572 \gamma_s + 6.07999 \gamma_s^{1.6364}}$$  
(9)

$$A_v = \frac{1}{9.9 + 0.043 m}$$  
(10)

where:

- $T_v$ - is the luminous turbidity factor;
- $P_v$ - is direct solar horizontal exterior illuminance (Klux);
- $E_v$ - is extra-terrestrial horizontal illuminance (Klux);
- $D_v$ - is diffuse sky illuminance (Klux);
- $G_v$ - is global illuminance (Klux);
- $m$ - is the air mass penetrated and $av$ its ideal luminous extinction, dependent on solar altitude $\gamma$ (degree) [13].

Calculation of the relative luminance distributions after the CIE general sky concept was provided with a functional formula. The position of the Sun and of the arbitrary sky element as well as parameters $a$, $b$, $c$, $d$ and $e$ which describe atmospheric conditions have to be taken as input calculation quantities.

$$\beta = \frac{L_{uv}}{L_v} = \frac{f(X)\phi(Z)}{f(Z)\phi(0)}$$  
(11)

The luminance gradation function $\phi$ relates the luminance of a sky element to its zenith angle:

$$\phi(Z) = 1 + a \exp\left(\frac{b}{\cos Z}\right)$$  
(12)
\[ \varphi(0^\circ) = 1 + a \cdot \exp b \]  

(13)

\[ f(X) = 1 + c \left[ \exp(dX) - \exp\left(\frac{d\pi}{2}\right)\right] + e \cdot \cos^2 X \]  

(14)

\[ f(Z_s) = 1 + c \left[ \exp(dZ_s) - \exp\left(\frac{d\pi}{2}\right)\right] + e \cdot \cos^2 Z_s \]  

(15)

When \( 0 \leq Z \leq \pi/2 \) and at the horizon is \( \varphi(\pi/2) = 1 \).

Standard parameters \( a, b, c, d \) and \( e \) can be estimated after the definition of the sky type from Table 1.

| Type | Gradation indicatrix | Standard parameters | Descriptors linked with various sky types |
|------|----------------------|---------------------|----------------------------------------|
|      |                      | \( a \)  | \( b \)  | \( c \)  | \( d \)  | \( e \)  | \( T_v \) | \( D_v/E_v \) |
| 1    | I                    | 1     | 4.0      | -0.7    | 0       | -1.0    | 0.00     | Over 45 | 0.10   |
| 2    | I                    | 1     | 4.0      | -0.7    | 0       | -1.5    | 0.15     | Over 20 | 0.18   |
| 3    | II                   | 1     | 1.1      | -0.8    | 0       | -1.0    | 0.00     | Over 45 | 0.15   |
| 4    | II                   | 2     | 1.1      | -0.8    | 2       | -1.5    | 0.15     | Over 20 | 0.22   |
| 5    | III                  | 1     | 0.0      | -1.0    | 0       | -1.0    | 0.00     | Over 45 | 0.20   |
| 6    | III                  | 2     | 0.0      | -1.0    | 2       | -1.5    | 0.15     | Over 20 | 0.38   |
| 7    | III                  | 3     | 0.0      | -1.0    | 5       | -2.5    | 0.30     | 12.0    | 0.42   |
| 8    | III                  | 4     | 0.0      | -1.0    | 10      | -3.0    | 0.45     | 10.0    | 0.41   |
| 9    | IV                   | 2     | -1.0     | -0.55   | 2       | -1.5    | 0.15     | 12.0    | 0.40   |
| 10   | IV                   | 3     | -1.0     | -0.55   | 5       | -2.5    | 0.30     | 10.0    | 0.36   |
| 11   | IV                   | 4     | -1.0     | -0.55   | 10      | -3.0    | 0.45     | 4.0     | 0.23   |
| 12   | V                    | 4     | -1.0     | -0.32   | 10      | -3.0    | 0.45     | 2.5     | 0.10   |
| 13   | V                    | 5     | -1.0     | -0.32   | 16      | -3.0    | 0.30     | 4.5     | 0.28   |
| 14   | VI                   | 5     | -1.0     | -0.15   | 16      | -3.0    | 0.30     | 5.0     | 0.28   |
| 15   | VI                   | 6     | -1.0     | -0.15   | 24      | -2.8    | 0.15     | 4.0     | 0.30   |

In Table 1 gave fifteen standard relative luminance distributions which are based on six groups of \( a \) and \( b \) values for the gradation function and six groups of \( c, d \) and \( e \) values for the indicatrix function.

According to formulas from (6) to (15) after the sky type of the location has been defined, using standard parameters \( a, b, c, d \) and \( e \) for target sky type, the values luminance distributions of the real sky are obtained.

2.2. Assessment the light climate for a particular location based on the cloudiness calculation \( K_0 \)

This is based on calculation the relative sky luminance distributions gap between two extreme CIE standard skies by using the cloudiness calculation and proposed by Aleksey K. Solovyov. The method of determining the estimated positions of the Sun in the sky is described in document [14, 15].

In short, the values of the elementary illumination of the sky sectors with angular dimensions in latitude \( 15^\circ \) and on the meridian \( 70^\circ \) (from \( 10^\circ \) to \( 80^\circ \)) were calculated (figure 1). These values are the sum of the elementary illuminance by the sectors of the sky. In regions with the clear sky, luminance distributions depend on the Sun’s position relative to the light opening. A position of the Sun is taken into account, where for a given orientation of the light opening, the value of Daylight Factor will be minimal, and the value of outdoor illumination will approach the critical \( E_c \). Then we have:

The condition of minimal Daylight Factor at the unfavourable point: From the articles [14, 15], the results show that the value of the angular distance of the sky element from the Sun \( X \) equals 105\(^\circ\) and 225\(^\circ\) are the most unfavourable orientation area of a light opening in relation to the solar meridian. In the calculations to definition sky luminance distributions, the position of the Sun has to be fixed as stated above as these formulas (1) and (2) can be suitable for practical calculations if \( X \) and \( Z_s \) values are used. It should be noted that in case of sky types 1, 3 and 5 respectively with the CIE Standard Overcast Sky,
Overcast moderately graded with azimuthal uniformity and the Sky of uniform luminance [6], when luminance azimuth uniformity takes place, sky luminance does not depend on the orientation of the light opening and in these cases, therefore, the Daylight Factor does not depend on the Sun’s position.

The condition of critical illuminance \( E_{cr} \): Method calculation for room natural illumination in the clear sky condition with proposing the adverse Sun’s latitude at a given light opening orientation and external illuminance tends to critical \((E_{cr})\). The \( E_{cr} \) values were selected according to the follow expression for determining the Sun’s latitude:

\[
E_{cr} = 100 \frac{E_{norm}^{art}}{e_{norm}} \tag{16}
\]

where \( E_{norm}^{art} \) is normalized artificial illuminance and \( e_{norm} \) is normalized Daylight Factor values.

In the study [16,17], the analysis daylight assessment for Vietnam was taken with the represent of diffuse horizontal illuminances for Hanoi. It shows relative of Daylight Factor \( e \) (%), critical external illuminance \( E_{cr} \) (lux) and normalized artificial illuminance \( E_{norm}^{art} \) (target illuminance, lux) based on the analysis period of time from the working time using daylighting in a space (Table 2). For instance, Mardaljevic J. et al. [18] were evaluated some most probable daily activity hours e.g. 7:00 – 20:00, 8:00 – 17:00, 8:00 – 19:00 or 9:00 – 16:00. For Vietnam this period from 08h00 to 17h00 is represented as 100% working. Thus, minimum critical external illuminance amounted approximately to 15000 lux, from which covers practically all \( E_{cr} \) value interval of the analysis period [7]. From numerous studies, which carried out in the field study of outdoor illumination, the most reliable are measurements of Khrochitsky, Zeker and Littlefair, as well as P. Tregenza [19-21], that confirm each other. As a result, P. Tregenza suggests the following empirical formulas for horizontal diffuse illumination:

\[
E_D = 10.5 \gamma + 5.5^2 \gamma^5, \quad \text{(with } -5^0 < \gamma \leq 5^0) \tag{17}
\]

\[
E_D = 48800 \sin^{1.105} \gamma, \quad \text{(with } 5^0 < \gamma \leq 60^0) \tag{18}
\]

Using expression (18) the angular height of the Sun is 20.1\(^0\) for the critical illuminance 15000 lux. If we assume that statistically, cloudiness ranges from overcast to clear sky conditions, a simple technique, which was proposed by G Gillette and S. Trido to account for local cloudiness can be used. The ratio of the diffuse to the global horizontal irradiances as well as the ratio of the diffuse to global illuminances, which named the cloudiness coefficient \( K_0 = E_D/E_0 \) provides a better information on cloudiness. This coefficient decreases from 1.0 under completely overcast skies to values around 0.2 under cloudless skies [7,16]. Hence, the luminance of any point of the sky determined can be presented at a time as the weighted average of its two-extreme value:

\[
L(z, \alpha) = \xi L(z, \alpha)_{\text{clear}} + (1-\xi) L(z, \alpha)_{\text{overcast}}
\]

Or \( \beta_{\text{real}} \approx \xi \beta_{\text{clear}} + (1-\xi) \beta_{\text{overcast}} \)

Where: \( L(z, \alpha)_{\text{clear}} \) is luminance of clear sky by R. Kittler’s formula; \( L(z)_{\text{overcast}} \) is luminance of overcast sky by Moon and Spencer’s law; \( \xi \) is a phase function corresponding to the normal distribution law confirmed in work [7,15].

\[
\xi = \frac{1 + \cos(K_0.\pi)}{2} \tag{20}
\]

2.3. Finding the uneven brightness coefficient \( q \)

For the final calculation of the coefficient of uneven brightness of the sky (q) depending on the height of the element Sky \( \gamma \), the formula was used:

\[
q = \frac{E_{\text{skyuniform}}}{E_{\text{realsky}}} \beta \tag{21}
\]

Where: \( q \) - uneven brightness coefficient; \( \beta \) - the brightness distribution coefficient; \( E_{\text{skyuniform}} \) - horizontal illumination in the open air with uniform brightness, lux. \( E_{\text{skyuniform}} = Lz.\pi; \)
E_{realsky} - horizontal illumination in the open air with a real distribution of brightness [14, 15], corresponding to a given height of the Sun, at which this level of critical illumination takes place, lux. From the formula (21):

\[E_{\text{realsky}} = \sum_{0}^{345} E_{H,\alpha} + 0.024 L_z + E_{2.5}\]  

(22)

\[\Delta E_{H,\alpha} = 0.046 L_z \sum_{\gamma=10^0}^{\gamma=80^0} \beta_\gamma \cos \gamma \sin \gamma\]  

(23)

\[E_{2.5} = 0.001 L_z \sum_{0}^{345} \beta_{0.2.5}\]  

(24)

where: The first term in the formula (22) is the sum of the illuminance values in the centre of the hemisphere from the sky sectors, determined at the height of the Sun corresponding to a given level of critical illumination; the second term is calculated as the illumination from the circle at the zenith with a radius; The third component is the illumination from the end at the horizon, with an angular height of 5° and with a centre line located at a height of 2.5° above the horizon (figure 1).

3. Results and discussion

The weather data of diffuse horizontal illuminances, global horizontal illuminances and extra-terrestrial horizontal illuminances are collected for Hanoi, Ho Chi Minh City cities from file ASHRAE IWEC2 - «White Box Technologies, weather data for energy calculations». This file was developed for ASHRAE by White Box Technologies, Inc. and based on the integrated hourly basis over the ISD surface for 3012 locations outside the US and Canada that have a minimum of 12 years of recording up to 25 years [17].

3.1. Define sky type with relative \(D_v/E_v\) and the luminous turbidity factor \(T_v\) based on a set of standard skies proposed by Kittler et al.

To obtain the relative of \(D_v/E_v\), the data of diffuse horizontal illuminance and extra-terrestrial horizontal illuminance were used in formulas (6) – (10). The result of calculations shown In Hanoi, the sky types identifies partly cloudy sky, no gradation towards zenith, slight brightening towards the Sun with sky type 6; While as the sky type 10 – partly cloudy, with brighter circumsolar region was represented for Ho Chi Minh City [7].

Figure 2a below shows the graphic of relative luminance distributions \(\beta\) in depending on sky types, which was computed from the formulas from (11) to (15). For the calculations, standard parameters of sky types were used. The position of angular distance of the sky element from the Sun \(X\) estimated equals 105° (or 225°) is the most unfavourable orientation area. The angular distances between a sky element and the zenith, \(Z = 90^0 - \gamma\) were determined when \(\gamma\) changes from 10° to 90°.

3.2. Define sky type based on the cloudiness coefficient \(K_0\)

To estimate sky types for these cities with the cloudiness coefficient \(K_0\), the values of diffuse and global illuminances were obtained. The results have shown the values of \(K_0\) average are 0.81 for Hanoi and 0.57 for Ho Chi Minh City [7].
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Figure 2. Distribution of relative luminance $\beta$: (a) - in depending on sky types (sky type VI for Hanoi and X for Ho Chi Minh City); (b) with different cloudiness probabilities

Using formulas from (19) and (20), the luminance distributions $\beta$ according to different cloudiness coefficient $K_0$ is determined by summing the values of illumination from the sky sectors. The results are obtained in Figure 2b.

3.3. Correction of the uneven brightness coefficient $q$

Based on the results of the luminance distribution $\beta$, the correction of the uneven brightness coefficient $q$ was given using the formulas (21) to (24). Results of the calculation are shown in the Tables 2,3 and Figure 3.

Figure 3. Coefficient $q$: (a) – from the calculation of $\beta$ by model of Kittler et al.; (b) from the calculation of $\beta$ by $K_0$ method
Based on the obtained calculated results, the following conclusions can be made:

1. To obtain the luminance distributions and coefficient of uneven brightness of real sky conditions using in daylighting calculations, the sky types of tropical Hanoi and Ho Chi Minh City were defined based on the two extreme CIE Standard Skies: Overcast Sky (Moon & Spencer) and Standard Clear Sky (R. Kittler). In this research, the two methods of calculation were presented: method define luminance distributions based on a set of fifteen skies proposed by R. Kittler and et al.; the method using the cloudiness calculation $K_0$ to define the real sky luminance distributions gap between two extreme CIE Standard skies. This first method must begin with the definition the sky type with the parameter of descriptors $D/E_v$ and $T_v$. As the results, sky types VI and X respectively were defined for Hanoi and Ho Chi Minh City.

2. The values of relative luminance distributions $\beta$ and coefficient of uneven brightness $q$ were presented. A comparison shows differences between the overcast sky CIE condition and the real sky conditions of HN and HCM city, which are defined by the two methods above.

3. Determining the type of intermediate sky according to $K_0$ cloudiness statistics is a simplified method compared to the Kittler method. Under the condition of a real tropical sky, the obtained values of the $q$

| $\gamma$ (grade) | $K_0$ | $D/E_v$, $T_v$ | $K_0$ | $D/E_v$, $T_v$ | $K_0$ | $D/E_v$, $T_v$ | $K_0$ | $D/E_v$, $T_v$ |
|------------------|-------|---------------|-------|---------------|-------|---------------|-------|---------------|
| 10               | 0.45  | 0.57          | 0.67  | 0.98          | 1.38  | 2.16          | 0.77  | 0.94          |
| 20               | 0.56  | 0.71          | 0.97  | 1.33          | 0.79  | 0.94          | 0.99  | 1.23          |
| 30               | 0.67  | 0.85          | 0.97  | 1.02          | 0.87  | 0.94          | 0.98  | 1.03          |
| 40               | 0.76  | 0.97          | 0.82  | 0.97          | 0.95  | 0.94          | 0.85  | 0.88          |
| 50               | 0.84  | 1.07          | 0.88  | 0.97          | 0.97  | 0.94          | 0.98  | 0.88          |
| 60               | 0.91  | 1.16          | 0.93  | 0.97          | 0.98  | 1.04          | 0.95  | 0.88          |
| 70               | 0.96  | 1.22          | 0.98  | 0.97          | 1.01  | 1.11          | 0.95  | 0.88          |
| 80               | 0.99  | 1.26          | 0.99  | 0.98          | 0.99  | 1.14          | 0.95  | 0.88          |
| 90               | 1.00  | 1.27          | 1.00  | 0.99          | 1.15  | 0.96          | 0.86  | 0.67          |

Finally, for an overview, a comparison results defining luminance distributions $\beta$ and the coefficient of unevenness brightness $q$ for Hanoi and Ho Chi Minh City sky conditions by difference methods has shown on Table 4.

| $\gamma$ (grade) | $K_0$ | $D/E_v$, $T_v$ | $K_0$ | $D/E_v$, $T_v$ | $K_0$ | $D/E_v$, $T_v$ | $K_0$ | $D/E_v$, $T_v$ |
|------------------|-------|---------------|-------|---------------|-------|---------------|-------|---------------|
| 10               | 0.45  | 0.57          | 0.67  | 0.98          | 1.38  | 2.16          | 0.77  | 0.94          |
| 20               | 0.56  | 0.71          | 0.97  | 1.33          | 0.79  | 0.94          | 0.99  | 1.23          |
| 30               | 0.67  | 0.85          | 0.97  | 1.02          | 0.87  | 0.94          | 0.98  | 1.03          |
| 40               | 0.76  | 0.97          | 0.82  | 0.97          | 0.95  | 0.94          | 0.85  | 0.88          |
| 50               | 0.84  | 1.07          | 0.88  | 0.97          | 0.97  | 0.94          | 0.98  | 0.88          |
| 60               | 0.91  | 1.16          | 0.93  | 0.97          | 0.98  | 1.04          | 0.95  | 0.88          |
| 70               | 0.96  | 1.22          | 0.98  | 0.97          | 1.01  | 1.11          | 0.95  | 0.88          |
| 80               | 0.99  | 1.26          | 0.99  | 0.98          | 0.99  | 1.14          | 0.95  | 0.88          |
| 90               | 1.00  | 1.27          | 1.00  | 0.99          | 1.15  | 0.96          | 0.86  | 0.67          |

4. Conclusions
Based on the obtained calculated results, the following conclusions can be made:

1. To obtain the luminance distributions and coefficient of uneven brightness of real sky conditions using in daylighting calculations, the sky types of tropical Hanoi and Ho Chi Minh City were defined based on the two extreme CIE Standard Skies: Overcast Sky (Moon & Spencer) and Standard Clear Sky (R. Kittler). In this research, the two methods of calculation were presented: method define luminance distributions based on a set of fifteen skies proposed by R. Kittler and et al.; the method using the cloudiness calculation $K_0$ to define the real sky luminance distributions gap between two extreme CIE Standard skies. This first method must begin with the definition the sky type with the parameter of descriptors $D/E_v$ and $T_v$. As the results, sky types VI and X respectively were defined for Hanoi and Ho Chi Minh City.

2. The values of relative luminance distributions $\beta$ and coefficient of uneven brightness $q$ were presented. A comparison shows differences between the overcast sky CIE condition and the real sky conditions of HN and HCM city, which are defined by the two methods above.

3. Determining the type of intermediate sky according to $K_0$ cloudiness statistics is a simplified method compared to the Kittler method. Under the condition of a real tropical sky, the obtained values of the $q$
Coefficient are larger than those under a cloudy sky, especially for Ho Chi Minh City, where the sky condition is brighter. In the process of calculating daylight, the correction of the uneven brightness coefficient $q$ leads to a change in the results of the daylight assessment.

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