Quality of Daylighting in Gereja Kristen Jawi Wetan in Indonesia

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ABSTRACT

Gereja Kristen Jawi Wetan (GKJW) is a church that has the remark of local community in East Java. At the beginning, GKJW was evolved in rural areas, and later development has embraced urban areas, where in total 158 congregations exist until now. Churches acommodating these congregations, commonly adopt four different layouts with windows at the perimeter. For lighting, the churches use daylight and electrical lights. Combination of the two lighting systems is believed contributing to religious atmosphere in the churches.

Lighting plays an important role not only in determining quantity of light for facilitating activities but also in creating aesthetic quality and certain expression in a building. For religious buildings, a designer considers the lighting system very carefully as it gives significant influence on the worship service. In the case of GKJW churches, there are variations in lighting quality, and the present study aims at exploring this quality, especially that relates to daylighting.

The study utilised field observations and measurements to describe the daylighting quality of four churches in Surabaya. Data taken during the worship service in the church was analysed and evaluated on the basis of distribution of the light. Results of the study showed that there is a relation between light distributions in building with building shape, position and width of the openings.

Keywords: *daylighting, Gereja Kristen Jawi Wetan,warm-humid tropics*

I. INTRODUCTION

The issue on green building is not a new thing. To optimize the natural lighting is one way to create a green building. The implementation of natural light in a room will lead to an efficiency of electricity used on mid day (Danusugondho et.all, 1976). Indonesia is a country that is located in warm tropical climate so Indonesia has the opportunity to cultivate and use the energy effectively and efficiently. According to Satwiko (2004) in Indonesia (Pontianak) at 12.00 on March 21st and December 23rd, the sun will be exactly over our head at the height of 90°. On April 15th or August 30th around 16.40 at 0°, the sun will be as high as 20° and azimuth

280°. At the same location on 28 Februari and 15 Oktober around 07.25, the sun will be at the height position of 20° and azimuth 100°. Besides, according to Lechner (2001) the sun radiation is very weak at the beginning and end of day, which is at 09.00-15.00. At this time, the sun light will enter the building conventionally.

GKJW is a church that initially developed in a rural area and the development enters the urban area. At the moment, there are 158 congregations. Among the churches spread all over the nation, GKJW is a unique church. One of the outstanding features is that this church develops in a natural process (Sir, 1976). GKJW has its root in its area, in East Java. The East Java way of thinking along with its life style becomes the identity of GKJW (-, 2010). GKJW also has the same building characteristics that specify the East Java building in rural areas although the layout is not always the same. The difference in the layout becomes the building typology in this study. As a place of worship along with variative activities always support its parishes to be involved in missionary activities at the church. To fulfil the parishes need with the activities, it is planned that there is a church that can suit the need (Hapsari, 2010). Generally, the holy service at GKJW is done 4 times every week; at 06.00, at 08.00, at 16.30 and at 18.30. This schedule may vary from one church to another because it is suited the number of the parishes in each area.

Lighting has a deep effect in human life, it has the main function as vision needed in all activities and building types. The light entering the building through the window will give the sense of dramatic, as an implementation of lighting factior and religious concept. The darker light entering the building will make the people feel more sacred when they have the worship service. In a religious building, the direct sunlight becomes a vital issue that has to be faced by the designer (Mazloomi, 2010). Besides that, lighting will influence the building shape and the availability of artificial light by the means of electricity becomes the last option for the designer. In GKJW building, lighting design should play an important role. In fact, artificial light is commonly used in 4 building tipology while the service is done. The consideration on lighting type and shape as well as the width can create integrity in GKJW building. The lighting quality from the top will give a transcendental effect. According to Barr (2006), the aim of designing the light in a church is a way for the church leader to sense the God presence in the worship. This thing makes the researcher curious and wants to evaluate deeper on the light quality entering the church while the service is conducted. To know and to evaluate the lighting quality in GKJW, the researcher uses the measurement of DF.

II. METHODS

2.1 Building Typology

The building typology taken is the GKJW churches in Surabaya as they represent the existing population. The spesifications on the building typology taken in this research are as follows:

a. A one-storey building with a rectangular layout representing 110 church congregations,

b. A two-storey building with a rectangular layout representing 28 church congregations,
c. A one-storey building with the cross layout representing 4 church congregations,
d. A two-storey building with the combined layout of rectangular and trapezium representing 16 church congregations.

Those 4 building typologies are represented by GKJW Sidotopo (building I) which is a one-storey building with a rectangular layout, GKJW Ngagel (building II) a two-storey building with a rectangular layout, GKJW Surabaya (building III) with the cross layout and GKJW Sukolilo (building IV) which is a two-storey building with the combined layout of rectangular and trapezium.

2.2 Daylight Prediction

A lot of designers find difficulty in predicting the light distribution in a religious building which is commonly stated as DF due to the complexity of the building interior (Mazloomi, 2010). As an example, GKJW needs lighting based on its DF standard. If it doesn't fulfil the DF standard, the parishes as the users of the church will not feel sacred during the worship and the essence of sacred is not achieved. The key parameters that may set the DF standard are:

(1) Orientation. The South orientation is the best for natural lighting. South area will receive a consistent sun light during days and years (Lechner, 2001).
(2) Shape. In the square layout, 16% cannot receive natural light and 33% can get the natural light. In rectangular layout, the center area will not receive any lighting; however, it still has wide area that receives the sunlight (Lechner, 2001).
(3) Opening. Opening which is set higher in every wall will give the same distribution of light to each room corner compared to the lower opening (Heerwagen, 2004). Besides that, according to Szokolay (2004) the effect on size, form, and opening position in natural light distribution may vary. As an example, if the opening on the side wall is varied in its width, the opening ob central room with the varied width and opening with the varied height, the opening above the head is varied in the height.
(4) Color. Interior with bright color does not only spread the light deeper into the room but also reduces the dark shadow, glare and too high ratio of brightness. The ordered level of the surface is roof, back wall, side wall, floor and furniture (Heerwagen, 2004).
(5) The brightness ratio. Eyes are very sensitive to brightness ratio which is near to the center of sight. (Lechner, 2001).
(6) Illumination level. The level of brightness equals to the level of illumination (Lechner, 2001).

According to Li et.all (2009) and CIE (*Commission Internationale De L'Eclairage*), the DF measurement is implemented when it is cloudy because this measurement is often used to overcome the lighting problem when the sky is cloudly. Meanwhile, according to Mazloomi (2010) DF is a light level ratio at mid day from the inside

point of the room with the line outside the room on the horizontal line accepting illumination from the sky. This is stated within the percentage as follows:

$$DF = \frac{Ep}{Ee} \times 100 \quad \ldots\ldots(1)$$

In which DF is daylight factor, Ep is lighting from the room inside and Ee is the lighting from the outside part of the room. The DF concept is only applicable when the sky has the equal spread of light (*overcast*) and there is no direct sunlight. The recommended DF score for religious building in UK according to Heerwagen (2004) based on *Illuminating Engineering Society of London* is 1% in the main area of the building (figure 1).

The determining point in this research will become the main rule so that it can ease the measurement process and make the process faster (figure 2). The measurement spots are in working field with the distance of 75 cm from the floor (Setiawan, 2010). In this study, the measurement is done 3 times which are at 08.00, 12.00 and 16.00 (sni-03-6197-2000), besides, the measurement can be done both inside and outside the room simultaneously so that we can reach a valid DF score.

III. RESULTS and ANALYSIS

Based on the measurement in the field, the ratio value from the spot inside the room with the line outside the room in horizontal field that receive illumination from the sky is Building I at 08.00; 12.00; 16.00 in order are 0,3; 0,5; 0,8. Building II, in order are 0,2; 0,1; 0,1. Building III, in order are 0; 0; 0,1. Building IV, in order are 0,1; 0,5; 2. While the value recommended by *Illuminating Engineering Society of London* is 1 (Heerwagen, 2004).

RECOMMENDED VALUES OF GENERAL OR MINIMUM DAYLIGHT FACTOR IN BUILDINGS (AS SPECIFIED BY THE [U.K.] BUILDING RESEARCH ESTABLISHMENT)

BUILDING TYPE	RECOMMENDED DAYLIGHT FACTOR (IN %)	QUALIFICATIONS AND/OR RECOMMENDATIONS
DWELLINGS		
Kitchen	2	Over at least 50% of floor area (minimum of 50 sqft or 4.5 m2)
Living room	1	Over at least 50% of floor area (minimum of 75 sqft or 7.0 m2)
Bedroom	0.5	Over at least 75% of floor area (minimum of 60 sqft or 5.5 m2)
SCHOOLS	2*	Over all teaching areas and kitchens
HOSPITALS	1	Over all ward areas
OFFICES		
General	1	Side-lighted, at a penetration of 12 ft or 3.5m
	2	Top-lighted, over whole area
Drawing offices	6	On drawing boards
	2	Over remainder of working area
Typing and composing	4	Over whole working area
LABORATORIES	3 to 6	Depending on dominance of side or top lighting
FACTORIES	5	General recommendation
ART GALLERIES	6	Maximum on walls or screens where no special problems of fading
CHURCHES	1	General, over whole area
	1.5 to 2	In sanctuary area
PUBLIC BUILDINGS	1	Depending upon function, the recommendation may exceed 1%, but a minimum value of 1% is generally desirable for amenity in most public buildings

Figure 1. The recommended minimum light level
Source: Heerwagen, 2004

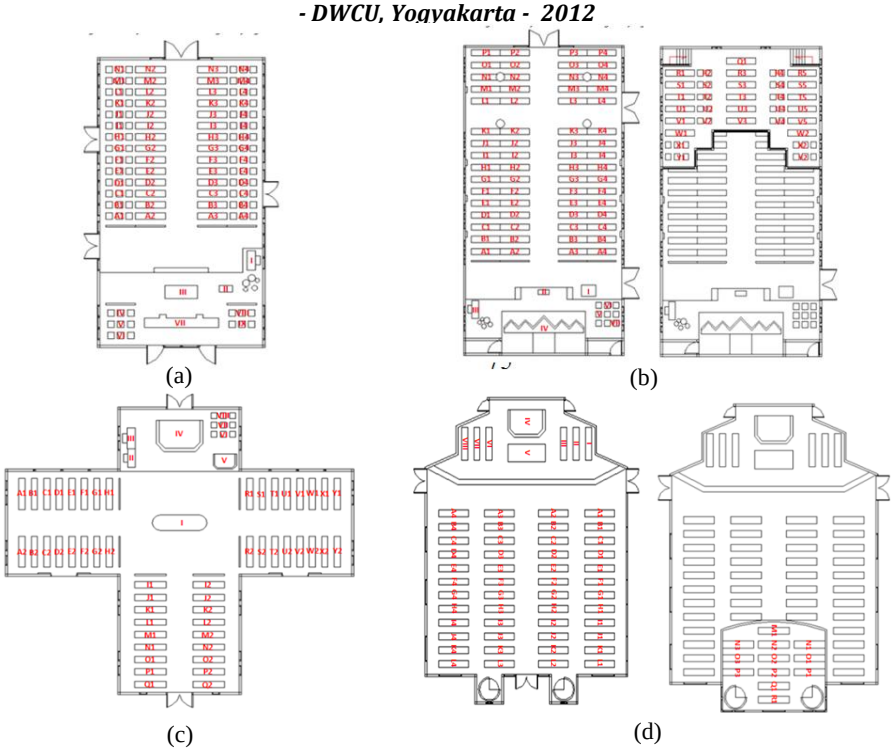


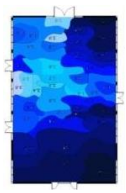
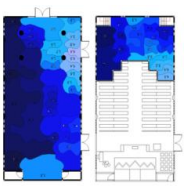
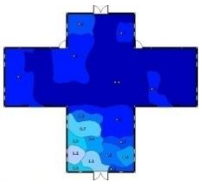
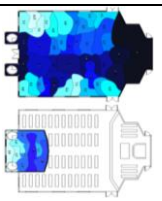
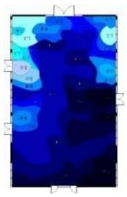
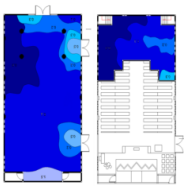
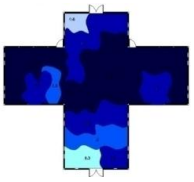
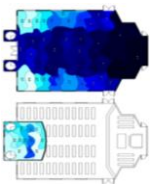
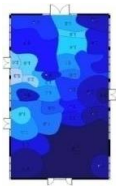
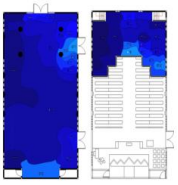
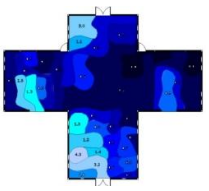
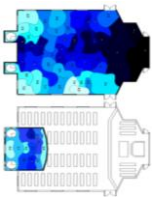
Figure 2. The spots of natural measurement (a). GKJW Sidotopo (Building I), (b). GKJW Ngagel (Building II), (c). GKJW Surabaya (Building III), dan (d). GKJW Sukolilo (Building IV).

It can be said that in Building I while the service is done in the morning, the artificial light is needed so that the DF value can fulfil the required and recommended value, but in the afternoon, it can be said enough although it still has minus 0.2. In the Building II Pada bangunan II, it can be said that DF value is smaller than recommended score so during the service both in the morning and in the afternoon the building needs artificial light. The DF value in Building III is not far from Building II even in the morning during the service, all parts of the building need artificial light. In Building IV, in the morning the artificial light is needed, but in the afternoon the artificial light is not needed as the DF score has been over the recommended value. (Table 1)

The difference of DF value in all 4 typologies consider some parameters such as shape, orientation and opening. In shape parameter (despite the view on the building orientation), building I and building II according to Lechner (2001) can eliminate the center area of the building that does not receive the light because of the rectangular shape of the building. Therefore, the light is enough in the longer side of the building. However, in the building in this shape, there is area that receives the light partially that is in its wide side. In building IV is not far from Lechner theory, although in the wide modified sides, light can enter maximally compared to building I and II which are unmodified. In Building III has the main problem that is found in room with the cross shape that is the 2 directions (Krier, 2001). It shows that the

interpretation of 2 similar type of rectangular shape will make someone feel that she / he becomes the center. It can be said that the parishes inside the church will direct the attention and concentration to the altar area.

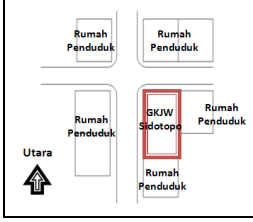
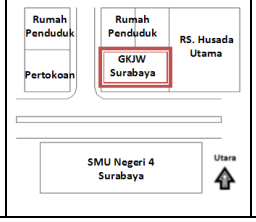
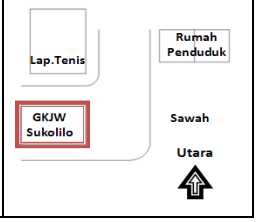
Table 1. The average DF score in 4 building typologies

No.	Time Remaks	Building I	Building II	Building III	Building IV
1.	08.00				
2.	12.00				
3.	16.00				

According to Lechner (2001), South orientation is the best in natural light. The south will receive the sunlight consistently throughout the days and years. However, in this study, this theory doesn't fit the fact. The building facing the south is Building III (South-West), the altar area in this building also faces the south. The DF score in this building is lower than the others. Besides facing the South, the other better orientation is North facing (Lechner, 2001). The north also gets regular and constant light although the amount and the the quality are less but acceptable. The building facing the north is Building I (west-north) and II (north-east). The theory stated by Lechner in this building does not match because the DF value matches the Heerwagen recommendation during the worship time. The worst orientation is facing east and west (Lechner, 2001). These two orientations will only get sunlight half part every day and even it leads to glare and shadow. The building facing the east is Building IV. Although based on the theory stated by Lechner it is not good, in fact, the DF value of building IV is above the recommended score. The explanation above can be seen in the following table 2.

Opening. According to Heerwagen (2004), the opening that is set higher on the wall will give an equal light distribution on every corner of the room compared to opening that is set lower. According to Szokolay (2004) the effect of shape, size and the opening position in the natural light distributin can also vary. In Building I the opening is at 75cm high from the floor and there is another opening at 2,85cm high. Meanwhile, in Building II, the opening is at 3.95cm high. Although it has the same rectangular shape, building I and II have different DF value. The theory stated by Heerwagen in this building is not completely right because in Building II the DF value is lower than Building I. However, if it is seen based on the theory stated by Szokolay the difference of DF value in Building I and II are corret.

Table 2. The orientation on 4 building typologies

Building I	Building II	Building III	Building IV
			

In Building III the opening position is at 1.50cm high and in Building IV, it is 75cm high from the floor and also 3.25 cm high from the floor (table 3). Being compared to building I or II, building IV matches Heerwagen theory more, in which that if the opening is put higher on the wall will give an equal distribution of light to all room corners compared the lower opening. Similar to it, Szokolay stated that opening on the wall has different width although in Building II there is an opening above the head (skylight).

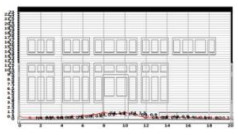
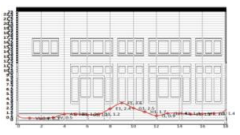
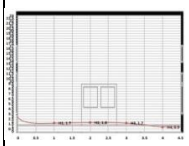
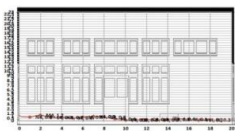
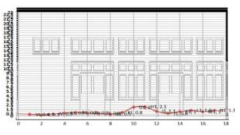
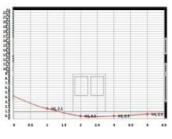
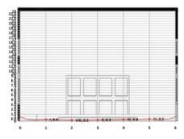
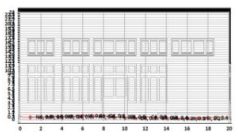
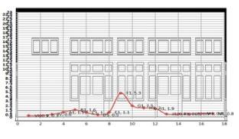
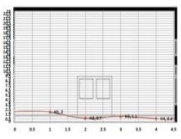
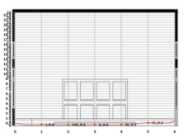
IV. CONCLUSION

Each church has its own standard in lighting so we need a precise measurement. In GKJW building typologies in which the building uses more artificial light than natural light, there are some parameters that influence. They are orientation, shape, and opening. Therefore DF measurement is needed so that the lighting inside the building can fulfil the recommended standard. DF ratio for high opening is smaller than it is in bigger opening.

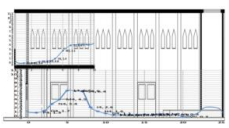
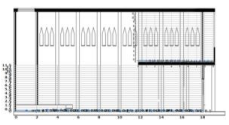
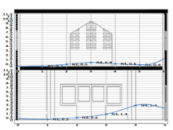
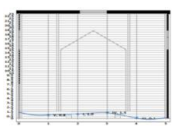
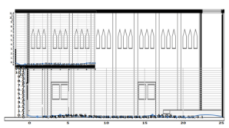
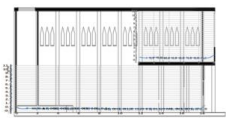
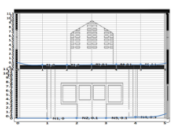
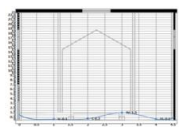
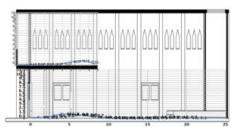
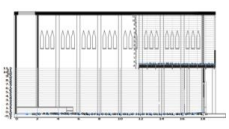
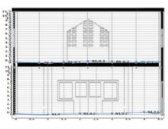
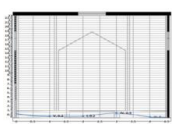
The lighting quality in GKJW building typologies should be the same although the quantity may vary. Besides that the lighting quality is playing its important role in setting the room ambiance.As indicated in this study, building III is an old church building that does not have wide opening as other do. Building I,II, and IV, however, is new churches buildings that have wide opening; therefore natural light can enter the room optimally. The consideration on the light type, shape and form

and width of opening can create integrity in GKJW interior. The above light quality will give a transcendental effect.

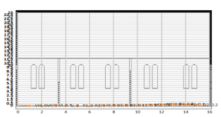
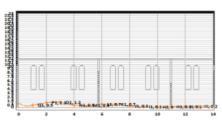
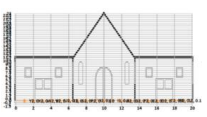
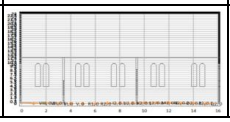
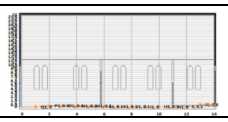
Figure 3. DF graph in 4 building typologies

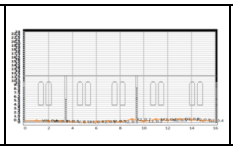
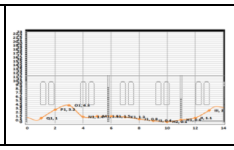
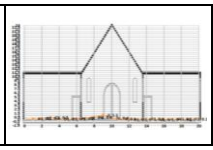
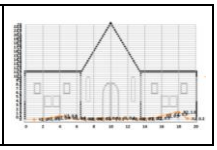
Time Remaks	A-A'	B-B'	C-C'	D-D'
08.00				
12.00				
16.00				

(I)

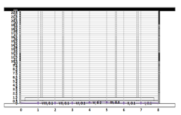
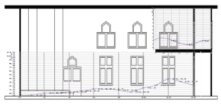
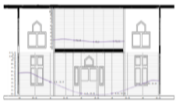
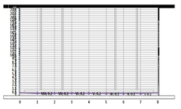
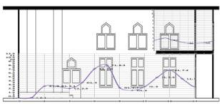
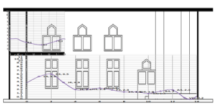
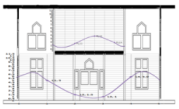
Time Remaks	A-A'	B-B'	C-C'	D-D'
08.00				
12.00				
16.00				

(II)

Time Remaks	A-A'	B-B'	C-C'	D-D'
08.00				
12.00				

16.00				

(III)

Time Remaks	A-A'	B-B'	C-C'	D-D'
08.00				
12.00				
16.00				

(IV)

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