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The Effect of blinds on lighting intensity in office building in the hot and humid tropics Indonesia

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Abstract: Many office spaces use natural lighting. through the many openings. Too much sunlight entering the room will cause glare. So the room is lined with curtains for visual comfort. In addition, a mechanism is needed to control the curtain so that it can enter sunlight optimally. The general objective of this research is to control the sunlight that enters the room through the curtains. While the specific objective is to seek optimization of natural lighting in office spaces that use vertical curtains. The research will be carried out using an experimental method in an actual room. In addition, a parameter study will be carried out using the DIALUX application to determine the use of vertical curtains and also other types of curtains in order to obtain an optimal sunlight control system. The results showed that light shelves can increase natural lighting in the space. The light and white shelf formations are made with flat angles and 45 degree angles. The maximum light obtained is 631 lux, 633 lux. Reflected Plane (RP) of aluminum provides a maximum illumination of 608 lux.

Keywords: Daylight, light control, blinds, visual comfort, reflected plane.

1. Introduction

Lighting is one of the important factors in designing a space to support user comfort. A room with a good lighting system can support the activities carried out in it. [19]. A good lighting system must be able to meet three main criteria, namely quality, quantity, and lighting rules. Illumination quality is the level of lighting that can affect eye fatigue, inadequate lighting will cause the iris muscle to adjust the pupil according to the intensity of the lighting.

The main source of natural lighting in the world and the most absolutely utilized by humans is sunlight. In addition to open areas, for the purposes of humans who are active indoors, for example in buildings, sunlight is needed as the main natural lighting, and artificial lighting in the form of lights is needed to support and support lighting if natural lighting is not functioning properly if the weather is moderate. cloudy or rainy where sunlight is not effectively distributed to provide lighting. [19]

Compared to artificial lighting, the natural lighting system has several advantages, among others, to reduce energy loads and optimize visual comfort because daylight is full-spectrum light that is most suitable for human visual response, so that the quality of natural lighting is much better than artificial lighting (Lim et al., 2012). [27] .

With Indonesia's tropical climate getting sunlight all year round, the use of artificial lighting can actually be reduced and replaced with natural lighting which at the same time can save energy consumption in buildings. However, so far the use of natural lighting still has a negative impact, namely less or too much light entering the room and glare that enters the room which ultimately affects the visual comfort of space users. [28].

To overcome this problem, several internal shading devices are used, such as blinds, horizontal blinds, and roller shading, which are the targets of investigations on thermal and optical properties [14], outer and inner shading, such as inner and outer curtains [22]. These various devices function to block direct sunlight. While the refracted solar radiation is transmitted and reflected radiation. This system has been widely used in buildings, especially offices.

Natural lighting in glass windows with blinds has been studied in various configurations and in different climatic conditions. In a high latitude region, a study conducted an experiment in a real office to measure the daylight working area of a double-glazed window with horizontal blinds and the resulting power consumption of a dimmable lamp [12]. The results showed that the daytime of the room was strongly influenced by the angle of the curtains, varying sky conditions, and the position of the sun related to the orientation of the window [22].In addition to horizontal curtains, vertical curtains have also been studied by researchers [22].[20]. The simulation results show that vertical blinds and electric lighting systems utilize daylight to save more than 24% of electric lighting energy each month. [22].

Office space is a work area that requires a comfortable level of natural lighting so that users in it can carry out activities smoothly and have good work productivity. The need for lighting in the office space which takes place during working hours between morning and evening causes users to prefer what is considered comfortable. Visual comfort in the office has been dominantly fulfilled through artificial lighting because the performance of natural lighting has not been optimal. [28]. Visual comfort can be achieved if the points of visual comfort are applied optimally, among others, by conformity of the design with the recommended light standards and the arrangement of room layouts in accordance with the distribution of lighting [28].

This study will evaluate the level of lighting in the workspace using vertical curtains carried out in the Mercu Buana University Rectorate building, Jakarta. This building uses two different types of blinds, namely roller blinds and vertical slat curtains. This research was conducted because there is a tendency to use roller blinds for all spaces. The question at the heart of the research is whether vertical blinds provide a lower level of light than roll curtains. Whether vertical blinds cannot achieve visual comfort compared to roll curtains. From the description above, the formulation of the problem can be formulated as follows: This study aims to determine: What is the effect of vertical curtains and roll curtains on the lighting level of the room? Can the use of vertical curtains and roll blinds achieve visual comfort in the room?

2. Materials and Methods

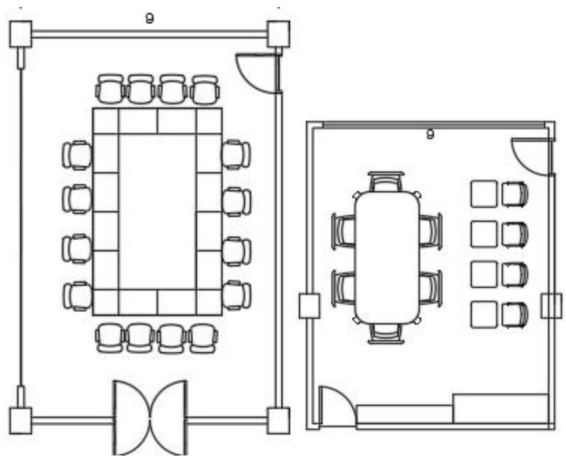
2.1 Research location

The research is located on the Mercu Buana University campus with the consideration that there are various examples related to sun protection. The room taken as a sample is a work room that has an inner curtain. The following figures (figure 1 and 2) are the atmosphere of the meeting room in the rectorate building

Figure 1. The first meeting room with white partitions, vertical blions and ceiling .

Figure 2. The second with white curtains, ceiling and floor

There are various kinds of curtains used on this campus, namely: vertical blinds, roller blinds, thin film glass. The room taken as a case has the same orientation and the same function. The area of the room has no effect on the light intensity. Methods of collecting data through surveys and direct observation in the field. Data is taken in several times and criteria. In the form of floor plan of the two meeting room is indicated in figure 3 and 4.



Figures 3 and **4.** Plans for small meeting rooms and the rector's meeting room. source: (authors documentation)

This small meeting room has a wide glass area on the right and has a vertical curtain. The wall on the left and in the form of a folding door. The upper wall is a glass wall covered by a vertical curtain. The lower wall is a brick wall. The level of room lighting in the rectorate building. The following is data on space, windows and the use of curtains in several sample spaces in the rectorate building.

2.2 Data collection

Measurement of light intensity in the research conducted using a Multifunction Environment Meter. The meter used has a Lux meter specification with a specification range of 20 Lux, 200 lux range, 2000 lux range, and 20000 lux with each tolerance in each range of 5% + 10 digits. The meter has passed KRISBOW laboratory calibration on 19 -8- 2011 with a validity period of 2 years after the calibration date. By taking measurement samples in the July to August 2013 timeframe, the accuracy of the data from the instruments used can be trusted. Parametric analysis will use Dialux simulation. Dialux is a standard software for calculating Lighting Layout, to perform lighting calculations in areas both indoors and outdoors. In addition, Dialux is software that functions to process data for lighting, namely with Dialux we can find out the light produced by lamps or the sun with three-dimensional simulations, with Dialux we can find out the spread and strength of light in an area.

3. Results and discussions

3.1 The intensity level in the rectorate meeting room

The following (Table 1) is data on space, windows and the use of curtains in several sample spaces in the rectorate building

Table 1. Room data, windows and curtain use in several rooms in the rectorate building

No	*Room*	*Orientation & obstruction*	*Room area (m2)*	*Window area (m2)*	*Wall to Window Ratio (%)*	*Blind type*
1.	Marketing room	West , nothing	84	24	66	Roller blind
2.	Supplementary room	West , nothing	72	24	66	Roller blind
3.	Secondary meeting room	North , trees	54	19.9	73	Vertical blind
4.	Rector meeting room	East, trees	45	12.1	66	Vertical blind

From the data above, the average lighting level of the room will be calculated. The following is the average lighting level in several sample spaces in the rectorate building. The following (data 2) is a table of the average light intensity of the room.

Table 2. Office space's average light intensity

No	*Room*	*Average existing light intensity (lux)*	
		The lights are on, the curtains are all open,	*The lights are off, the curtains are all open*
1.	Marketing room	200.3	156
2.	Supplementary room	261	128
3.	Secondary meeting room	183.3	78.5
4.	Rector meeting room	123.7	26.4

From the data above, it can be seen that the marketing room and glass room have a higher average level of lighting compared to secondary meeting and rector rooms. From this data, it will be continued with measurements and calculations of vertical simulations in selected rooms, namely small meeting rooms and rectorate meeting rooms.

3.2 Installed Power for Lighting System.

Measurements of light intensity were carried out in 4 rooms that were sampled. The first data taken is data on installed lights and the existing area of the room to calculate whether the installed power for the lighting system does not exceed the required standard limits. The data obtained and the calculation of the installed power for the lighting system per unit area of the room are shown in Table 3. From the calculation results, the average installed power of the lamp is 7.65 watt/m2. From these results, it can be seen that the installed power in these rooms still meets the standard, which is below the maximum limit of 15 watts/m2.

Table 3. Data and calculation of installed power

No.	*Room name*	*Area (m2)*	*Lamp FL*	*Power (watt)*		*Watt/m2*
			Number	*Per lamp*	*Total*	
1	Marketing room	84	36	18	648	9
2.	Supplementary room	72	36	18	648	9
3.	Secondary meeting room	54	24	18	432	8

4.	Rector meeting room	45	18	18	324	7.2

3.3 The experiments of vertical blinds with daylight and artificial light

3.3.1 Simulation of vertical blinds with natural light in a small meeting room

In the following, the results of the measurement of natural lighting levels in a small meeting room with three curtain schemes are presented at 9:00, 12:00 and 15:00. These results are presented in Tables 4, 5 and 6. below.

Table 4. Simulation of vertical blinds with natural light in a small meeting room at 09.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	14.4	29	7	0.48	0.24
2.	The blinds are half open	61.1	125	26	0.42	0.21
3.	The blinds are all open	78.5	144	37	0.47	0.25

Table 5. Simulation of vertical blinds with natural light in a small meeting room at 12.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	12	19	7	0.58	0.37
2.	The blinds are half open	59.8	156	22	0.36	0.14
3.	The blinds are all open	74.1	148	37	0.49	0.25

Table 6. Simulation of vertical blinds with natural light in a small meeting room at 15.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	7	12	4	0.57	0.33
2.	The blinds are half open	36.3	84	15	0.41	0.18
3.	The blinds are all open	63.6	123	37	0.58	0.30

In the table above, it can be seen that the average value of the lighting level in the existing small meeting rooms is on average below the standard. From these data, it can be seen that the level of lighting in the office spaces does not meet the SNI standard of 250 lux. From the light intensity data obtained when the lights are turned off, it is only between 36.3 to 61.1 lux. Meanwhile, when the curtains are open, the average lighting is between 63.6 to 78.5 lux. This shows that the natural lighting in this small meeting room is low.

3.1 Simulation of vertical blinds with artificial lighting in a small meeting room

Here, we present the results of measuring the level of artificial lighting in a small meeting room with three schemes for opening and closing the curtains at 9:00, 12:00 and 15:00.

Table 7. Simulation of vertical blinds with artificial light in a small meeting room at 09.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	130.2	153	105	0.81	0.69
2.	The blinds are half open	170.4	246	130	0.76	0.53
3.	The blinds are all open	191	264	135	0.71	0.51

Table 8. Simulation of vertical blinds with artificial light in a small meeting room at 12.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	131.9	156	104	0.79	0.67
2.	The blinds are half open	171.6	244	133	0.78	0.55
3.	The blinds are all open	183.3	271	131	0.71	0.48

Table 9. Simulation of vertical blinds with artificial light in a small meeting room at 15.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	122.9	141	99	0.81	0.70
2.	The blinds are half open	145.1	192	114	0.79	0.59
3.	The blinds are all open	182.3	296	128	0.70	0.43

When artificial lighting is turned on, the table above shows thatthe average value of lighting levels in small meeting rooms that exist today is on average below the standard. From this data, it can be seen that the level of lighting in the office spaces does not meet the SNI standard of 250 lux. From the light intensity data obtained when the lights are turned off, it is only between 36.3 to 61.1 lux. Meanwhile, when the curtains are open, the average lighting is between 63.6 to 78.5lux. This shows that the natural lighting in this small meeting room is low.

The intensity when the lights are turned on is only 180.45 lux on average, while according to SNI, the light intensity in an office space should be at least 250 lux. This shows that the light intensity in the classroom is below the recommended standard, therefore it is necessary to make improvements so that the light intensity in the room is sufficient.

3.2 Simulation of vertical curtains with natural light in the rector's meeting room

In the following, we present the results of measuring the level of natural lighting in the rector's meeting room with three schemes for opening and closing the curtains at 9:00, 12:00 and 15:00.

Table 10. Simulation of vertical curtains with natural light in the Chancellor's meeting room at 9.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	3.12	6	2	0.64	0.33
2.	The blinds are half open	7.67	17	4	0.52	0.24
3.	The blinds are all open	17.12	46	9	0.53	0.20

Table 11. Simulation of vertical curtains with natural light in the Chancellor's meeting room at 12.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	1.75	4	1	0.57	0.25
2.	The blinds are half open	7.5	16	4	0.53	0.25
3.	The blinds are all open	16	32	8	0.50	0.25

Table 12. Simulation of vertical curtains with natural light in the Chancellor's meeting room at 15.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	3.1	6	2	0.65	0.33
2.	The blinds are half open	7.3	16	3	0.41	0.19
3.	The blinds are all open	26.4	50	14	0.53	0.28

3.3 Simulation of vertical curtains with artificial light in the rector's meeting room

Here, we present the results of measuring the level of artificial lighting in the rector's meeting room with three schemes for opening and closing the curtains at 9:00, 12:00 and 15:00.

Table 13. Simulation of vertical blinds with artificial light in the rector's meeting room at 9:00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	110.12	130	83	0.75	0.64
2.	The blinds are half open	113.37	132	83	0.73	0.63
3.	The blinds are all open	123.67	144	88	0.71	0.61

Table 14. Simulation of vertical curtains with natural light in the Chancellor's meeting room at 12.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	108.12	126	78	0.72	0.62
2.	The blinds are half open	109	128	77	0.71	0.60
3.	The blinds are all open	106.5	140	33	0.31	0.24

Table 15. Simulation of vertical curtains with natural light in the rector's meeting room at 15.00

No	*Blind scheme*	*Existing light intensity (lux)*			*Uniformity*	*Diversity*
		Average	*Maximum*	*Minimum*	*Min/average*	*Min/max.*
1.	The blinds are all closed	99.4	116	74	0.74	0.64
2.	The blinds are half open	110.5	129	79	0.71	0.61
3.	The blinds are all open	129	153	88	0.68	0.58

3.3 Illumination level simulation with the Relux application

3.3.1 Simulation of vertical blinds with Relux application in small meeting rooms.

Application of the Reflective Plane (Light Shelf) at the front of the Mercu Buana University small meeting room, Meruya Campus. Simulation time: March 21 and September 23, representing the position of the sun at the northern equinox (the equator), at 10:00 and 14:00 WIB, respectively. Artificial Lighting: 22 Watt Downlight 29 points. Reflector Type: A flat (pxwxh) 800x100x10cm plane with three angular changes (flat, 30°, and 45°). Reflecting material: white paint and standard aluminum (specularity 0.362, Roughness 1.78, Reflectivity 60%). Measurement Coordinates: Latitude -6.21°, Longitude 106.73°. The following is a summary of the simulation results using the Relux application.

Table 17. Summary of simulation results in small meeting rooms

Measurement Date			*21 March*		*23-September*	
Measurement time			*10.00*	*14.00*	*10.00*	*14.00*
EXISTING	DAYLIGHT	Average Illuminance (Lux)	196	196	177	212
		Minimum Illuminance (Lux)	35	35	31	37
		Maximum Illuminance (Lux)	709	711	640	768
		Uniformity (Uo)	0.17			
		Diversity (Ud)	0.05			0.05
	ARTIFICIAL LIGHT	Average Illuminance (Lux)	936			
		Minimum Illuminance (Lux)	442			
		Maximum Illuminance (Lux)	1360			
		Uniformity (Uo)	0.47169			
		Diversity (Ud)	0.32467			
FLAT REFLECTOR	WHITE	Average Illuminance (Lux)	167	167	151	181
		Minimum Illuminance (Lux)	30	30	27	32
		Maximum Illuminance (Lux)	604	605	544	653
		Uniformity (Uo)	0.18			
		Diversity (Ud)	0.05			
	ALUMINUM	Average Illuminance (Lux)	160	160	144	173
		Minimum Illuminance (Lux)	28	29	26	31
		Maximum Illuminance (Lux)	581	582	524	628
		Uniformity (Uo)	0.17793			
		Diversity (Ud)	0.48971			
REFLECTOR 30°	WHITE	Average Illuminance (Lux)	174	174	157	188
		Minimum Illuminance (Lux)	31	31	28	34
		Maximum Illuminance (Lux)	618	619	557	668
		Uniformity (Uo)	0.18			
		Diversity (Ud)	0.05			0.05
	ALUMINUM	Average Illuminance (Lux)	167	168	151	181
		Minimum Illuminance (Lux)	29	29	26	31

		Maximum Illuminance (Lux)	600	601	541	649
		Uniformity (Uo)	0.17			
		Diversity (Ud)	0.05			0.05
REFLECTOR 45°	WHITE	Average Illuminance (Lux)	178	178	161	193
		Minimum Illuminance (Lux)	34	34	31	37
		Maximum Illuminance (Lux)	631	633	569	683
		Uniformity (Uo)	0.19			
		Diversity (Ud)	0.05			
	ALUMINUM	Average Illuminance (Lux)	170	171	154	184
		Minimum Illuminance (Lux)	30	31	27	33
		Maximum Illuminance (Lux)	608	609	548	658
		Uniformity (Uo)	0.18			
		Diversity (Ud)	0.05			

Simulation results on small meeting rooms

1. Assessment of the success of the reflecting plane is assessed not only by how much the Reflecting Plane (RP) is able to increase the intensity of light, however, RP must be able to increase the distribution value in the form of Uniformity (Uo) and Diversity (Ud). Uo and Ud values should be close to 1.00
2. Existing conditions are divided into two: with artificial lighting, and with natural lighting. In conditions with artificial lighting, the lamp can increase a maximum of 1360 Lux, a minimum of 442 Lux, with an average room illumination of 936 Lux. The use of 29 light points can reach Uo 0.47 and Ud of 0.32
3. In the existing condition with natural lighting, the maximum value at the four measurement times, the maximum illumination occurred on September 23, at 14.00, with a value of 768 lux, with an average illumination of 212 Lux. While the Uo value is 0.17605, Ud is 0.04868
4. Flat RP made of white paint is more capable of producing a better average value of illumination than RP made of aluminum on September 23, 14.00 with a value of 181 Lux. While RP is flat made of aluminum, it is more capable of increasing the Uo value at the same time with a value of 0.17793
5. RP of 30° angle made of white paint is more capable of producing a better average value of illumination than RP made of aluminum on September 23, 14.00 with a value of 188 Lux. The Uo and Ud values are also the same, the best between white paint and aluminum, with a Uo value of 0.178, a Ud value of 0.0503.
6. RP angle of 45° made of white paint is more capable of producing a better average value of illumination than RP made of aluminum on September 23, 14.00 with a value of 193 Lux. The Uo and Ud values are the same, the best between white paint and aluminum, with a Uo value of 0.1904, a Ud value of 0.0537

Conclusion of small meeting room lighting simulation

1. White paint RP material is able to increase the illumination value better than aluminum RP. This is because white paint has an almost perfect reflectivity value (almost 90%), the use of a mirror (100% Reflectivity) is not recommended because it will only increase visual discomfort in the form of glare in the room.
2. The use of RP in fact tends to lower the illumination value, when compared to the existing condition. However, the use of RP is able to increase the distribution of lighting (Uo and Ud). This is because the use of RP will direct natural light towards the ceiling, which in the end will be reflected into the room more evenly compared to direct lighting.
3. The best result of using RP is the use of RP 45° made of white paint This type of RP is able to distribute light more into the room when compared to other types of RP

3.4 Simulation with the Relux application on Rectorate meeting room

Application of the light shelf at the front of the Mercu Buana University Rectorate Meeting Room, Meruya Campus. Simulation time: March 21 and September 23, representing the position of the sun at the northern equinox (the equator), at 10:00 and 14:00 WIB, respectively. Artificial Lighting: 22 watt downlight 29 points. Reflector Type: A flat (lxwxh) 800x100x10cm plane with three angular changes (flat, 30°, and 45°). Reflecting material: use white paint and standard aluminum (specularity 0.362, Roughness 1.78, Reflectivity

60%). Measurement Coordinates: Latitude -6.21°, Longitude 106.73°. The following table is a summary of the simulation results.

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		Minimum Illuminance (Lux)	35	35	31	37
		Maximum Illuminance (Lux)	709	711	640	768
		Uniformity (Uo)	0.17605			
		Diversity (Ud)	0.04868		0.04866	
	ARTIFICIAL LIGHT	Average Illuminance (Lux)	936			
		Minimum Illuminance (Lux)	442			
		Maximum Illuminance (Lux)	1360			
		Uniformity (Uo)	0.47169			
		Diversity (Ud)	0.32467			
FLAT REFLECTOR	WHITE	Average Illuminance (Lux)	167	167	151	181
		Minimum Illuminance (Lux)	30	30	27	32
		Maximum Illuminance (Lux)	604	605	544	653
		Uniformity (Uo)	0.17761			
		Diversity (Ud)	0.04916			
	ALUMINUM	Average Illuminance (Lux)	160	160	144	173
		Minimum Illuminance (Lux)	28	29	26	31
		Maximum Illuminance (Lux)	581	582	524	628
		Uniformity (Uo)	0.17793			
		Diversity (Ud)	0.48971			
REFLECTOR 30°	WHITE	Average Illuminance (Lux)	174	174	157	188
		Minimum Illuminance (Lux)	31	31	28	34
		Maximum Illuminance (Lux)	618	619	557	668
		Uniformity (Uo)	0.17857			
		Diversity (Ud)	0.05027	0.0503		
	ALUMINUM	Average Illuminance (Lux)	167	168	151	181
		Minimum Illuminance (Lux)	29	29	26	31
		Maximum Illuminance (Lux)	600	601	541	649
		Uniformity (Uo)	0.17331			
		Diversity (Ud)	0.048309		0.048333	
REFLECTOR 45°	WHITE	Average Illuminance (Lux)	178	178	161	193
		Minimum Illuminance (Lux)	34	34	31	37
		Maximum Illuminance (Lux)	631	633	569	683
		Uniformity (Uo)	0.19047619			
		Diversity (Ud)	0.053763441			
	ALUMINUM	Average Illuminance (Lux)	170	171	154	184
		Minimum Illuminance (Lux)	30	31	27	33
		Maximum Illuminance (Lux)	608	609	548	658
		Uniformity (Uo)	0.178890877			
		Diversity (Ud)	0.050150451			

The result of the rector's meeting room lighting simulation

1. Assessment of the success of the reflecting field is assessed not only by how much the Reflecting Plane (RP) is able to increase the intensity of light, however, RP must be able to increase the distribution value in the form of Uniformity (Uo) and Diversity (Ud). Uo and Ud values should be close to 1.00.
2. Existing conditions are divided into two: with artificial lighting, and with natural lighting. In conditions with artificial lighting, the lamp can increase a maximum of 1360 Lux, a minimum of 442 Lux, with an average room illumination of 936 Lux. The use of 29 light points can reach Uo 0.47 and Ud of 0.32
3. In the existing condition with natural lighting, the maximum value at the four measurement times, the maximum illumination occurred on September 23, at 14.00, with a value of 768 lux, with an average illumination of 212 Lux. While the Uo value is 0.17605, Ud is 0.04868
4. Flat RP made of white paint is more capable of producing a better average value of illumination than RP made of aluminum on September 23, 14.00 with a value of 181 Lux. While RP is flat made of aluminum, it is more capable of increasing the Uo value at the same time with a value of 0.17793
5. RP of 30° angle made of white paint is more capable of producing a better average value of illumination than RP made of aluminum on September 23, 14.00 with a value of 188 Lux. The Uo and Ud values are also the same, the best between white paint and aluminum, with a Uo value of 0.178, a Ud value of 0.0503.
6. RP angle of 45° made of white paint is more capable of producing a better average value of illumination than RP made of aluminum on September 23, 14.00 with a value of 193 Lux. The Uo and Ud values are the same, the best between white paint and aluminum, with a Uo value of 0.1904, a Ud value of 0.0537.

Conclusion of rector's meeting room lighting simulation

1. White paint RP material is able to increase the illumination value better than aluminum RP. This is because, white paint has an almost perfect reflectivity value (almost 90%), the use of mirrors (Reflectivity 100%) is not recommended because it will only increase visual discomfort in the form of glare in the room.
2. The use of RP in fact tends to lower the illumination value, when compared to the existing condition. However, the use of RP is able to increase the distribution of lighting (Uo and Ud). This is because the use of RP will direct natural light towards the ceiling, which in the end will be reflected into the room more evenly compared to direct lighting.
3. The best result of using RP is the use of RRPP 45° made of white paint This type of RP is able to distribute light more into the room when compared to other types of RP

Discussion

6.4.1 Discussion of Manual Measurement with Luxmeter

Based on the data that has been obtained, it can be seen in the table that the natural lighting conditions in small meeting rooms are inadequate or do not reach the lux standard of 250 lux. The conditions of closed curtains, half open curtains, and fully open curtains did not reach the SNI standard of 250 lux. The condition of the curtains fully open does contribute to increasing the lighting in a small meeting room. But it still doesn't reach the standard of lux, which is 250 lux.

Likewise with artificial lighting conditions. The lighting conditions with artificial lighting still do not reach the standard according to SNI, which is 250 lux. Although the lux value of artificial lighting is higher than natural lighting, this means that artificial lighting contributes to lighting in small meeting rooms. The conditions of closed curtains, half open curtains, and fully open curtains did not reach the SNI standard of 250 lux. The condition of the curtains fully open does contribute to increasing the lighting in a small meeting room. But it still doesn't reach the standard of lux, which is 250 lux. Given this fact, the solution that can be given to increase the standard of lux in small meeting rooms is to add light points and use artificial lighting/lamps with adequate lighting power. Of course, this needs to be reviewed to determine where the additional light points are and what type of lamp should be used to make the lighting in a small meeting room adequate or reach the lux standard according to SNI, which is 250 lux.

For the rector's meeting room, it can be seen in the table that the natural lighting conditions in the rector's meeting room are inadequate or do not reach the lux standard of 250 lux. The conditions of closed curtains, half open curtains, and fully open curtains did not reach the SNI standard of 250 lux. The condition of the curtains fully open does contribute to increasing the lighting in a small meeting room. But it still doesn't reach the standard of lux, which is 250 lux.

Likewise with artificial lighting conditions. The lighting conditions with artificial lighting still do not reach the standard according to SNI, which is 250 lux. Although the lux value of artificial lighting is higher than natural lighting, this means that artificial lighting contributes to lighting in the rector's meeting room. The conditions of closed curtains, half open curtains, and fully open curtains did not reach the SNI standard of 250 lux. The condition of the curtains is fully open indeed contributed to increasing the lighting in the rector's meeting room. But it still doesn't reach the standard of lux, which is 250 lux. Given this fact, the solution that can be given to increase the standard of lux in the rector's meeting room is to add light points and use artificial lighting/lamps with adequate lighting power. Of course, this needs to be reviewed to determine where the additional light points are and what type of lamp should be used to make the lighting in the rector's meeting room adequate or reach the lux standard according to SNI, which is 250 lux.

6.4.2 Relux . Simulation Measurement Discussion

In small meeting rooms, white paint RP material is able to increase the illumination value better than aluminum RP. This is because white paint has an almost perfect reflectivity value (almost 90%), the use of a mirror (100% Reflectivity) is not recommended because it will only increase visual discomfort in the form of glare in the room.

The use of RP, in fact, tends to lower the illumination value, when compared to the existing condition. However, the use of RP was able to increase the distribution of lighting (Uo and Ud). This is because the use of RP will direct natural light towards the ceiling, which in turn will be reflected into the space more evenly than direct lighting.

The best result of using RP in small meeting rooms is the use of RP 45° in white paint. This type of RP is able to distribute light more into the room when compared to other types of RP

In the rector's meeting room, RP white paint is able to increase the illumination value better than RP aluminum. This is because white paint has an almost perfect reflectivity value (almost 90%), the use of mirrors (100% Reflectivity) is not recommended because it will only increase visual discomfort in the form of glare in the room.

The use of RP, in fact, tends to lower the illumination value, when compared to the existing condition. However, the use of RP was able to increase the distribution of lighting (Uo and Ud). This is because the use of RP will direct natural light towards the ceiling, which in the end will be reflected into the room more evenly than direct lighting.The best result of using RP in small meeting rooms is the use of RP 45° in white paint. This type of RP is able to distribute light more into the room when compared to other types of RP

4. Conclusion

In this study, it has been proven that vertical blinds are not effective for use in rooms with trees around them. From an open curtain simulation. In a small meeting room that is oriented to the north, it is proven that when all the curtains are opened and all the lights are turned on, the maximum lighting level is 296 lux and the average lighting is 182.3 lux. Meanwhile, the rector's meeting room which is oriented to the east gets a maximum lighting level of 153 lux with all the curtains open and the lights on. The use of Reflecting Plane (RP) does not really affect the level of lighting in the room, but rather makes the lighting in the room more evenly distributed.

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