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Annexing Green Building Rating Points through Multipurpose Vertical Light Pipes

Y. A. Dodo*, L. X. Lei and A. Hussein

Universiti Teknologi Malaysia, Faculty of Built Environment, Department of Architecture 81310, Johor, Malaysia; yadodo@utm.my

Abstract

Objective: To determine how many points can be annexed in a green building by a combination of the two processes and test the viability of combining daylight and rainwater harvesting in a pipe. **Method/Analysis**: An experiment was carried out using a 4m (width) x 6m(height) x 12m(depth) model at a scale of 1:25. Three light pipes of different transparency were used. The first pipe has a fully transparent surface, allowing most of the light to penetrate. The second pipe has a translucent surface. Light that penetrate through it would be partial, with the translucent surface acting like a layer of diffuser to diffuse the light. The third pipe is a combination of transparent and translucent surface. Water will act as the transporting medium for light and at the same time as a barrier for heat to enter. Although water does have certain amount of thermal mass, the heat stored in water can be minimized by circulating the water throughout the system. **Findings**: Up to 13 points could be earned in non-residential new construction (NRNC), while up to 15 points in Residential New Construction (RNC). **Application/Improvement**: The novelty of this study proposes the use of a tube for daylighting and rainwater harvesting simultaneously in a space through an experimental process at a small scale. This result could be further developed to an industrial scale for commercial purposes.

Keywords: Advocacy Monitoring, Decision Tree C4.5, Search Approach, Support Vector Machine

1. Introduction

Malaysia is a country in the tropics region that receives sufficient amounts of sunlight throughout the year, with an average of 6 hours of sunshine per day. According to the International Commission on Illumination (CIE), the tropical region experiences overcast and illuminous sky. The illumination received can be as high as 130klux[1]. High level of illuminance without proper design considerations will result in a bad indoor environment quality. High radiant energy transmitted along the light increases the indoor temperature. Glare and thermal discomfort are among the problems faced by the building occupants. Providing available daylight in building is not only desirable for energy efficiency reasons, but also improves the environment for the occupants in terms of health and comfort[2].

2. Terminology

Reducing energy usage especially artificial lighting load is a critical step towards sustainable and energy-efficient buildings[8]. The application of the daylighting mechanism proved to be an effective way to save on energy consumption in a building[8,9]. Operating costs can be reduced due to lower energy bills. Research in the effect of daylighting on the occupants concludes that it increases productivity, health, human well-being as well as visual comfort and psychological needs to the users[10]. The effective design of

*Author for correspondence

daylighting can reduce the dependency on artificial lighting, though the performance of daylighting technology depends on the dynamic nature of the external illuminance.

A windowless space may be referred to as a sub-basement area or a room in a deep plan building where openings to the external environment is impossible to locate. These spaces usually have poor indoor environ-

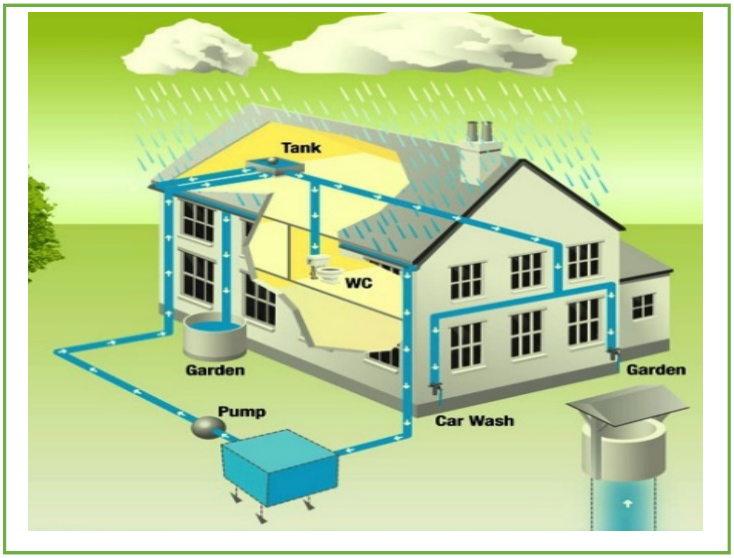

Figure 1. Rainwater harvesting[3].

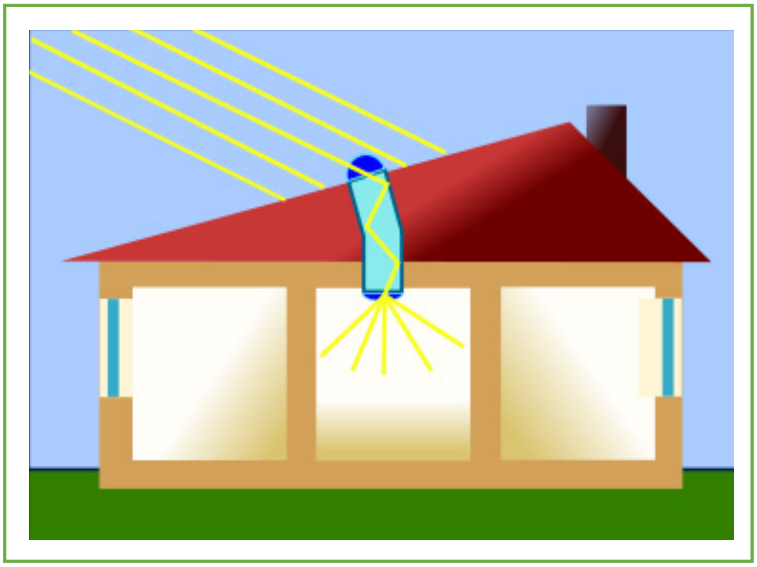

Figure 2. Daylight harvesting[4].

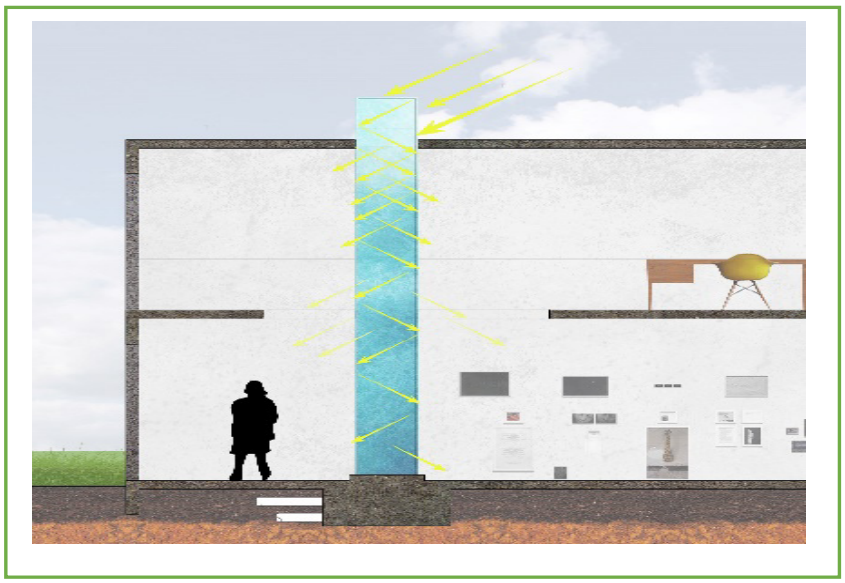

Figure 3. Novel harvesting pipe (authors sketches)[5].

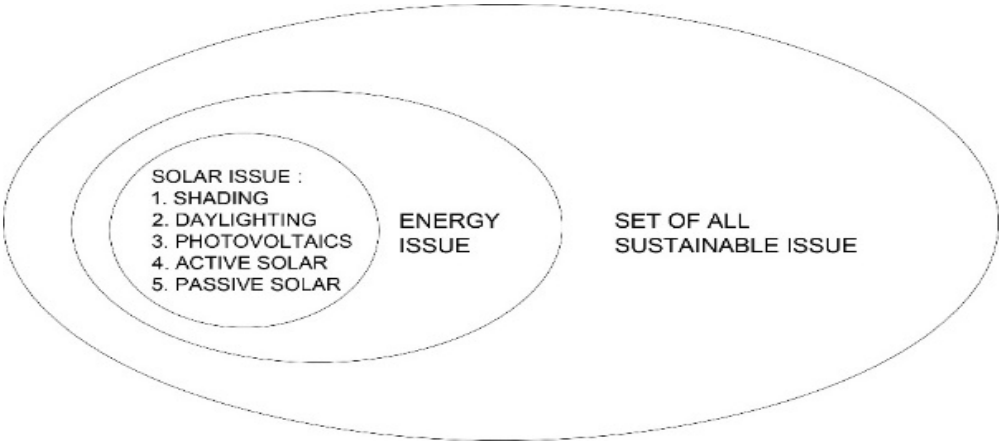

Figure 4. Daylighting is categorized under solar issues and is a much larger subset of the energy issues[7].

ment quality due to lack of natural daylighting and poor air flows.

Figures 1–5 Water (chemical formula: H_2O) is a transparent fluid at standard ambient temperature and pressure. In the tropical climate, the hydrological cycle involves the physical processes of evaporation, condensation, precipitation and water falls as rain. Data from the Malaysia's Meteorological Department shows that

Figure 5. Scaled model was constructed and tested under real sky condition.

Malaysia receives an average rainfall of 250cm per year[11]. As a natural and sustainable resource, green technology includes rainwater harvesting and implementing it into building systems.

The light pipe or also known as the tubular daylighting device is a structure designed to direct natural or artificial lighting for the purpose of illuminance to a dimmer space where daylight cannot reach. The system transports illuminance by the principle of reflection. A hollow structure contains the light with a reflective lining and a transparent solid contains the light by total internal reflection. The light pipe has great potential in tropical climate like in Malaysia due to the strong global illuminance received[12].

A multipurpose light pipe refers to the combination of a light pipe and a rain water harvesting system with the light pipe being the principle function. The proposed design attempts to fill the hollow space in the light tube with fluid, particularly rain water, to act as a medium in transmitting daylight to the interior space. The vertical light pipe acts as a place to store the rainwater harvested, allows light to transmit in the water by total internal reflection.

3. Methodology

The refractive index of water (1.3325) is slightly higher than air (1.00293) (Tables 1, 2). The refractive indices also determine the amount of light that is reflected when reaching the interface, as well as the critical angle for total internal reflection and Brewster's angle[13]. Refraction occurs when light passed through water. An empty light tube transmits light but concurrently increase the amount of solar heat gain. Unlike air, water has high thermal conductivity. Thus, the tube acts as a barrier for heat but allows light to enter.

Acrylic Panels is more translucent than glass and a great insulator. Nowadays, it is used as an alternative to traditional float glass. The burning of acrylic generates a small amount of non-toxic and non-corrosive smoke.

Table 1. Possible points to annex from Green Building Index assessment[6]

Part	Criteria	Item	GBI Points	Possible Point to Annex Total	Total Points
EQ	Indoor Environmental Quality				
	Lighting, Visual & Acoustic Comfort				
	EQ8	Daylighting	2	2	
	EQ9	Daylight Glare Control	1	1	
SM	Sustainable Site Planning & Management				
	SM11	Storm water Design – Quantity & Quality Control	1	1	
WE	Water Efficiency				
	Water Harvesting & Recycling				
	WE1	Rainwater harvesting	2	2	
	WE2	Water Recycling	2	2	
IN	INNOVATION				
	IN1	Innovation in Design & Environmental Design Initiatives	6	6	
				14	100

Table 2. A comparison between acrylic panel and mineral glass[14]

	Acrylic	Mineral Glass
Light Transmission	Up to 92% of visible light	80-90% depending in type of glass and manufacturer
UV Resistance /Aging	Yellow may occur depending on manufacturer	Yellow may occur depending on manufacturer
Heat Transfer	Barrier to transfer heat and cold	Double glazing is better insulator than but cannot be used under water
Density	1150-1190 kg/m3	2400-2800 kg/m3
Load bearing	Able to withstand significant load	Certain thickness is require to withstand load thereby reduce transparency
Strength	High impact strength shattering will not occur	Low impact strength shattering may occur
Maintenance	Scratches can be buffed out	Glass will need to be replaced if got scratched
Production & Assembly	Light in weight thus easy to transport to site. It is also easier to work with in construction cite	Heavy and need to handle carefully on site to prevent shatter

4. Method

The experiment was carried out using a 4m(width) x 6m(height) x 12m(depth) model at a scale of 1:25. Three light pipes of different transparency were used. The first pipe has a fully transparent surface, allowing most of the light to penetrate. The second pipe has a translucent surface. Light that penetrates through it would be partial. Translucent surfaces act like a layer of diffuser to diffuse the light. The third pipe is a combination of transparent and translucent surfaces. A lux meter was position inside the model to record the illuminance level. The experiment was carried out on 26th February, 2016, 9:15a.m. at roof top of Block B12, Faculty of Built Environment, University Technology Malaysia. Sky condition was intermediate. Results were recorded in Figures 6–8.

The second experiment was carried out to investigate the design of voids in helping to transfer more light to the

= Tube filled with water

Figure 6. The results between different transparency of surface, and pipes filled with and without water.

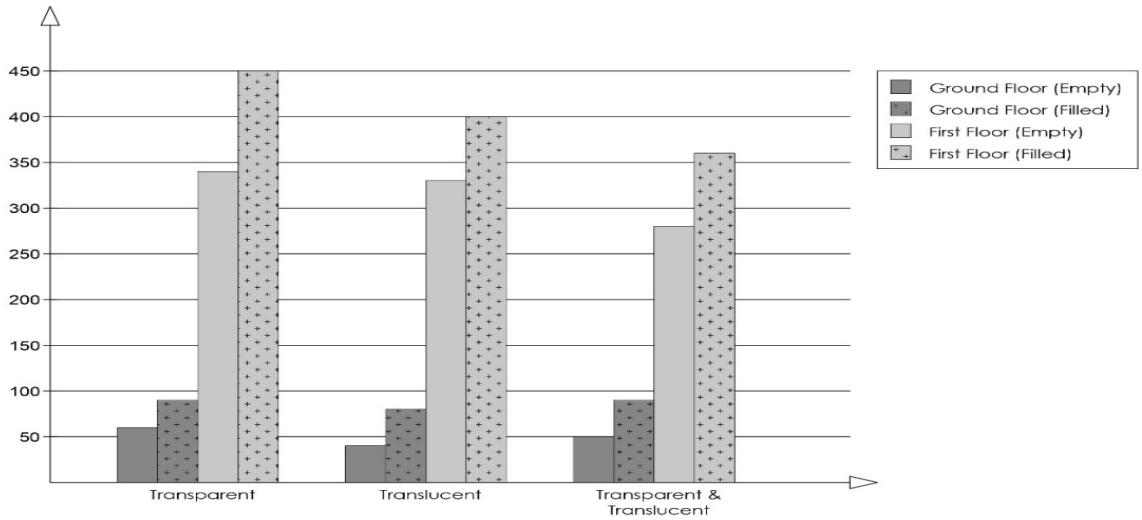

Figure 7. Result gathered for different transparency of surface.

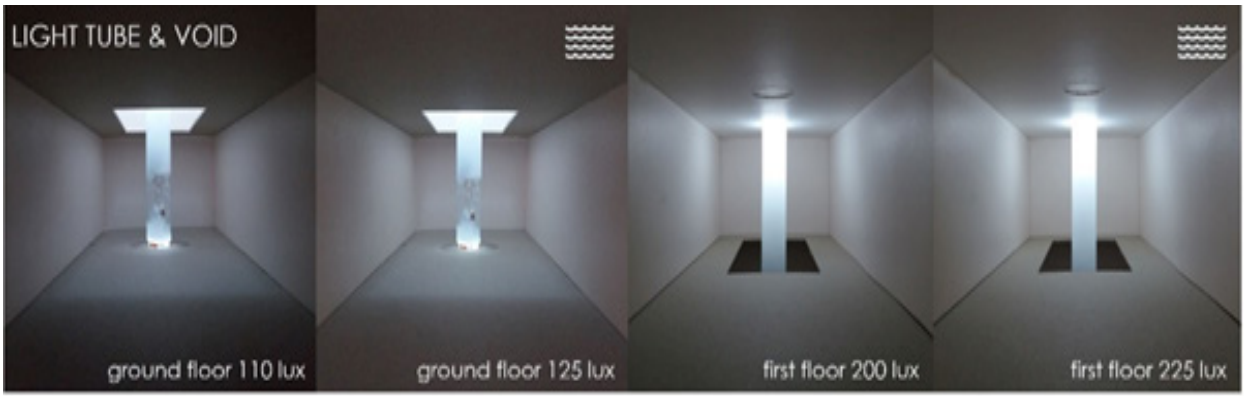

Figure 8. Void will increase the light intensity at the ground floor.

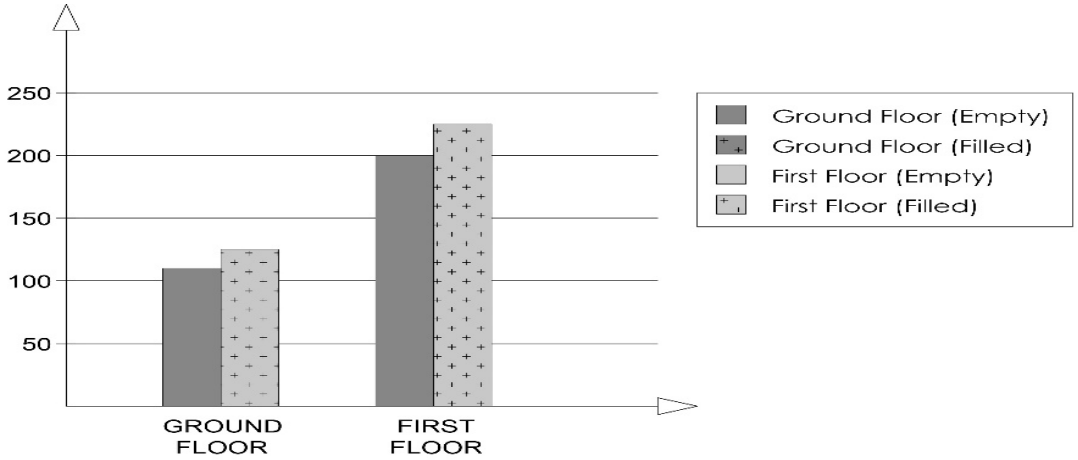

Figure 9. Result gathered for the combination of light pipe and void.

ground floor. A void of area 20m^2 was made at the area where the light tube was placed. Results were recorded in Figure 8 and Figure 9.

The limitation faced while conducting the experiment that is the weather condition is unpredictable and inconsistent. This, more or less will affect the readings. The material used as the light pipe may have different refractive index compared to the actual material used.

5. Results and Discussion

The transparent surface transmits the highest level of illuminous especially to the ground floor. The illumination received for first floor is high but the light is sharp and cause glare due to direct transmission of light. The translucent surface distributes daylight evenly to the interior space, creating an ambient environment. For the transparent and translucent surfaces, the amount of light was

optimal for the ground floor but not suitable for workspace usage. The diffused light at the first floor is ideal and gives visual comfort. According to the reading of the lux meter, it is suitable for workspace usage.

The experiment is then continued with transparent & translucent pipe as it has the best visual comfort. A void was created to allow better transmission of light to the ground floor area.

The light pipe has potential to be used to provide lighting to a deep floor plan building where no opening is allowable, especially in the tropics climate where natural illumination is always sufficient. It reduces the dependence on artificial light in lower floors where top lighting is unavailable. Natural daylighting is proved to increase productivity, improve health and reduce stress. The proposed design functions as storage for harvested rain water aside from its aesthetic value.

However, some constraint still needs to be overcome, such as the construction that may be costly and these needs to be considered in the early stage of design. The light transmitted is still limited to certain depth, particularly suitable for low rise buildings.

6. Novelty

The studies propose the use of a tube for daylighting and harvesting rainwater simultaneously in a space through an experimental process at a small scale. This result could be further for commercial purposes at an industrial scale.

7. Conclusion

In the tropical climate, there is actually an abundant quantity of daylight, but it is yet to be utilized[15]. The light pipe has a large potential to be used in Malaysia if it can overcome the constraints on the light quality to the lowest floor and radiant heat that is brought to the interior space. Thus, the proposed light tube filled with water attempts to overcome this issue. The circular shaped pipe harvests light from all directions before distributing it evenly to the interior space through the light diffuser.

Implementation of this system could contribute some points on the rating of green building in both NRNC residential RNC categories of Green Building Index (GBI) Malaysia[6]. Possible points that could be scored are from the criteria of daylighting (2 points), glare (1 point in NRNC), rainwater harvesting (4 points in RNC, 2 points in NRNC), water efficient irrigation and landscaping (2 points) and innovation of light pipe (6 points).

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