GLOBAL AND DIFFUSE ILLUMINANCE DATA IN MAKASSAR-INDONESIA

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ABSTRACT

In an effort to join and participate in international daylight measurement program (IDMP) and collect data in the tropics, a measurement stations which measured the daylight and solar radiation data have been established in Makassar and has been operating since 1995 until 2000. Furthermore, measurement data to global illuminance (Evg) and diffuse illuminance (Evd) have been resumed from April to October 2010. Data processing begins with the daily data tabulated in intervals of 15 minutes each day comes with a chart of daily data fluctuations. The results obtained by the number of quality control for the Evg data 99.99% of the total data recorded. The results of quality control data 100% of the total data recorded. The result of quality control comparison between Evg and Evd shows the result of 93.44% of the data that pass quality control.

The result of measurement of Evg and Evd held in Makassar in 2010 is a qualified data and valid for further analysis under guidelines of the CIE-IDMP. The results of the data tabulation and daily fluctuation graphs are intended for ease of comparison and analysis and preparation of data exchange, nationally and internationally.

Keywords: Data measurement; Daylight and Solar Radiation; Sky conditions.

I. INTRODUCTION

The basic daylight data for the scheme of environment of building interiors are absolutely short now. International Daylight Measurement Program (IDMP) has been promoted by CIE for last several years, in order to collect measurement data of solar radiation and arrange them into useful standard materials for building design. Technical Committee (TC307) has been organized and almost completed a guide which instructs the measurement of daylight and solar radiation. Many proposals
have been made by various researchers in the world for the prediction and design of daylight and solar radiation environment interior. However, all fundamental materials for those proposals are based upon the measured data at areas of high latitude were the solar altitude rather low. So they cannot be applied in low latitude area where the solar altitude often becomes very high.

In order to investigate daylight availability data in low latitude/tropic area which are extremely lacking at the present stage, a daylight and solar radiation station has been established in Makassar – Indonesia.

II. EXPERIMENT METHODS

2.1 Measurement Location

This measurement station is established based on the collaboration research between Department of Architecture, the University of Hong Kong and the Department of Architecture, Hasanuddin University. Two sets of BF3 sunshine sensor have been installed for this purpose. One station is installed in the Hasanuddin University main campus (UNHAS station) and another one is installed in the University of Hong Kong (HKU Station). The UNHAS station is located at the roof top of Department of Architecture, Hasanuddin University, Tamalanrea, Makassar - Indonesia (05°04’ S, 119°33’ E, and 27m above the sea level) (Rahim et.al, 2010). Makassar lies in South Sulawesi Province, Sulawesi (Celebes) island, the central part of Indonesia. It has a warm tropical climate tempered by the trade wind and only two seasons as well as all over Indonesia. The local time is GMT +8 hours. Average of temperature, relative humidity, yearly rainfall amount, yearly percentage of sunshine duration are 26.6°C (1951-1988), 79% (1961-1964), 2815.8 mm (1951-1980), 67.1% (1995-2000), respectively (Rahim, 2001, 2002).

2.2 Data Acquisition and Processing

This station consists of one BF3 sunshine sensor that measure global and diffuse solar radiation and sunshine data. The daylight data are gained at every fifteen-minute intervals continuously for twenty-four hours by instruments and transferred to a GP1 data logger for recording data. A personal device assistant (PDA) or personal computer (PC) was used for data downloading purpose. The outputs can be set up in either energy (W/m²), or PAR (photo synthetically active radiation) (mmol.m⁻².s⁻¹), or illuminance (Klux). For the purpose of this study, the output was set up in energy (W/m²) and illuminance (Klux). In each time, the BF3 sensor collects daylight data as follows:

a) Global irradiance (Eeg)/illuminance (Evg)
b) Diffuse horizontal irradiance (Eed)/illuminance (Evd)
c) Sunshine duration

According to BF3 manual (Delta-t Devices Ltd, 2002), BF3 was designed to measure the Direct and Diffuse components of incidents solar radiation, and provide a measure of sunshine hours, in a sensor that used no moving parts, and required no specific polar alignment or routine adjustment. It consists of seven photodiodes; six photodiodes on a hexagonal grid with the seventh at the center
gave the smallest number of photodiodes necessary for a shading pattern such that wherever the sun is in the sky (Delta-t Devices Ltd, 2002):

a. At least one photodiode was always exposed to full solar beam
b. At least one was always completely shaded
c. Both photodiodes receive equal amounts of diffuse light from the rest of the sky hemisphere.

The shadow pattern consists of equal areas of black and clear bands (Figure 2). This means that all of the photodiodes receive 50% of the diffuse radiation, sampled from all over the sky, and at least one photodiode receives only this radiation. At least one photodiode also receives the full amount of direct radiation from the sun. When a reading is taken, the seven photodiode outputs are measured, but only the largest (MAX) and smallest (MIN) of these values are used in the calculation. Global and diffuse outputs are calculated using the relation (Wood et al., 2003):

\[
\text{Diffuse} = 2 \times \text{MIN} \quad (1)
\]

\[
\text{Global} = \text{MAX} + \text{MIN} \quad (2)
\]

The spectral response of the photodiodes used is from 400 nm to 700 nm, which is appropriate for visible light measurements such as PAR and Illuminance. However, in measuring the energy it gives some variability, especially in diffuse. This is due to the widely differing spectral content of blue sky light compared to overcast light. In order to compensate for this, the diffuse value is further modified by a function of the direct beam fraction (\(F_b = \text{direct}/\text{global}\)) which gives an estimate of the amount of cloud cover. So for solar radiation measurement:

\[
\text{Diffuse} = 2 \times \text{MIN} \times (1-F_b^4) \quad (3)
\]

The WMO has defined sunshine presence as when the energy in the direct beam is greater than 120 W/m² measured perpendicular to the beam. This cannot be measured directly using cosine corrected sensors, so the BF3 uses an algorithm based on the measured global and diffuse values that has been found to give good results. BF3 results substantially more accurate than Campbell-Stokes recorder. Sunshine presence when:

\[
\frac{\text{Total}}{\text{diffuse}} > 1.25 \text{ and Total} > 50 \text{ mol.m}^{-2}.\text{s}^{-1} \text{ or Total} > 24\text{W.m}^{-2} \quad (4)
\]

The measurement results have been calibrated with Kipp CM11 for total and diffuse irradiance and with Campbell-Stokes for sunshine data. The calibration errors were 4.7% and 1.4% for total and diffuse irradiance, respectively. The measured sunshine hours were significantly more accurate than Campbell-Stokes recorder (Wood et al., 2003).

### 2.3 Quality Control

There is a tendency that some diffuse components exceed the global components. Such errors often occurred in both illuminance and irradiance when the illuminance/irradiance was low. Most of them are negligible but serious errors should be excluded before applying in further analysis. Raw data tested via quality
control with regards of four quantities i.e.: global illuminance (Evg), global irradiance (Eeg), diffuse illuminance (Evd) and diffuse irradiance (Eed). Those tests were according to the Guide by CIE (CIE, 1994). The first category of test is as follows:

a) $0 < E_{vg} < 1.2$ (ETI);
b) $0 < E_{eg} < 1.2$ (ETR);
c) $0 < E_{vd} < 0.8$ (ETI);
d) $0 < E_{ed} < 0.8$ (ETR).

The second category of test is as follows:

a) $E_{vd} < E_{vg} + 10\%$;
b) $E_{ed} < E_{eg} + 10\%$.

E.T.I. and E.T.R. are respectively the extraterrestrial normal illuminance and irradiance. E.T.I. = 127.5 klx; E.T.R. = 1367 W/m². These are rough absolute checks, which should ensure that no major problem exists.

Methods of processing data followed almost those similarly used in the IDMP (International Daylight Measurement Program) in Japan (Koga et al., 1993, Nakamura et al., 1993) that is:

a) Monthly average, standard deviation and number of data, classified by solar altitude in 6-degree intervals, separately in the morning and those in the afternoon.
b) Monthly average, standard deviation and number of data, classified by fifteen minute intervals, separately in the morning and those in the afternoon.
c) Daily average classified by fifteen minute intervals.

III. DISCUSSION AND RESULT ANALYSIS

3.1 Global Illuminance (Evg) and Diffuse Illuminance (Evd)

For the purpose of analyzing the validity of data collected by BF3 sunshine sensor, the authors have carried out several measurement tests. For this purpose, irradiance and illuminance data have been collected in 5-minute interval. The tests have been conducted in two periods i.e. 5 to 14 May 2010 and 14 to 23 May 2010 for irradiance and illuminance data, respectively. Total data processed in the tests are 2827 and 2644 for irradiance and illuminance, respectively. The illuminance data satisfy the first category test (1) and (3), while the irradiance data satisfy the first category test (2) and (4). Both data also satisfy the second category test. This indicate that data recorded at UNHAS station using BF3 sensor satisfy the quality control according to CIE guidelines (CIE, 1994). After carrying out the validity tests, the BF3 sensor is then adjusted to record the illuminance data in 15-minute interval. This set-up is the same as the set-up of BF3 sensor installed in HKU station.

Data compiled monthly fluctuations in monthly data and graphs. Total days of measurement as much as 143 days with the amount of data recorded on as many as 6.971 Evg data. Daily data processing done for each month of measurement that
indicates the data recorded every 15 minutes. Furthermore, every day is equipped with a measurement of each image fluctuations of daily data for Evg and Evd. The results obtained by the quality control for the Evg data are 6970 or 99.99% of the total data recorded as many as 6.971 data. The results of quality control data are 6.971 Evd data or 100% of the total data recorded as many as 6.971 data. Tables 1 and 2 show the total measurement days, total data recorded and total data passed by quality control of global (Evg) and diffuse illuminance (Evd), respectively.

### Table 1
Total measurement days, total data and total data passed QC – Evg 2010

<table>
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<tr>
<th>Month</th>
<th>Total Days</th>
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<td>Total/Mean</td>
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<td>6.971</td>
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### Table 2
Total measurement days, total data and total data passed QC – Evd 2010

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Measurement data of global illuminance (Evg) and diffuse illuminance (Evd) have been resumed from April to October 2010. Data processing begins with the daily data tabulated in intervals of 15 minutes each day comes with a chart of daily data fluctuations. Figure 1 shows example of the daily fluctuation of global illuminance (Evg) with the polygonal curve $y = -0.213x^3 + 10.801x - 29.582$ and $R^2 = 0.9639$ on August 15, 2010. Figure 2 shows example of the daily fluctuation of diffuse illuminance (Evd) with the polygonal curve $y = -0.039x^3 + 2.0338x - 2.8087$ and $R^2 = 0.9726$ on August 15, 2010.

Data processing performed each for Evg and Evd every day with a sequence of presentation: Time, Mean, Standard Deviation, Number of Data, Maximum and Minimum Values. Tables 3 and 4 show examples of monthly mean of global illuminance (Evg) and diffuse illuminance (Evd) in August 2010 (intervals in 30 minutes), respectively.

Table 3 shows the analysis of global illuminance collected in August 2010. As seen in the table, the highest illuminance of 143.63 Klux was recorded at 12:31-13:00 and
the lowest one is recorded in the morning and late afternoon. The highest average illuminance of 94.74 Klux with standard deviation (STDV 34.96) is recorded at 12:00-12:30. This indicates a very high global illuminance is available in August 2010.

Table 3 shows the analysis of diffuse illuminance collected in August 2010. As seen in the table, the highest diffuse illuminance of 71.50 Klux was recorded at 12:01-12:30 and the lowest one is recorded in the morning and late afternoon. The highest average illuminance of 38.13 Klux (STDV 14.56) is recorded at 11:01-11:30. This indicates a very high diffuse illuminance is available in August 2010.
IV. CONCLUSION

One of the crucial problems in predetermining the role of daylight in energy efficient buildings is the need for reliable local data on daylight availability. Furthermore, one of the basic aims of collecting and measuring daylight and solar radiation levels in many locations on the globe is the mutual comparison and evaluation of available data gathered. The measured data of daylight and solar radiation in Makassar-Indonesia are unique as they were measured in the equatorial location. The evaluation of these data is surely produce useful information on daylight and solar radiation. Moreover, based upon the measurement data, various quantities concerning daylight and solar radiation can be calculated and predicted, i.e.: Cloud ratios on illuminance and
irradiance, Horizontal illuminance from unobstructed sky, Luminous Efficacy, and so on.

It has been considered that the data gathered will be excellent raw data in order to extend the daylight and solar predictions in tropic area in the future. With the availability of this daylight data, the authors look forward to have more collaboration with other national or international institutions which enable daylight data exchanges, in order to strengthen the daylight research in the tropical area.

V. ACKNOWLEDGEMENT

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BIBLIOGRAPHY


