Retrofitting Thermal And Lighting Condition Of A Production Warehouse

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Abstract : The proper building is constructed from several aspects, begin from the structure until the simple things on it. Two of factors that can be designed as parameter in deciding the building is proper or not are seen from the lighting condition and thermal condition. Those factors can be designed as a suitable parameter for a home living, a building and an office. The object of this study is a place called Decorator Indonesia Production Warehouse in Yogyakarta. This building consists of one floor-building that divided into two areas; an office and a warehouse area. The purpose in the study is concern in the minimum space of the building which need to be retrofitted. The researcher used some support software such as EGDE and Ecotect to work on the study. The methods that used in this study are re-designing building plans, first measurement of the building, Ecotect simulation, EDGE simulation, making scenario and calculating retrofitting cost. The result of this study is collected from the increasing score of lux, the decreasing thermal load until 5.000 kWh with score 11.289.395 kWh, the decreasing of temperature and the construction's cost Rp. 35.097.400..

Index Term : Retrofitting, Thermal, Lighting, Ecotect, EDGE

1. INTRODUCTION

The high quality employee and the work space which are conducive enough can affect their productivity. The lighting and thermal condition are like a parameter which used to measuring the work space. The Decorator Indonesia Production Warehouse located in Kalasan, Sleman, DIY is knowing as the building with bad lighting and thermal condition. The explanation below is talking about lighting condition detail.

***Table 1**. Measurement of Lighting and Thermal Condition's Data*

No	Room	Point	Lux	Temperature (°C)
1	Director	1	145	30,2
2	Design (Point 1)	2	39	30
3	Design (Point 2)	3	20	
4	Space Room	4	350	29,9
5	Meeting (Point 1)	5	11	31,2
6	Meeting (Point 2)	6	40	
7	Tool Warehouse	7	95	31,4
8	Production Area (Front)	8	42	30,7
9	Production Area (Back)	9	45	30,9
10	Iron Workspace	10	21	31,2
11	Wooden Workspace	11	20	31,5
12	Kitchen	12	10	31,5

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From the Table 1 seen that lux score still under the standard regulation of SNI 03-6575-2001 which arranged about lighting system product that suitable with healthy, security term, and filled conditions apply for a building [1]. The temperature of the building is less from the standard regulation. The purpose of this study is to fix the lighting and thermal condition of Decorator Indonesia Warehouse Production by retrofitting the building. The lighting and thermal condition of this building are need to be improved. From the early, the research found that the thermal in some specific condition still over standard. The using of software like Ecotect and EDGE is needed as the guide for making good scenario.

2 THEORETICAL REVIEW

2.1 Lighting Condition

The excessive lighting condition is surely not recommended for a building, also a building with lack of lighting will affect the occupant's quality. The consumption of lighting affected by some factors, such as; the type and function of building, lighting condition, and then the occupant's effectively. Good lighting makes the employee easily focus on their object-work [2]. A space with lighting condition called lighting average in the field work. A space with lighting average explained as a horizontal field imaginary on the space [3]. This study explained that field work is on between 70 cm until 80 cm above the floor level. Those numbers are based on the assumption of optimal high from the proper lighting condition. Illumination (lux) is a denomination to measuring the brightness of the surface that illuminated. One lux is equal with one lumen per square-meter. The lux is not only considering the light scattered but also the position or distance from the illuminated surface [4]. However, the standard regulation SNI 03-6575-2001 is the regulation of standard requirement of lighting condition in Indonesia which ruled lux's score of a space.

***Table 2**. The recommendation of minimum lighting condition*

Building	Function Room	Lighting Level (Lux)
Offices	Director	350
	Workspace	350
	Computer	350
	Meeting	300

Industri (Umum)	Design	750
	Parking Space	50
	Warehouse	100
	Rough Works	100-200
	Medium Works	200-500
	Fine Works	500-1000
	Color Examination	750

2.2 Thermal

A proper thermal is one of factors that surely important to human life. Human sense the heat and cold in the body cause of the tactile toward temperature at around. Human activity will disrupted if there is discomfited felling in the body. A proper thermal in a space is very important for the function of all part of the body [5].

Based on the regulation SNI 03-6390-2011[6], in order to fulfill a proper thermal of building, the condition of building plan which located in lowland with maximum temperature around 34ºC DB and 28ºC WB (called monthly average temperature around 28ºC) explain that:

- A work space has dry bulb temperature around 24ºC until 27ºC or 25,5ºC ± 1,5ºC with relative humidity 60% ± 5%.
- A transit room (lobby and corridor) has dry bulb temperature around 27ºC until 30ºC or 26,5ºC ± 1,5ºC with relative humidity 60% ± 10%.
- The physiological and environment factors that affect the proper thermal are explained in below [7]:
- The metabolic rate of human body in a room can determined how many heat energy from the body that can be seen in human activity. The generated heat is affected by the activity.
- Temperature in the room is the temperature from the individual around the room. It is can be explained as main factor from the proper thermal.
- Radiant temperature from every individual can be explained that radiation happens from the individual which generating the heat. This phenomena brings effect toward how that individual release and receive the heat from a room or environment.
- The high humidity in a room can avoid evaporation sweat from te skin. In the heat area the individual will generate less of sweat because of the high humidity then make some sultry in exertion.
- Air speed is the thing that affect the proper thermal in a building. Air with bad circulation makes the individual generate more sweat in the building.
- Insulation clothes affect toward the body heat production. The proper thermal is very determined by insulation clothes effect from the individuals

3 METHODOLOGY

This study is divided into main five steps. The first was about measuring all the production warehouse area to get the right building dimension because the building did not has building plan. The second was about measuring the light intensity in the building then making note for every electronic objects in the building and measuring the room temperature and humidity. This measurement held on May 13th 2019 at 12:10 pm using lux meter and temperature humidity digital in every room. The third was about making simulation using Ecotect application by inputting measurement data in order to comparing between standard condition and the real condition in the building.

The fourth was about measuring the building thermal. Before jumping into the last step, the researchers using EDGE application to get best increasing result. Then, the last was about making the scenario. The researchers picked the best scenario and the most effective cost in order to optimizing the light intensity and thermal of building.

4 DISCUSSION

4.1 Design

In recent decades, the architects and engineers have begun to model their project on 3D image than 2D. This is the beginning of a new approach. This project can be understood in the form of 3D image and its details can be developed to improve the communication amongst the subjects. In other words, it can create great potential to visualize and communicate the previously information that only certain people can see. Now it can be seen by all the people related involving in the project and make the information accuracy level better and faster in its delivery process [8].

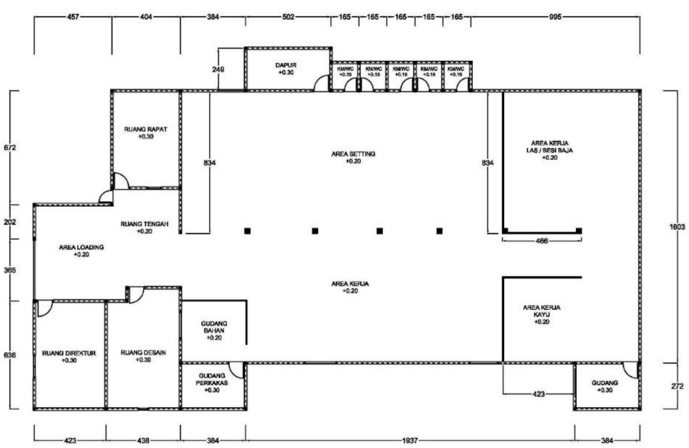

***Fig 1**. Decorator Indonesia Production Warehouse Plan*

AutoCad is used to the first step before jump to the making of 3D design. After measuring the building, the next step is drawing the plan using AutoCad. One of the problems in this study is the lack of 2D or 3D picture of the building, so that te researchers have to re-draw the building plan. The area is divided into two; Office and Production area. In the front of building there are manager room, design room, meeting room, and in the back is for production room. The dimension broad of the building is 611,537 m².

4.2 Ecotect

ECOTECT software is an environmental analysis tool that allows designers to simulate building performance right in conceptual phase. It includes a wide array of detailed analysis functions with a highly visual and interactive display that make analytical results can be directly presented within the context of the building model [9]. The score of the building after measuring using lux meter is still far from the standard regulation based on SNI 03-6575-2001. As the same with some areas like manager and staff room that should have score 350 lux but those areas just get score 145 lux and some others area that just close enough from the recommendation score. Thermal environment analysis. The hourly temperature, hourly heat gain/loss, and hourly energy consumption for the RRSAB were obtained using Ecotect [10]. By the simulation using Ecotect, the researchers will know how score for the light intensity and thermal of building.

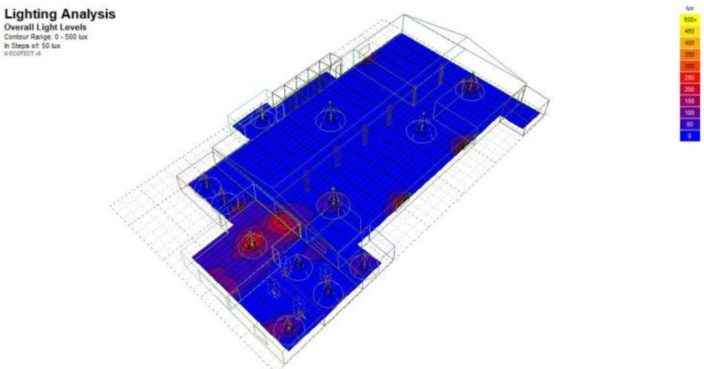

***Fig 2**. Existing Building Condition*

In the Picture 2, seen some parts of the building that more have blue color, and in the below the purple means there are areas that still have score under 120 Lux. It means that the score did not reach the standard score. The front building has some color variety because of the light that comes in is not blocked by the wall. The simulation continues by observing thermal load from the building including some different temperature that used as guide to planning the scenario. The next is explained about total score result from all the thermal load profiles which are analyzing using Ecotect software.

***Table 3**. Thermal Load Comparison*

No	Thermal Load	Total (kWh)
1	Fabric Gains	9.312,728
2	Indirect Solar Gains	5.208,924
3	Direct Solar Gains	53,349
4	Ventilation Gains	278,847
5	Internal Gains	1.254,888
6	Interzonal Gains	-83,893
	TOTAL	16.024,843

4.3 EDGE

EDGE is the building design tool, system certification, and global green standard that almost used by 100 developing countries. This platform is for anyone who interest in green building design, such an architect, an engineer, developer, or also building owner. EDGE makes the discovery technic solution in the first step of the design stronger to reduce operational and environment effect cost. According to user information and green measures, EDGE explains about operational and reducing carbon emissions cost projection. Description from all this study helps explaining the interesting business case. The analysis of this step is used for help in making what scenario that should create to get the best result. From this analysis, the researchers created 30 fixing steps that can be done. Then, from this study the researchers pick some steps that can be used. The steps are:

1. OFE02 Reflective Paint/Tiles for Roof - Solar Reflectivity (albedo) of 0.7
2. OFE03 Reflective Paint for External Walls - Solar Reflectivity (albedo)
3. OFE09 Natural Ventilation with Operable Windows and No A/C
4. OFE10 Ceiling Fans for Office Spaces
5. OFE24 Energy-Saving Light Bulbs - Internal Spaces
6. OFE25 Energy-Saving Light Bulbs - External Spaces

4.4 Scenario Planning

In this study there is a scenario made for increasing the light intensity and thermal. There are some steps done in this study, the first is adding some windows, then adding some ventilation and skylight. From those three steps, the researchers create three scenarios that later will be compared by considering the cost. After those three steps planned, the next is to transforming the color in the outside wall and color roof that suitable based on EDGE recommendation. It can be seen as in explanation below.

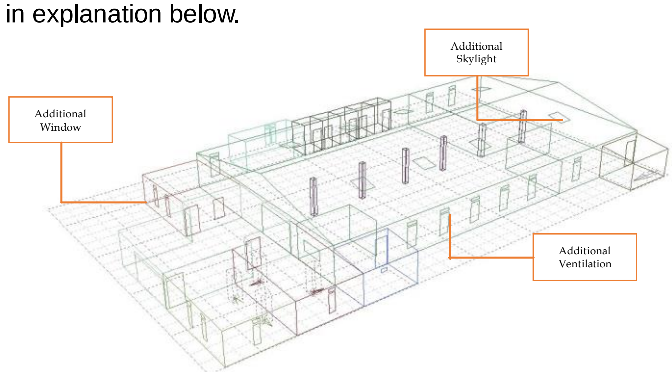

***Fig 3**. Additional Window, Ventilation, and Skylight*

4.4.1 Scenario 1

In this step, the researchers adding 27 glasses or windows in the building, also 31 ventilations and 4 skylight. The placement of those are set according the needs of light intensity of the building. Here the additional placement.

4.4.2 Scenario 2

In this step, the researchers adding 23 glasses or windows, 26 ventilations, and 5 skylight. The placement of those are set according the needs of light intensity of the building. Here the additional placement.

4.4.3 Scenario 3

In this step, the researchers adding 17 glasses or windows, 18 ventilations, and 8 skylight. The placement of those are set according the needs of light intensity of the building. Here the additional placement.

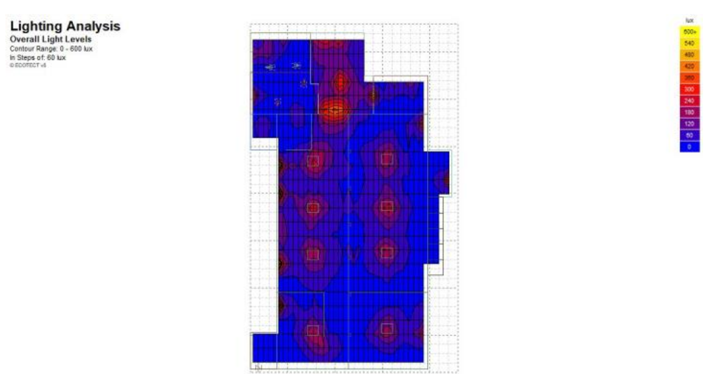

***Fig 4**. The Lighting Condition of the Building*

The transforming color that happened from existing condition to scenario condition explained that there is an increase in lux's score in the some measurement points. The significant transformation seen from the transformation of blue color into the color that has a score. However the transformation was not the best transformation to achieve the standard score. It brings the result of the lux's score comparison between the three scenarios and thermal load's score from those scenarios.

***Table 4**. Lux Score Comparison in each Scenarios*

No	Room	Scenario 1 (Lux)	Scenario 2 (Lux)	Scenario 3 (Lux)
1	Director	235	238	165
2	Design (Point 1)	239	297	91
3	Design (Point 2)	449	228	324
4	Space Room	390	390	358
5	Meeting (Point 1)	67	265	74
6	Meeting (Point 2)	273	303	176
7	Tool Warehouse	127	118	118
8	Production Area (Front)	146	140	258
9	Production Area (Back)	263	289	252
10	Iron Workspace	194	253	240
11	Wooden Workspace	239	223	212
12	Kitchen	55	55	120

In the table above seen that there is significant improvement from lighting intensity before. Here the table comparison thermal load in each scenarios.

***Table 5**. Thermal Load Score Comparison in each Scenarios*

No	Colors	Fabric Gains (kWh)	Indirect Solar Gains (kWh)
1	Black	6.947,283	3.649,145
2	Green	6.583,216	3.285,077
3	Red	6.799,915	3.501,769
4	Dark Blue	6.919,997	3.621,852
5	White	6.456,032	3.157,898
6	Grey	6.700,566	3.402,424
7	Brown	6.910,169	3.612,026

4.4.4 The Wall Color Changing Scenario

In this phase, the scenario is done by stimulating the change of paint color on the wall. There are seven colors chosen in this phase as the comparison. Those colors are black, green, red, dark blue, white, grey, and brown. Here is the chart of fabric gains and indirect solar gains score towards each paint color.

***Table 6**. The comparison of Color Score on the Wall*

No	Room	Lux Exist	Lux Scen	Temp (°C) Exist	Temp (°C) Scen
1	Director	145	238	30,2	28,3
2	Design (Point 1)	39	297	30	28,6
3	Design (Point 2)	20	228		
4	Space Room	350	390	29,9	29,7
5	Meeting (Point 1)	11	265	31,2	30
6	Meeting (Point 2)	40	303		
7	Tool Warehouse	95	118	31,4	29,6
8	Production Area (Front)	42	140	30,7	29,4
9	Production Area (Back)	45	289	30,9	
10	Iron Workspace	21	253	31,2	
11	Wooden Workspace	20	223	31,5	
12	Kitchen	10	55	31,5	29,8

From the result of thermal load above, it shows the score comparison at the graphic below.

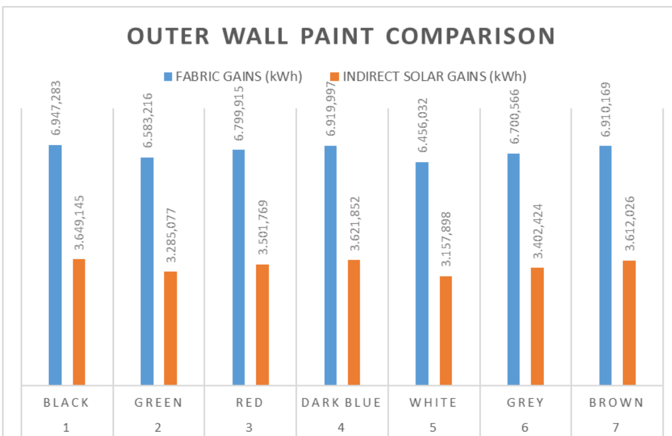

***Fig 5**. The comparison of Outer Wall Paint Color*

4.4.5 The Roof Color Changing Scenario

Referring to the suggestion of EDGE simulation, the scenario is done by stimulating the change of paint color on the building roof. In this phase, there are seven colors chosen as the comparison. These colors are black, green, red, dark blue, white, grey, and brown. Here is the chart of fabric gains and indirect solar gains score towards each paint color.

***Table 7**. The comparison of Color Score on the Roof*

No	Thermal Load	Total (kWh)			
		Existing	Scen 1	Scen 2	Scen 3
1	Fabric Gains	9.314,521	6.679,491	6.662,719	6.629,611
2	Indirect Solar Gains	5.214,594	3.351,043	3.347,684	3.331,474
3	Direct Solar Gains	111,807	309,368	258,737	239,28
4	Ventilation Gains	332,121	446,823	442,733	446,823
5	Internal Gains	1.254,888	663,156	663,156	663,156
6	Interzonal Gains	-121,502	-85,539	-85,634	-94,911
	TOTAL	16.106,429	11.364,342	11.289,395	11.215,433

From the result of thermal load above, it shows the score comparison at the chart below:

***Table 8**. The Calculation of Production Cost*

No	Type Of Work	Cost (Rupiah)		
		Scenario 1	Scenario 2	Scenario 3
1	Work Introduction	5.000.000	5.000.000	5.000.000
2	Additional Window, Ventilation, and Skylight	20.409.200	20.718.900	25.700.550
3	Work Painting	9.378.500	9.378.500	9.378.500
	Total Cost	34.787.700	35.097.400	40.079.050

***Table 9**. The Second Scenario's Lux Score and Temperature*

No	Colors	Fabric Gains (kWh)	Indirect Solar Gains (kWh)
1	Black	9.188,275	5.890,115
2	Green	7.676,850	4.378,705
3	Red	7.659,868	4.361,718
4	Dark Blue	8.905,234	5.607,082
5	White	4.093,602	795,461
6	Grey	6.629,611	3.331,474
7	Brown	7.665,524	4.367,380

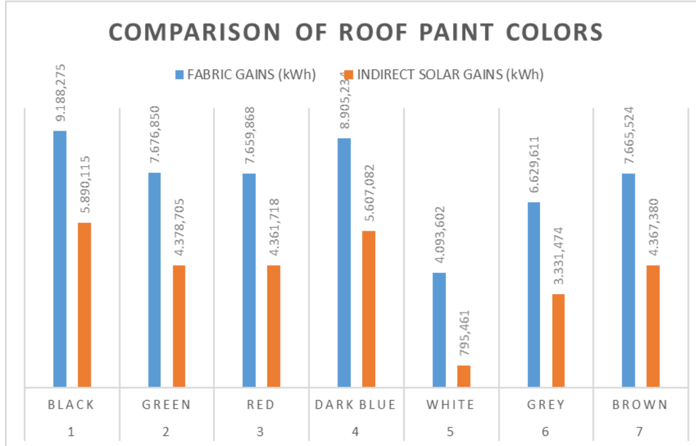

***Fig 6**. The comparison of Roof Paint Color*

4.5 The Cost Calculation

After doing all the simulations, the next scenario is to determine or understand the cost needed to retrofit the building. Here is the cost calculation from the scenario above. From the calculation above, it shows the biggest cost of third scenario due to the number of skylight given and the significant change of thermal load. The difference of thermal load at each scenario is not too far or different. By considering the cost and the result of Ecotect scenario, the researcher suggests the second scenario whose cost is not too high compared to the first and third scenario and the thermal load score is not too far and it has the biggest lux score at the working area and other important sectors. By considering the production score, it seems that second scenario is more effective than the first and third scenario. Each calculation includes the calculation of the roof and wall color changing. The thermal load at the second scenario is obtained 11.289,395 kWh which decreases from the existing score around 5.000 kWh, by the increasing lux score at the building area and the retrofitting cost of Rp. 35.097.400,-. Here is the lux score and temperature obtained from the second scenario.

***Tabel 10**. The Comparison of Thermal Load of Second Scenario*

No	Thermal Load	Total (kWh)	
		Existing	Scenario 2
1	Fabric Gains	9.314,521	6.662,719
2	Indirect Solar Gains	5.214,594	3.347,684
3	Direct Solar Gains	111,807	258,737
4	Ventilation Gains	332,121	442,733
5	Internal Gains	1.254,888	663,156
6	Interzonal Gains	-121,502	-85,634
	TOTAL	16.106,429	11.289,395

5 CONCLUSION

The result of the research is concluded that:

1. The Lux score result when doing the second scenario shows the significant improvement approaching to the standard which has been managed in SNI of 03-6575-2001, although some of those have not been referring to

the regulation.

2. The decreasing temperature is around 1° C up to 2°C in the scenario without using AC at some areas. It is also affected by the temperature outside the building, since May is the hottest month of the year based on Ecotect analysis.
3. The decreasing thermal load is up to 5.000 kWh by the score of 11.289,395 kWh. The cost can be seen from the comparison of first and third scenario, the cost needed is Rp. 35.097.400.

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