DAYLIGHT FACTOR DISTRIBUTION IN INTERIOR BASED UPON THE MEAN SKY

Toshio ONAI and Masato OKI
Department of Architecture, Ashikaga Institute of Technology,
Ashikaga-Shi 326-8558 - Japan

ABSTRACT

Daylight illuminance is one of the most important element which comprises the luminous environment by daylight both in interior and at outdoor of building. Daylight is taken into interior mainly through the window. Therefore, the plan of daylighting is closely connected with the design of openings such as window.

Examples of application for daylight factor distribution in interior were calculated in several rooms with facing several orientations by using a simulation technique. The outstanding characteristics of the daylighting prediction relying upon the Mean Sky are that the effects of the orientation of windows can be revealed.

INTRODUCTION

The Mean Sky had been proposed as the numerical tables in 1983[1] based upon the three skies that are the CIE[2] Standard Overcast Sky[3], CIE Standard Clear Sky[4] and the Intermediate Sky[5] in absolute luminance values and then recently the Mean Sky has been proposed as the mathematical equation[6]. The daylighting calculation method revised agree with the Mean Sky is theoretically regarded to more reasonable than the old method that is the Uniform Sky or the CIE Standard Overcast Sky. A program for personal computer was developed for the prediction of the daylighted luminous environment [7,8].

Never the real skies usually observed are the Uniform Sky resembles or the CIE Standard Overcast Sky, which are often assumed as the luminance distribution of the sky when the luminous environments of the daylighted interior are predicted. The Mean Sky is designed as the mean luminance distribution of the sky during rather long period, and regarded to more suitable than the Skies recommended previously for the estimation of the expected daylight for practical daylight design.

Daylighting estimation program developed for personal computer as described above can be applied to the sky luminance distribution of the Mean Sky, when they can provide the direct daylight factor per configuration factor at the all sky elements. It can also be applied to the interior luminous environment with windows of various scales and orientations.

THE MEAN SKY

A daylight environment of interiors can be calculated assuming the luminous distribution of the sky to be, for instance, the Uniform Sky or the CIE Standard Overcast Sky, etc. The real skies usually observed are not represented by those typical Skies recommended previously.

The Mean Sky was developed in order to estimate the real daylighted environment more closely, and to predict more accurately the electric power consumption by artificial light in the daytime. The Mean Sky can be regarded as the mean luminance distribution of the sky during rather long period at a reference point. The Mean Sky was originally composed depending upon the three Skies described in relative values, that is, the CIE Standard Overcast Sky, the CIE Standard Clear Sky and the Intermediate Sky which was proposed based upon the data actually measured, taking account of both the estimated relative frequency of occurrence of the three Skies [9,10] and the calculated relative frequencies of occurrence of the solar position in the sky at reference point.

The Mean Sky in relative values can now composed progressively as absolute value in Japan by the mathematical equation [6] which was made based upon the previous numerical table[11].

Luminance of the Mean Sky is shown as following equation.

$$LME(As,Hs)=a(Hs)+b(Hs)\,[1.022(As)+c(Hs)] \qquad (1)$$

Where,

$a(Hs) = 4.356 + 0.0333Hs + 0.993\sin(2.0Hs)$

$b(Hs) = -2.465 + 0.0385Hs$
$\quad - 2.0\sin(2.0Hs - 30.0)$

$c(Hs) = -22.2 + 0.132Hs$
$\quad - 1.70\sin(4.0Hs - 20.0)$

. LME: Luminance of the Mean Sky(kcd/m^2)
As: Azimuth of sky element(deg.)
Hs: Height of sky element(deg.)

Composition method of Luminance distribution of the Mean Sky in Japan is shown in Figure 1.

CALCULATION OF DAYLIGHT FACTOR

Input items and procedure are shown as follows.

Setting the room
(1)Orientation of room,
(2)Size of room,
(3)Height of ceiling,
(4)Reflection coefficient of each finished surface in interior,
(5)Height of working space,
(6)Height of measuring point.

Setting the window
(7)Maintenance factor of windows,
(8)Average height of obstruction facing windows,
(9)Transmission coefficient of window glasses,
(10)Effective coefficient of windows,
(11)Wall thickness of window frames.

The diagram of outline of the process of the calculation program named "DAYLIGHT" is shown in Figure 2.

Daylight factor is shown as the ratio of horizontal illuminance in interior and diffuse horizontal illuminance from unobstructed sky. Therefore, it is influenced by the orientation of windows, reflection factor of finished surface in interior, and obstructions such as buildings outside of the windows. Additionally, the total electric power consumed by supplementary artificial light is also can be predicted. All calculated results are shown on CRT.

RESULTS OF THE INVESTIGATION

The results of calculation of daylight factor distribution of various orientations of windows were investigated in this study. The input items and data of the calculation of the simulated room are shown in Table 1. The plan and windows of the simulated room are shown in Figure 3.

All the rooms were set in the same condition, except the orientation of the window, which was changed east, west, south and north.

Calculated results of daylight factor distribution in the room changing the orientation of window is shown in Figure 4. As the results of simulation, it was cleared that when the orientation of the window was west, the room is lightest and the orientation of the window was east, the room is darkest.

Daylight factor distribution in a room of dwelling house was measured. A photo and the plan of one of the investigated room is shown in Figure 5(a). The size of the room is 5,610 mm x 3,640 mm and the height of ceiling is 2,500 mm. The room has two windows facing the south and east with two small windows facing north. Diffuse horizontal illuminance at outside of the house and horizontal illuminance in interior were measured at each room to calculate the daylight factor. The measured daylight factor and estimated daylight factor are shown in Figure 5(b). The results of measurement and calculated values were investigated and compared.

CONCLUSIONS

By this research work, the effects of the orientation of windows could be revealed to luminous environment by daylight.
The different of daylight factor distribution by the orientation of window was expressed in figures by simulation technique by personal computer. It was cleared that this simulation method was able to investigate the luminous environment in interior by orientation of window at the initial stage of visual environment design.

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REFERENCES

1.H.Nakamura and M.Oki: Composition of mean sky and its application to daylight prediction, Proceedings of CIE 20th Session, Vol.I, D303/1-4, 1983.

2.CIE (Commission Internationale de l'Eclairage): Only one International Organization regarding lighting researches and techniques.

3.Natural Daylight, Official recommendation, Compte Rendu CIE 13e Session 1955, Committee(E-3.2), P.II, 1955.

4. Standardization of luminance distribution on clear skies, Publication CIE No.22(TC-4.21), 1973.

5.H.Nakamura, M.Oki and Y.Hayashi: Luminance distribution of intermediate sky, Journal of Light and Visual Environment, Vol.9, No.1, pp.6-13, 1985.

6.K.Anai, H.Nakamura, Y.Koga & T.Watanabe: Mathematical expression of Mean Sky in Japan, daylighting calculation method with Mean Sky(Part 1), Journal Illuminating Engineering Institute of Japan, Vol.83, No.11, pp.854-859, (in Japanese)1999.

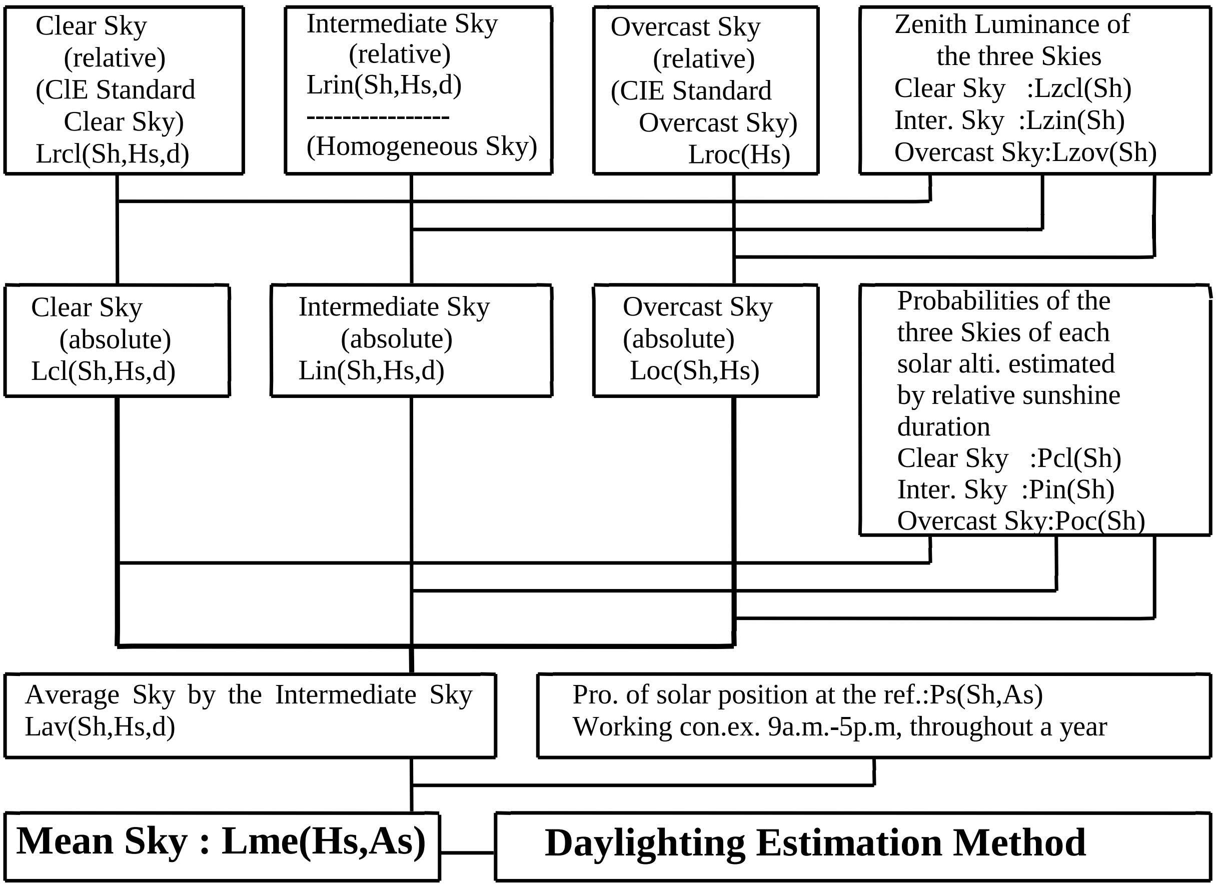
7.H.Nakamura, M.Oki and Y.Suzuki: Inspection of the daylighting interior luminous environment predicted upon the newly improved Mean Sky, Proceedings 1 of International Daylighting Conference, Long Beach, California, U.S.A., pp.115-119, 1986.

8.M.Oki and T.Onai: Simulation of Luminous environment in interior with windows by personal computer, Computers Engineering, Vol.27, No. 1-4, pp.301-304, 1994.

9.H.Nakamura & M.Oki: Investigation on the relation between the probabilities of occurrence of the three skies and the relative sunshine duration, Compte Rendu CIE 21st Session, Vol.1, pp.228-229, 1987.

10.M.Oki, H.Nakamura, M.R.Rahim,I.Shin and T.Iwata: Relative sunshine duration at various points in the world, Proceedings of CIE 22nd Session, Vol.1, Part 1, pp.7-8, 1991

11.H.Nakamura, M.Oki, Y.Hayashi and T.Iwata: The mean sky composed on the absolute luminance value of sky elements and its application to daylight prediction, Proceedings 1 of International Daylighting Conference, Long Beach, California, U.S.A., pp.61-66, 1986.



Sh: Solar altitude(deg.) Hs: Altitude of an arbitrary sky element(deg.)
Sa: Solar azimuth(deg.) As: Azimuth of an arbitrary sky element(deg.)
d: Angular distance from the sun to the sky element(deg.)

Figure 1. Composition method of Iluminance distribution of the Mean Sky in Japan

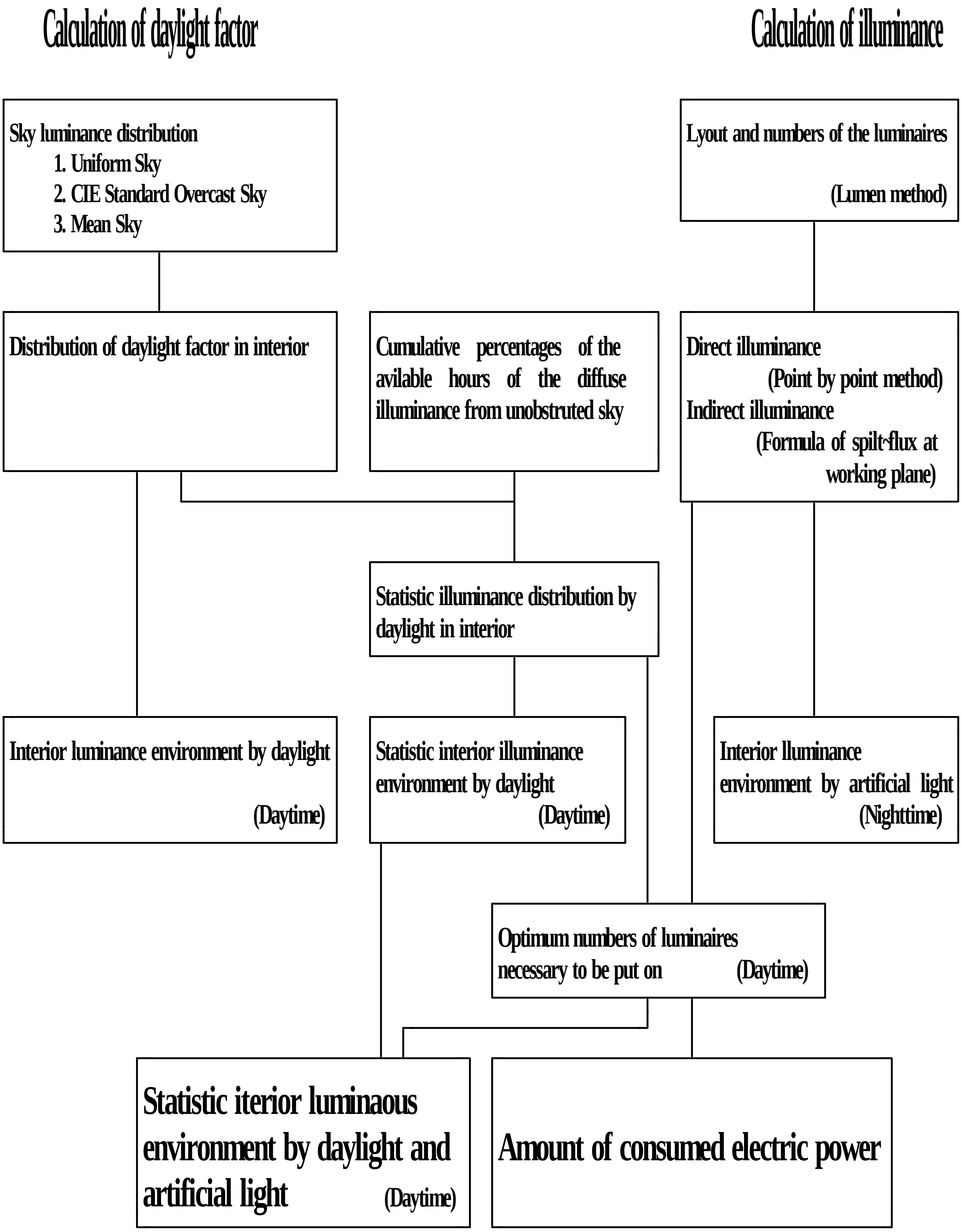


Figure 2.   The outline of the process of the calculation of daylight factor in interior

Table 1. The input item and data of the calculation of the simulated room

Daylight factor	Illuminance & consumed electric power
1) Orientation of room: 0-350deg., every 10deg. 2) Size of room: 3050mm x 7900mm 3) Height of ceiling: 2480mm 4) Reflection coefficient of each finished surface in interior: Ceiling: 81% Wall: 74% Floor: 17% 5) Height of measuring point: 750mm 6) Correction factor of window: 70% 7) Average altitude of obstruction: 0 deg. 8) Transmission coefficient of window glass: 85% 9) Effective coefficient of window: 85% 10) Wall thickness: 150mm	1)Distance from wall of point on work field to investigate level: 800mm 2)Necessary illuminance level to work: Nighttime: 500 lx Daytime: 500 lx 3)Annual working days: 270 days 4)Setting of lighting equipment: Type BZ5 5)Flux per lamp: 3000 lm 6)Height of installed lamp: 2480mm 7)Possibility of work at window: Yes 8)Condition of maintenance of luminaire: Normal

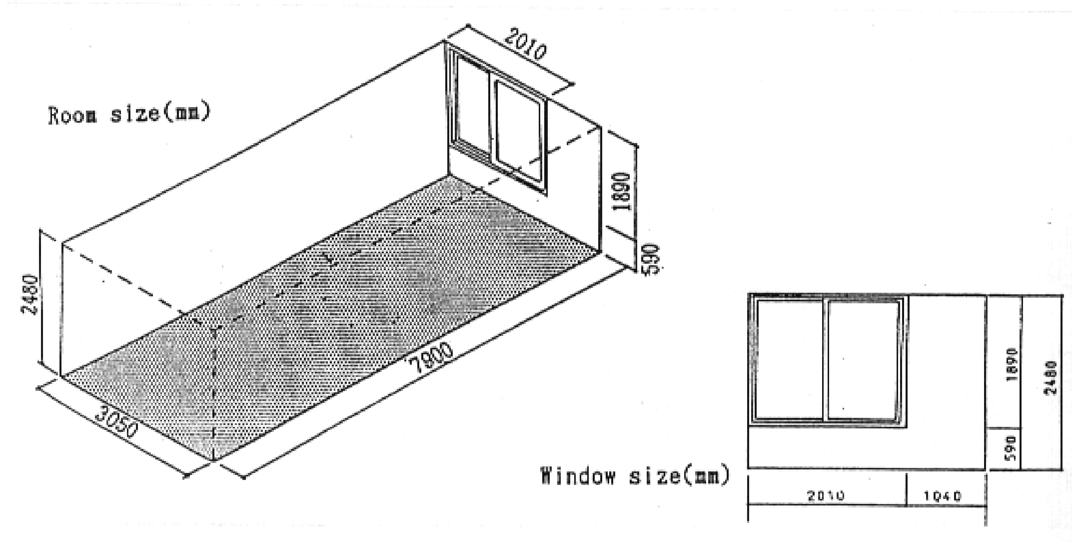


Figure 3. The plan and windows of the simulated room

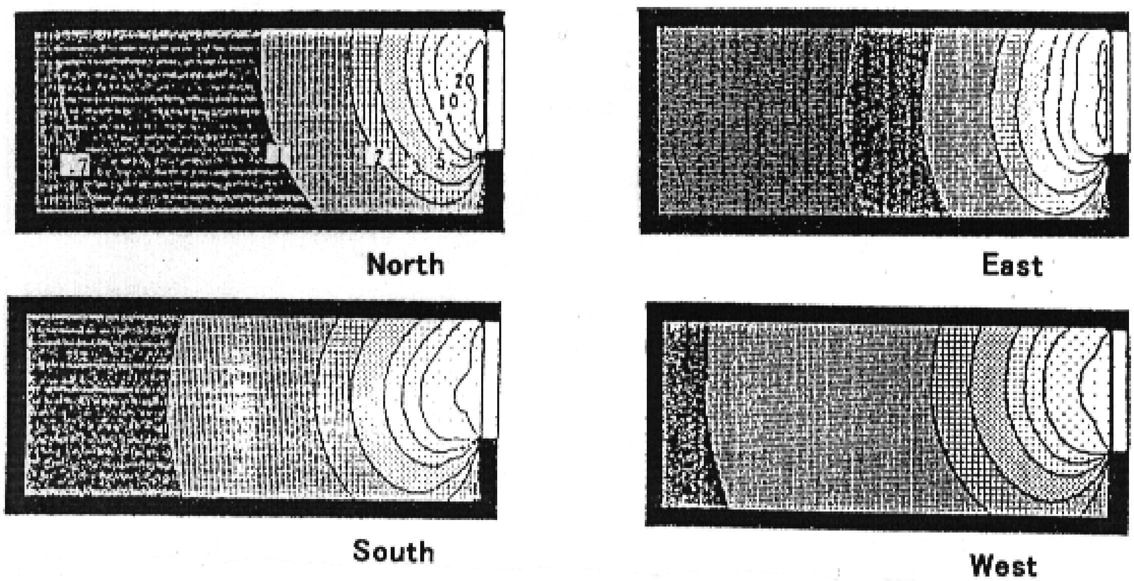
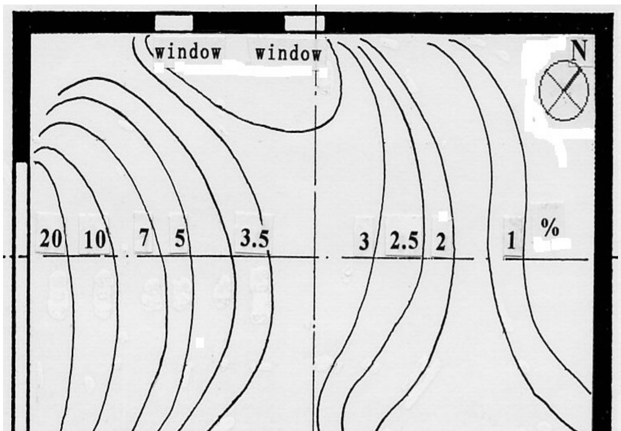
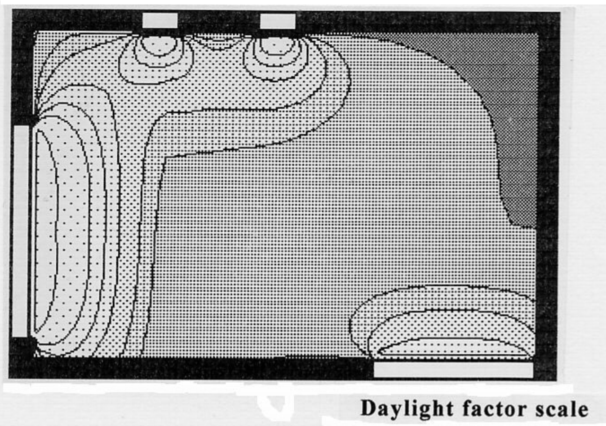


Figure 4. Daylight factor distribution in the room changing the orientation of window

(a) Photo of the house and room



(b)-1 Measured daylight factor distribution



(b)-2 Simulated daylight factor distribution

Figure 5. Examples of the measured and simulated daylight factor distribution of the investigated actual dwelling room