Comparison of Conventional Materials with Advance Materials to Operational Costs and Energy Efficiency Based on Sefaira

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ABSTRACT

In the design process, consideration of energy efficiency is one of the crucial aspects of a design. Energy efficiency will affect the amount of carbon dioxide emissions released. In addition, energy efficiency also affects operational costs that will be maintained by the manager. During the construction process, conventional lightweight brick wall often takes longer to study than panel-shaped materials or modules. Currently there is an assumption that conventional lightweight brick wall has little influence on energy consumption and operational costs, so it is necessary to review the exploration of the use and composition of materials that can respond to the energy context in the surrounding area. This paper describes comparison of conventional materials with advance materials to operational costs and energy efficiency which in this case is apartment design from 3rd year architecture studio. The research uses Sefaira simulation methods and values need to be reviewed such as energy use, operational costs, and other factors that can affect. Reference research assessment using ASHRAE-based standards 90.1 – 2013 by following the *2030 energy challenge* system. The results showed that brick pairs can result in much more significant energy expenditure and anticipational costs. It is necessary to review the material to reduce energy use and operational costs to obtain an ideal comparison of cooling and natural lighting loads in existing areas.

Keywords: *Energy, Cost, Emmisions, Simulation, Material.*

1. INTRODUCTION

In general, there are two categories of building costs. The first category is pre-construction costs and post-construction costs. The pre-construction costs include design, commissioning, documentation costs, construction costs, materials, and building services. Second, post-construction prices include building operational costs from energy consumption, water use, maintenance, and management. Benefits include financial savings and help during construction and post-construction phases, such as higher property market values, higher rents, marketing opportunities resulting from social benefits, lower carbon taxes, energy savings, and higher productivity [1].

Building costs relate to energy efficiency and innovative materials to achieve energy savings. In developed countries, energy consumption in buildings comprises 20-40% of total energy use. For this reason, energy efficiency strategies are a priority in energy policy, with new regulations and certification schemes, including minimum requirements. There are various approaches to achieving energy efficiency. Among them are energy savings in buildings that enable a sustainable energy future [2].

New materials with unique properties start at a higher level. These materials are often referred to as advanced materials and enable technological innovations that benefit society [3]. Today's modern technologies in construction can dramatically reduce the energy consumed in buildings for mechanical heating and cooling [4]. Comparison of conventional materials with new materials will have special long-term effects, such as the effect on a building's energy efficiency and operational costs.

In the design process, it is necessary to pay attention to materials related to energy efficiency and operational costs. In addition, designers design, construct, maintain, rehabilitate, and demolish sustainable buildings through the efficient use of natural resources and protecting global ecosystems. The selection of suitable building materials helps to use energy efficiently [5].

In apartments, there are often cases of swelling operational costs in several operational aspects due to using energy efficiency in a building. Some of them are intrinsic in a property, and others are external or even incidental. The property's value will essentially depend on both of these characteristics and the type of valuation carried out. One of the characteristics is the level of energy efficiency of the property or the performance of the energy itself [6]. Energy efficiency is influenced by several aspects, one of which is material. The use and preparation of materials is an essential aspect of planning. In this case, the preparation of materials aims to implement energy efficiency so that it can reduce operational costs in a building. Energy use in buildings depends on a good combination of architectural and energy system design and effective operation and maintenance after occupying the building. There are sophisticated, integrated, and interrelated systems [7].

This paper describes comparison of conventional materials with advance materials to operational costs and energy efficiency which in this case is apartment design from 3rd year architecture studio. This study uses the Sefaira simulation method, so it is necessary to review values such as energy use, operational costs, and other influence factors. The reference for the research assessment uses ASHRAE 90.1 – 2013 based standards by following the 2030 energy challenge system. The case used in this simulation uses an apartment design adopted from design studio 5 with an apartment typology. An apartment is a type of residence expected to provide comfort, especially for prospective residents later.

2. METHODS

There are various stages of this research, starting from the design of the results of the study object design (working drawings, visualizations, and 3-dimensional models of buildings), surveys using secondary data, and area analysis based on secondary data obtained.

In analyzing to apply energy efficiency to reduce operational costs in a building, a simulation process is needed to obtain efficiency figures and exact figures for operating expenses. Energy efficiency will result in differences in the several simulation experiments carried out. In this context, simulation is carried out based on the materials used and the comparison between conventional materials and the recommended materials.

Sefaira is one of the plug-ins for 3-dimensional modeling software that can provide visualization while considering the energy used in case studies of the buildings used. Sefaira is also a software that can compare energy use and efficiency, which will impact operational costs.

In the analysis process, make with one modeling with two different analyzes. The analysis carried out differs based on the materials used to consider energy efficiency and operational costs in a building. Some of the limitations and conditions of the two models:

- Make a model by paying attention to every existing field so that no areas are duplicated to get optimal results
- The two models have different material coefficients by consistently adjusting the material settings.
- Setting the openings in the building in a uniform manner as a “window” to get the analysis results based on the actual situation of the case.
- Sefaira can run analysis if there are at least four types of fields, namely roof, window, floor, and wall.
- Using the top floor as a service area to place properties that support the functional residential area.
- Set the top service area as a roof to conduct a thorough analysis.
- Using part of the space in the apartment as a floor and wall as an area for walls.
- Create a three-dimensional model on a plane by plane basis to avoid duplication in the desired plane.
- Lighting and infiltration settings follow the default settings by following the 2030 energy challenge system.

Simulation using Sefaira with basic standards based on ASHRAE 90.1 - 2013 by following the 2030 energy challenge system. The simulation was carried out several times based on the materials used. In the simulation, there is a replacement of materials that are suitable for their function to reduce operational costs in a building and increase energy efficiency in a building and reduce carbon dioxide emissions.

In simulating, the use of an air conditioning machine using the default settings. For HVAC machines, it is also set using the settings by default based on the settings selected by Sefaira. The aim is to facilitate the simulation to pay close attention to the comparison of results (Figure 1).

Figure 1 Building design perspective view.

The conclusion of this simulation is obtained by comparing the results namely; energy consumption, operational cast, CO2 emission, and HVAC detail, between the first simulation using conventional materials and the second simulation using new materials that can reduce energy efficiency so that later it can reduce building operational costs.

3. RESULTS AND DISCUSSION

Data collection was carried out based on secondary data and observing the design process in the apartment case study. The design process also looks at energy use and operational costs, considering the user's target market aimed at millennials. The targets include students, start-up actors, and other millennial generations, so it is necessary to pay attention to energy efficiency to reduce building operational costs. Two scenarios will carry out different material arrangements in collecting simulation data, making it easier to see differences in energy efficiency and operating costs, especially case studies of apartment buildings.

3.1. Building Design Condition

The shape of the building directly affects the energy consumption of the building [8]. The shape of the building is the most visible characteristic of a building and has a tremendous impact on its energy performance. When the envelope's shape is defined at the initial design stage, energy performance information is usually absent because modeling for energy simulation becomes a time-consuming task [9]. In the case of an apartment building, it has a basic rectangular shape that considers space efficiency so that all areas are used optimally. For the dimensions of the building itself, it uses a structural column module with a span of 8 meters to produce efficient space for residential rooms later (Figure 2).

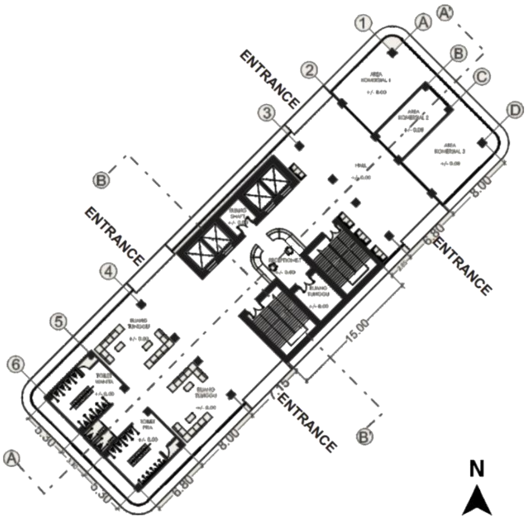

Figure 2 Building 1st floor plan.

There are three types of rooms in the building, namely studio, two-bedroom, and three-bedroom, which have various sizes based on the required amount. The span of the column module is 6 to 8 meters with column dimensions of 80cm*80cm. The building uses a columnar structure with a flat slab which uses a floor plate as a load recipient and does not use beams.

Buildings consume energy at different rates at each stage of the life cycle. Building materials occupy a large portion of this consumption. Therefore, the amount of energy consumed by materials used in buildings during their life cycle is an essential parameter in determining the energy efficiency of buildings [10]. The use of materials that can affect energy efficiency needs to be considered to reduce operational costs. The initial use of material used was conventional lightweight brick wall material without materials that support energy efficiency, so this study focuses on the use of materials used and the comparison of changes between conventional materials and innovative materials.

3.2. 3D Modelling

The apartment case study modeling uses SketchUp software which has equal integration to measure energy efficiency and to see the operational costs of 1 case study of buildings with different regulated materials. The use of materials in simulations with advanced materials is applied to several areas such as walls, floors, roofs, and even the selection of glass types that use three layers which can be explained as follows.

- On the exterior walls, use the material shown in the picture with a u-value of 0.18. The wall material has its layer to anticipate the amount of energy used in the building (Figure 3).

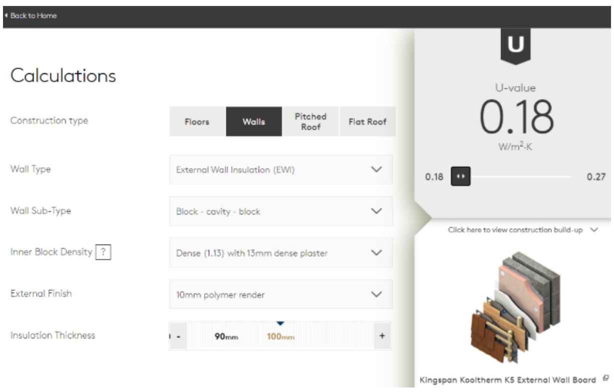

Figure 3 Advance material for exterior wall.

- Exterior walls have a different arrangement from interior walls considering that exterior walls require resistance to outdoor conditions so that interior wall materials are selected based on the u-value according to needs (Figure 4).

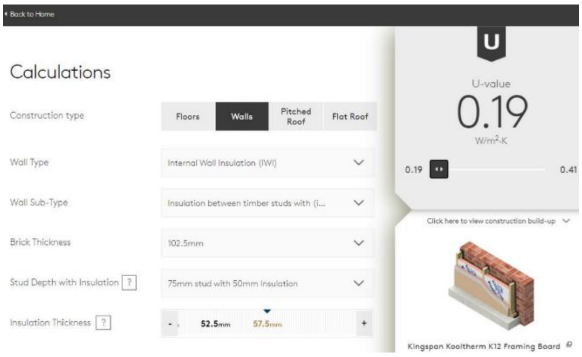

Figure 4 Advance material for interior wall.

- The roof used is also a material that can reduce energy use so that the building can apply the concept of energy efficiency from all aspects. The top of the building has a u-value of 0.19.
- On the ground floor using materials as shown in the following image with a u-value of 0.09 to reduce the use of natural energy in the building (Figure 5).

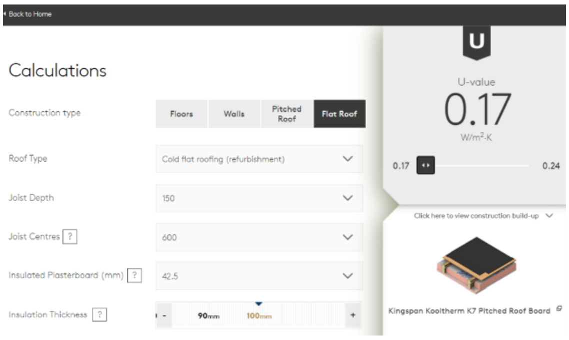

Figure 5 Advance material for roof.

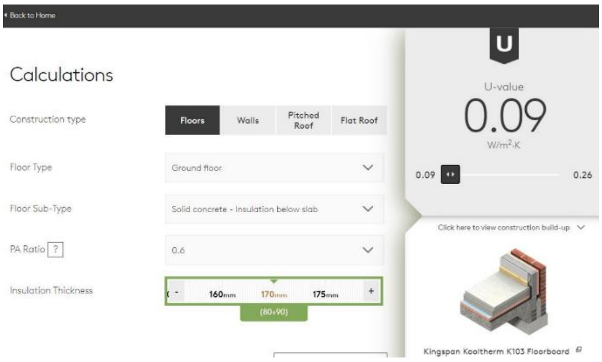

Figure 6 Advance material for floor.

Energy-efficient materials can support construction both ecologically and economically. In addition, materials that consume less energy simultaneously cause fewer harmful emissions and reduce environmental pollution resulting from construction materials (Figure 6). In addition, with its various thermal properties (such as heat storage and heat retention), the material contributes to creating comfort in the indoor environment [11] (See Fig. 7).

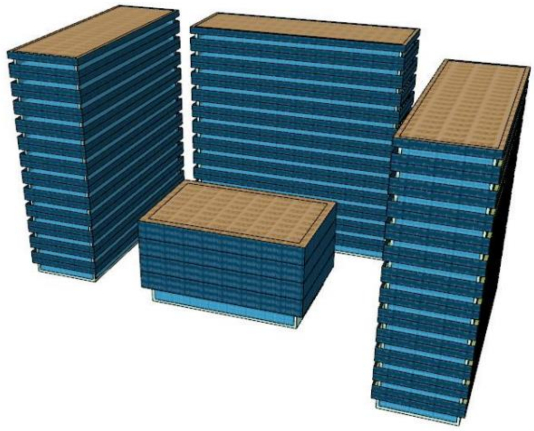

Figure 7 Building model for simulation.

The test model, there are several stages carried out, namely:

- Conduct case studies and in-depth explanations of fair simulation.
- Use of methods based on ASHRAE 90.1 – 2013 to get more accurate results.
- Designing 3D modeling to run the simulation process.
- When making 3D modeling, periodically check to avoid duplicate fields.
- Duplicated fields cause an equal simulation not to run, or the results obtained are inaccurate.
- Material studies are also carried out in determining the placement of materials.
- Final modeling inspection is carried out and arranges each area based on its function, such as setting the topmost plane as a roof, setting the floor area as flooring, setting the opening window as a window, and setting the secondary skin as shading.
- In fairness, you can change the material based on the existing modeling by changing the u-value.

3.3. Results Comparison

- Energy Cost that is required is quite different with a reasonably high margin between conventional materials and advance materials, almost 700 MWh annually. Means that the model with advance materials (with complete insulation material) requires less energy. From this analysis, it can conclude that the second simulation that uses advanced material needs less energy if compared to conventional material (Figure 8).

Figure 8 Energy consumption for conventional model (left) and advance model (right).

- The effect caused by the energy usage margin is quite significant. The cost difference of conventional model and advance model analysis is $400,000/year. Building with conventional materials costly in operational section rather than building with insulation material. It can be concluded that the use of insulation material has lower operational cost (Figure 9).

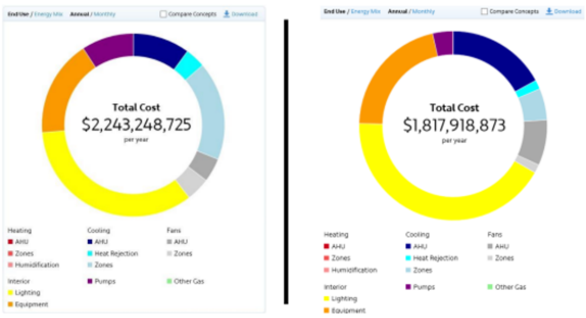

Figure 9 Operational cost for conventional model (left) and advance model (right).

- Energy-saving effects not only operational cost reduction but also CO2 gas emission. Using default material emits more CO2 if compared to insulation material. So it also can be concluded that the use of insulation material is also helpful to reduce CO2 emission (Figure 10).

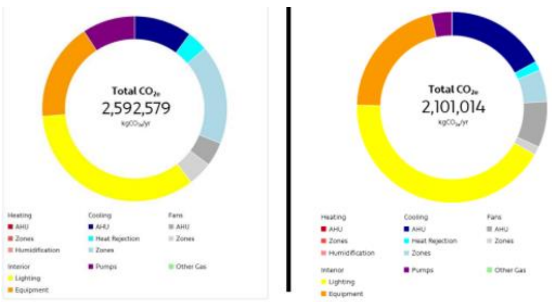

Figure 10 CO2 emission for conventional model (left) and advance model (right).

- They are significant results from the analysis. For conventional model, the required cooling is quite substantial, even reaching 2,500 kW, but in advance model analysis, it's only necessary to provide 1000 kW to the building with complete insulation material. The extreme difference between 1st and 2nd analysis is the heating aspect. The first analysis result requires 30.9 kW heating, while the 2nd one doesn't require heating. The heat rejection of 1st analysis is very different if compared to 2nd one; 1st analysis has 3,541.6 kW heat rejection while the 2nd one has 1,200 kW. By the analysis result, it can conclude that complete insulation material on building save much energy.

Energy-saving technology and innovation of energy-saving materials are interrelated, and energy efficiency in buildings should be based on the development of new energy-saving materials with good thermal insulation characteristics [12]. Advanced materials can absorb energy from and release energy into the environment. Such materials can better solve space and time's energy supply and demand mismatch [13]. At the same time, with the use of materials capable of storing latent heat, it has the characteristics of high energy storage density and constant temperature equivalence in the heat storage process. This material has the effect of being relatively easy to apply continuous room temperature control [14]. This material is especially true for the field of building temperature insulation and energy conservation, which have broad application prospects and are expected to be a pioneer in energy saving in construction in the low-carbon economy era [12].

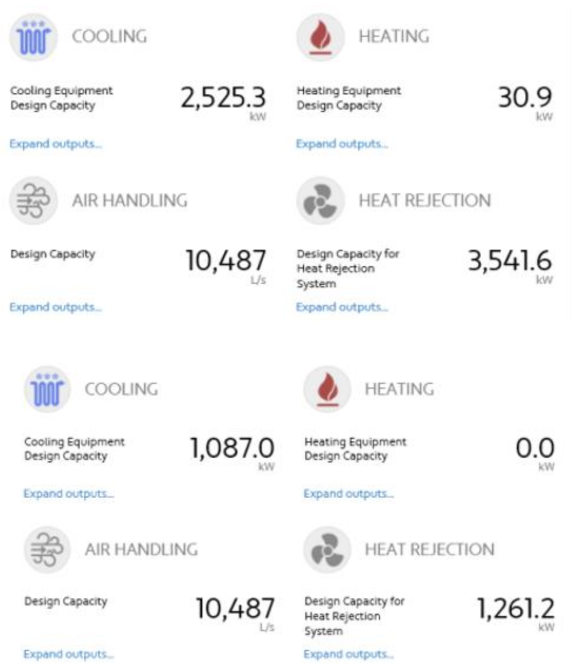

Figure 11 HVAC simulation results conventional model (top) and advance model (bottom).

Insulation material is highly considered in the energy saving of buildings, especially the energy contained in the material, which affects the entire life cycle of the material. The choice of insulation material in terms of thermal behavior has a significantly different impact on embodied energy and, consequently, environmental impact [15].

4. CONCLUSION

The conclusion for comparing conventional materials with advanced materials is that the difference in conventional materials with advanced insulation materials affects energy efficiency, operating costs, and CO2 emission expenditures. Therefore, the insulation material will indirectly affect user comfort. This case is an apartment as a residential area. Using materials that support comfort for users is also an added value in carrying out a design process

ACKNOWLEDGMENTS

This article was supported by the Ministry of Education, Culture, Research, and Technology of Republic Indonesia. Grant numbers 317/UN40.LP/PT.01.03/2021 under LPPM-Universitas Pendidikan Indonesia.

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