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Daylight Intensity of Reading Room with Shading Device's Opening (Case Study: The Library of Universitas Budi Luhur, South Jakarta)

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***Abstract*— Daylight entering through the window can be obtained from several sources, namely direct sunlight, clear sky, clouds or reflections of the lower surface and surrounding buildings. Light from each source differs not only in the amount and heat it carries, but also in other qualities, such as color, distribution, and savings. To get natural lighting in the space required large windows or glass walls at least 1/6 of the floor area. Light is the most important part of human life, to get the right lighting in a space, it is necessary to design the right natural lighting according to their needs so that visual comfort can be achieved. Visual comfort is the recommended lighting level that does not exceed the stated threshold and brightness level, and no glare space occurs. Not only to illuminate a room, but the level of lighting also affects the condition of the room created. But visual comfort will be disrupted if glare problems occur. Visual disturbances in the form of "glare" affect visual performance which adversely affects the ability to see. Based on previous research, it was found that the average value of the natural lighting intensity in the reading room of the 3rd floor of the library of Budi Luhur University was 663 lux, this shows that the average value of the natural lighting intensity that occurred exceeded SNI standards and caused glare problems that could interfere with comfort library users, so there needs to be a natural lighting system strategy that can be applied to achieve visual comfort in the library reading room on the 3rd floor. This research was conducted with the main objective is to get a shading device design solution that can reduce glare problems to achieve visual comfort. The research method used in this study is a quantitative research method with an experimental approach. The variables in this study are experimental variables (visual comfort, opening orientation, shading device design) and non-experimental variables (direct light source, sky conditions, and direct glare). The stages of this research are in the form of; i) identification and data collection in the form of library studies related to natural lighting, visual comfort and shading devices, ii) identification and data collection in the form of library studies related to shading devices, iii) observation of case studies in the form of taking pictures in the form of photographs and work drawings, iv) conducting simulation of several alternative shading devices designs that will be applied to the window openings of the 3rd floor library reading room of Budi Luhur University, v) analysis and synthesis, vi) making research results and drawing conclusions. The results of this study in the form of the most optimal design of shading devices that can reduce lighting intensity is an alternative horizontal overhang 4 design with an overhang width of 200 cm. Whereas the most optimal design of vertical overhang shading devices that can reduce lighting intensity is alternative vertical overhang design 1 with overhang width of 50 cm and vertical fin distance every 50 cm.**

Keywords: daylight intensity, visual comfort, glare, shading devices

I. INTRODUCTION

The existence of a library in the world of education is highly prioritized, moreover at a university to support learning and teaching activities, it should be the center of the library's attention. One of them is the library at Budi Luhur University, located in South Jakarta. Budi Luhur University Library operates from Monday to Saturday, with operating hours Monday through Friday open from 08:00 am until 09:00 pm and on Saturdays from 08:00 am until 03:00 pm. Based on operating hours, it should be able to exploit the potential of natural lighting from morning to evening, while at night it depends on artificial lighting.

Natural lighting is lighting that comes from sunlight that appears from morning to afternoon to evening, with the lighting source coming from direct sunlight and the distribution of sunlight or skylight, called diffuse. Natural lighting is intended to get lighting in the room from natural light. The design of natural lighting systems needs to know the availability of natural light received at the local location [1]. The general goal of natural lighting is to produce efficient quality light while minimizing direct glare, reflecting layers, and excess light ratio. Natural light entering through the window can come from several sources, namely direct sunlight, clear sky, clouds or reflections of the lower surface and surrounding buildings. The light from each of these sources varies not only in the amount and heat it carries, but also in other qualities, such as color, dispersion, and savings. To get natural lighting in space required large windows or glass walls of at least 1/6 of the floor area [2].

Visual comfort is the convenience of accessing all visual information and is closely related to the sense of sight [3]. Visual comfort is the recommended lighting level that does not exceed the stated threshold and brightness level, and no glare space occurs. Not only to illuminate a room, but the level of lighting also affects the condition of the room (comfort and pleasure) created [4]. Visual comfort is closely related to the distribution of room light, generally, lighting design uses standards recommended by SNI that explain

illumination standards in various building functions. Indonesian National Standard SNI-03-6575-2001 concerning Energy Conservation in Lighting Systems, recommends an illumination standard in libraries of 300 lx. Visual comfort is achieved when the level of illumination in the library reading room is recommended, especially in the work field, so that activities can be carried out properly and comfortably. But visual comfort will be disrupted if glare problems occur. Visual disturbances in the form of "glare" affect visual performance which adversely affects the ability to see. Glare is divided into two namely direct glare and glare due to reflection. Direct glare is caused by a bright light source that is distracting, uncomfortable or missing in visual performance. Whereas glare due to reflections from light sources on shiny tabletops or polished floors can cause the same problems as direct glare [5].

Based on previous studies, it was found that the average value of natural lighting intensity in the reading room of the 3rd floor of the library of Budi Luhur University was 663 lux, this shows that the average value of natural lighting intensity that occurred exceeded SNI standards and caused glare problems that could interfere with comfort library users, so there needs to be a natural lighting system strategy that can be applied to achieve visual comfort in the library reading room on the 3rd floor [5]. Architectural solutions to get visual comfort and reduce glare in the library reading room both on the 3rd floor can be in the form of shading devices with horizontal overhang and vertical overhang types. However, the design of shading devices needs to be analyzed and studied in more detail in their application to openings or windows in the reading room of the 3rd-floor library of Budi Luhur University. Thus, further research is needed to apply the shading devices design recommendations that will be applied to window openings and prove the level of visual comfort that occurs in the library reading room on the 3rd floor of Budi Luhur University.

II. Library of Budi Luhur University

Budi Luhur University Library is a unit that serves to provide information services to the academic community in carrying out the duties of the Higher Education Tri Dharma which includes education, research and community service. Budi Luhur University Library continues to develop itself following the development of science and technology, especially the development of information and communication technology, which is realized by implementing information technology in carrying out activities and providing facilities and infrastructure that supports library users. Data of the noble university library building as follows:

Building name	:	Unit 3 of the building, 2sc floor, and 3rd floor
Address	:	Jl. Ciledug Raya Petukangan Utara Jakarta Selatan
Building area	:	975 m^2
Number of floors	:	2 floors

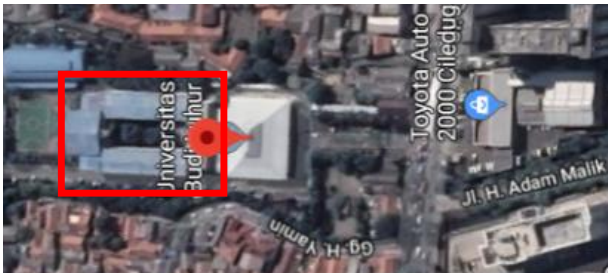


Fig. 1. Map of Budi Luhur University
Source: https://www.google.co.id/maps/place/Universitas+Budi+Luhur

Budi Luhur University Library is located in the unit building 3 floors 2 and 3 floors. The object of research is the 3rd-floor library containing a thesis/thesis room, library headroom, and reading room. Library map can be seen in Figure 2.

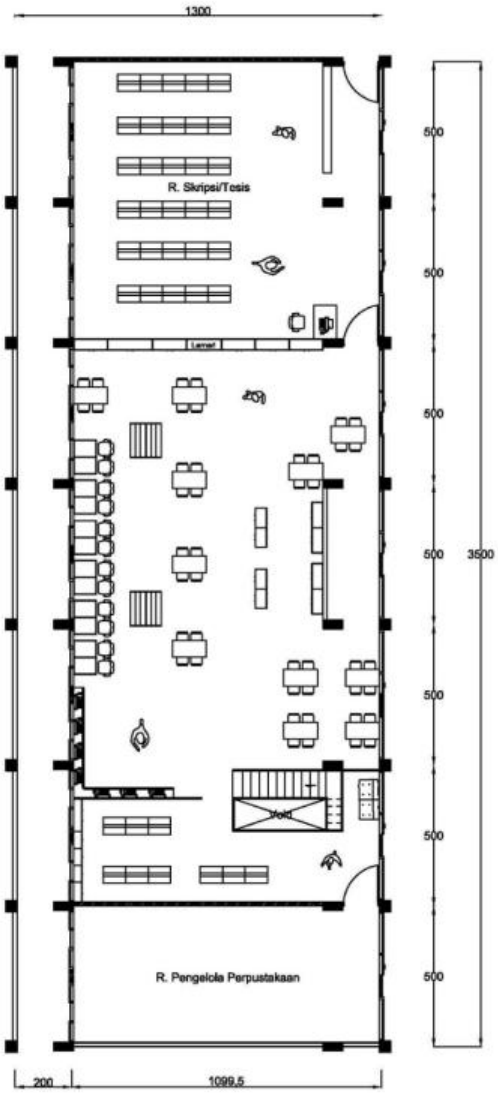


Fig. 2. Floor Plan of the 3rd floor of the Budi Luhur University

The appearance of the Budi Luhur University library building is integrated with the unit 3 building which functions as a classroom. The protrusion of the building's structure columns can be a shading device for wide windows in the reading room that line up throughout the lifetime of the

library building. The appearance of the library building can be seen in Figure 3.

(a) Right side view (East)

(a) Left side view (West)

(b) Column protruding out as shading device

Fig. 3. The Facade of the Library Building of Budi Luhur University.

Budi Luhur University Library on the 3rd floor is dominated by reading rooms. The condition of the library's reading room at Budi Luhur University in general experiences glare along the side of the building facing East and West. Although the opening of the window in the reading room is quite wide, the lighting in the reading room is still assisted by artificial lighting, which is using lamps.

Fig. 4. Lighting conditions on the 3rd-floor reading room

Measurement of natural lighting intensity in the library's reading room at Budi Luhur University has been carried out at each reading table on each floor so that lighting conditions can be represented.

Based on SNI 03-6197-2000 concerning Energy Conservation in Lighting Systems, the average lighting level in a library reading room is 300 lx [6]. Conditions for measuring lighting levels in the library reading room at BudiLuhur University are:

1. Library reading room on the 3rd floor with window openings facing East and West.
2. Measurements were made at each reading room table.
3. Measurement Measurements are made at 09:00 a.m, morning at 11:00 a.m. and afternoon at 03.00 a.m. when the sky is clear, in March - April – May - June 2018.
4. Measurements were made of the level of lighting in the reading room with conditions without artificial lighting with a measuring point height of 80 cm.

The results of measurements of lighting levels in the reading room of the 3rd floor of the library of Budi Luhur University can be seen in table 1:

TABLE 1. THE INTENSITY OF NATURAL LIGHTING AVERAGE LIBRARY READING ROOM

Location	The intensity of daylighting (lx)			Average daylighting intensity (Lx)
	Time: 9:00 am	Time: 11:00 am	Time: 3:00 pm	
Library reading room on the 3rd floor	294	462	1232	**663**

Based on the results of measurements of the intensity of natural lighting in the library reading room on the 3rd floor, the value of natural lighting intensity was 663 lx. The value of the natural lighting intensity exceeds the SNI 03-6197-2000 standard on Energy Conservation in the Lighting System where the value of lighting intensity for the reading room with the function of the building as a library is 300 lx [6]. As a result of excessive lighting intensity, heat radiation and glare can occur in the reading room and can disturb the comfort of the user of the room.

III. RESEARCH METHOD

The research method used in this study is a quantitative research method with an experimental approach. The quantitative research method is a process of finding the knowledge that uses data in the form of numbers as a tool to analyze information about what you want to know. Experimental research is research conducted to find out the consequences arising from a treatment given intentionally by researchers [7]. Experimental research is research conducted to find out the consequences arising from a treatment given intentionally by researchers [8]. Based on the definitions of some of the experts, it can be understood that experimental research is research conducted to determine the effect of giving a treatment or a treatment of research subjects.

In experimental research, several variables are known. Variables are anything related to conditions, conditions, factors, treatments, or actions that are expected to affect the results of an experiment. Variables that are directly related and applied to find out a particular situation and are expected to have an impact/result from experiments are often called experimental variables (treatment variables), and variables that are not intentionally done but can affect the results of experiments are called non-experimental variables. Experimental variables are conditions that want to be

investigated for how they affect a symptom. Non-experimental variables can be partially controlled, both for the experimental group and the control group. This is called a controlled variable. However, some of the non-experimental variables are outside the power of the experiment to be controlled or controlled. This type of variable is called an extraneous variable or extraneous variable.

The variables used in this study are shown in Table 2.

TABLE 2. VARIABLES IN RESEARCH

Variable Type	Variable	Sub Variable
Experimental Variable	Visual Comfort	Tingkat pencahayaan alami (intensitas cahaya)
	Opening orientation	Timur - Barat
	Design of Shading Devices	*Horizontal Overhang*
		Vertical Overhang
Non-experimental variable	Control Variable	-
	Extraneous Variables	Natural light source
		Sky conditions
		Direct glare

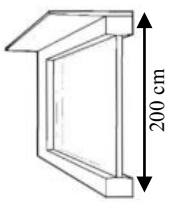
The research method used is:

a) Quantitative Method which is to measure the intensity of natural lighting on the window openings that have been applied shading devices in the library reading room on the 3rd floor of Budi Luhur University.
b) Experimental Approach, namely the manufacture and installation of shading devices on window openings to determine the effects of an intentional treatment given by researchers, in this case knowing the consequences of using shading devices on window openings.

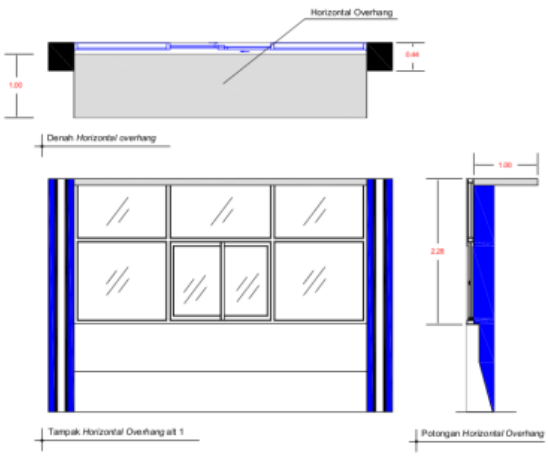
IV. SHADING DEVICES

a. Dimension Calculation for Alternative Design of Shading Devices

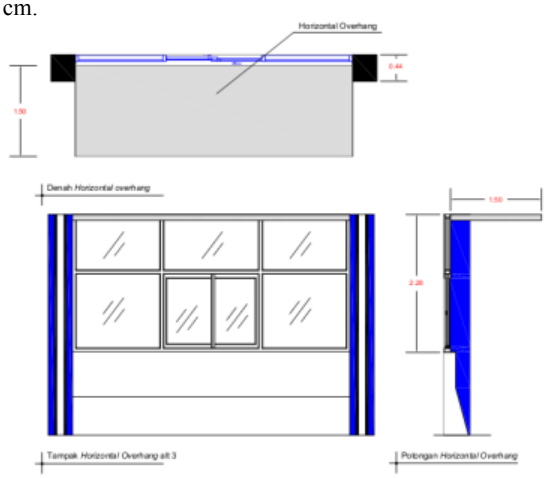
Before making the design of shading devices, the thing to do is to determine the dimensions of the shading devices to be designed. This dimension consists of horizontal overhang and vertical overhang dimensions. Based on the library's existing window dimensions, the calculation of the dimensions of the shading devices design is obtained as follows:

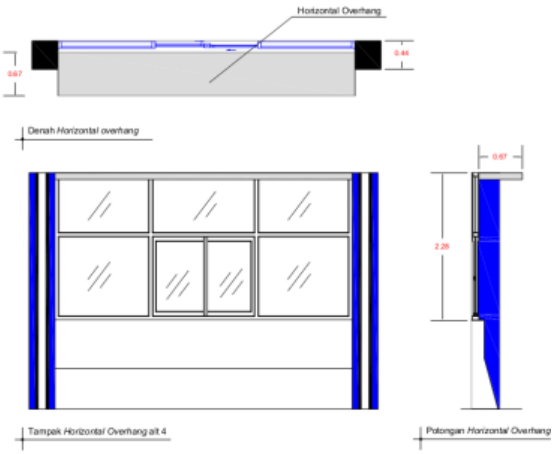
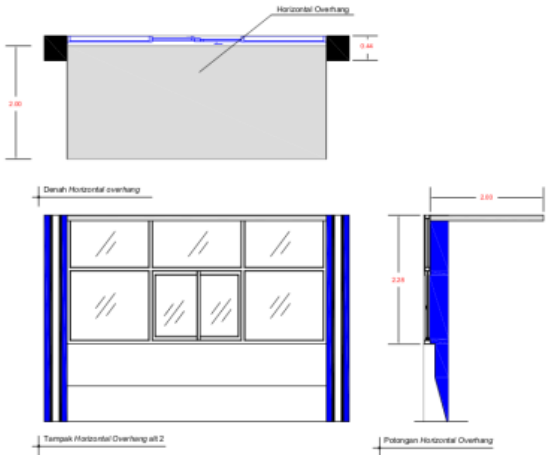
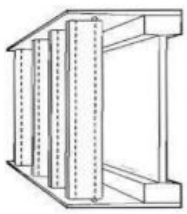
No.	Types of Shading Devices	Alternative Design	Calculation
1	*Horizontal Overhang* 	*Alternative Horizontal Overhangs 1*	Window opening height (H) = 200 cm Width (L) of horizontal overhang: $L = \frac{H}{2}$ $L = \frac{200\ cm}{2}$ L = 100 cm
2		*Alternative Horizontal Overhangs 2*	Window opening height (H) = 200 cm Width (L) of *horizontal overhang*: $L = \frac{3H}{4}$ $L = \frac{3\,.\,200\ cm}{4}$ L = 150 cm
3		*Alternative Horizontal Overhangs 3*	Window opening height (H) = 200 cm Width (L) of horizontal overhang: $L = \frac{H}{3}$ $L = \frac{200\ cm}{3}$ L = 66,7 cm L = 67 cm

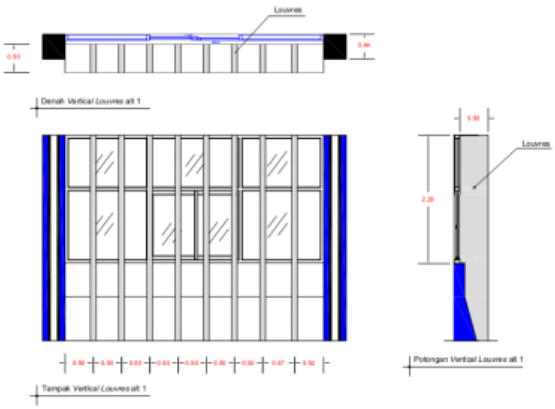
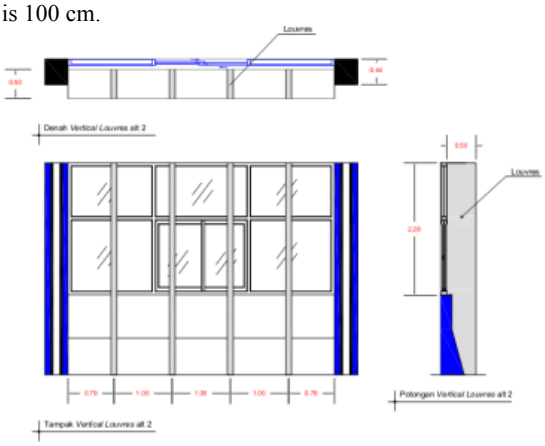
The width of the horizontal overhang used is 100 cm.

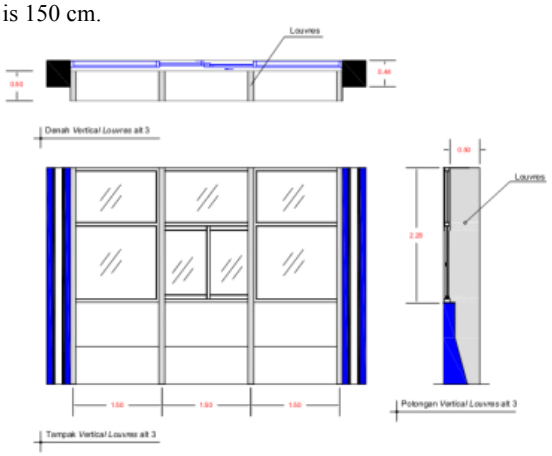


The width of the horizontal overhang used is 150 cm.



No.	Types of Shading Devices	Alternative Design	Calculation
	The width of the horizontal overhang used is 67 cm.		
			
4		*Alternative Horizontal Overhangs* 4	Window opening height (H) = 200 cm Width (L) of horizontal overhang: $L = H$ $L = 200\ cm$ L = 200 cm
	The width of the horizontal overhang used is 200 cm.		
			
5	Vertical overhang  *Opening widht* (d) = 100 cm Width (L) of vertical fin:	*Vertical Overhang Alternatives 1*	Window opening height (L) = 50 cm Width (L) of horizontal overhang: $\frac{d}{L} = 1$ $\frac{d}{50\ cm} = 1$ $d = 50\ cm$

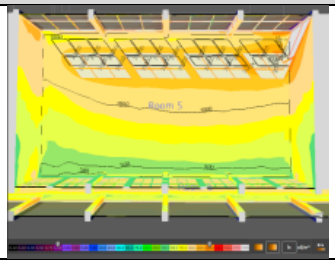
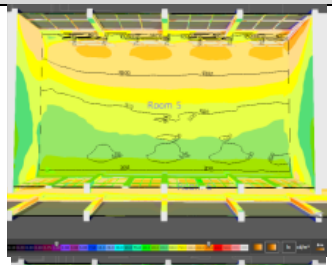
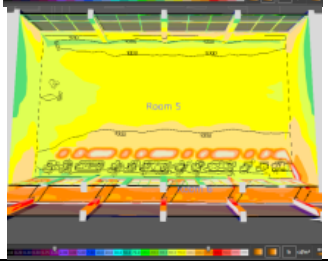
No.	Types of Shading Devices	Alternative Design	Calculation
	$L = \frac{d}{2}$ $L = \frac{100\ cm}{2}$ L = 50 cm		
		Vertical Overhang Alternatives 1	Window opening height (L) = 50 cm Width (L) of horizontal overhang: $\frac{d}{L} = 1$ $\frac{d}{50\ cm} = 1$ $d = 50\ cm$
	the distance between the louvers on the vertical fin used is 50 cm.		
			
6		*Vertical Overhang Alternatives 2*	Window opening height (L) = 50 cm Width (L) of horizontal overhang: $\frac{d}{L} = 2$ $\frac{d}{50\ cm} = 2$ $d = 100\ cm$
	the distance between the louvers on the vertical fin used is 100 cm.		
			

No.	Types of Shading Devices	Alternative Design	Calculation
7		*Vertical Overhang Alternatives 2*	Window opening height (L) = 50 cm Width (L) of horizontal overhang: $\frac{d}{L} = 3$ $\frac{d}{50\ cm} = 3$ $d = 150\ cm$ the distance between the louvers on the vertical fin used is 150 cm. 

V. Results and Discussion

A. *Simulation of Existing Condition of Library Reading Room*

Simulation of existing library reading room conditions is carried out to determine the value of natural lighting intensity using DiaLux Evo 8.1 software. The results of the simulation with this software will be compared with the results of manual measurement. Existing condition simulations were carried out in June 2019 at 09.00 WIB, 11.00 WIB, and 15.00 WIB. The results of the existing condition simulation will be shown as follows:

Time	Existing Condition Simulation	The intensity of daylighting (lx)
09:00 am		5242
11:00 am		1659
03:00 pm		1505

The simulation results of the existing library reading room conditions on Monday, June 10, 2019, can be seen in table 3:

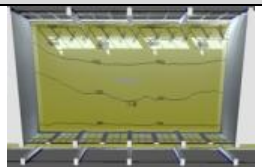
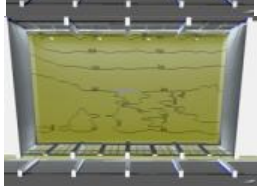
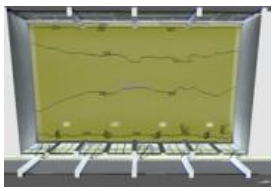
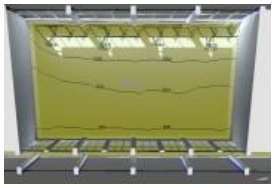
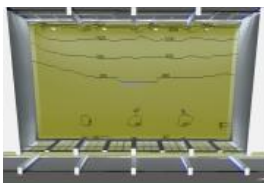
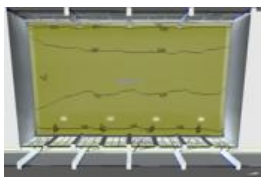
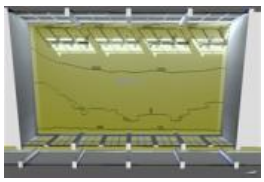
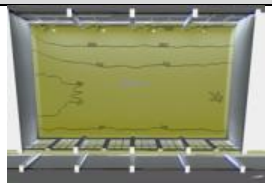
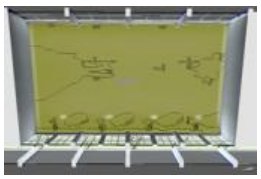
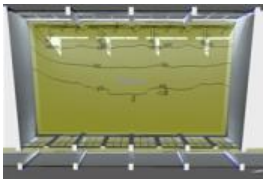
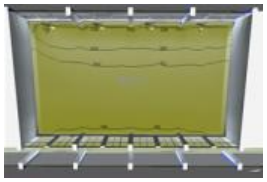
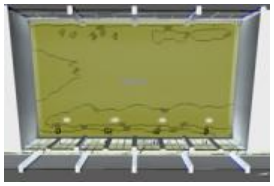
TABLE 3. SIMULATION RESULTS OF EXISTING LIBRARY READING ROOM CONDITIONS

Simulation Time	The intensity of natural lighting (lx)	Average Natural Lighting Intensity (lx)	*Daylight Factor* (%)
09.00 am	5242	2802	4,263
11.00 am	1659		
15.00 pm	1505		

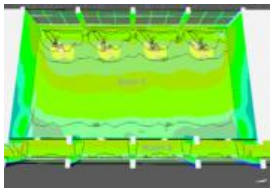
Based on the simulation results, the natural lighting intensity of the library reading room is 2802 lx. This lighting intensity exceeds the standard lighting intensity for the library reading room which is 300 lx. The daytime factor in the existing condition is 4.263%, the daylight factor for the library should be 5% so the daylight factor does not meet the standards.

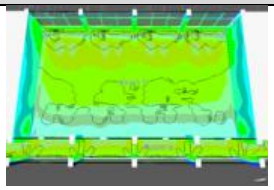
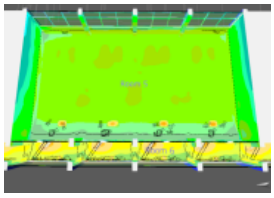
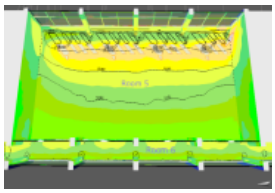
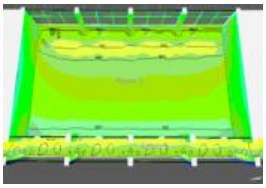
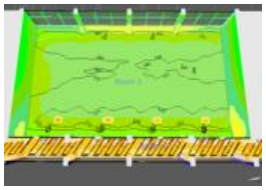
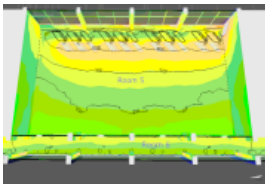
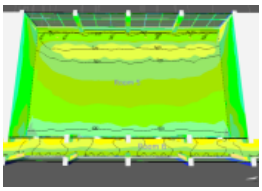
This causes the reading room to be over-lighting intensity, resulting in glare. The solution to this problem can be in the form of a design of shading devices to reduce excess lighting intensity and reduce glare, so that reader comfort can be achieved.

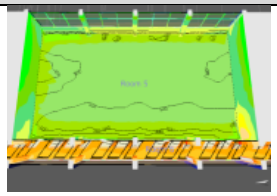
B. Simulation of Horizontal Overhang Shading Devices Simulation

Types of Shading Devices	Time	Existing Condition Simulation	The intensity of daylighting (lx)
Horizontal Overhang alternative 1	09:00 am		3189
	11:00 am		501
	03:00 pm		595
Horizontal Overhang alternative 2	09:00 am		2644
	11:00 am		450
	03:00 pm		545
Horizontal Overhang alternative 3	09:00 am		3693
	11:00 am		583
			
	03:00 pm		678
Horizontal Overhang alternative 4	09:00 am		1113
	11:00 am		334
	03:00 pm		422

C. Simulation of Vertical Overhang Shading Devices Simulation

Types of Shading Devices	Time	Existing Condition Simulation	The intensity of daylighting (lx)
Vertical Overhang alternative 1	09:00 am		558
	11:00 am		175

Types of Shading Devices	Time	Existing Condition Simulation	The intensity of daylighting (lx)
			
	03:00 pm		194
Vertical Overhang alternative 2	09:00 am		1705
	11:00 am		311
	03:00 pm		388
Vertical Overhang alternative 3	09:00 am		1812
	11:00 am		298
	03:00 pm		404

Types of Shading Devices	Time	Existing Condition Simulation	The intensity of daylighting (lx)
			

D. Shading Devices Design Simulation Results in the Library Reading Room

Based on the simulation results of existing conditions and alternative design of shading devices as a solution to the problem of excessive lighting intensity and the occurrence of glare in the library's reading room at Budi Luhur University, the following conclusions are presented in the simulation results in table 4:

TABLE 4. SIMULATION RESULTS DATA

Information	Average Daylighting Intensity (lx)	Daylight Factor (%)
Existing Condition	2802	4,263
Horizontal Overhang 1 (overhang width = 100 cm)	1428	2,61
Horizontal Overhang 2 (overhang width = 150 cm)	1213	2,256
Horizontal Overhang 3 (overhang width = 67 cm)	1651	3,088
Horizontal Overhang 4 (overhang width = 200 cm)	623	1,555
Vertical Overhang 1 (overhang width = 50 cm, distance = 50 cm)	309	0,913
Vertical Overhang 2 (overhang width = 100 cm, distance = 50 cm)	801	1,662
Vertical Overhang 3 (overhang width = 150 cm, distance = 50 cm)	838	1,770

Based on the results of simulations that have been carried out on several alternative design shading devices, it can be seen that by using shading devices excessive lighting intensity in library reading rooms can be reduced so that glare problems can be resolved. From various shading devices design alternatives, it can be seen that the vertical overhang 1 design with overhang width = 50 cm and vertical fin distance = 50 cm) which maximally reduces the natural lighting intensity, from the lighting intensity of the existing conditions

2802 lx to 309 lx and almost meets the standard lighting intensity for the library reading room is 300 lx.

Similar research was conducted by Primastiti Wening Mumpuni, Rahmanu Widayat and Silfia Mona Aryani in 2017 concerning Natural Lighting in the Reading Room of the Surabaya Public Library. This research concludes is that the daylight in the reading room of Surabaya's public library does not meet the recommended standards. These conditions can be improved by adding openings of the right size and arrangement of furniture that does not block the lighting. This research did not provide a design solution that only added furniture openings and arrangements. While this research resulted in a design solution in the form of shading devices that can answer research questions. This is what distinguishes the research conducted by Primastiti and friends with this research.

VI. CONCLUSIONS

Based on data processing, analysis, and synthesis of the problem of excessive lighting intensity so that the glare in the library reading room at the 3rd floor of Budi Luhur University, the conclusions can be drawn as follows:

1. The simulation results of the existing condition of the library reading room obtained the average value of the natural lighting intensity in the reading room on the 3rd floor of the library of Budi Luhur University is 2802 lx.
2. Shading devices can reduce excessive lighting intensity so that glare problems can be resolved.
3. The optimal design of horizontal overhang shading devices that can reduce lighting intensity is alternative horizontal overhang 4 design with overhang width of 200 cm.
4. The most optimal design of vertical overhang shading devices that can reduce lighting intensity is alternative vertical overhang design 1 with overhang width of 50 cm and vertical fin distance of every 50 cm.

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