การประมาณปริมาณแสงสว่างด้วยวิธีการใช้ท่อนำแสงแนวดิ่ง ในเมืองสุราบายา ประเทศอินโดนีเซีย

Estimating Illuminance Through Vertical Light Pipe in Surabaya, Indonesia

Hanny Chandra Pratama* และ ยิ่งสวัสดิ์ ไชยะกุล**
Hanny Chandra Pratama and Yingsawad Chaiyakul

Received : 2019-05-07 Revised : 2019-05-08 - 2019-07-10 Accepted : 2019-07-11

บทคัดย่อ

ระบบท่อนำแสงแนวดิ่ง (Light pipe) ช่วยเพิ่มแสงในอาคารในตอนกลางวันได้ดี โดยเฉพาะพื้นที่ที่อยู่บริเวณเส้นศูนย์สูตร เนื่องจากการโคจรของดวงอาทิตย์ ทำให้ตำแหน่งดวงอาทิตย์ในเวลากลางวันอยู่ด้านบนของอาคาร จากงานวิจัยที่ผ่านมาในประเทศในเอเชียตะวันออกเฉียงใต้ เช่น ประเทศไทยและประเทศมาเลเซีย พบว่า ประเทศมาเลเซีย เป็นประเทศที่มีความเหมาะสมในการใช้ระบบท่อนำแสงแนวตั้งได้เป็นอย่างดี แต่สำหรับประเทศไทยยังไม่สามารถใช้ระบบท่อนำแสงได้ดี เนื่องจากปริมาณแสงสว่างที่ได้จากท่อนำแสงมีปริมาณแสงสว่างต่ำ ในปัจจุบันยังไม่มีการศึกษาเรื่องระบบท่อนำแสงในประเทศอินโดนีเซีย ในการศึกษานี้ มีวัตถุประสงค์เพื่อหาประสิทธิภาพการใช้ท่อนำแสงแนวดิ่งสำหรับประเทศอินโดนีเซีย โดยใช้เมืองสุราบายาเป็นพื้นที่ศึกษา ท่อนำแสงที่ใช้ในงานนี้มีขนาดเส้นผ่าศูนย์กลาง 0.6 เมตร 0.8 เมตร และ 1 เมตร โดยความยาวของท่อมีขนาดตั้งแต่ 1 ถึง 6 เมตร ทำการจำลองแสงสว่างในโปรแกรม DIALux 4.13 ในวันสำคัญ 4 วัน ได้แก่ วันที่ 21 มีนาคม 21 มิถุนายน 21 กันยายน และ 21 ธันวาคม ภายใต้สภาพท้องฟ้าแจ่มใส สภาพท้องฟ้ามีเมฆปานกลาง และสภาพท้องฟ้ามีเมฆครึ้ม จากการศึกษาพบว่าการใช้ท่อนำแสงแนวตรงในเมืองสุราบายา มีส่วนช่วยเพิ่มประสิทธิภาพในการเพิ่มปริมาณและคุณภาพของแสงได้ โดยเฉพาะอย่างยิ่งในช่วงเวลา 9:00-15:00 น. ท่อที่เส้นผ่าศูนย์กลางขนาด 0.8 เมตรและ 1 เมตร เป็นขนาดท่อที่สามารถให้แสงสว่างเพียงพอสำหรับการใช้งานภายใต้ทุกสภาพท้องฟ้า สำหรับท่อขนาด 0.6 เมตร ไม่สามารถช่วยเพิ่มแสงได้อย่างเพียงพอในสภาพท้องฟ้าที่มีเมฆปานกลาง หรือมีเมฆครึ้ม ส่วนสุดท้ายนำเสนอสมการและวิธีการคำนวณปริมาณแสงสว่างที่ได้จากระบบท่อนำแสงแนวดิ่ง

ABSTRACT

Light pipes provide daylight and enhance the lighting conditions of buildings. Guidelines and other information of light pipe performance are necessary to meet standard lighting requirements. In locations near the equator, there is a potential supply of daylight that can be used strategically

*, ** Master of Architecture in Building Technology Program, Faculty of Architecture, Khon Kaen University, Khon Kaen 40002, Thailand
Corresponding author E-mail: hannychandrapratama@kkumail.com

by vertical light pipes to bring light into buildings. Previous studies in Southeast Asian Countries have suggested that Malaysia has great potential to utilize vertical light pipe mechanism. Whereas, Thailand faces challenges to use vertical light pipe due to the low illuminance it receives from the sun. Countries that are positioned close to the equator have greater potential to use vertical light than countries that are further away. However, the vertical light pipe mechanism has yet to be studied and applied in Surabaya, Indonesia. Therefore, this study presents the potential performance of the vertical light pipe strategy and its application in Surabaya, Indonesia. In this study, various pipe configurations were considered and analyzed, namely: three pipe diameters of 0.6 m, 0.8 m, and 1.0 m and the length of pipe was from 1 - 6 m. A simulation study in DIALux 4.13 was performed on four critical dates under varying sky conditions: clear, intermediate, and overcast. The results demonstrated that a vertical light pipe strategy in Surabaya, Indonesia has high potential to increase the quality and quantity of light between the hours 9:00 and 15:00. The research showed that pipes with diameter of 0.8 and 1.0 m were the most usable in typical sky conditions. However, the pipe with diameter of 0.6 m obtained an adequate illuminance level under clear skies, but it would not provide a sufficient illuminance level under intermediate nor overcast conditions. The final section suggests a model for predicting levels of illuminance from vertical light pipes.

คำสำคัญ: แสงธรรมชาติในอินโดนีเซีย ท่อนำแสง แนวทางการใช้แสงธรรมชาติ
Keywords: Daylighting in Indonesia, Light pipes, Daylighting strategy

Introduction

Over the past few decades, the construction of homes and buildings has been increasing steadily. As the number of buidings and houses grows, this causes energy consumption to be increased simultaneously. Nowadays, lighting is one of the largest consumers of energy in buildings (Pemerintah Provinsi DKI Jakarta, 2012). This is a direct result of electric lamps continually being used throughout daytime hours to the neglect of a source of outside of those buildings. Therefore, delivering adequate daylight into building is necessary to avoid the use of useless electricity consumption. The potentiality of daylight in Indonesia is considerably high due to close approximation of Indonesia to the equator (6° N - 11° S latitudes). In addition, the sun’s altitudes tend to orbit vertically (between 59° North to 73° South) throughout the year. Based on previous studies, outdoor illuminance can reach up to 143,600 lux (Muladi, Jamala, & Rahim, 2007, August). Therefore, there are several advantages to sourcing daylight which can be maximized and achieve top lighting performance.

Providing daylight in buildings is a substantial aspect for it enhances a room’s environment (Sok, 2017). Typically, daylighting options can differ depending on side lighting or top lighting windows.

Based on the side lighting's rule of thumb, windows deliver daylight in a limited range up to 1.5 times of the height of a window to the inside of a room (Lechner, 2015). Consequently, buildings planned with wide rooms cannot achieve adequate lighting from side windows alone. Top lighting is another daylight strategy which increases the potential of daylight drawn from the top side of a building. Top lighting delivers the light directly into interior spaces. This type of lighting is to draw light from the suitable sun's altitude in countries near the equator such as Indonesia and Malaysia. Top lighting however, also has its disadvantages, as the transfer of solar heat or obstruction of surrounding buildings which might block the sun's rays entering into interior spaces.

Typically, there are four types of top lighting: skylight, saw tooth, clerestory, and monitor as seen in Figure 1. A previous comparison study of top lighting systems along the equator has been concluded that skylight system provides the highest illuminance compared another types system (Cabfis & O. IL Pereira, 1996). However, skylight draws a lot of thermal heat into interior spaces as well. Vertical light pipes are often called as tubular skylight, where the skylight system is still applied through a pipe system as seen in Figure 2. Vertical light pipes are an innovative design and are capable of distributing natural light into a space without the additional heat transfer (Malet-Damour, Boyer, Fakra, & Bojic, 2014).

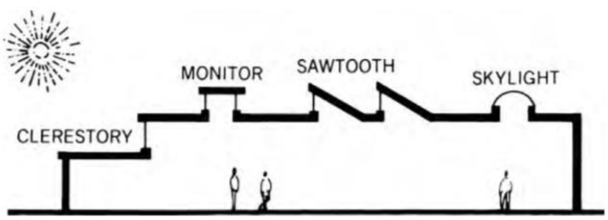


Figure 1 Type of lighting strategies.

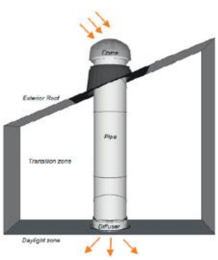


Figure 2 Vertical light pipe system.

This research used Surabaya city as a case study. Surabaya is a metropolitan city located at 7° S latitude and 112° E longitude. Nowadays, a lot of new buildings have been constructed, such as factories, offices, and hospitals in Surabaya. The high level of development creates a building pattern where neighboring buildings are in close proximity to one another. Consequently, the right and left sides of buildings are unable to install side windows. Another critical problem is for buildings with wide rooms that cannot get sufficient light to reach into the interior spaces. As shown in Figure 3, an office in Surabaya turns on electric lights during the daytime. This is in a part why Surabaya was chosen as the sample for this study because of its mass consumption of electricity through use of electric lights.

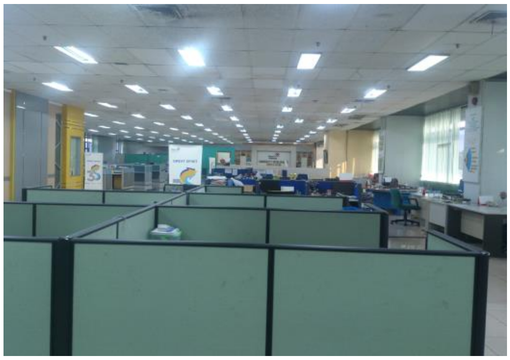


Figure 3 Lights are turned on during the day in office.

Light pipe study in Indonesia is scarce. There have been several vertical light pipe studies in neighboring countries in Indonesia. In Johor, Malaysia, a model test was created with dimension of 3x3x3 m^3 at 2° N latitude and 100° E longitude. A straight cylinder light pipe with dimension of 1.2 m length pipe and 0.3 m diameter was mounted on the roof of a building. The results demonstrated that the minimum and maximum illuminance was 150 lux and 350 lux respectively. (Kadir, Ismail, Kasim, & Kaamin, 2016).

In Bangkok, Thailand, a room with dimensions of 20 x 20 x 3 m^3 positioned at 16° N latitude and 102° E longitude was researched as well. This simulation study used light pipes with diameter of 0.6 m, 0.8 m, and 1.0 m and pipe lengths between 0.5 m - 6 m, at 0.5 m interval. These results showed that light pipes may not be practical in Thailand as only the pipes with the diameter of 1.0 m and the length of 0.5 m reached an average illuminance of 200 lux. (Chaiyakul, 2013, March).

Sky conditions in Indonesia

Surabaya, Indonesia is located at 7° S latitude and 112° E longitude where the sun shines for approximately 12 hours each day throughout the entire year. As previously mentioned, vertical light pipe is a tubular skylight, able to deliver natural light without the accompanying thermal heat transfer. Therefore, vertical light pipe has good criteria for maximizing daylight from the skies in Surabaya. As shown in Figure 4, the four dates in relation to the sun's altitudes at 12 o'clock noon in Surabaya show the reflection of the sun in a pipe with length of 6 m. The dates with the greatest potential for use of this mechanism are 21st March and 23rd September where the sun reflects with the least amount of light bouncing in the tube.

Another factor which affects the use of vertical light pipe is cloud coverage conditions in the sky where the vertical light pipes obtain abundant light under clear skies, sufficient light under intermediate skies, but insufficient light under overcast skies. A previous study in Makassar, Indonesia explained that sky coverage in Indonesia ranges at 30.3%, 55.9%, and 13.7% for clear, intermediate, and overcast skies respectively (Rahim, 2000).

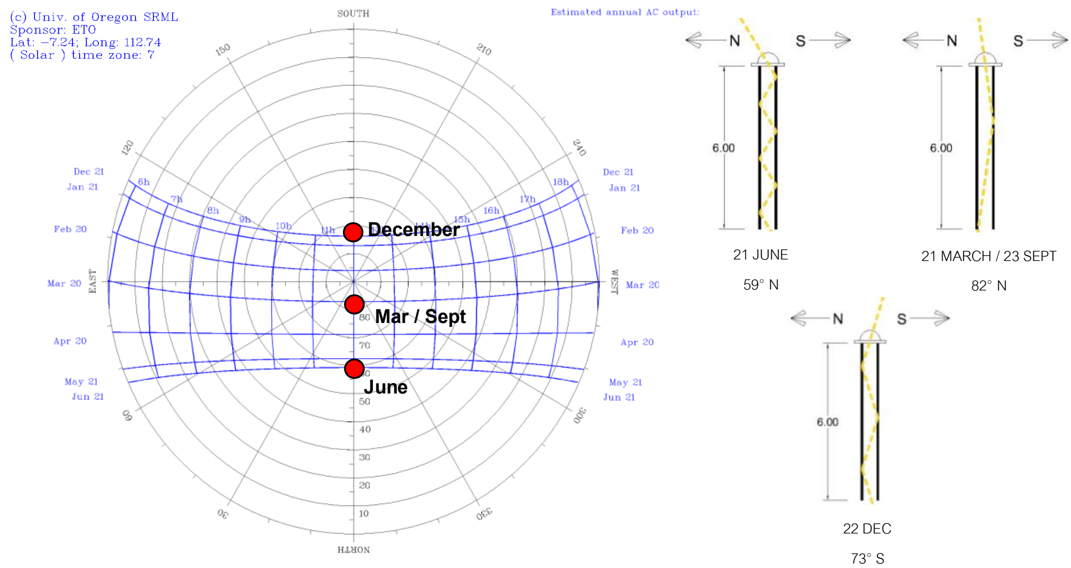


Figure 4 Correlation between sun path in Surabaya and reflected sun inside the light pipes.

Lighting standard in Indonesia

Ministry of standardization of Indonesia proposes the "National Standard of Indonesia" *(SNI: Standar Nasional Indonesia)* as the regulation in all aspects. One of the aspects mentioned in the National Standard of Indonesia is the guideline for lighting design which was released in SNI no. 03-6197-2000 of the Energy Conservation in Lighting System (Badan Standar, 2000). The SNI of lighting system set minimum illumination standards for specific task and accompanying recommendations for lighting design. Table 1 below illustrates the various illuminance levels for varying rooms and work stations.

Table 1 Requirement task in SNI documents.

Task	Illuminance (lux)	Application	Task	Illuminance (lux)	Application
Simple visual task	60	Terrace	Common visual task	200	Canteen
	60	Garage		200	Cafeteria
	100	Warehouse		300	Books store
	100	Lobby, Corridor		200	Mosque
	120 - 150	Living room		200	Church
Common visual task	120 - 250	Dining room		200	Vihara
	120 - 250	Office room		500	Laboratory
	120 - 250	Bedroom		200 - 500	Medium work
	250	Bathroom	Special visual task	750	Drawing class
	250	Kitchen		500 - 1000	Soft work
	250	Classroom		1000 - 2000	Softer work
	300	Library		750	Color identity work

In addition, illuminance levels are classified in three groups. These are determined by the aims of the lighting used. The first group is simple visual task, ranging from 20 - 150 lux. The second group is common visual task, ranging from 150 - 500 lux. The third group is special visual task, ranging from 1,000 - 3,000 lux (Kadir et al., 2016).

Since the standard have been established by the government, architects must comply accordingly, as mentioned in Table 1. In fact, in one survey study gathered by architects in Surabaya showed results which concluded that 72.5% architects did not consider the SNI lighting system (Pratama & Chaiyakul, 2018). The reported reason from architects was that no simple guidelines were established for natural lighting assessments. Based on the several issues mentioned above, a study to provide mathematical models for predicting vertical light pipes into buildings were proposed. Therefore, this vertical light pipe study presents a new technique for passing the illuminance standards that are required by law.

Vertical light pipe

The vertical light pipe system has three components: a dome collector that is usually on the roof, the light pipe body and a diffuser which releases the daylight uniformly and distributes it into the room. The principles of light pipe are sourced from natural light as it is received by the dome collector on the roof. Following that, the light pipe body reflects the natural light continuously towards the output of the diffuser. Finally, the diffuser spreads out the light into the interior space of a room.

Nowadays, many vertical light pipe providers promote this innovative top lighting strategy. One of light pipe providers mentioned that their aluminum tube coated using highly reflective material of 99.7%. With this added feature, the light input will not drop as it bounces along the inside pipe surface.

In this particular simulation study, the light pipe setting affects the light pipe at its factors such as diameters, lengths, and the reflectance value, whereas the dome collector and output diffuser were not affected as it assumed as a clear glass.

Methodology

The aim of this simulation is to evaluate average illuminance of each light pipes with varying diameters. The simulation in the DIALux 4.13 program has been conducted using several controlled factors. The factors of these simulations are the pipes, the room configuration, and set time.

First, the vertical light pipe was created in the DIALux with 3 differing diameters (0.6 m, 0.8 m, and 1.0 m) of various length (1.0 m - 6.0 m) with 1.0 m interval. The reflective material inside the pipe was set to the DIALux highest at 90%.

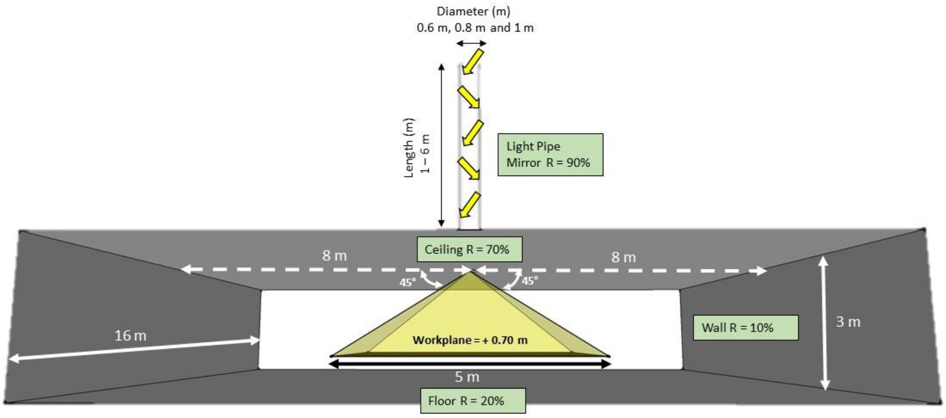


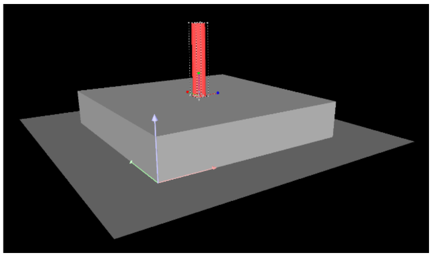
Figure 5. Room simulation section on DIALux.

Second, as shown in Figure 5, a simulation room was created with configuration 16 x 16 x 3 m^3. The pipe was mounted in the middle of ceiling of the room. In order to avoid any obstruction illuminance from the wall, the room was modified to a wider width where the reflected illuminance from the wall would not skew the task results. Obviously, this simulation will not provide perfectly calibrated material properties when predicting the illuminance. Thus, the reflectance ratio was set as the typical default material which based on previous study in Thailand where the ceiling : wall : floor = 70 : 10 : 20 respectively (Chaiyakul, 2013, March). The work plane was set at 0.70 m above the floor with a wide surface of 5.0 x 5.0 m. The wide work plane surface was used light at 45° and it spread from the diffuser and reached the work plane at 0.70 m (Littlefair, 2011).

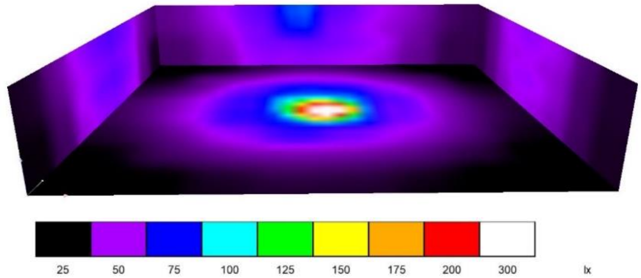
The cloud coverage was set using three various sky conditions: clear sky, intermediate sky, and overcast sky. The simulation time was set at 09:00, 12:00, and 15:00. The results are grouped into three illuminance categories: simple visual, common visual, and special visual task. Lastly, the mathematical model is derived from the result of each simulation time. This mathematical model will be used for predicting vertical light pipe illuminance towards the pipe length configuration.

Results

The graphs below show the results from DIALux simulation under the three sky conditions; clear, intermediate, and overcast skies. Figure 6 shows examples of the DIALux output of simulation for the vertical light pipe with 0.6 m diameter and 6.0 m length under clear sky.



(a)



(b)

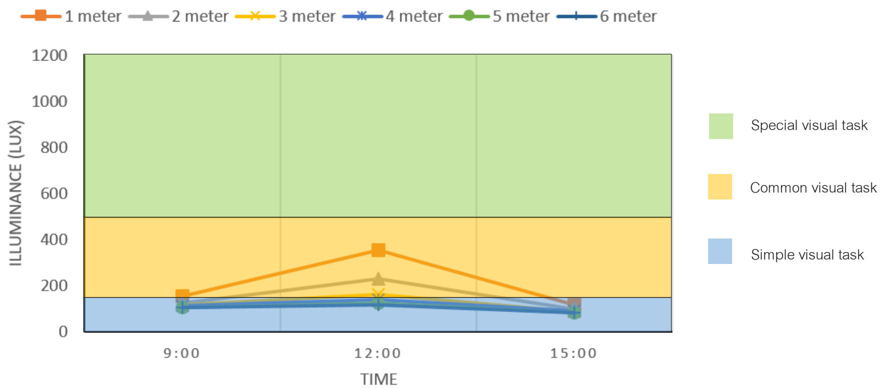
Figure 6 (a) Light pipe is put outside room simulation, (b) Light spread from simulation result.

The data showed that under clear and intermediate skies, the vertical light pipe can be used for lighting up interior spaces adequately. The details are explained as follows:

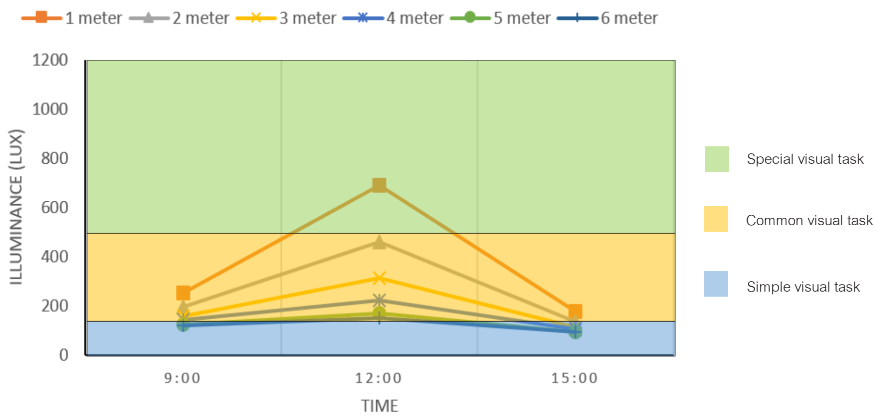
a. Clear sky result

Figures 7(a-c) show the results of illuminance for 0.6, 0.8, and 1.0 m diameters under clear sky respectively and it suitable for working tasks and exact tasks. For the pipe with 0.6 m diameter, the number of illuminance was still sufficient to use in buildings where the minimum requirement for the lowest illuminance task was 60 lux (See Table 1). Areas of lowest task illuminance is 60 lux such as in terraces and garages.

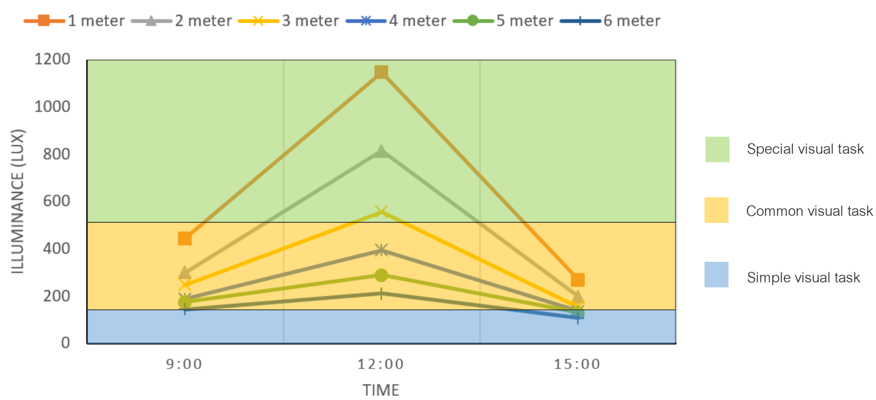
The pipe with 0.8 m diameter provided lower illuminance than the 1.0 m diameter as expected. However, it can still be utilized for common tasks and special tasks. The pipe with 1.0 m diameter provided high illuminance with the lowest level at 220 lux and the highest levels reached 1,200 lux at noon time. Figure 8 shows the relationship of illuminance level and the pipe configurations under clear sky.



(a) Diameter of 0.6 m



(b) Diameter of 0.8 m



(c) Diameter of 1.0 m

Figure 7 Average illuminance under clear sky for the pipe with diameter (a) 0.6 m, (b) 0.8 m, and (c) 1.0 m.

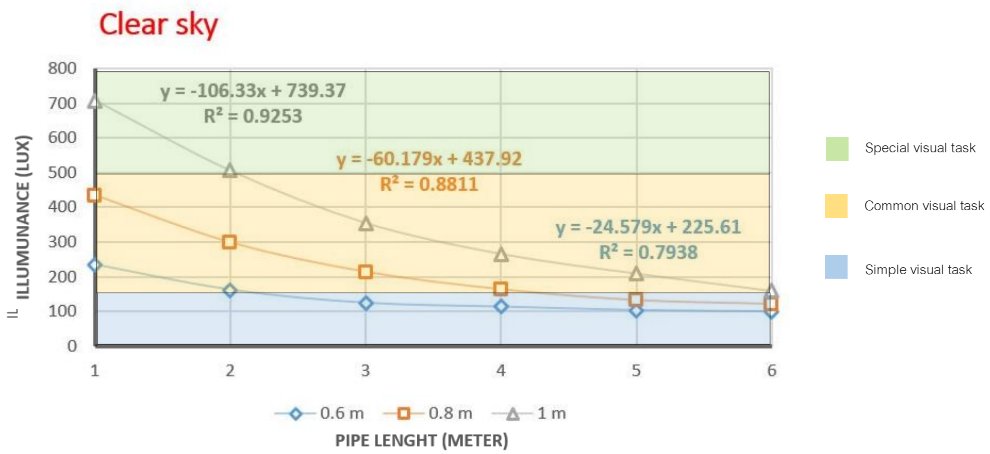
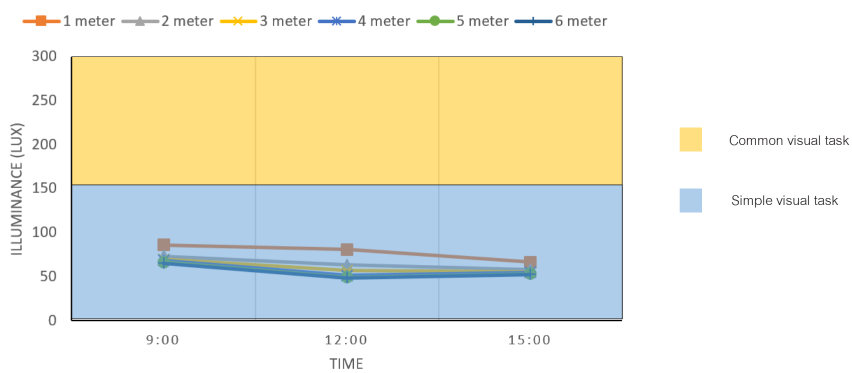


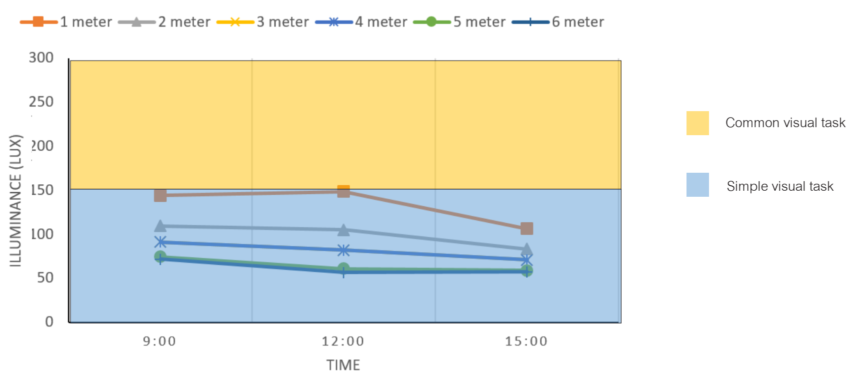
Figure 8 Average illuminance from clear sky.

b. Intermediate sky result

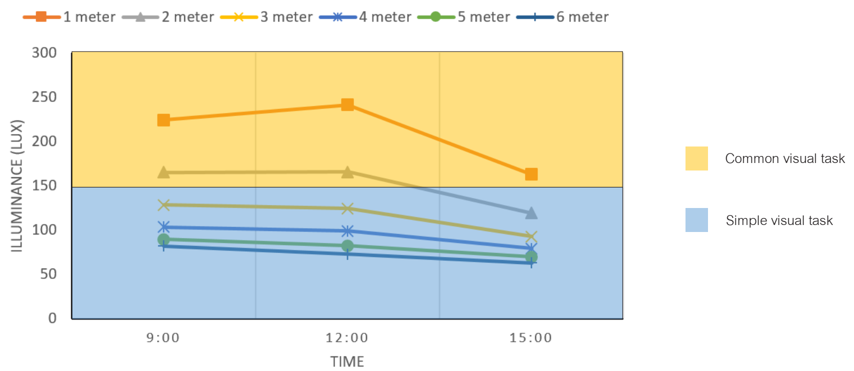
Figures 9(a-c) show the results of illuminance for 0.6 m, 0.8 m, and 1.0 m diameter under intermediate sky conditions. The result from clear sky compared with intermediate sky showed how sky conditions affect vertical light pipe usage.



(a) Diameter of 0.6 m



(b) Diameter of 8.0 m



(c) Diameter of 1.0 m

Figure 9 Average illuminance under intermediate sky for the pipe with diameter (a) 0.6 m, (b) 0.8 m, and (c) 1.0 m.

For the pipe with diameter 0.6 m provided illuminance range up to 90 lux. The pipe with diameter of 0.8 m provided illuminance range up to 150 lux. Both a pipe of 0.6 m and 0.8 m of diameter can be applied for simple visual task only. The pipe with 1.0 m diameter provided a minimum illuminance level of 70 lux and a maximum illuminance level 250 lux at noon. This sky condition is sufficient for simple visual and common visual task categories.

Figure 10 shows relationship of illuminance level and the pipe configurations under intermediate sky conditions.

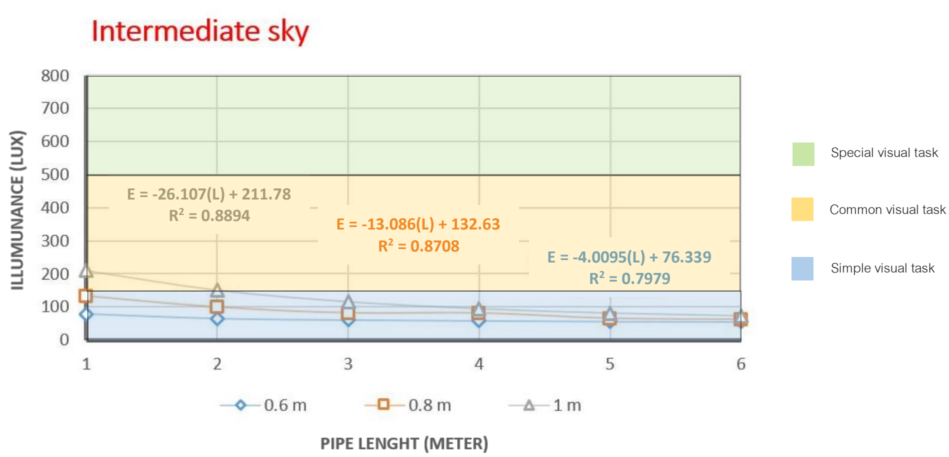
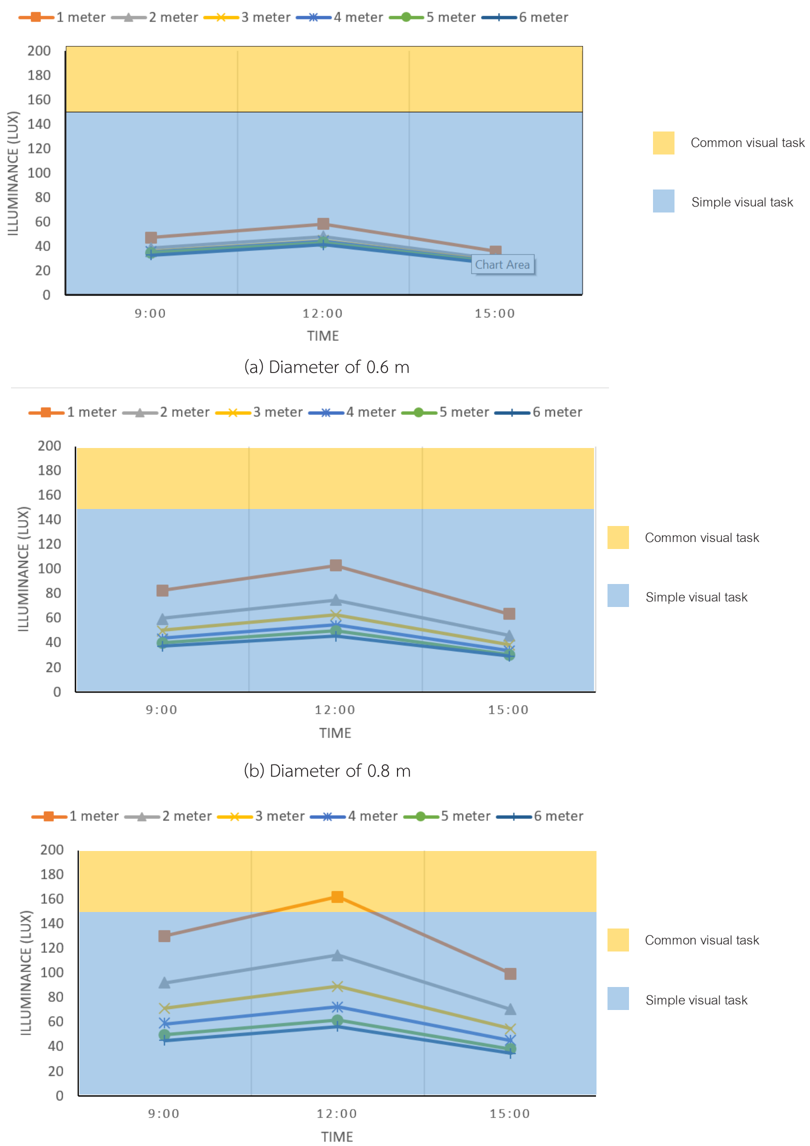


Figure 10. Average illuminance from intermediate sky.

c. Overcast sky

Figuress 11(a-c) shows the results of illuminance for diameters of 0.6 m, 0.8 m, and 1.0 m under overcast sky conditions. As expected, overcast sky had the lowest result compared with any other sky conditions. For the pipe with 0.6 m diameter, its illuminance level too low to be used effectively. The pipe with 0.8 m diameter provided illuminance range up to 110 lux. However, pipes with a length of 3 m to 6 m cannot be used for terraces and garages. These spaces require a minimum of 60 lux according to the SNI document.The pipe with 1.0 m diameter provided illuminance at the 50 lux as its lowest and 150 lux as its highest at noon. Ranging from 50 to 150 lux was not sufficient or simple tasks and common visual tasks, Figure 12 shows relationship of illuminance level towards the pipe configurations under overcast sky.



(a) Diameter of 0.6 m

(b) Diameter of 0.8 m

(c) Diameter of 1.0 m

Figure 11. Average illuminance under overcast sky for the pipe with diameter (a) 0.6 m, (b) 0.8 m, and (c) 1.0 m.

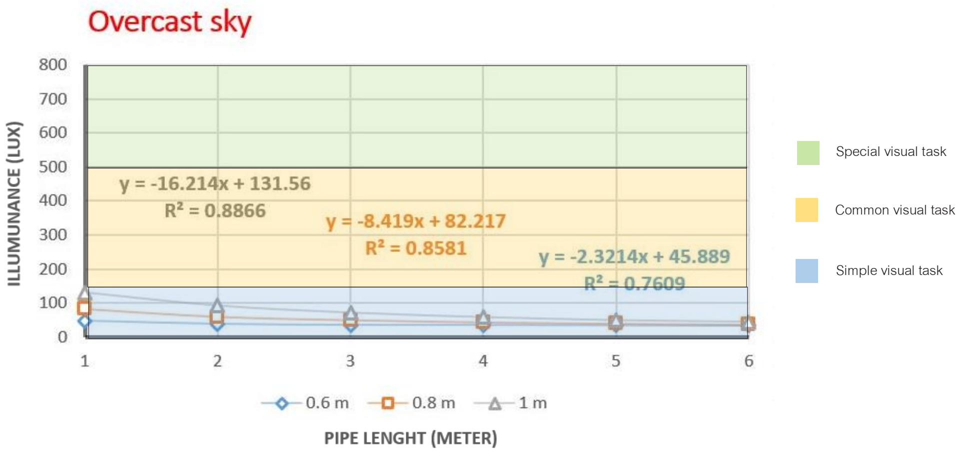


Figure 12 Average illuminance from overcast sky.

The average illuminance levels have been gathered in order to provide an estimation formula. The estimation before installing a vertical light pipe into the mount is necessary to achieve adequate illuminance level. This estimation formula was gathered as a simply assessment for architects as they consider the correlation of the length of vertical light pipe (L) and the illuminance level on the work plane (E_{wp}). The results of the study above formulated a mathematical model under the three various sky conditions.

Table 2 Mathematical predicting formula

No	Pipe diameter (m)	Clear sky		Intermediate sky		Overcast sky	
		Model	R^2	Model	R^2	Model	R^2
1.	0.6	E_{wp} = -24.579(L) + 225.61	0.7938	E_{wp} = -4.0095(L) + 76.339	0.7979	E_{wp} = -2.3214(L) + 45.889	0.7609
2.	0.8	E_{wp} = -60.179(L) + 437.92	0.8811	E_{wp} = -13.086(L) + 132.63	0.8708	E_{wp} = -8.419(L) + 82.217	0.8581
3.	1.0	E_{wp} = -106.33(L) + 738.37	0.9253	E_{wp} = -26.107(L) + 211.78	0.8894	E_{wp} = -16.214(L) + 131.56	0.8866

As an example for predicting vertical light pipe, a case study was taken in one of the office in Surabaya. The interior is shown in a previous figure (Fig. 3) and the dimension of that office is shown in Figure 13.

The initial simulation was conducted for recording the illuminance level using a side lighting only. As shown in Figure 14, the initial simulation showed levels of 175 lux. However, the SNI standard for office use is at 350 lux. In order to pass the standard, office must add an additional 175 lux.

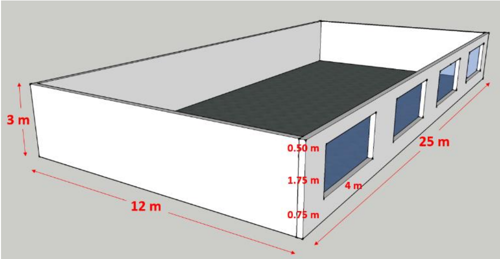


Figure 13 Existing office plan

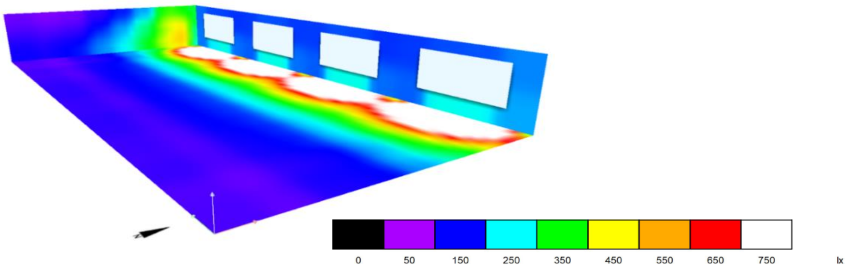


Figure 14 False color rendering in existing office without lamps.

The predicting formula was used to determine the vertical light pipe configuration. As previously mentioned, the most common sky condition in Indonesia is intermediate sky. Therefore, the calculation will be counted using intermediate sky predicting formula.

(Ø 1.0 m) $175 = -26.107(L) + 211.78$

$L = 1.408$ m

The calculation concluded that by adding 175 more lux through a vertical light pipe, the pipe must be configured with a diameter of 1 m and at least a length of 1.408 m or shorter. In addition, a pre-simulation was conducted after adding vertical light pipes (diameter of 1 m and length of 1.408 m) as seen in Figure 15. The false color image depicted that the average illuminance was roughly at 350 lux.

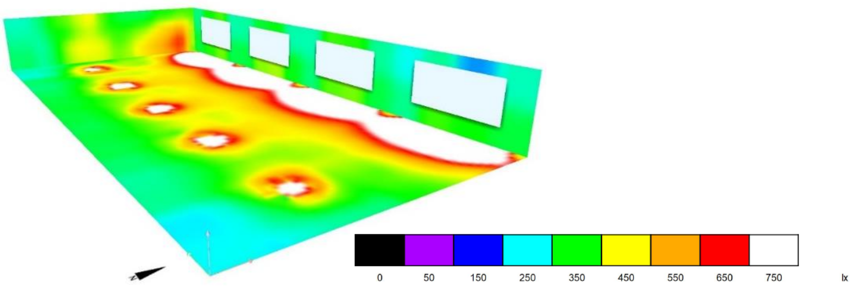


Figure 15 False color rendering after input vertical light pipe.

Discussions and conclusions

The illuminance provided by the vertical light pipe depended on its diameter, length, and the sky condition. It is noted that the ratio of sky conditions in Indonesia was 30.3% : 55.9% : 13.7% for clear sky, intermediate sky, and overcast sky respectively. The output result shows that vertical light pipes can be used for common tasks with a range started from 150 - 220 lux, under intermediate sky conditions. However, 13.7 % of days in a year would be the least effective times for using a vertical light pipe strategy.

When comparing the amount of sunlight that Malaysia and Thailand receive. It showed that Malaysia has good potential to use a vertical light pipe strategy. However, Thailand faces an obstacle in the use of light pipe due to its typically lower level of illuminance. Research indicates that areas near the equator have greater viability to use vertical light pipes effectively.

The result from this study suggested that vertical light pipes have good potential to use as daylight strategy in covering simple visual tasks at 60 - 150 lux and common tasks at 150 - 500 lux in a place such as Surabaya, Indonesia.

Acknowledgements

The authors are grateful for the KKU Scholarship for ASEAN and GMS Countries' Personnel for providing support both financially, and through the use of its facilities.

References

Badan Standar. (2000). *Energy consevation on lighting system*. Jakarta: Badan Standar Nasional.

Cabfis, R. C., & O. IL Pereira, F. (1996). Luminous efficacy of daylighting in intertropical region: An analysis for toplighting systems. *Renewable Energy, 8*, 210-213.

Chaiyakul, Y. (2013, March). *Daylighting in building through a vertical light pipe in Thailand.* Paper presented at the Lux Pacifica, Bangkok, Thailand.

Kadir, A. A., Ismail, L. H., Kasim, N., & Kaamin, M. (2016). Potential of light pipes system in Malaysian climate. *International Engineering Research and Innovation Symposium (IRIS), 160*, 8.

Lechner, N. (2015). *Heating, cooling, lighting* (4th ed). Hoboken, NJ: John Wiley & Sons.

Littlefair, P. (2011). *Site layout planning for daylighting and sunlight* (2nd ed). Watford: IHS BRE Press.

Malet-Damour, B., Boyer, H., Fakra, A. H., & Bojic, M. (2014). Light pipes performance prediction: inter model and experimental confrontation on vertical circular light-guides. *Energy Procedia, 57*(1), 1977-1986.

Muladi, E., Jamala, N., & Rahim, R. (2007, August). *An examination on daily horizontal illuminance data in Indonesia*. Paper presented at the 8th SENVAR & 2nd MALAY, Surabaya, Indonesia.

Pemerintah Provinsi DKI Jakarta. (2012). *User guide for green building in Jakarta* (Vol. 1). Jakarta: Pemprov DKI.

Pratama, H. C., & Chaiyakul, Y. (2018). Implication of the National Standard Indonesia (SNI) on lighting conversation as a basis of architectural design. *Journal of Building Energy & Environment, 1*(2018), 7.

Rahim, R. (2000). Analysis of sky illumination through sky ratio. *Journal of Dimensi Teknik Arsitektur, 28*(2), 5.

Sok, E. (2017). The (hidden) benefits of daylighting. *SageGlass Europe & Middle East.* Retrieved from https://www.sageglass.com/eu/sites/.../the_hidden_benefits_of_natural_light