Quantity of Light Through Glass Block Wall

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ABSTRACT

Glass block as building material has many advantages. As transparent material, glass block can both transmit and diffuse light penetrate it. There are many kinds of glass block pattern and color which can affect the light transmission. This research attempts to seek the quantity of light through glass block wall. The research was conducted by field experiment using 5 model boxes, size 1m x 1m x 1m; they were 3 mm standard clear glass, three different glass block types and one with 1 side remained open, called under-shade. The measurement found that glass block pattern and its structural depth reduced the light quantity and increase uniformity toward the center and the ceiling position compared to 3 mm standard clear glass.

***Keywords**: glass block, light quantity, light transmittance.*

1. Foreword

1.1. Glass as an External Wall

Some intention using transparent material as building facades are as follows: for aesthetic building elevation, for interaction from the user inside to the building environment outside, to apply daylight into the room, etc. Contrary to this, the heat as produced by a long-wave sun-radiation can raise the room indoor temperature. That's why in selecting glasses shading coefficient is of the most important factor. (Givoni 1998:58) Later on, in the development of glass as a building façade, we face on some selection in transparent-translucent material such as a refracting glass and or a prismatic glass-block.

Glass-block has been popular as a building material, especially as non-structural wall. It's produced in many kinds of pattern and colors in order to bring aesthetics into the room. It has advantage to make a curve as well as straight wall, and also besides its performance in maintenance, the hole inside can raise its thermal capacity and its quality to block the sound.

Light performance of glass-block made by its capacity to transmit light and shade given into the room. Sometimes using glass-block as a material depends on its performance to reduce the light penetrates it. But mostly, the user hopes not the heat but the light comes in. So, how the patterns perform different penetration of light or illumination will be researched further. The method of findings the percentage of light brought by comparing some patterns of glass-block to the standard clear glass.

1.2. Former Idea in Refracting Glass and Prismatic Glass-block Application

Refracting glass can be used to improve the penetration of daylight. A series of horizontal prisms is formed onto the interior surface of the glass. Each prism is designed to accept light from high incident angles and refract it to the far side of the room. Fluted and ribbed glass may be used to do a similar job. The incident light is diffused in many directions by the horizontal flutes, resulting in a certain part of the light being directed to the far side of the room. However, the system does not give efficient optical control and is less satisfactory than a designed refracting glass.(Phillips,1964:100-101)

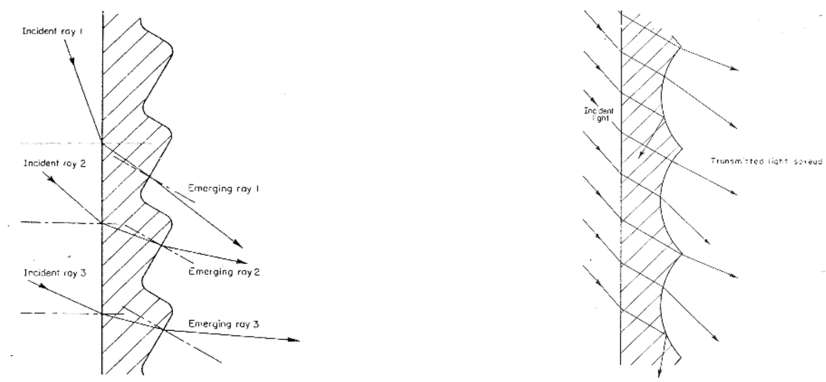

Figure 1.a. Refracting glass used for daylight control; b. Ribbed glass used for daylight control

A more widely adopted method of obtaining increased ceiling illumination and deeper daylight penetration is by the use of structural prismatic glass block and since the prismatic glass block redirects light upward to the ceiling, it will also have the effect of reducing the light toward an observer in the room. It thus acts as a means of controlling the brightness from the sky. (Phillips, 1964: 102)

2. Theoretical Approach

2.2. Terms of Light (and Thermal) Performance in Glass products

In Elkadi, 2006 :

Visible Light Transmittance (VLT) factor is the amount of the visible portion of incident radiation that penetrates a window, expressed as percentage (Button and Pye 1993). A typical clear glass has a visible light transmittance of 60 – 80 %, between about 400 and 2500 nanometres.

The American Society of Heating and Refrigerating and Air-Conditioning Engineers (ASHRAE 1986) defined the shading coefficient (SC) as ‘the ratio of solar heat gain through fenestration, with or without integral shading devices, to that occurring through unshaded 1/8 inch (3mm) thick clear double strength glass’.

Solar Heat Gain Coefficient (SHGC) is gradually replacing the shading coefficient (SC) in glass window literature as the key solar parameter. It indicates how much solar heat is blocked by the window. SHGC differs from the shading coefficient (SC) as it expresses the amount of solar heat that penetrates the window compared with the amount that strikes outside (Saridar 2004)

In 1986, Sweitzer and his colleagues from Laurence Berkley Laboratory suggested the Ke factor, where Ke = VLT/SC (Givoni 1998, Elkadi 2006). This factor is one criteria to evaluate the window's performance. It is helpful in selecting glazing products for different climates, in terms of those that transmit more heat than light and those that transmit more light than heat. The higher the number, the better the glass filters heat from the sun's daylight.

Light Transmission and Refraction of Glass-block :

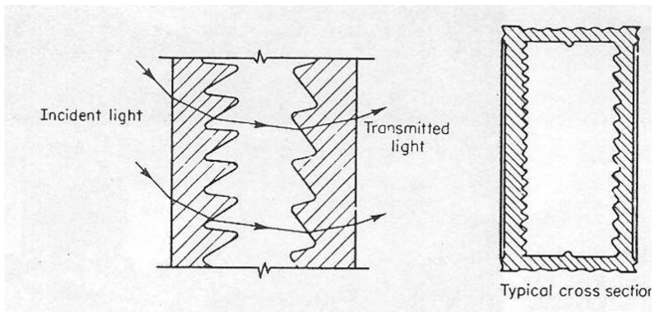

Figure 2. Detail of principle glass-block design(Phillips, 1964: 102)

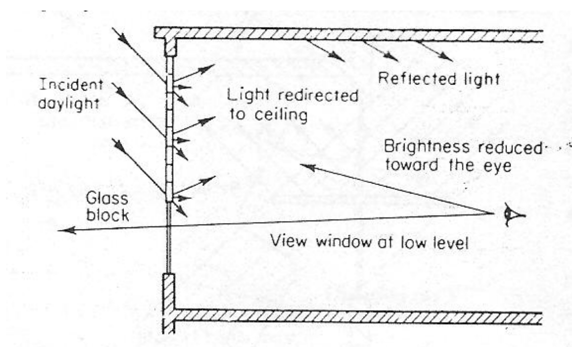

Figure 3. Application of glass-block to assist daylight penetration (Phillips, 1964: 102)

3. RESEARCH METHODOLOGY

This research categorized in experimental research, done using models and field measurement.

3.1. Variables

This experiment using 3 patterns of glass-block that have been popular used in buildings; *Grid pattern*, called Type A; *Wave pattern* called Type B and *Diamond pattern* called Type C. The glass-block color is clear. All variant measure 1m x 1m applied to one side of box model, a modification of Stevenson screen that all other sides are wrapped by black board in order to hinder from interior reflection. Another box models covered with standard 3mm thickness glass as comparable model. And one model with one side remained open called under-shade, also as comparable model.

Figure 4. a. Type A: Grid pattern; b. Type B: Wave pattern; c. Type C: Diamond pattern

Parameter used are illumination (in lux) outside compared to illumination (in lux) inside the model (in lux) ; and the differences between illumination inside compared to outside, in %.

3.2. Research Devices and Models

This research conducted at outdoor deck area of P building 7th floor Petra Christian University, Surabaya-INDONESIA from July to August 2009 using some devices and 5 model boxes as follows:

1 unit lightmeter for illumination measurement outside the models.

Figure 5. Lightmeter tipe AEMC 0814

5 units Hobo data logger for illumination measurement in the models at the same time.

Figure 6. Hobo H 8 and H 12 family

5 units model boxes; which are 1 unit for standard glass measurement, 1 unit for under-shade (one side of box without glass applied) measurement and 3 units for each glass-block type; Type A (grid), Type B (wave) and Type C (diamond).

Figure 7. Unit models

3.3. Variant Point of Measurement position

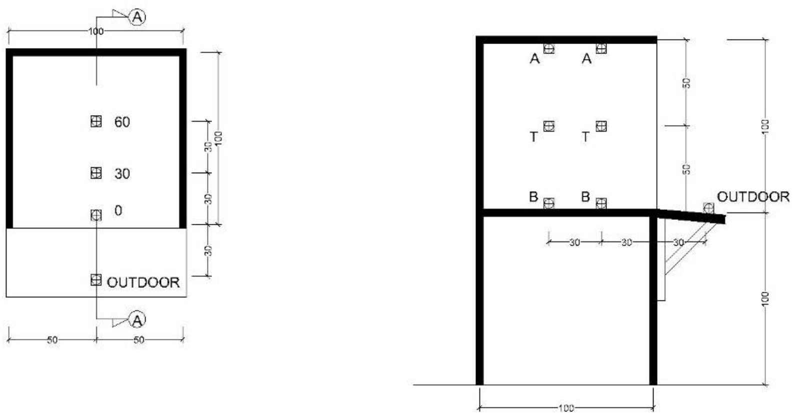

Figure 8. Point of measurement position

Measurement step by step

1. All models at the same time; sensor positioned at 30 cm from perimeter; facing the floor of the box. Called ‘atas_30’
2. All models at the same time, sensor positioned at 30 cm from perimeter; facing the ceiling of the box. Called ‘bawah_30’
3. All models at the same time, sensor positioned at 30 cm from perimeter; facing right-forward the glass plane of the box. Called ‘tengah_30’
4. All models at the same time; sensor positioned at 60 cm from perimeter; facing the floor of the box. Called ‘atas_60’
5. All models at the same time, sensor positioned at 60 cm from perimeter; facing the ceiling of the box. Called ‘bawah_60’
6. All models at the same time, sensor positioned at 60 cm from perimeter; facing right-forward the glass plane of the box. Called ‘tengah_60’
7. Every models, sensor positioned at 30 cm from perimeter; all direction (facing floor, ceiling, and forward the glass-plane at the same time). Called ‘GrupX_30’

8. Every models, sensor positioned at 60 cm from perimeter; all direction (facing floor, ceiling, and forward the glass-plane at the same time). Called 'GrupX_60'

4. RESULT AND ANALYSIS

From the field measurement can be seen that the glass-block pattern made different result of indoor light intensity.

4.1. The result of position 60 cm from the perimeter

For directing the light into the ceiling position, best light intensity got by applying the *Wave* type, followed by the *Grid* type (lower 15.1% than the *Wave*) and the smallest light intensity is the *Diamond* type (lower 59.2% than the *Wave*). Compared to the *standard glass*, the result of *Wave type* lower 4.8%; and lower 64.4% compared to the *under-shade* (the remained open model).

The light intensity profile increased from time to time, start at 06.00 am; 21.5 lux was the lowest intensity of Wave and Diamond type; while the highest intensity was 107.6 lux of the Under-shade. The peak intensity at 11.00 am (Standard glass was 4,131.8 lux and the Wave type was 2,991.3 lux) and at 12.00 am (Under-shade was 5,014.2 lux, Grid type was 1,915.3 lux and Diamond type was 1,205.1 lux. Then the light intensity decreased until 05.00 pm; 53.8 lux was the lowest intensity of Wave and Diamond types; while the highest was Under-shade at 193.7 lux. The result found that all glass-block types give light uniformity better than standard glass which average difference factor was 1.57. The most light uniformity given by glass-block Grid type with 1.36 average difference factor, followed by Wave type with 1.41 and Diamond type with 1.49 as average difference factor of light intensity from 08.00 am to 04.00 pm.

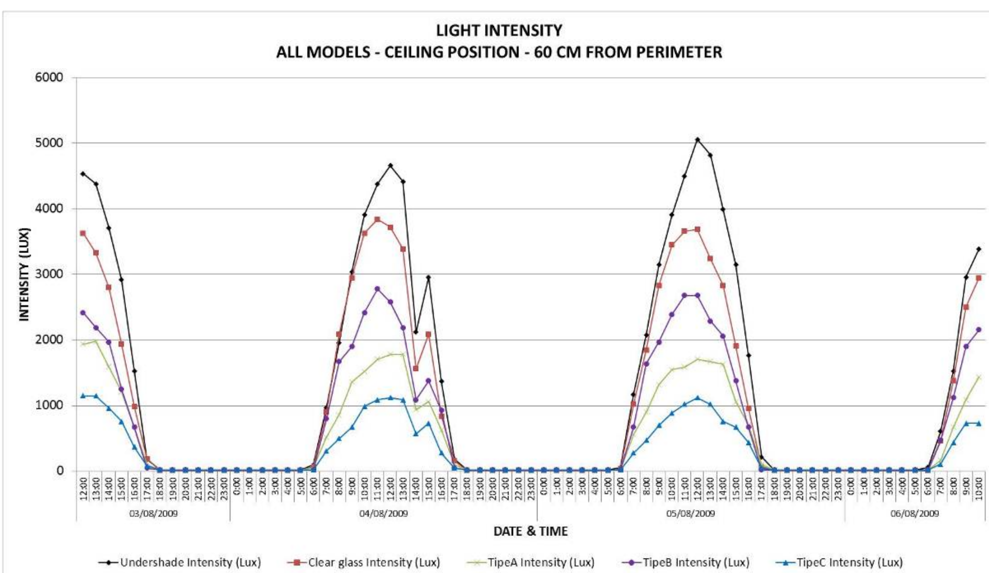

Figure 9. Light intensity of all models at ceiling, 60 cm from perimeter

The same result for directing the light to the center of the box; the *Wave type* still give the best light intensity, followed by the *Grid* (lower 8.6% than the *Wave*) and the *Diamond* type (lower 12.6% than the *Wave*).

The light intensity increased from time to time, start at 07.00 am; the lowest light intensity was 613.3 lux of the Wave type; while the highest intensity was 1130.9 lux of the Under-shade. The peak intensity was 12,195.4 lux for Standard glass at 11.00 am followed accordingly by Under-shade, Wave type, Grid type and Diamond type as the lowest at 7639.6 lux at 12.00 am. The light intensity then decreased until 05.00 pm; 505.72 lux was the lowest intensity of Diamond type; while the highest was Under-shade at 1036.2 lux.

At this position, the most uniformity given by glass-block Diamond type with 1.73 average difference factor, followed by Grid type with 1.76 and Wave type with 1.93 as average difference factor of light intensity from 08.00 am to 04.00 pm. While the average difference factor of standard glass was 1.95.

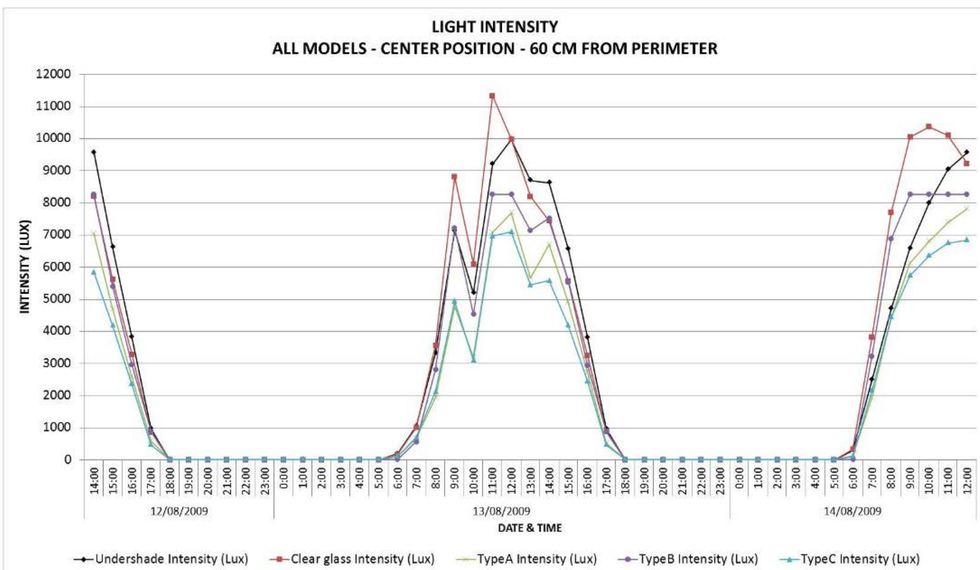

Figure 10. Light intensity of all models at center position, 60 cm from perimeter

The result for directing the light into the floor, the *Wave* type give the best, followed by the *Diamond* type (lower 13.2% than the *Wave*) and the smallest light intensity given by the *Grid* type (lower 19.4% than the *Wave*).

The light intensity increased from time to time, start at 07.00 am; the lowest intensity was 473.4 lux of Grid type; while the highest intensity was 1,474.1 lux of the Under-shade. The peak intensity was 6,122.4 lux for Under-shade at 01.00 pm followed accordingly by Standard glass, Wave type, Diamond type and Grid type as the lowest at 2,291.9 lux at 02.00 pm. The light intensity then decreased until 05.00 pm; 139.9 lux was the lowest intensity of Grid type; while the highest light intensity was Under-shade at 871.6 lux.

At this position, Standard glass brought the most uniformity at 1.41 average difference factor; followed accordingly by Grid type glass-block with 1.44, the Diamond type was 1.45 and the Wave type was 1.53 as average difference factor of light intensity from 08.00 am to 04.00 pm.

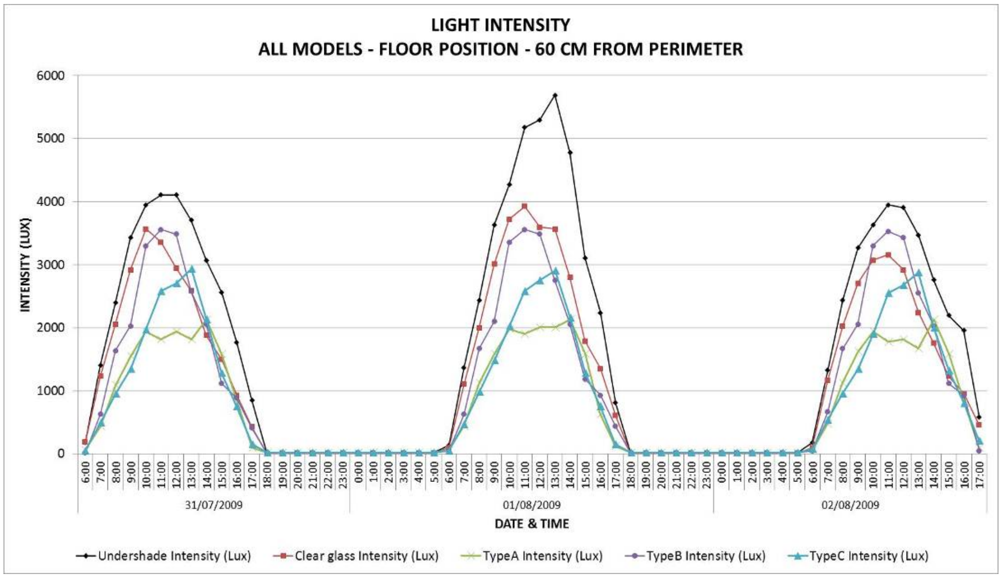

Figure 11. Light intensity of all models at floor position, 60 cm from perimeter

4.2. The result of position 30 cm from the perimeter

For directing the light into the ceiling position, best light intensity got by applying the *Wave* type, followed by the *Diamond* type (lower 12.3% than the *Wave*) and the smallest light intensity is the *Grid* type (lower 18.9% than the *Wave*).

The light intensity increased from time to time, start at 07.00 am; the lowest intensity was 634.8 lux of Grid type; while the highest intensity was 1,258.9 lux of the Under-shade. The peak intensity was 8,349.8 lux for Under-shade at 12.00 am followed accordingly by Standard glass, Wave type, Diamond type and Grid type as the lowest at 3,615.4 lux. The light intensity then decreased until 05.00 pm; 182.9 lux was the lowest intensity of Grid type; while the highest light intensity was Under-shade at 322.8 lux.

At this position, the Diamond type brought the most uniformity at 1.46 average difference factor; followed accordingly by Grid type glass-block with 1.5 and the Wave type was 1.51. While the average difference factor of standard glass was 1.52 from 08.00 am to 04.00 pm.

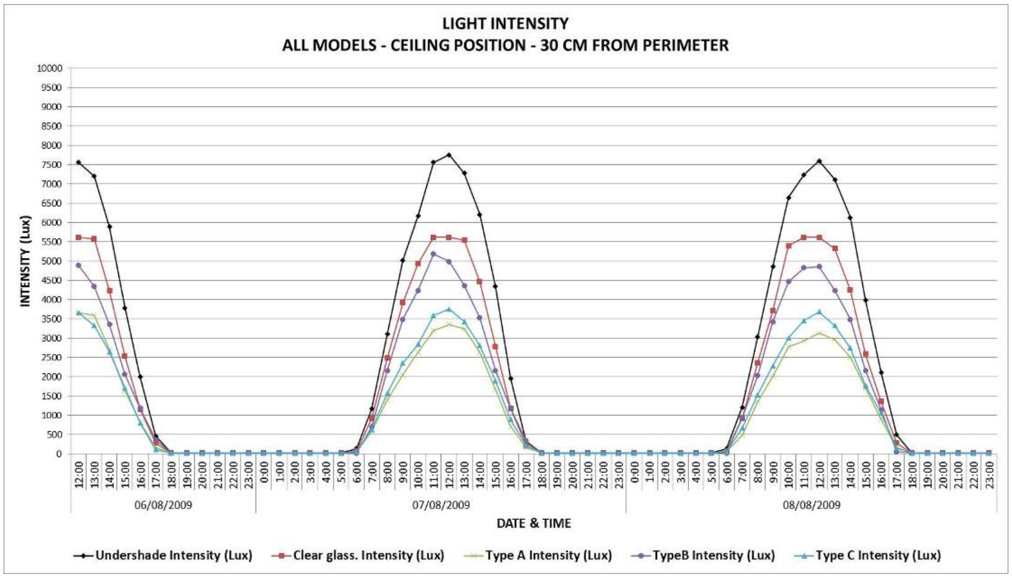

Figure 12. Light intensity of all models at ceiling position, 30 cm from perimeter

Unfortunately, because of the light intensity over the capacity of the devices, this research can not give the result for the center and floor position.

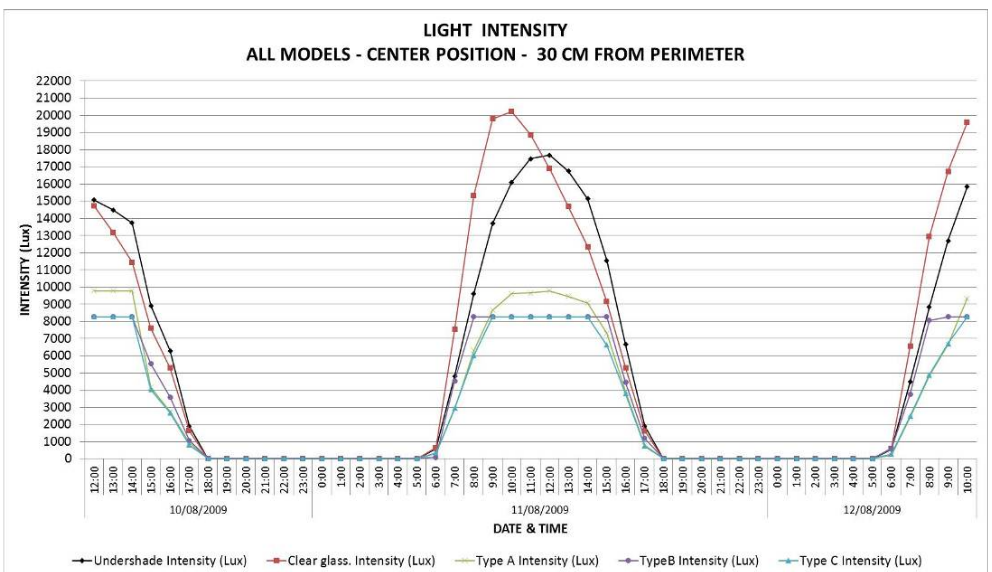

Figure 13. Light intensity of all models at center position, 30 cm from perimeter

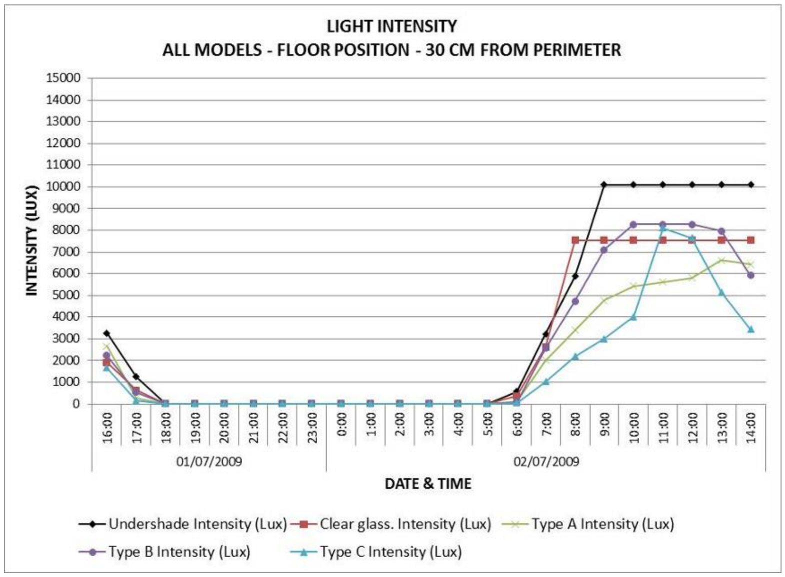

Figure 14. Light intensity of all models at floor position, 30 cm from perimeter

From figure 14, can be seen the differences of the three glass-block pattern; especially for the *Diamond* type, which the light intensity it transmitted between 10.00 -11.00 am rose intensely. This behavior did not happen in the others glass-block type.

4.3. The result of lighting spread at 30 cm from the perimeter

Measurement on undershade model found that light intensity at floor position rose intensely between 10.00 am – 02.00 pm. Unfortunately, the light intensity was over the capacity of the devices. It was recorded that light intensity at 09.00 am was 12.499 Lux; rose exceed than 30.000 Lux and then decrease to 13.300 lux at 14.00 pm. While measurement at center and ceiling position, light intensity increased normally and got the highest level at 12.00 am; 7.233 Lux at ceiling position and 21.834 Lux at center position.

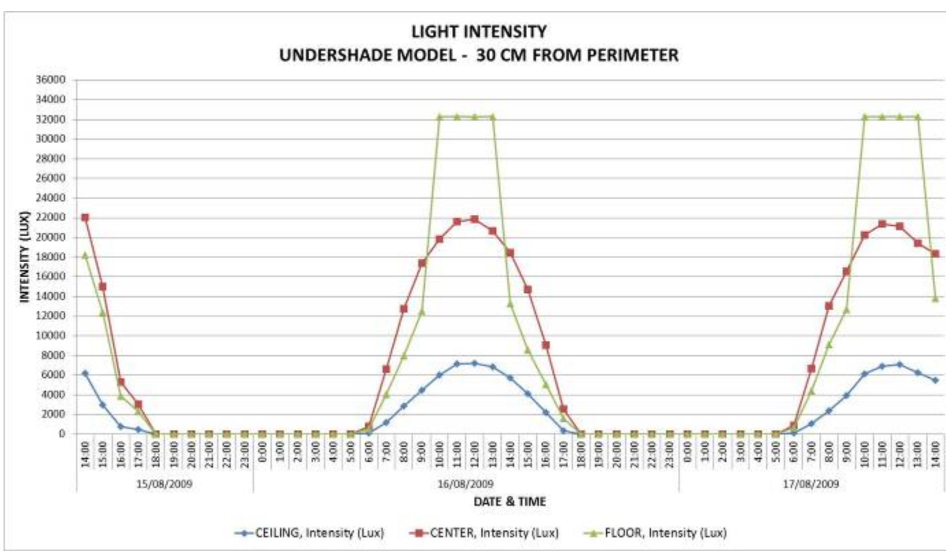

Figure 15. Light intensity of undershade model, 30 cm from perimeter

Measurement on clear glass found that light intensity on the floor position rose intensely at noon. The highest light intensity at 11.00 am was 32.280 Lux, and then decreased at 12.00 am. Light intensity at center position met the highest level at 10.00 am which was 24.530 Lux. Meanwhile, light intensity at ceiling position met the highest level at 12.00 am which was 8.035 Lux (figure 16).

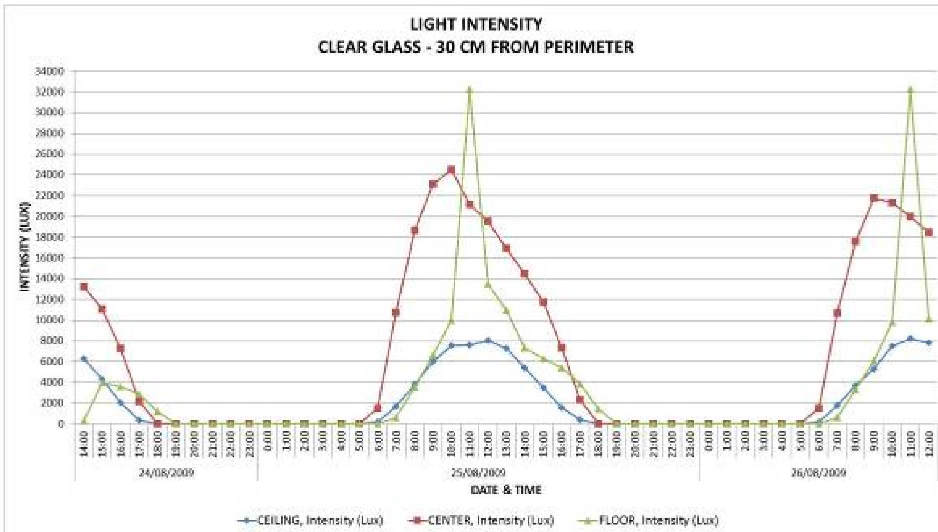

Figure 16. Light intensity of Clear-glass model, 30 cm from perimeter

Light spread at glass block models showed different performance with the undershade and clear glass models. However, from measurement, it was found that the highest level of light intensity was found at center position. From type A (*grid*) measurement at 12.00 am, light intensity at ceiling position was 10.613 Lux; at floor position was 3.939 Lux and at ceiling position was 4.154 Lux.

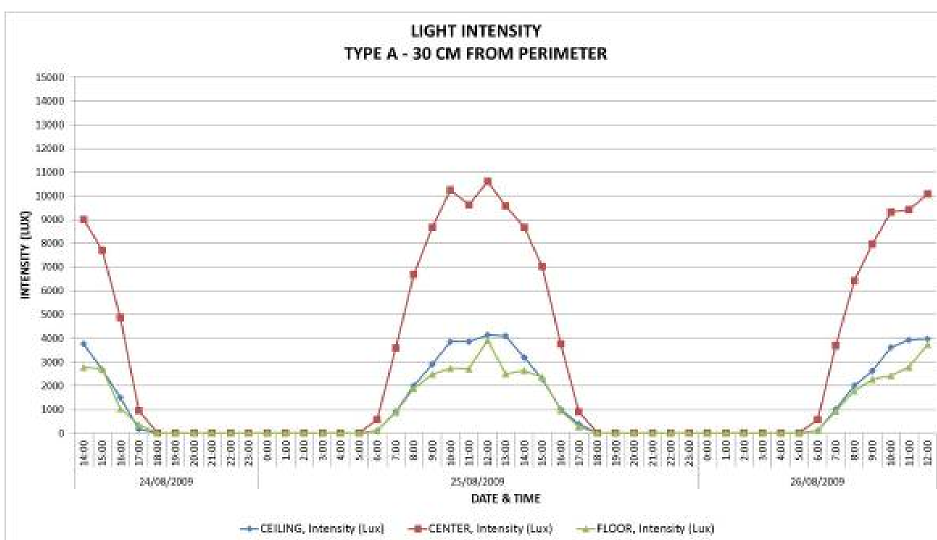

Figure 17. Light intensity of type A model (grid), 30 cm from perimeter

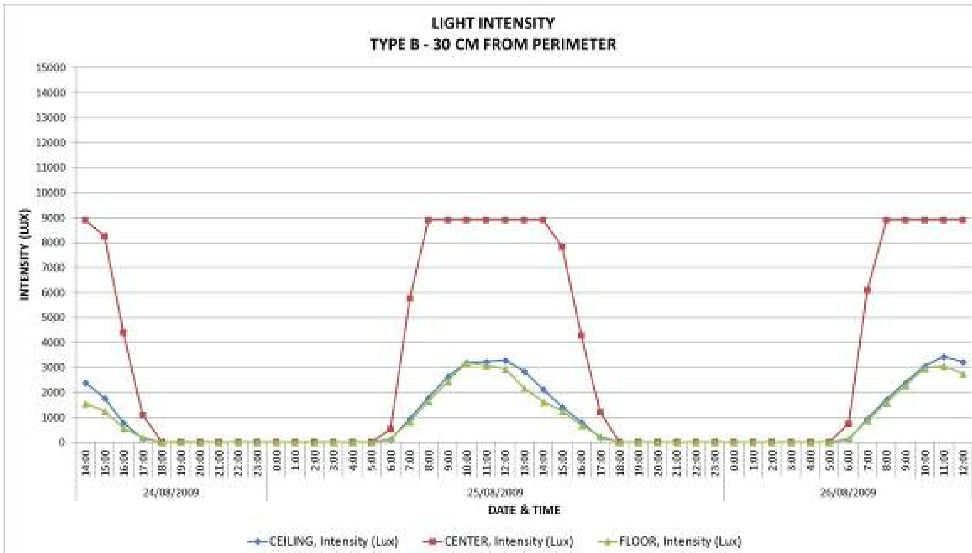

Figure 18. Light intensity of type B model (wave), 30 cm from perimeter

Measurement on type B (*wave*) model found that light intensity at center position was higher than 9000 Lux and the device couldn't record due to over capacity. From figure 18, it can be seen that light intensity at ceiling position was higher than light intensity at floor position. At 12.00 am, light intensity on floor position was 2.933 Lux; on ceiling position was 3.305 Lux.

On the contrary, light intensity of type C (*diamond*) at floor position was higher than ceiling position at noon (11.00 am – 14.00 pm) but lower than ceiling position at morning time and after 14.00 pm (figure 19). At 10.00 am and 15.00 pm, light intensity at ceiling position was about 300 Lux higher than floor position.

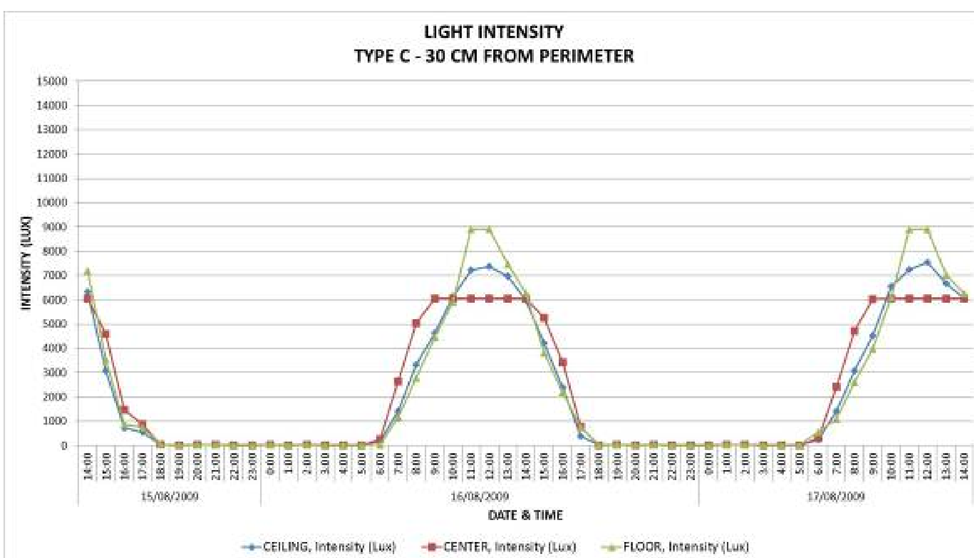

Figure 19. Light intensity of type C model (diamond), 30 cm from perimeter

4.4. The result of lighting spread at 60 cm from the perimeter

Measurement on undershade model at 60 cm from perimeter found that light intensity at ceiling position decreased intensely than the result at 30 cm from perimeter. Highest level found at center position, around 10,000 Lux. While light intensity at floor position was below the ceiling position (figure 17).

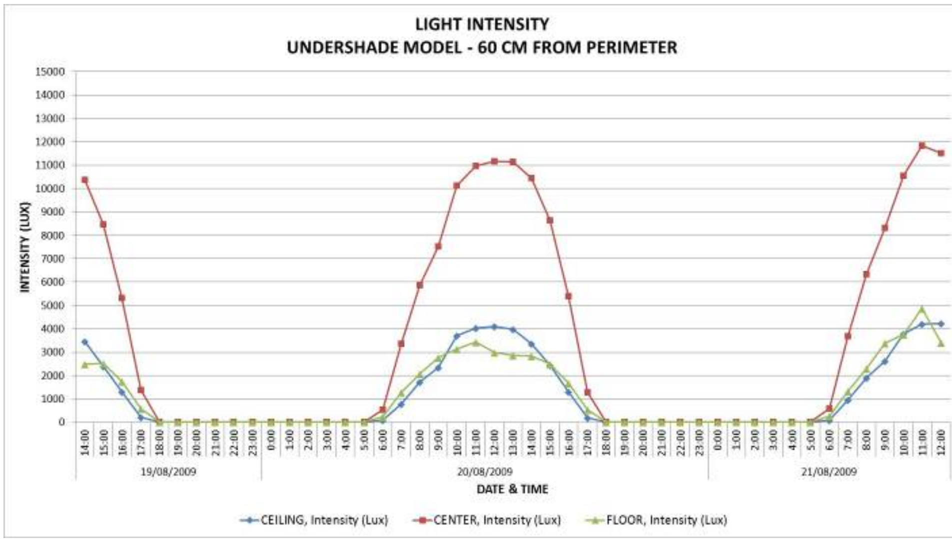

Figure 20. Light intensity of undershade model, 60 cm from perimeter

Meanwhile, measurement on clear glass model found that light intensity at center position was higher than other positions. Lowest intensity found at ceiling position. Same result also found on glass block models. From figure 22, can be seen that type A (*grid*) could direct light to the ceiling position better than to the floor position. Type B (*wave*) directed light equally, both to ceiling and floor position. While, Type C (*diamond*) type could direct light to the floor position better than ceiling position (figure 24).

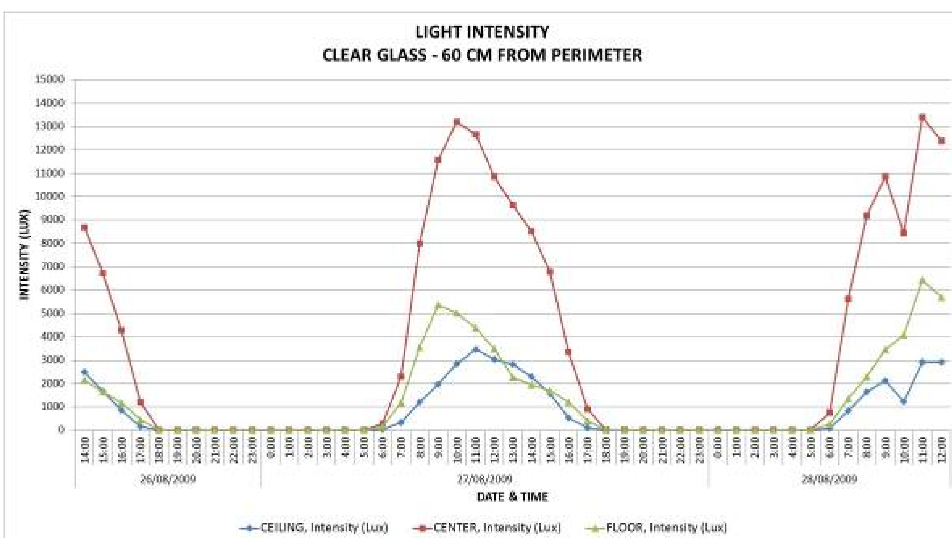

Figure 21. Light intensity of Clear-glass model, 60 cm from perimeter

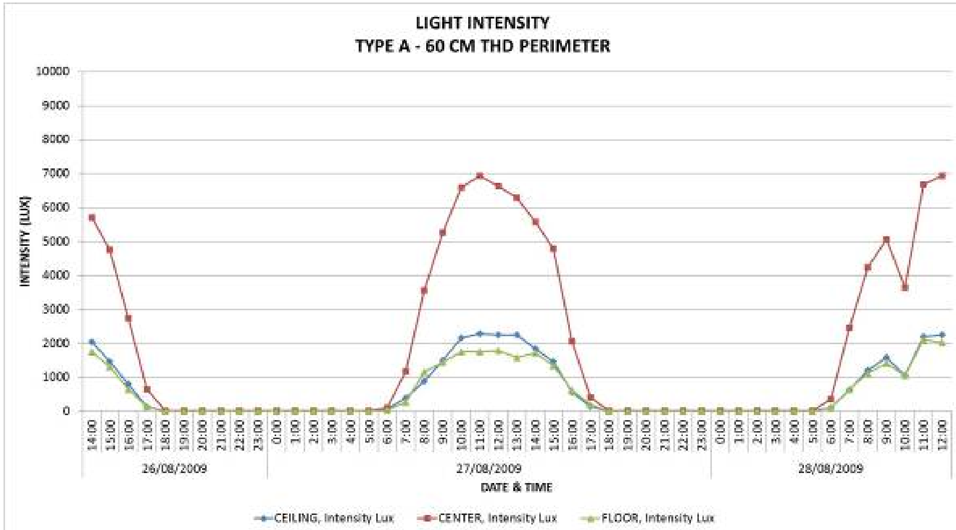

Figure 22. Light intensity of type A model (grid), 60 cm from perimeter

Measurement on type A (*grid*) model found that light intensity at center position was higher than other positions. From figure 22, it can be seen that light intensity at ceiling position was higher than light intensity at floor position. At 12.00 am, light intensity on floor position was 1.798 Lux; on ceiling position was 2.250 Lux; on center position was 6.641 Lux.

Measurement on type B (*wave*) model found that light intensity at center position was still be the highest value than other positions; similar phenomena with measurement which conducted at 30 cm from perimeter. Unfortunately, the device couldn't record the precise value, but from figure 23, it can be seen than light intensity at noon was higher than 9000 Lux. Light intensity at floor and ceiling position had insignificant differences. Compare to the measurement on type A (*grid*), type B (*wave*) transmitted light in large amount to the center position; light intensity at floor and ceiling position was reduced.

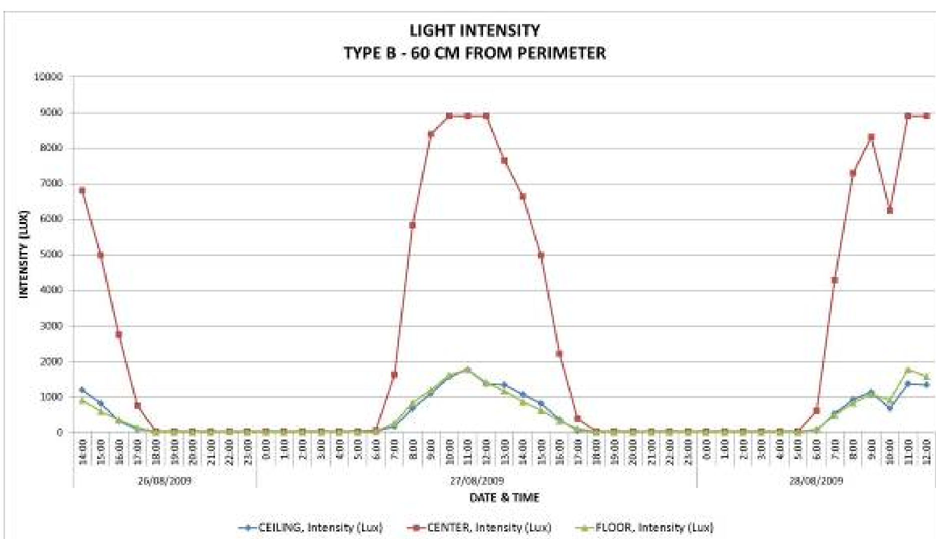

Figure 23. Light intensity of type B model (wave), 60 cm from perimeter

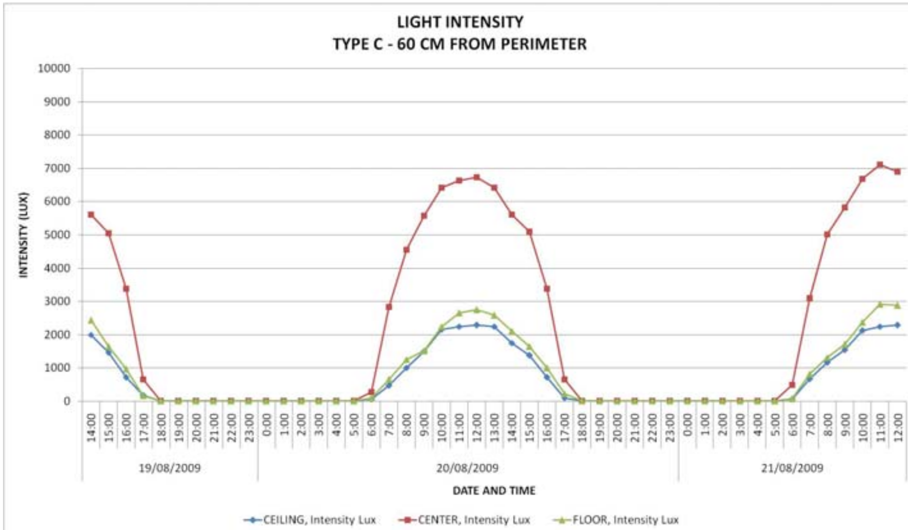

Figure 24. Light intensity of type C model (diamond), 60 cm from perimeter

Type C (*diamond*) model showed different result. Light intensity at center position showed same behavior with type A (*grid*) model. But, different with type A, light intensity at floor position was higher than ceiling position. Light intensity at floor position was about 250 Lux higher than ceiling position.

5. Conclusion

This research which was conducted in 24 hours a day conclude,

1. Compared to the standard glass, the thickness of glass-block structure decrease the light intensity, it transmitted and raise the uniformity toward the center and ceiling position.

2. Different pattern of glass-block produce different light spread to the room; since the pattern in its structure influenced different light diffraction.

3. Since the light intensity data show that any glass-block has different direction of light distribution, it is recommended to select carefully the pattern of glass-block to get a special effect for different type of room. Pattern of glass-block can lead the light to different direction eg. To ceiling, to the right or left side of room.

4. For direct lighting requirement, the best would be the standard glass and or the remained open one.

5. For indirect-diffused lighting, a more privacy room condition and protective wall, glass-block is the preference

6. If the goal is the highest light intensity into the room, the opening without glasses is still better than the glass-plane façade which reflects only some portion of light to the external side.

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