EVALUATION OF NATURAL LIGHTING SYSTEM OF LECTURE BUILDING

Ariska Desy Haryani[1], Yatnanta Padma Devia[2], Eva Arifi[2]

[1]Student, Master Program, Department of Civil Engineering, Faculty of Civil Engineering, Brawijaya University
[2]Lecturer, Department of Civil Engineering, Faculty of Civil Engineering, Brawijaya University
Korenpondensi : Ariskaadesy@gmail.com

ABSTRACT

Visual comfort the most important thing a building need. A building with proper passive design can fulfill the users' visual comfort through natural lighting. On the other hand, a passive design that is less precise always requires energy to accomplish the users' visual comfort. Lecture building is one of buildings that is effectively used for 8 hours a day and 5 days a week. The high operating hour cause the visual comfort in the building becomes very important. The purpose of this study is to determine the performance of the building passive design in terms of lighting to comprehend various visual problems of the building. The method used in this research is quantitative comparative by comparing the value of building lighting. From the results of field measurements which was carried out by using building modeling simulations with Ecotect software and SNI 03-6197-2000 parameter, several problems were found in the building's natural lighting system such as inadequacy of lighting on the facade with southwest orientation, enormous lighting on the facade with a northeast orientation, uneven lighting causing various visual discomforts.

Keywords : Ecotect software, natural lighting, visual comfort

1. INTRODUCTION

Indonesia is one of countries with the high consumption of energy which always increases each year. In 2005, Indonesia is among the 20 countries which consumes 80% of world's energy [1]. The consumption of energy in Indonesia was 878 kWh/capita in 2014 and reached 1,064 kWh/capita in 2018. In other words, the increase of its energy spending was as big as 21% within 4 years (Ministry of Energy and Mineral Resoures, 2018).

Research concerning the optimization of building passive design has been massively conducted to improve building performance [2]. Several parameters were used to evaluate the building performance, one of which is energy consumption.

Energy consumption spent by artificial lighting and plug load in the building reached up to 15%-25% from the total of building energy consumption [3]. The attempts to decrease the use of artificial lighting can compress the building energy consumption and increase building performance. By implementing the appropriate passive design, the use of natural lighting increase building performance particularly in terms of visual comfort and reduce the use of artificial lighting [4].

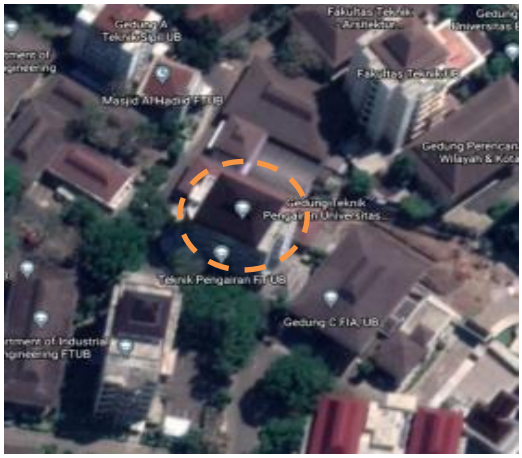
The purpose of this study is to evaluate the natural lighting system based on building passive design towards users' visual comfort. The visual comfort is reviewed based on the measurement of lighting values towards the standardized visual comfort which is relevant to SNI 03-6197-2000 about energy conversion on lighting system [5].

By employing Ecotect software as an assisting tool for simulation, the building performance particularly lighting can be revealed. Meanwhile, the analysis in using simulation often limited to its inability in appropriately modelling the recent condition of the existing building and its surrounding [6]. Therefore, the field measurement is urgently

needed as an attempt to validate the values which had been generated in the data analysis.

Lecture building which becomes the object in this study is where the teaching and learning activities are carried out as well as other related activities located in 7○56'57" SL and 112○36'48" EL. This building has 6 floors and the operation hour is almost 8 hours per day that is 08.00 – 16.00.

Building and the vegetation surrounding the building is fairly tight so that it affects its natural lighting. The following is the situation map depicted from the aerial view of the building as seen through **Picture 1** as follows.

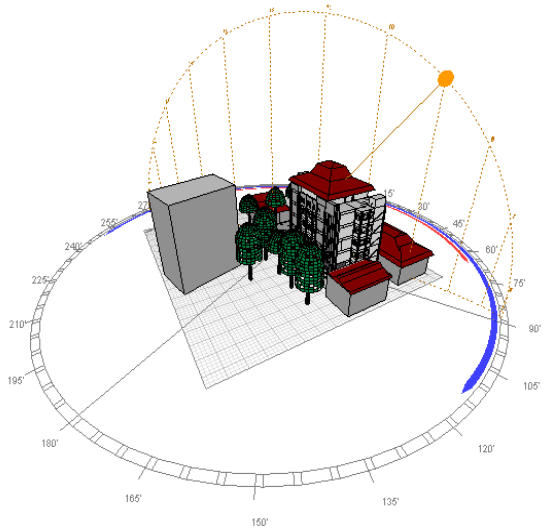


Picture 1. The Aerial View of The Building

Building entrance is west-oriented yet the west facades has the smallest area of all the facades. In floor 3 to 6, the west facades were almost entirely in the form of window. The front view of the building can be seen through **Figure 2** as follows.

Picture 2. The Front View of The Building

Field measurement was conducted in 24 March 2021 at 08.00, 12.00 and 16.00 WIB with overcast sky condition and no rain. Based on the result of the simulation, the position of the sun in March is perpendicular to the top of the building. The trajectory of the sun can be seen in **Figure 3** below.



Picture 3. Sun Trajectory

2. LITERATURE REVIEW

2.1 Previous Studies

1. The study of natural lighting in a reading room of Indonesia Library revealed that the orientation of the building affects its lighting. The best building orientation in a tropical climate is facing north or south because the direct sun radiation can be avoided. Based on the research result, it was figured out that the total value of lux in the library is below the standard of visual comfort of the reading room that is 250 lux so that improvement is needed for room lighting [7].
2. The analysis of energy audit, the attainment of energy efficiency in AB building, Tangerang Regency, Banten, reported that the history of energy usage in an important matter as it is used to uncover the pattern of energy usage of a building. According to this study, the lighting condition of the building in each room is ranging from 45 lux – 146.5 lux which is considered as energy saving yet it does not have comfort element thus refinement is mandatory for the lighting of the building [8]
3. The study on the energy efficiency of the inpatient room of the Islamic Hospital of

Yarsis in Surakarta revealed that natural lighting is one of factors in using energy appropriately and efficiently. By correctly planning, the use of natural energy can be realized without decreasing its comfort. Based on this study, it was also revealed that the increase of lighting by using a design scenario of adding up the ventilation, windows, and lamps, the average number of each room was obtained as big as 250 lux [9].

2.2 Building Lighting System

In planning a building, the lighting system of a building must be considered carefully particularly for a building which is designed for energy saving. In a building, there are two lighting systems namely natural and artificial lighting system. The energy-saving building needs a more meticulous planning as the natural lighting system must be optimized so that the use of artificial lighting can be reduced.

2.3 Visual Comfort

Visual comfort is a condition where the lighting provided in a room has reached the lighting standard needed as well as the glare standard allowed. Factors affecting visual activities, such as lighting, may give impacts to the teaching and learning activities happened in classroom [4]. Related to the standard lighting required for a building, there must be parameter applied to measure the standard. The standard of visual comfort in a room is regulated in SNI 03-6197-2000 with a certain level of visual comfort which has been adjusted to the needs and activities of the building. The lighting parameter can be seen through **Table 1**.

Table 1 Average Luminance Level, Rederence, and Color Temperature SNI 03-6197-200

Room Function	Lighting Level (lux)	Color Retention Group	Color Temperature		
			Warm White < 3300 K	Coll White 3300K-5300K	Daylight >5300K
Educational Institution					
Classroom	250	1 or 2		●	●
Library	300	1 or 2		●	●
Laboratory	500	1		●	●
Drawing Room	750	1		●	●
Toilet	250	1 or 2		●	●
Canteen	200	1	●	●	
Archieve Warehouse	150	1 or 2		●	●

Based on aforementioned SNI standard, the value of classroom lighting is 250 lux and library is 300 lux. By considering that classroom is not only used for teaching but also reading, the standard used was 250 lux – 300 lux for this research.

3. RESEARCH METHOD

The methodology employed in this study is comparative quantitative by comparing the result of Ecotect simulation with the result of direct measurement in the field. The evaluation towards the condition of the building was conducted by using the result of comparison and compared to the standard of SNI 03-6197-2000 about Energy Conversion in a Lighting System.

3.1 Data Collection Technique

In a research, the appropriate and well-planned data collection technique is needed to ease the research process. The techniques used in this research are:

1. Field Measurement
   The field measurement conducted in this study is measuring light intensity of a building with several rooms as the chosen zones.
2. Secondary Data Collection

Secondary data used in this research consisted of technical data of a building i.e. building area, layout, pictures and materials of the building as well as data from BMKG in the form of climatology and sun radiation.

3.2 Data Retrieval Technique

The primary data of this study is in the form of lighting which is measured by using luxmeter type AS803. The measurement was conducted at 08.00, 12.00 and 16.00 on 18 room zones. The techniques of light measurement is adjusted to SNI 16-7062-2004 related to the Measurement of light intensity in work place [10].

3.4 Building Modeling

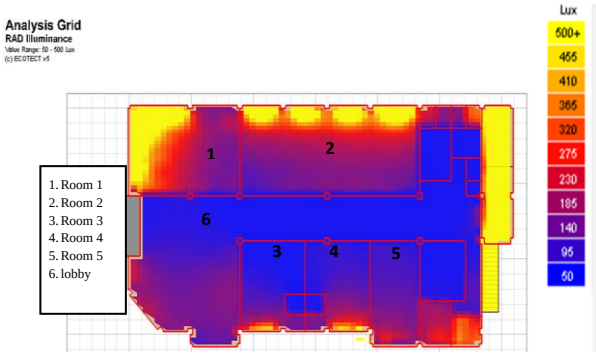
The model used to analyze the Ecotect is adjusted to the condition of the existing building. Several obstruction such as vegetation in its surrounding is also adjusted although the model has not been perfect yet and several obstruction details were ignored. The building modeling can be seen through **Picture 4** below.

Picture 4. Building Modeling

4. RESULTS AND DISCUSSION

4.1 Ecotect Simulation

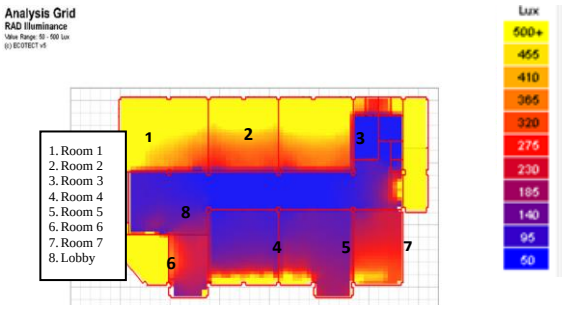
The Ecotect lighting simulation was carried out in floor 2-6 which consisted of 80 zones or rooms. According to the result of Ecotect simulation in each floor, it can be revealed that the northeast side of the building obtained bigger sun light compared to the other sides. The result of the field measurement showed that the zones located in the northeast has a lighting which exceeds the ideal room lighting. The lighting simulation on floor 2 can be seen through **Picture 5**.



Picture 5. Simulation of Floor 2

The color of blue, purple, and deep orange showed that the lighting level is under 260 lux meaning that the light penetration inside the room cannot reach the whole room so that it causes the inside darker. The yellow space showed that the value of the light is above 450 lux which is potential to cause glare. The lack of natural lighting in floor 2 is caused by the abundant obstruction from its surrounding such as building and vegetation.

In floor 3, the lighting increased due to the increased height and the reduced obstruction particularly in several parts which are northeast-oriented. Floor 3 is locate in +7.00 m elevation from the ground level. The following are the results of simulation of floor 3.



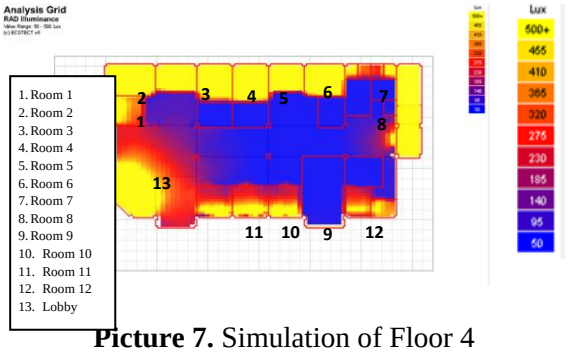
Picture 6. Simulation of Floor 3

Room 1, 2, and 3 which are northeast-oriented possessed higher lighting compared to room 4, 5, and 6 which are southwest-oriented. The yellow space showed that the lighting is above 500 lux while the orange to red space is ranging from 215 – 490 lux. The lighting which is above 500 lux has a potential in causing glare so that it did not fulfill users' visual comfort.

Blue zones indicate that the lighting of the room is less than the lighting standard. In

using the room, artificial lighting assistant is needed to reach the users' visual comfort. One of reasons causing the lack of lighting is the obstruction from the vegetation and southwest-oriented building.

Floor 4 is the lecturer's room which has the most zones. Floor 4 is located in +11.00 m elevation of ground level. The result of lighting simulation can be seen from **Picture 7** below

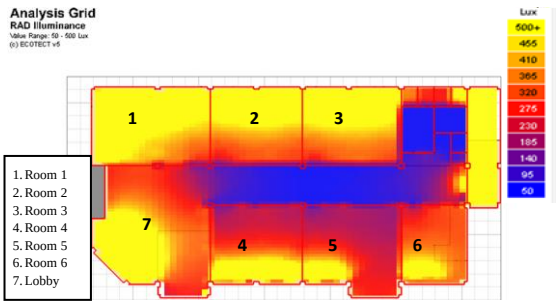


Picture 7. Simulation of Floor 4

Blue color indicates that the value of lux is under 1000 lux. In some parts of the building which is southeast oriented has bigger lighting which is above 500 lux yet this makes the users' visual comfort distracted due to glare.

In a room which is southwest-oriented, the lighting is lower than the northeast-oriented. The lighting which is located near the window is more than 500 lux while the lighting which is far from the window is in range 230 – 275 lux.

Floor 5 is located in +15.00 m elevation from the ground level and is used as classroom and independent learning room. In floor5, the obstruction from the vegetation and other building is relatively small. The result of lighting simulation of floor 5 can be seen through **Picture 8** below.

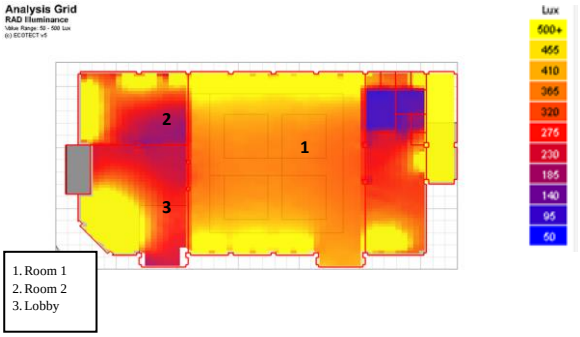


Picture 8. Simulation of Floor 5

In a room which is northeast oriented showed yellow and orange which is dominant. This shows that the lighting is in range 400 lux and above. The visual comfort of lighting in those rooms did not accomplish the visual comfort as it exceeds the lighting standard. Besides, the wide yellow space has a potential of causing glare.

In room 4, 5, and room for independent learning, the maroon and purple color shows that the inside room has a lighting level below 185 lux. The yellow part near the window shows that the lighting is above 400 lux.

Floor 6 is located in +19.00 elevation from the ground level. It functions as a meeting room. Below are the results of lighting simulation in floor 6. The result of lighting simulation can be seen from Picture 9 below



Picture 9. Simulation of Floor 6

The meeting room has varied lighting. In a spot which is in the front of the window which directs to the northeast has more yellow space. It shows that the lighting level is approximately above 450 lux.

The edge after the yellow light of the whole room lighting starts turning to light orange spread evenly. This indicates that the value of lux is in range 365-400 lux. Although the value of lux is fairly high, it does not have sufficient color which is evenly spread in the middle of the building. This indicates that the potential of causing glare is almost none.

4.2 Field Measurement

In validating the lighting simulation, field measurement is required to know the preciseness of the simulation result. The field measurement was conducted to several zones inside the building. The zone was selected based on the frequency of building usage and its orientation as well as its height to compare between one zoon with another. The result of lighting measurement of room lighting can be seen through Table 2 below.

Table 2. Room Lighting

No	Room	Floor	Room Orientation	Building Natural Lighting (Lux)			
				Morning 08.00	Noon 12.00	Afternoon 16.00	Average
1	Room 2	2	Northeast	238	189	165	197
2	Room 2	3	Northeast	952	585	394	643
3	Room 3	3	Northeast	1052	462	472	662
4	Room 4	3	Southwest	93	106	85	95
5	Room 5	3	Southwest	33	84	57	58
6	Room 6	3	West - Southwest	1101	2805	1243	1716
7	Room 1	4	Northwest	491	815	258	521
8	Room 2	4	West	762	1077	1060	966
9	Room 3	4	Northeast	1071	1087	938	1032
10	Room 4	4	Northeast	899	1020	760	893
11	Room 5	4	Northeast	777	1377	946	1033
12	Room 6	4	Northeast	1120	1630	960	1237
13	Room 7	4	Northeast	1008	1319	958	1095
14	Room 8	4	Southwest	171	278	331	260
15	Room 9	4	Southwest	189	292	345	275
16	Room 2	5	Northeast	747	917	641	768
17	Room 3	5	Northeast	761	950	661	791
18	Room 4	5	Southwest	178	318	316	270

Several differences appear between the value generated from direct measurement and simulation. This is due to the limitation in modeling the condition of the surrounding. The visual comfort in a room can be revealed by comparing the measurement result with the standard of SNI 03-6197-2000. The room lighting standard can be seen through Table 1. Particularly for a room with lighting value beyond the SNI, whether it is less or more than the standard that is 250 – 300 lux, in considered not accomplishing the standard.

Table 3. The Comparison of Lighting Value

No	Room	Floor	Field Measurement (Lux)	Ecotect Simulation (Lux)	SNI Standard Lighting (Lux)	Note
1	Room 2	2	197	240	250 - 300	Less
2	Room 2	3	643	592	250 - 300	Exceed
3	Room 3	3	662	608	250 - 300	Exceed
4	Room 4	3	95	120	250 - 300	Less
5	Room 5	3	58	63	250 - 300	Less
6	Room 6	4	1716	1350	251 - 300	Exceed
7	Room 1	4	521	563	253 - 300	Exceed
8	Room 2	4	966	840	254 - 300	Exceed
9	Room 3	4	1032	922	255 - 300	Exceed
10	Room 4	4	893	752	250 - 300	Exceed
11	Room 5	4	1033	846	250 - 300	Exceed
12	Room 6	4	1237	1028	250 - 300	Exceed
13	Room 7	4	1095	924	250 - 300	Exceed
14	Room 8	4	260	315	252 - 300	Adequate
15	Room 9	4	275	321	253 - 300	Adequate
16	Room 2	5	768	629	250 - 300	Exceed
17	Room 3	5	791	659	250 - 300	Exceed
18	Room 4	5	270	301	250 - 300	Adequate

Based on the result of field measurement and the analysis of lighting pattern, it is obtained several points explained in the following:

1. The building facade which is northeast-oriented in floor 1 and 2 is lack of lighting due to the obstruction from the other buildings.
2. The building facade which is northeast-oriented in floor 3 up to 5 has natural lighting which is amplifying so that it causes glare and the visual comfort cannot be accomplished.
3. In a room with northeast orientation, the lighting is not evenly spread due to limited light penetration.
4. The facade of southwest-oriented building in several rooms in floor 4, 5, and 6 have sufficient lighting ranging from 250 – 300 lux yet it is not evenly spread as the lighting level which is quite big is located near the window so that it is potential in causing glare.
5. Rooms in floor 1, 2, and 3 which are southwest-oriented has lighting which is far from the standard.

5. CONCLUSION

The passive design of the lecture building in this study is inadequately supporting the use of natural lighting. The rooms which are northeast-oriented tend to have higher lighting value which is more than 300 lux. The rooms which are southwest-oriented tend to have lighting value which is lower than 250 lux in floor 1, 2, and 3. In floor 4, 5, and 6, the rooms which are southwest-oriented has lighting value which reached the standard of lighting. Nevertheless, the lighting distribution is not well spread so that it may cause glare.

With the miscellany of issues aforementioned, improvement in the passive design of building needs to be conducted to support the use of natural lighting in a building such as the implementation of secondary skin, the application of vertical shades, or the use of reflective glass or the application of lightshelf.

6. REFERENCES

[1] World Bank Group. 2015. *Global Tracking Frameworld Report.* 2015.: Wina.

[2] Arif Kamal, M. 2012. *An Overview of Passive Cooling Technic in Building: Design Concept and Arcitectural Interventions. Acta Technica* Napocensis: Civil Engineering and Arsitektur Vol 55 no 1 2012.

[3] Pemprov DKI Jakarta. 2013. *Panduan Pengguna Bangunan Gedung Hijau Jakarta. Jakarta*: *Greenbuilding* Jakarta.go.id

[4] Lechner, Nobert. 2015. *Heating, Cooling Lighting Fourth Edition*. John Wiley & Sins Inc: New York.

[5] Badan Standardisasi Nasional. 2000. *Konservasi Energi Pada Sistem Pencahayaan.. SNI 03-6197-2000*. Badan Standardisasi Nasional. Jakarta.

[6] Satwiko, Prasato. 2005. *Fisika Bangunan 1*. Andi: Yogyakarta.

[7] Dewantara, Fajar dkk. 2019. *Kajian Pencahayaan Alami Ruang Baca Perpustakaan Indonesia*. Arcade Jurnal

[8] Biantoro, Agung Wahyudi dan Dadang S Permana. 2017. *Analisis Audit Energi untuk Pencapaian Efisiensi Energi di gedung AB, Kabupaten Tangerang, Banten*. Jakarta.

[9] Kurniawati, Ria. 2017. *Efisiensi Energi Ruang Rawat Inap Bangunan Rumah Sakit Islam Yarsis Surakarta*. Jurnal Muara Vol 01. No. 01: 157-163.Arsitektur Vol 01. Nol. 03: 94-99

[10] Badan Standardisasi Nasional. 2004. *Pengukuran Intensitas Penerangan di Tempat Kerja. SNI 16-7062-2004*. Badan Standardisasi Nasional. Jakarta.