DIMENSI TEKNIK ARSITEKTUR Vol. 32, No. 1, Juli 2004: 68 - 76

A PRELIMINARY STUDY ON VEGETATIVE SHADING TO MINIMISE GLARE

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ABSTRACT

In low cost housing of warm humid regions where natural ventilation is usually employed, the presence of large openings will also cause unnecessary glare and heat gain of solar radiation This paper reports a preliminary study to handle glare issue without impairing natural ventilation. The use of climbing vegetation planted on a frame with fully adjusted foliage dense as shading devices is investigated. The frame is placed at the most possible position of the low cost housing and two variables, i.e. foliage porosity and leaf surface reflectance is studied using two computational simulation methods. Radiance is employed to calculate glare index after the vegetative shading and Brevent is used to assess ventilation flow rates occurred indoors toward indoors thermal comfort of the modelled housing. The study indicates that using climbing vegetation is possible for both reducing glare and supplying the required ventilation flow rates at the same time.

Keywords: glare, vegetative shading, ventilation flow rates

INTRODUCTION

The sun offers so many advantages for us. However, some disadvantages do exist, such as unnecessary glare of solar daylighting and too much heat gain, especially for those living on the tropics. In order to control heat gain, buildings shall have edequate both of natural or conditioned means. For building employing natural ventilation such as domestic low cost housings, the presence of large openings is necessary to create adequate natural ventilation. However, such openings like windows and doors are critical elements where glare and heat can easily enter. The level of glare and heat entering openings depends upon their positions (both horizontally and vertically), dimension, materials, and possible shading devices (Givoni, 1976). When glare and heat enter the buildings too much, these should be intercepted with shading devices at the outside of a window -not inside the window-, because once the sun's rays pass through the glazing, they are in the building for good (Johnson, 1981). Since the presence of openings is of importance and shading devices to control glare and heat gain is also required, a compromised design of shading devices to do the task but not impair the airflow is considered. This study will then redefine the most effective position and dimension of shading devices to reduce glare, assess the glare index, and assess the ventilation flow rates. Since earlier studies show that vegetation is capable of creating microclimate condition to lower indoor heat gain, the use of vegetative shading is proposed.

THEORETICAL APPROACHES

Controlling Glare of Daylighting

Glare is the discomfort or impairment of vision caused by an excessive range of brightness in the visual field result of any unwanted light in the visual field (McMullan, 1992). Most glare issues arise on sunny days, but cloudy days can also cause some forms of glare. There are two type of glare, i.e. disability glare and discomfort glare. Disability glare is the aspect of glare that lessens the ability to see detail, which does not necessarily cause visual discomfort (McMullan, 1992). Disability glare depends upon the location of the aperture with respect to the field of view, the size of the aperture, and the brightness of the source of light seen through the aperture. The effect of disability glare is particularly pronounces in the elderly because the internal eye fluid becomes cloudier, resulting in more light scattering. Disability glare can be overcome by reducing contrast by raising the light surrounding the object. Discomfort glare is the glare that causes visual discomfort without necessarily lessening the ability to see detail (McMullan, 1992). The amount of discomfort depends on the angle of view and the type of location. A common example of discomfort glare caused by sunlight for inhabitants happens when areas of sky are seen against dark mullions, dark mouldings or other dark surfaces adjacent to the window. Discomfort glare is the glare type that will be alleviated by such design strategy in this paper.

The research drawn of this paper would not go beyond such qualitative assessment, partly because except what has been discussed above, glare is a very subjective phenomenon, depending very much on human expectation, adaptability and mood. However, still, there are some quantitative assessment could be made to measure whether such condition causing glare, such as using the day lighting glare index. Glare Index is a numerical measure of discomfort glare to be assessed and acceptable limits recommended. Glare is determined by:

$$G = K\left[\frac{L_s^{1.6}\Omega^{0.8}}{L_b + (0.07\omega^{0.5}L_s)}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

And Glare Index (GI) is found from:

$$GI = 10\log_{10}\Sigma G \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Glare Index is an index of glare uses to measure whether source of glare causes glare for given visual tasks. A typical recommended glare index is 19, the minimum is 10 and the maximum is 30. There are several different glare indexes can be adopted as standards of measurement (Koenigsberger et al 1973, Szokolay 1980 and Robbins 1986). However, in general most of the standards have no significant different and is resumed in Table 1.

This study mostly focuses on intolerable to uncomfortable glare.

Prospect of Using Vegetation

Vegetation creates canopy to protect objects down the canopy from climatic condition, such as solar heat, sunlight, and rain. Vegetation canopy is also considered capable of diffusing sunlight thus reducing glare. This consideration is supported by fact that vegetation could also create micro- temperature under the canopy which in most cases lower than the macro-temperature. Trees are the best types of vegetation to create canopies. Unfortunately, trees are not always available in the required position and planting takes time to mature. Fast growing vegetation such as shrubs, climbing, or hanging vegetation is preferred. However, because they grow short, shrubs and bushes are not capable to shade building and thus incapable to create microclimatic condition and to reduce glare. They also, in some cases, grows to fast and thus block the entire airflow and difficult to maintain. The ideal is likely to be climbing vegetation that is planted on a self-designed frame or hanging vegetation placed on containers. These types of vegetation allow us to adjust their thickness and position to suit the requirements. Climbing vegetation grows at the ground whilst hanging vegetation grows on soil put in containers hanging metres from the ground. Based on the easiness of grow and maintain, climbing vegetation which is deliberately grown on a self designed frame is selected for this study. The selected vegetation has to meet several requirements to perform a good diffuser for reducing glare, as follows (Johnson, 1981):

- View to the outside cannot be impaired

Table 1. Glare Criteria and Glare Index (After, Koenigsberger et al 1973, Szokolay 1980 and Robbins 1986)

Visual Task	Maximum Glare Index	Mean Response to the Maximum Glare Index
Exceptionally severe task (working with very small instruments, such as watch making or repairing)	10	Imperceptible
Very severe, prolonged task (such as gem cutting)	13-16	Perceptible
Severe, prolonged task (such as fine assembly)	16-22	Acceptable
Fairly severe task, small detail (such as drawing)	19-22	Acceptable
Ordinary task, medium detail	25	Uncomfortable
Rough task, large detail	25-28	Uncomfortable
Casual seeing	28	Intolerable

- The diffuser cannot become a bright source of light
- Light must be broken up and distributed uniformly
- Solar gain must be maintained
- Ventilation must be possible

Concerning the last requirement of permitting natural ventilation, the most important characteristics of vegetation to be assessed are position, dimension, and porosity. Whilst for minimising glare, beside the above requirements, the most important characteristic is position, dimension, porosity and surface reflectance. Surface reflectance is represented by the unique surface of leaf such as furry or hairy (less reflective) and waxy or shiny (more reflective).

Controlling Heat Gain

Once shading devices to control glare and reducing heat gain are installed, it is then important to assessed whether the elements impairing indoor ventilation. There is a mechanism to detect whether indoor environment having adequate ventilation flow rates, i.e. by calculating the amount of air change per hour (ach). Air change per hour (ach) is a value without any particular unit and always relates to the volume of the room to where the value of air changes per hour should be supplied. For example if a room with a volume of 150 m^3 requires 30 air changes per hour to maintain indoor thermal comfort, the air to be supplied is 150 m^3 x 30 = 4500 m^3/h (1.25 m^3/s). There is a guidance to adopt in supplying adequate ventilation for different purposes (Table 2). When this is obeyed, a postulation could be drawn that heat gained indoors has been perfectly controlled.

Table 2. Ventilation Rates for Specific Purposes (After EnRei Report, 1995)

Ventilation Purposes	Suggested Ventilation rates (Air change per hour)
Health	0,5 –1
Comfort	1-5
Comfort Cooling	5-30

Those living in warm humid climate are suggested to adopt the comfort cooling ventilation rates at 30-air change per hour to achieve indoor comfort (Moore, 1993).

OBJECTIVES

The objective of this study is to see possibility of using vegetation as shading devices to control daylighting-glare without impairing the openings beyond the devices to ventilate indoor environment.

METHODOLOGIES

Methodologies carry out in this study are as follows: reference study to find and redefine possible design strategies, modelling building design and building elements referring to theoretical approaches and field conditions, and examination using two computational simulations to calculate Glare Index and to assess ventilation flow rates.

MODELLING THE OBJECT

The first step of this research is to develop building model referring to particular location of the warm humid region. This model is required for both glare and ventilation flow rate calculation. Location selected for the model is Yogyakarta. The reason of choosing Yogyakarta is as follows:

- The city is located on the tropic with abundance sun light where discomfort glare potentially occurs
- Earlier research which provides secondary data for this research was held in Yogyakarta
- This research is a continuation of earlier research investigating a phenomenon of low cost housing and such design strategies to apply in providing comfort in the indoor environment in natural means.

The model is adopted from a low cost housing, i.e. approximately 45 sq.m, based on postulation that low cost housing is generally incapable of employing conditioned ventilation to control heat gain and of using coated glass window to reduce glare. Within low cost housing that employs natural ventilation and uses ordinary window glassing, the presence of such additional element to control heat gain and glare is necessary. The most effective low cost housing layout to maximise natural ventilation is in ‘L’ shape (Mediastika, 2000). The most effective model of window to drive airflow is a combination between jalousie and casement windows (Mediastika, 2000).

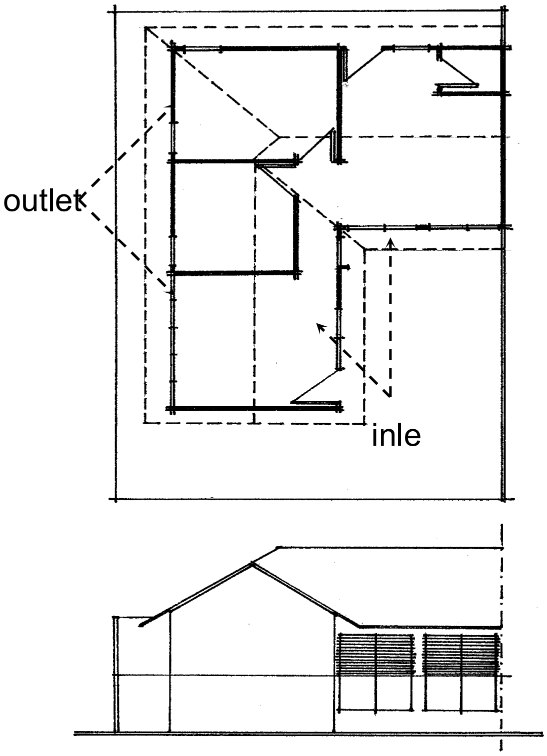


Figure 1. Plan and Front Elevation of The Model (After Mediastika, 2000)

When housing model including its openings have been determined, the next stage is to build a model of vegetation that will effect both glare minimisation and natural ventilation. Variant of vegetation to be modelled for glare assessment is porosity and leaf reflectance within a fixed position and dimension selected manually from the most possible condition.

COMPUTATIONAL SIMULATION

RADIANCE to Calculate Glare

RADIANCE was developed as a research tool for predicting the distribution of visible radiation in illuminated spaces. It takes as input a three-dimensional geometric model of the physical environment, and produces a map of spectral radiance values in a colour image. This allows the user analyse opening design strategy to optimise the efficiency of day lighting systems and lighting technologies. Desktop Radiance is a plug-in module that works with other popular computer aided design (CAD) tools to provide the user interaction and 3-d modelling capabilities. Desktop Radiance relies upon the popular Radiance Synthetic Imaging System to provide its renderings and analytical results. The first step in the process of performing a day lighting analysis is the creation of a 3D model in a Graphic Editor program. In this study we use AutoCAD to set the model. The 3D model then to be detailed appropriately using the Desktop Radiance library of materials, glazing, luminaries and furnishings. Once the model is complete, the next stage is to define the analysis parameters, i.e. reference point calculations, building orientation and zone of interest.

Physical properties of building design for Radiance input is described in Table 3.

Table 3. Physical Properties of Building Design for Radiance

Elements	Properties				
	Code	Reflect-ance (%)	Transmitt-ance (%)	Reflec-tancy (%)	Rough-ness (%)
Wall	Off-white 2k205 LESO 91	67.5	0	0	0
Roof	Brown gray 3k312 LESO 91	17.9	0	0	0
Ceiling	Off-white 2k205 LESO 91	67.5	0	0	0
Floor	Concrete-gray RAL 1e105	20	0	3	2
Fence	Off-white 2k205 LESO 91	67.5	0	0	0
Window & door frame	Beige brown RAL 8024	29.47	0	0	0
Window grills	Alumi-num LBNL aluminum	88.6	0	80	2
Grass	Grass green RAL 6010	34.17	0	0	0
Conblock	Dark gray 1k134 LESO 91	13.8	0	0	0
More reflective vegetation	Green 7k711 LESO 91	41.2	0	0	0
Less reflective vegetation	Green 7k714 LESO 91	22	0	0	0
Window glass	Float glass single pane LBNL – glz - 1	Visual reflectance	Visual transmittance	Thickness (inc)	color
		88	12	0.22	clear

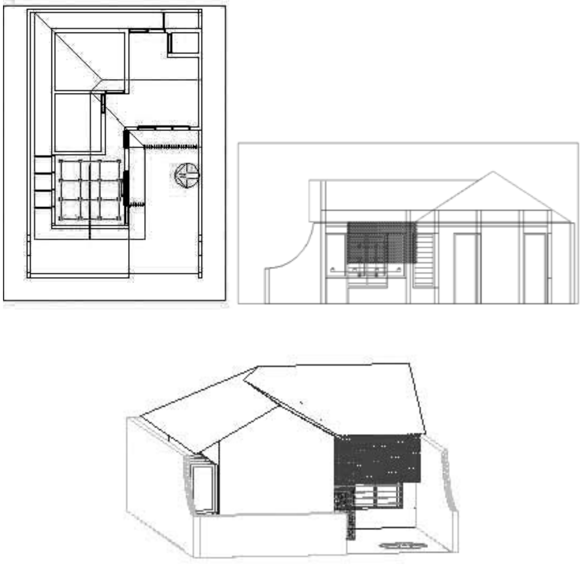


Figure 2. Bird-Eye Elevation, Side Elevation and Perspective of The Model for Radiance

The climatic data for Radiance input are as follow: Latitude = -7.5^0, Longitude = -110^0, Turbidity = 2, Sky condition = CIE Clear.

Within very constraint resources, the Radiance is set to simulate the phenomenon of glare only at one solar position onto the selected location (one date of a year, i.e. 22 April). The date was selected upon consideration that within this period, the sun is exactly upright the selected location which is resulted in maximum solar radiation and sunlight. During this day, the simulation was run twice: at 10.00 and at 12.00. These times were selected upon consideration that at 10.00 the sun is high enough above horizon and ready to enter the room through windows. This then represents condition when the sun is at narrow angle to the windows. Position at 12.00 represents when the sun is approximately upright the building. The Glare Index (GI) was measured on the window from position projected on the seated area of the given room (i.e. living room).

Table 4. Parametric Matrix for Radiance

PARAMETER										Case No.
Shading					Orientation			Time: 22 April		
No shading	More reflective leaves		Less reflective leaves		Perpendi-cular	Oblique toward Front side	Oblique toward Back side	10.00	12.00	
	15%	50%	15%	50%						
0					0			0		1
0					0				0	2
0						0		0		3
0						0			0	4
0							0	0		5
0							0		0	6
	0				0			0		7
	0				0				0	8
	0					0		0		9
	0					0			0	10
	0						0	0		11
	0						0		0	12
		0			0			0		13
		0			0				0	14
		0				0		0		15
		0				0			0	16
		0					0	0		17
		0					0		0	18
			0		0			0		19
			0		0				0	20
			0			0		0		21
			0			0			0	22
			0				0	0		23
			0				0		0	24
				0	0			0		25
				0	0				0	26
				0		0		0		27
				0		0			0	28
				0			0	0		29
				0			0		0	30

BREVENT to Assess Indoor Ventilation Rates

A computational model is chosen to examine the air changes per hour within the modelled housing. Brevent was chosen for this examination. Prior to Radiance and Brevent Simulation, a manual calculation using Calculation Sheet of Florida Solar Energy Centre (Moore, 1993) to narrow the most possible position and dimension of openings is conducted. The manual calculation results lead to the most effective openings to be used for supplying the required ventilation flow rates within a given situation, which is then to be validated by Brevent.

The Brevent software was modelled for predicting ventilation rates in dwellings. It is based on a set of equations that describe infiltration through building fabric, and flow through discrete elements such as openings (e.g. trickle ventilators and air bricks, etc.), windows, extract fans, combustion appliances (flues), and passive stack ventilation devices (vertical ducts). This is a single-zone model but becomes two-zone if a ventilated subfloor space is included. In using Brevent, there is a set of climatic data such as temperature, relative humidity, wind speed and wind direction, required to run the program. The data could be prepared both primarily or secondarily from the last couple of years. In this research, the climatic data are both gained primarily and secondarily.

Table 5. General Housing and Climatic Data for Brevent Input

Specification	Value	Description
Housing type	Semi detached	One side of their walls attaches to neighbouring wall, see Figure 1
Orientation of the front face	0º	Primary data
Lowest internal temperature	24º C	Primary data
Highest internal temperature	32º C	Primary data
Lowest external temperature	24º C	Secondary data
Highest external temperature	32º C	Secondary data
Lowest wind speed	0 m/s	Secondary data
Highest wind speed	2 m/s	Secondary data
Starting wind angle	30º	Secondary data
Final Wind angle	60º	Secondary data
Wind profile exponent	0.33	Quoted from Brevent manual for exponent in the city centre
Pressure difference	50 Pa	Quoted as a normal value
Leakage exponent	0.6	Quoted as a common value
Leaky value	20 ach	Value for a leaky house (Brevent specifications)

Table 6. Building Elements of the Modelled Housing for Brevent Input As It is for Radiance

Building Elements	Position	Dimension	Detailed Specification
Inlet: glassed-jalousie window*	At the windward side 0.50m above ground	0.65 m x 1.60 m	Refer to Figure 2
Outlet: casement window*	At the leeward side 0.80m above ground	0.65 m x 1.30 m	Refer to Figure 2
Framed-climbing vegetation	At the windward side	Alongside inlet window 0.85m down from the roof edge	15% porosity **, 50% porosity **, Refer to Figure 4

(* After Mediastika, 2000, ** After Mediastika, 2000: very dense climbing vegetation is identical to 15% porosity and less dense is identical to 50%, less than 50% porosity is not being assessed as it is considered far too slim to do the task.)

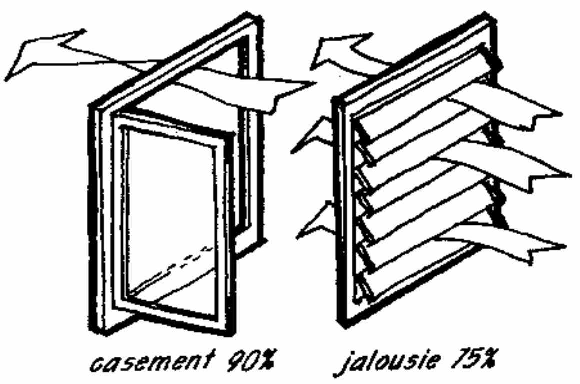


Figure 3. Outlet and Inlet Windows (After Moore, 1993 and Mediastika, 2000)

Opening type used in this research – openable glassed-jalousie and casement windows - has been showed by Mediastika (2000) as the most effective opening model to drive the required ventilation flow rates of low cost housing within zero outdoor wind speed.

Limitation of Computational Simulation

Using computational simulation to investigate such objects is useful of saving time and cost. However, still, there are conditions where the software is difficult to represent physical property of the objects as it is in reality. Both of computational simulations used in this study are incapable to represent the unique physical properties of vegetation, such as overlapping among leaves, leaf surface and natural colour of leaf. Vegetation for this simulation is then represented by models that are specifically designed to be as close as possible to physical property of vegetation in reality. It consists of vegetation density or thickness (represented by porosity) and leaf reflectance.

RESULT AND DISCUSSION

RADIANCE Result

Within constraint resources, the Radiance Simulation shows result as presented in Table 7.

Table 7. Radiance Simulation's Result

Conditions	Glare Index (GI) on Given Orientation					
	at 10.00			at 12.00		
	Perpendicular	Oblique toward Front Side	Oblique toward Back Side	Perpendicular	Oblique toward Front Side	Oblique toward Back Side
No shading	**27**	**31**	**27**	**28**	**32**	**28**
Vegetative shading of 15% porosity, more reflective leaves	24	28	24	27	30	25
Vegetative shading of 50% porosity, less reflective leaves	26	30	24	27	31	26
Vegetative shading of 15% porosity, more reflective leaves	26	30	26	28	31	27
Vegetative shading of 50% porosity, less reflective leaves	27	31	25	28	31	26

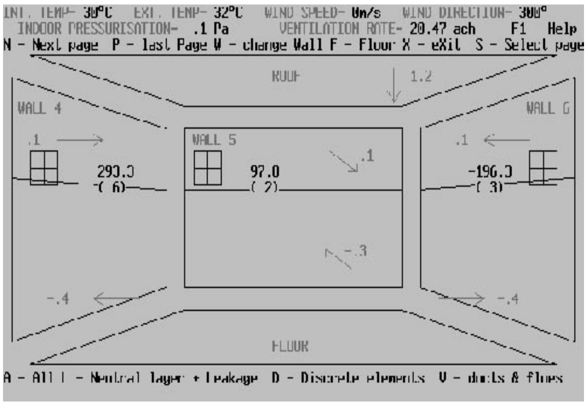
BREVENT Result

Within the modelled housing, the Brevent shows ventilation flow rates as presented in Table 8.

Table 8. Brevent Simulation's Result

Housing Specification	Approximate Ventilation Flow Rates (air change per hour)	
As those specified in Table 3 and 4	of 15% porosity of look alike vegetative shading***	of 50% porosity of look alike vegetative shading***
Number of openings is 6 of inlet windows (0.65 m x 1.60 m) 0.50 m above ground and 8 of outlet windows (0.65 m x 1.30 m) 0.80 m above ground. This is a realistic number of openings to be used concerning esthetical aspects. Ratio to the floor area is approximately 30%.	20 to 25	25 to 30

(*** Brevent could not physically represent such unique properties of vegetation)



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INT. TEMP- 30°C   EXT. TEMP- 32°C   WIND SPEED- 0m/s   WIND DIRECTION- 300°
  INDOOR PRESSURISATION-  .1 Pa       VENTILATION RATE- 20.47 ach     F1   Help
N - Next page  P - last Page W - change Wall F - Floor X - eXit  S - Select page
A - All I - Neutral layer + leakage  D - Discrete elements  V - ducts & flues
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Figure 4. Example of the Exploded View of Brevent's Simulation Result

DISCUSSION

The Radiance simulation shows that, at this stage, the modelled vegetative shading offers rather insignificant reduction of Glare Index. Table 1 shows that a significant difference of Glare Index is noticed when the difference is at least 3. In most cases, the objects use in this study could only reduced Glare Index by 1 or 2. Reflectance of the shading's surface also has insignificant effect at this stage. Table 7 shows that the shading offers significant difference only four times out of the whole 26 simulation (please refer to the underlined Glare Index). In general, we learn that more reflective vegetation reduce slightly more glare than less reflective vegetation (i.e. darker leaf surface). This indicates that shading with darker surface creates high level of contrast and thus higher level of Glare Index.

Whilst the Brevent simulation shows that the modelled housing, with detailed specification as presented in Tables 5, 6 and 8, is capable of supplying the requested ventilation flow rates of approximately 30 air change per hour. The design consists of numbers of windows in the inlet and outlet position and look alike framed-vegetative shading. When the porosity of the shading is at maximum (15%) the design only provides ventilation flow rates of 20 to 25 air change per hour. This increases gradually when the porosity reduces.

The Radiance shows that in most cases, more reflective vegetative shading of 15% porosity works better than the rest of the tested objects, but still, we need to consider the result of ventilation flow rates calculation that porosity of 50% works better than the 15% ones.

CONCLUSION AND RECOMMENDATION

From the investigation made by computational simulation of vegetative shading to reduce glare whilst also providing the suggested ventilation flow rates, there are some indications borne out as follows:

1. To reduce significant level of Glare Index, it is better for the house to use more reflective vegetation of 15% porosity. However, since this porosity significantly obstructs the ventilation, it is suggested to use vegetative shading of 50% porosity as a compromised design.
2. Low cost housing that adopts the specified window designs and uses more reflective vegetative shading of 50% porosity fulfils the suggested ventilation flow rates and reduces Glare Index of approximately 1.5, which is considered rather insignificant.
3. The modelled housing, which is capable of slightly reducing glare and supplying the suggested ventilation flow rates in warm humid regions at 30 air change per hour, consists of 6 windows at the inlet and 8 windows at the outlet positions with specification shown in Table 6.
4. Vegetative shading of more reflective leaves reduces slightly more glares than vegetative shading of less reflective leaves.

Concerning such constraint of resources, this preliminary study could only draw indications rather than conclusion. The constraint makes deeper study of adequate variant is difficult to be conducted at the same time. Further study to investigate the effect of position, dimension, porosity and reflectance of vegetative shading within different solar position and different timing of each day is recommended to provide more comprehensive conclusions.

ACKNOWLEDGEMENT

The authors would like to express their deepest gratitude to Slamet Rijadi Foundation for making this study as a series of research possible.

NOTATION

K = Constant
L_s = Luminance of the source of light (Lux)
L_b = Luminance of the background light (Lux)
Ω = Solid angle subtended by the source of light (Steradians)
ω = Solid angle of the source with respect to the eye (Steradians)

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