Comparative Study on Green Building Implementation on Educational Building Design

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ABSTRACT

As a developing country, the development of human resources is one of the country's priority programs in enhancing national competitiveness of the current economic globalization era. The necessity of university campus development is required in ensuring the fulfilment of facilities and infrastructure of the human resource development. Since 2010, the infrastructure development at ITB Campus has been carried out using green building policies. However, the implementation has not indicated a significant impact. It is apprehensive that the ineffective application of green concept in the construction of new buildings will have a negative impact on the environment, especially the carbon emission effect emitted throughout the building's life cycle. It is important to ensure that the implementation of green building concept of new building construction, starts from the planning and design phases, contributes to carbon emission reduction. Therefore, a green building assessment is carried out for all new building designs. This assessment provides an opportunity to select the most optimum green design alternative to reduce the impact of carbon emissions up to 30% from existing designs. The building design assessment employs the open studio application and the EDGE platform from the World Bank. This paper will analyze the result of the green assessment of three new building designs (Labtek XV, Labtek XVI, Labtek XVII). The analysis will be managed comparatively, to obtain significant factors and to determine optimum alternatives.

Keywords: *Carbon Emission, Educational Building, Embodied Energy, Green Building, Sustainable Design*

1. INTRODUCTION

The Paris Agreement aims to reduce carbon emissions by 20% by 2030 in order to hold the rate of global warming to an average below 2 °C. In contributing to curb the increase of global warming, Indonesia as a high-growth country needs to change its development approach from business as usual to a sustainable approach.

Carbon emissions (CE) are one of the causes of rising global temperatures. CE arises from various sources of emissions such as waste of energy use and greenhouse effect [1]. Therefore, efforts to reduce energy consumption and reduce greenhouse gas emissions need to be a major consideration for building development, to avoid an environmental impact because of carbon emissions production [2].

The principle of sustainable development that is environmentally friendly was initially discussed by E. Howard as Garden City in 1898, also by T. Garnier in 1917, Le Corbusier in 1928, and N. Miliutin in 1933 [3]. This principle was further developed with the holding of the first Earth Day in 1970 and the occurrence of the OPEC petroleum crisis in 1973. According to Baweja [4], these two events triggered the 'green' movement in development during this era, by starting to save energy consumption. This movement continued to expand exponentially until the 1980s, in 1987 when the United Nations held the World Commission on Environment and Development (WCED) and introduced the concept of 'sustainability in the general context' and 'Green Architecture' in the context of the development of the built environment.

This movement continued until 1992, with the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, which established 'Agenda 21' consisting of guidelines for ordering the implementation of Sustainable Architecture. In 1993, the United States Green Building Council (USGBC) was founded. It focused on buildings with the first green concept in the world, until finally in 1999, a meeting was held in California, and became the forerunner to the formation of the World Green Building Council (WGBC) [5].

The green concept paradigm is increasingly developing, including in Indonesia. This is proven by the establishment of the Green Building Council Indonesia (GBCI) in 2009, and also with the founding of government regulations governing development with standards that apply the green concept. As the green building concept paradigm develops, the application of this concept slowly begins, especially in public buildings. This concept is applied in public buildings because they are generally built with government funds that can be controlled. Likewise, the construction of educational buildings in ITB.

Nevertheless, the implementation of the concept of green buildings at this time both in ITB and in Indonesia is still going very slowly, due to numerous obstacles in the field that complicate the process. Therefore, this paper will discuss the process of applying green concepts in education buildings, as learning in disseminating the application of green concepts, practically and theoretically.

2. METHODOLOGY

This research was conducted with a case study approach in the preparation of Detailed Engineering Design (DED) educational buildings in ITB. Case studies in this study are three educational facility building designs at ITB, namely LabTek XV, LabTek XVI, and LabTek XVII. This study aims to develop a design process to achieve a green concept.

The process started with measuring the performance of the original design. During this measurement process, the base line design was also measured, namely the design without the implementation of passive strategies. The measurement results were then compared to identify significant factors that influence the building design performance. Based on the identification results, an alternative design that implemented green strategy was developed. The performance of the alternatives design was also measured. Then, the results were compared with the original design and the base line design. In the last stage, the design with the most optimum performance was selected.

The framework of design approach is shown in the figure below (Figure 1).

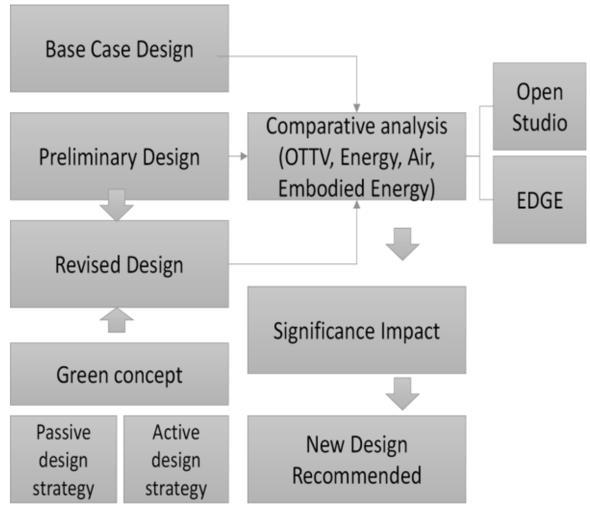

Figure 1. Framework of design approach

The performance analysis was conducted through simulation process to determine the performance of design components that have a significant impact, especially on the reduction in cooling and lighting energy loads. The software that used to determine the performance of design components was EDGE Building application. It is a platform developed by the International Finance Corporation (IFC). EDGE calculates the energy, water and embodied energy (EE) consumption of the material based on data collected in every city in all countries. The data is compiled into a base case, which shows the common practices of the building industry in each city.

Regarding the design framework, the green concept is implemented on design stages for three case studies, as follow:

1. Initial Design Engineering and Detailed (DED) development done without green approach
2. Building performance simulation of initial DED
3. Data collection and design strategy for green concept implementation
4. Revision for DED with green approach
5. Final design improvement based on revision

The DED green performance analysis is carried out with several approaches including:

1. Bioclimatic and green-metric approaches
2. Comparative approach between initial design and revised design

The building performance analysis uses the climate (bioclimatic) and green-metric approach. Bioclimatic architecture is to take advantage of local bioclimatic conditions with the benefit of the natural and built environment [6]. Therefore, Bioclimatic design is a passive approach of sustainable design criteria aimed at adapting buildings from negative climatic impacts depending on a building's geographical position (place-based problem-solving in design process). The bioclimatic architecture is an attribute for optimizing energy efficiency in buildings and improving user comfort [7]. The initial data needed consists of:

1. (Existing data) Data on the natural environment around the site. This data is needed to ensure that building planning meets aspects of appropriate site development. The data needed including the orientation of buildings, vegetation, and existing buildings around the site.
2. Building Material around the site. This data is needed to identify embodied energy and to identify whether materials commonly used around the construction area are included in the category of "green" material or not.

The next analysis is building performance analysis consisting of three performance indicators as follow:

(1) OTTV Value
(2) Energy Consumption
(3) Water Consumption, and
(4) Embodied Energy (EE) of Building material

The OTTV value is analysed using 'open studio' software for regarding that the analysis focus on the building envelope design. The building envelope has at least four functions in managing solar radiation, namely to support, control, finish, and distribute. Related to this control function, the regional regulation about green building concept, the Regulation of Bandung Major No. 1023 of 2016 concerning green building, used Overall Thermal Transfer Value (OTTV) as building envelope indicator. It is basically the average heat transfer rate of the building envelope material. In general, good building materials have a low transmittance value (U-value), thus giving a low OTTV value to the building [8]. Regional regulations require a maximum OTTV building value of 35 W / m2 [9]. Therefore, the basic analysis of OTTV value comparison is in accordance with the regional regulation. Quantitative analysis of the energy consumption, water consumption and embodied energy (EE) of building materials was carried out using EDGE Building platform. Furthermore, based on EDGE calculation, the building design performance was improved by implementing a number of proposed design changes. Building performance improvement can be seen from three determined indicators, such as energy consumption, water consumption and embodied energy. The results were used to provide recommendations consisting of two categories, passive design strategies and active design strategies. The comparison of building performance with various proposed strategies can be measured again using EDGE Buildings.

3. DATA AND ANALYSIS

3.2. The Simulation Result and Design Analysis of LABTEK XV Building

3.2.1. OTTV reduction

To achieve the OTTV value as required, it can be done in two ways, reducing the window to wall ratio (WWR), and reducing the thermal transmittance value of a material by replacing the material or decreasing the material thickness. It is also necessary to consider the embodied energy value of the material.

The LABTEK XV Building is planned with WWR of 27.42% on the north side, 37.80% on the South, 0.8% on the East and West sides (Figure 2 and Figure 3). This amount of WWR is quite high on the North and South sides. The solution for building openings is by using Low-E glass to reduce the impact of excess heat transfer on that side.

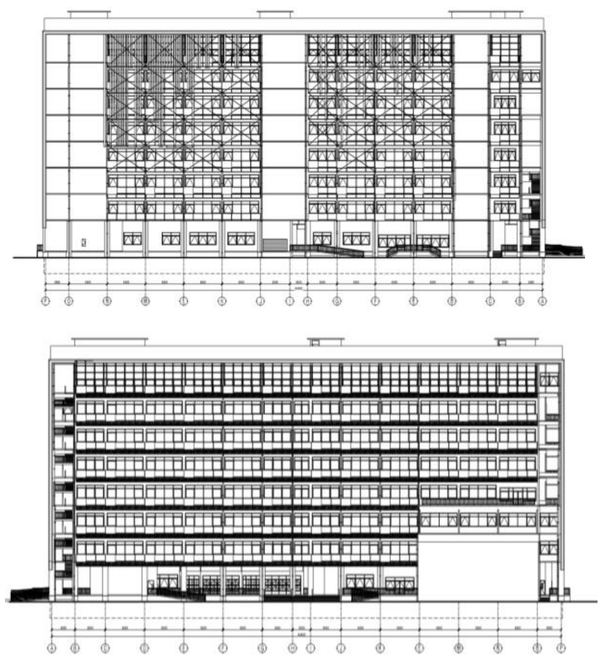

Figure 2 North – South Elevation of LABTEK XV using shading devices

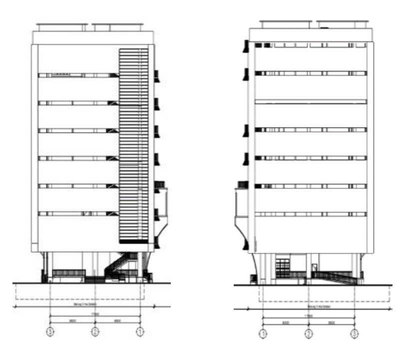

Figure 3 East – West Elevation of LABTEK XV using building envelope and low WWR

On the other hand, the material used for exterior walls is brick, with a thermal transmittance value of 2 W / m²K and containing embodied energy of 3MJ / kg. In comparison, Singapore applies a baseline U-value standard for walls that must be ≤ 2 W / m²K. This means that the thermal transmittance value of bricks is already high for Singapore standards. If it is coupled with thermal transmittance from the window, the value of OTTV of Chemical Engineering Building will certainly be more than 2 W / m²K.

Therefore, in the design of Labtek XV building, all design approaches need to be optimized in achieving the lowest OTTV value. The longest side of the building is certain to face North-South, with a very thin mass in the East-West area. With this mass orientation and composition, high radiation on the east and west sides can be avoided, while to avoid radiation during the day the buildings on the north and south sides are controlled by shading devices.

The additional strategy is to maintain sufficient vegetation around the site, reducing the heat received by the building envelope. The vegetation can also reduce the temperature around the site through shading and evapotranspiration of plants that can work as heat exchanger for the surrounding area. In addition, the vegetation can also encourage momentary air movement, so that the comfortable microclimate can be maintained.

As a result, the OTTV value achieved by this design is as shown in Table 1. This value has reached the maximum standard target of below 35 w / m2, or the average value achieved is 17.79 w / m2.

Table 1. OTTV Value of LABTEK XV

No	Side	Conduction Through Wal	Conductio n Through Window	Radiation Through Window	Total	Total Fasad Area	OTTV
		Watt	Watt	Watt	Watt	m²	Watt/m²
		A	B	C	D=A+B+C	E	D/E
1	NORTH	6,781.8	6,778.7	54,505.9	68,066.5	3,051.7	22.3
2	NORTH EAST	-	-	-	-	-	-
3	EAST	2,063.4	54.84	367.7	2,485.9	813.3	3.1
4	SOUTH EAST	-	-	-	-	-	-
5	SOUTH EAST	5.152,6	8,283.9	45,325.8	58,762.4	2,705.4	21.7
6	SOUTH WEST	-	-	-	-	-	-
7	WEST	2,075.2	-	-	2,075.2	815.6	2.5
8	NORTH EAST	-	-	-	-	-	-
		16,073.0	15,117.4	100,199.5	131,390	7,386.0	17.79
		TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL

3.2.2. Utilization of passive design strategies in reducing the cooling energy load

Calculation of energy consumption, water consumption, and embodied energy for LABTEK XV ITB can be seen in Figure 4. Figure 4 shows the results of building performance simulations that apply all strategies and combination of strategies to building energy savings based on EDGE Building application.

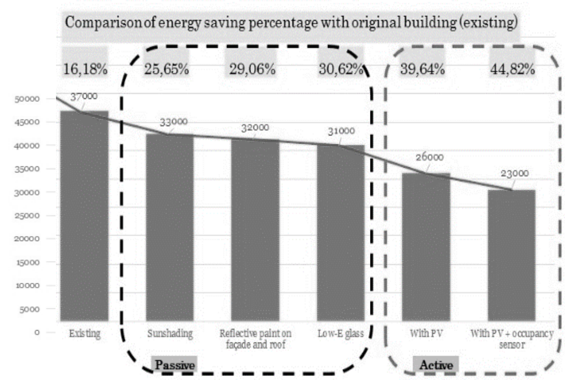

Figure 4. Comparison of various energy saving schemes for LABTEK XV

Energy savings with a passive design approach through the addition of shading devices, reflective paint on facades and roofs, and the use of low e-glass can reduce the cooling energy load by up to 30%. Maximum savings are achieved if the application of a passive design strategy is combined with several active strategies (such as the installation of solar panels and light sensor systems). Total savings with the implementation of a passive and active design can reach 44% of the base case or more than 28% of existing design.

In fact, the application of active design is not an option in this case due to the investment costs and maintenance capabilities. Therefore, optimizing the application of passive design strategies (sun-shading, reflective paint, and low-e glass) is considered sufficient because it can provide significant energy saving up to 29% compared to initial design savings without considering green concepts.

3.2.3. Design strategy on reducing water consumption

The results of the analysis for reducing water consumption are shown in Figure 5.

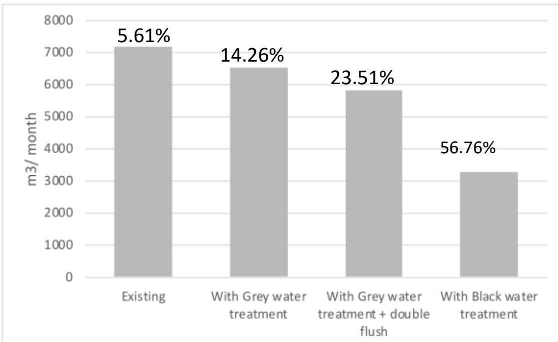

Figure 5. Comparison of water consumption with various water saving systems

The simulation results by applying three water saving strategies, through the design of environmentally friendly sanitary and plumbing systems that use the double flush system, grey water treatment, and black water treatment, show saving up to 56% from the base case or more than 50% of the existing designs. This proposal has been discussed with mechanical & plumbing experts to see the possibility of initial costs for each strategy.

3.2.4. Design strategy on reducing Embodied Energy Material

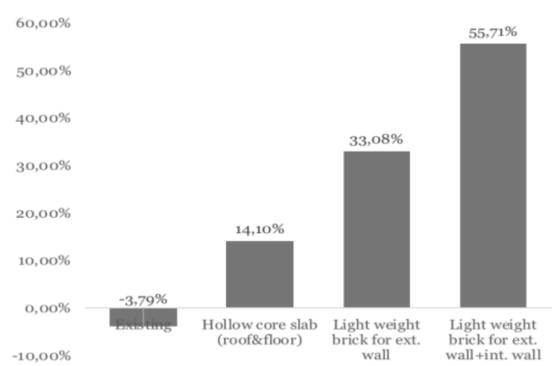

Figure 6. Comparison of building embodied energy for the proposed material selection

The Figure 6 shows the percentage reduction in embodied energy due to material selection strategies. The material selection strategy is easily accepted by architects and owners as the change construction initial cost are not significant. The material selection is also necessary to consider the ease of construction and calculation of structural loads.

The proposed material selection strategy is to use lightweight materials and reduce the volume of material without disturbing the stiffness of the building, including the hollow system of structural materials. The use of prefabricated hollow concrete plate material reduces the value of EE up to 14% and can reduce waste in production through increasing the accuracy of material use in reducing the value of EE. The use of lightweight brick material for walls also has a significant effect in reducing the EE value, up to 40% or a total of 55% when combined with the use of hollow prefabricated floor plates. The lightweight bricks are used for both interior and exterior areas of buildings.

3.3. The Simulation Result and Design Analysis of LABTEK XVI Building

3.3.1. OTTV Reduction

In accordance with site orientation, the building is elongated on the North and South axis. The base design of Labtek XVII has an average WWR of 49%, with 54% on the North side, 58% in the South, and 16% in the East. The percentage of WWR is relatively high and has an impact on the high value of OTTV. Table 2 shows that the OTTV value with the initial design is 65.23 Watt/ m2. This value exceeds the standard of OTTV value in Bandung, where the maximum is 35 Watt / m2. The radiation component through openings, especially on the North and South sides, contributes most to heat transfer in the building.

The energy reduction strategy through OTTV on both sides is then controlled by reducing the opening area, adding shading devices, and using low-E glass. All of the strategies have different potential to reduce the value of OTTV. These design changes are illustrated in Figure 7.

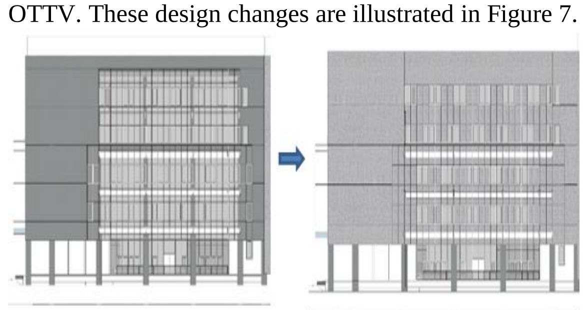

Figure 7. The adjustment of the facade to reduce OTTV

Based on Table 2, the reduction in aperture area and the replacement of the glass type potentially reduce OTTV larger than just adding a shade to the opening. The combination of both strategies can be considered in order to get more optimal results in decreasing OTTV. In addition, changing the colour of the glass from clear glass to euro grey also results in the minimum OTTV.

Table 2. OTTV Calculation of LABTEK XVI Building Design

No	Side	Conduction Through Wal	Conductio n Through Window	Radiation Through Window	Total	Total Fasad Area	OTTV
		Watt	Watt	Watt	Watt	m^2	Watt/m^2
		A	B	C	D=A+B+C	E	D/E
1	NORTH	6,301.9	6,182.3	46,963.0	59,447.1	774.2	79.8
2	NORTH EAST	-	-	-	-	-	-
3	EAST	4.620.2	812.7	6722.3	2,485.9	813.3	3.1
4	SOUTH EAST	-	-	-	-	-	-
5	SOUTH EAST	1,335.0	6,761.6	39,008.2	47,104.8	757.5	62.18
6	SOUTH WEST	-	-	-	-	-	-
7	WEST	-	-	-	-	-	-
8	NORTH EAST	-	-	-	-	-	-
		12,257.2	13,756.6	92,693.4	118,707.2	1,819.7	65.2
		TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL

3.3.2. Utilization of passive design strategies in reducing the cooling energy load

Figure 8 summarizes the building energy savings through the combination of several passive design strategies.

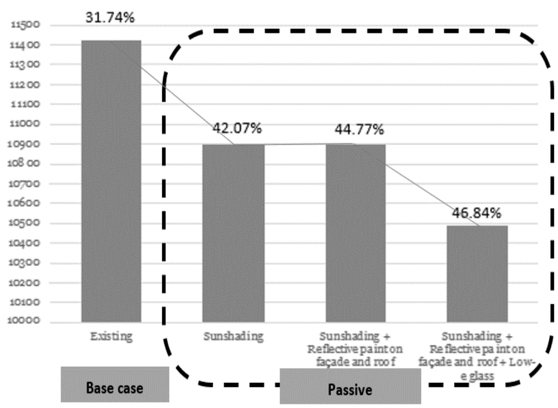

Figure 8. The comparison of various combinations of energy saving schemes in LabTek XVI

Ideally, the maximum savings can be potentially achieved by combining passive and active design strategies, such as the installation of solar panels and light sensors. However, due to the limited initial building cost, the active design strategies cannot be applied. Therefore, the building only focuses on the passive design strategies. In addition, based on the calculation of three passive design proposal, sun shading, reflective paint, and low-e glass, the energy saving is sufficient to meet the standard requirement. The total energy saving of the three passive design implementations can reach 46% compared to the base case design or around 16% compared to the existing design (initial design).

3.3.3. Design strategy on reducing water consumption

Figure 9 shows the results of an EDGE analysis of possible reduction of water consumption through a passive design strategy.

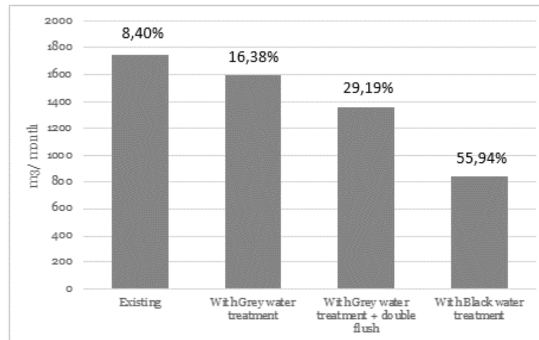

Figure 9 The comparison of water consumption with various water saving systems

As proposed in DED of Labtek XV, the water saving implements three design strategies, double flush, gray water treatment, and black water treatment. Based on the simulation results, three proposals indicate the energy saving of up to 55% from the base case or more than 47% from the existing design (initial design).

3.3.4. Design strategy on reducing Embodied Energy Material

Figure 10 represents the percentage of Embodied Energy reduction through various consideration of material selection. Material selection takes into account the use of lightweight material and the reduction of building material volume that does not have impact on building stiffness.

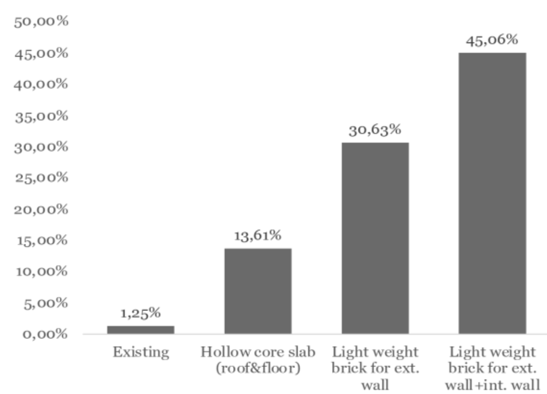

Figure 10 The comparison of embodied energy in the building

The use of hollow core slab in roof and floor can reduce the EE value by 13%. The addition of lightweight brick for exterior and interior wall has significant impact on the reduction of EE value, up to 45%. This proposal has been discussed with structural experts and has been approved for implementation. Apart from reducing construction waste due to residual material, the use of prefabricated materials also accelerates the building construction process.

3.4. The Simulation Result and Design Analysis of LABTEK XVII Building

3.4.1. OTTV Reduction

The difficulty in developing the design of Labtek XVII Building is on the site orientation which the longest side of the building is facing West-East (Figure 11 and Figure 12). Because of this condition, the building is elongated on West-East axis. With this orientation, the building gains a lot of solar radiation from the East and West sides. To avoid high solar radiation during the day the building needs to use shading devices from the eaves, especially on the west and east sides.

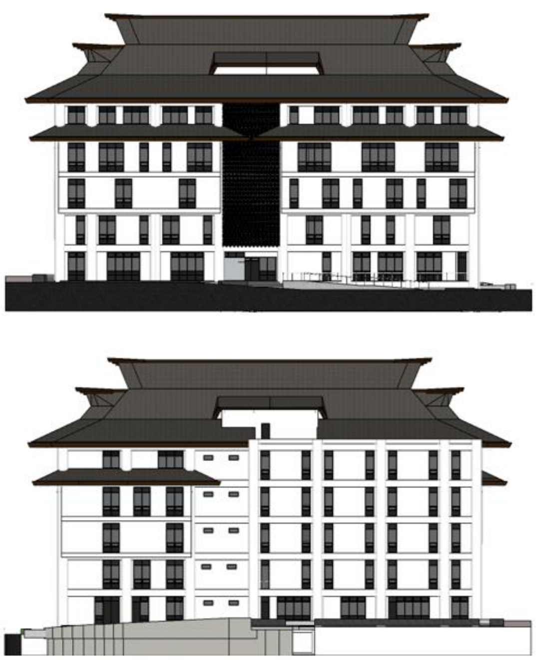

Figure 11 East-West Elevation of LabTek XVII using shading devices

Figure 12 North-South Elevation of LabTek XVII using shading devices

The base design of Labtek XVII has an average WWR of 22.19 %, with 24.13% on the North side, 4.95% on the South, 27.60% on the West side, and 23.82% on the East. Table 3 shows that the value of OTTV with this proposed design is 18.85 Watt / m2. This value is far below the standard of OTTV value in Bandung, which is maximum 35 Watt / m2. It can be seen in Table 2 that solar radiation from openings contributes to a total of 47,186.49-Watt heat transfer in the building, with 18,496.26-Watt and 19,943.04 Watt are receiving from the East and West sides openings, respectively.

Table 3. OTTV Calculation of LABTEK XVII Building Design

No	Side	Conduction Through Wal	Conductio n Through Window	Radiation Through Window	Total	Total Fasad Area	OTTV
		Watt	Watt	Watt	Watt	m^2	Watt/m^2
		A	B	C	D=A+B+C	E	D/E
1	NORTH	1,148.0	704.7	4,221.5	6,074.4	360.6	16.8
2	NORTH EAST	-	-	-	-	-	-
3	EAST	2,704.1	1,654.1	14,102.1	18,496.3	857.2	21.6
4	SOUTH EAST	-	-	-	-	-	-
5	SOUTH EAST	1,593.0	160.2	919.6	2,672.8	399.4	6.7
6	SOUTH WEST	-	-	-	-	-	-
7	WEST	2,691.8	1,980.6	15,270.6	19,943.0	886.0	22.5
8	NORTH EAST	-	-	-	-	-	-
		8,172.9	**4,499.6**	**34,513.8**	**131,390**	**2,503.0**	**18,85**
		TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL

3.4.2. Utilization of passive design strategies in reducing the cooling energy load

Figure 13 summarizes the combination of passive and active strategies for building energy savings. The simulation results show that the passive strategy proposal does not have a significant effect of 1%, compared to the initial design. This is because the design and site conditions meet bioclimatic design principles that support energy savings. Meanwhile, the proposed active strategy achieves saving up to 41% and 9% more efficient compared to the base case and existing design.

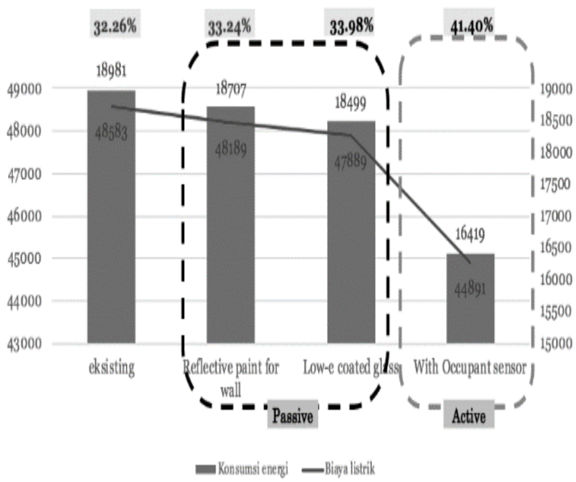

Figure 13 The comparison of various combinations of energy saving schemes in LabTek XVII

3.4.3. *Design strategy on reducing water consumption*

For water savings, the active strategies are applied through the use of double flush and black water treatment. The savings analysis can be seen in Figure 14. The simulation result of the two proposals shows saving up to 55% from the base case or more than 30% of the existing design (initial design). This proposal has been discussed with mechanical and plumbing experts and is approved to be implemented because it is still under reasonable development costs.

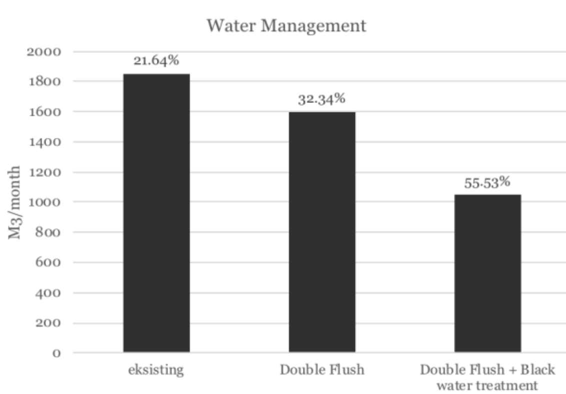

Figure 14 The comparison of water consumption with various water saving systems

3.4.4. *Design strategy on reducing Embodied Energy material*

Figure 15 illustrates the percentage of embodied energy that can be reduced through the selection of alternative materials.

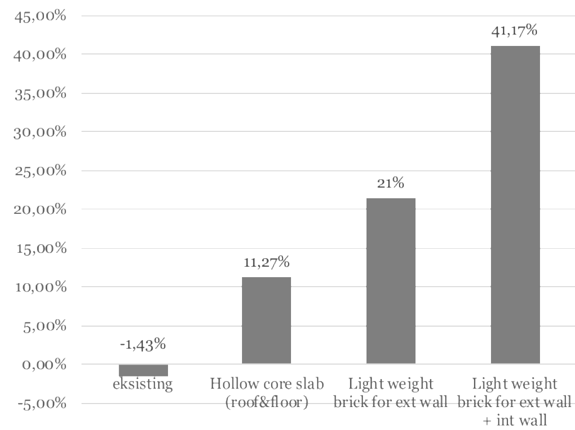

Figure 15 The comparison of building embodied energy for proposed material selection schemes

The use of hollow core slab in roof and floor can reduce the EE value by 13%. Furthermore, it can reduce construction waste by increasing the accuracy of material utilization. In addition, the use of lightweight brick material for the walls also had a significant effect in reducing the EE value, up to 41% in total.

4. CONCLUSION

In all three cases, the Labtek XVII base case design is a building design with the most optimal energy use. This is because the existing conditions of the site are highly supportive for the implementation of a passive design strategy, namely with a north-south orientation. In addition, Labtek XVII's existing site conditions have a lot of vegetation which allows heat exchange. Based on the results of the analysis, it is known that appropriate site development is one of the most influencing aspects of energy decline.

In addition, another approach that can be used as an energy reduction strategy is the design and use of building envelope materials. In all cases, it appears that the building envelope can reduce OTTV significantly, especially in the case of Labtek XV and XVI where the orientation of the building is not completely facing North-South. The use of shading devices, reflective paint and low-e glass in the simulation can reduce up to 50% compared to the initial design.

Meanwhile, water saving shows saving up to 50% in all cases when using a water saving strategy through the use of a double flush system, gray water treatment, and black water treatment. In line with this, the use of alternative, more modern materials like prefabricated hollow floor slabs leads to positive result. This positive impact can be seen from the simulation results which show that in all three cases there is a decrease in energy of more than 50% with the use of prefabricated floor slabs and light bricks. The following figures illustrate the final design of three Education Buildings (Figure 16, 17, 18).

Figure 16. Image of the design of Labtek XV building

Figure 17. Image of the design of Labtek XVI building

Figure 18. Image of the design of Labtek XVII building

With the evidence of a significant impact on the concept implementation, various stakeholders will pay more attention to the proposed design changes, so that design changes with the consideration of implementing the green concept can be well accepted.

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