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ENERGY ANALYSIS OF WALL MATERIALS USING BUILDING INFORMATION MODELING (BIM) OF PUBLIC BUILDINGS IN THE TROPICAL CLIMATE COUNTRIES

Aidin Nobahar Sadeghifam[a], Abdul Kadir Marsono[a*], Iman Kiani[a], Umit Isikdag[b], Ali Asghar Bavafa[a], Sanaz Tabatabaee[a]

[a]Department of Structure and Material, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Department of Informatics, Mimar Sinan Fine Arts University, Istanbul, Turkey

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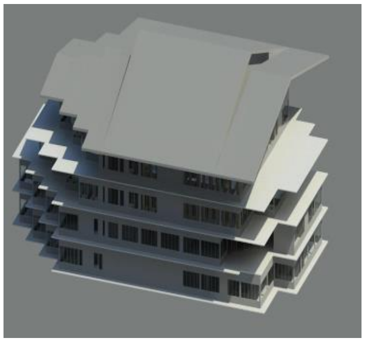
*Corresponding author
akadir@utm.my

Graphical abstract



Abstract

During the previous two decades, the energy saving potential using systematic building management is considered to be important which should be considered through the building lifecycle. Among the wide range types of different buildings, Public buildings are considered as one of the biggest energy-consuming sector in the world and major part of this amount is used by the air conditioning system especially in tropical climates. The most effective decisions related to sustainable design of a building facility are made in the feasibility and early design stages. Building Information Modeling (BIM) can expedite this process and provide the opportunity of testing and assessing different design alternatives and materials selection that may impact on energy performance of buildings. This paper aims at evaluating the efficiency of various types of wall materials with regard to theirs properties on energy saving. The case study in this paper is modeled by means of BIM application and then simulated by software, which is appropriate for energy analysis. The current energy consumption patterns of this case identified and shifted to the optimized level of energy usages by changing the walls materials to find most optimized of walls materials. Modification most optimized wall materials and energy analysis indicated 9347 Wh in Per meter square of electrical energy saving.

Keywords: Energy saving, public buildings, tropical climate, wall material, BIM

Abstrak

Dalam tempoh dua dekad yang lalu, potensi penjimatan tenaga menggunakan manajemen pengurusan gedung yang sistematik dianggap penting yang perlu dipertimbangkan melalui kitaran hayat bangunan. Di antara pelbagai jenis bangunan, bangunan awam dikenali sebagai salah satu segmen yang memakan tenaga utama di dunia dan sistem penghawa dingin menggunakan bahagian terbesar daripada jumlah ini khususnya di kawasan iklim tropika. Keputusan yang paling berpengaruh mengenai reka bentuk yang ramah lingkungan pada suatu fasiliti bangunan dibuat dalam kelayakan dan peringkat reka bentuk awal. Dengan penggunaan model informasi bangunan (BIM) proses ini dapat dipercepatkan dan peluang untuk menguji dan menilai pelbagai seleksi bahan-bahan dan alternatif-alternatif reka bentuk akan disediakan yang mungkin mempengaruhi pencapaian tenaga bangunan. Kertas kerja ini cuba untuk menilai efesiensi pelbagai bentuk bahan-bahan dinding yang berkaitan dengan properti penjimatan tenaga. Dalam kertas kerja ini kajian kes dimodelkan menggunakan aflikasi BIM dan kemudian dengan menggunakan perisian disimulasikan, yang sesuai untuk analisis tenaga. Corak yang sedia ada dalam penggunaan tenaga pada kes ini dipindahkan dan dikenal pasti demi kelaziman tahap tenaga yang dioptimumkan dengan menukar bahan-bahan dinding untuk penemuan yang paling dioptimumkan pada bahan-bahan dinding. Pengubahsuaian bahan-bahan dinding yang paling dioptimumkan dan analisis tenaga ditunjukkan 9347 Wh dalam Per meter persegi penjimatan tenaga elektrik.

Kata kunci: Penjimatan tenaga, bangunan awam, iklim tropika, bahan dinding, BIM

1.0 INTRODUCTION

Based on the International Energy Agency (IEA), the world energy consumption has risen by 48% in the past two decades. There is a growing concern over the exhaustion of resources and related heavy environmental impacts. The building sector is the largest contributor to energy use, accounting for more than one-third of all final energy and one-half of total electricity consumption worldwide [1]. According to the IEA energy efficiency is defined as the "fuel" that makes a change to reinforce a more sustainable energy system. In line with this opinion is the significant share of the potential to improve energy efficiency more than 80% of building sector's potential is untapped [2]. It is anticipated that with population growth, demand for building comfort levels and services will increase, along with the increase in time spent inside buildings will urge greater demand for energy in future. Thus, buildings designed for energy effectiveness becomes much more crucial.

Same as the other Asian countries Malaysia has been experiencing a fast technological and economic development and consequently its energy usage amount has been amplified throughout these years. Figure 1 shows the trend of electrical energy consumption trends have been raised from 52 kWh in 2000 to 100 kWh in 2012 [3].

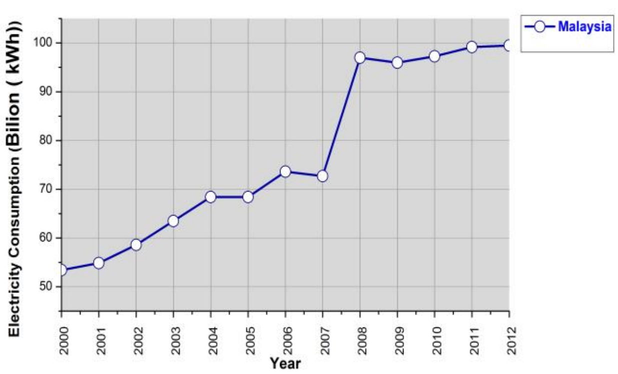


Figure 1 Electricity consumption in Malaysia from 2000 to 2012

In a study by the CETDEM center which was conducted in 2006 on energy usage of household for environment, Technology & Development, Malaysia revealed that, refrigerator and cooling use almost 70% of the average consumption of the electricity in buildings. The largest electricity consumer in the buildings is air conditioning [4].

Since the past decade many new methods have been employed to present materialized sustainable design and effective energy optimization and analysis. Building envelope is generally known as a main feature that effects building energy consumption [5]. The parameters that affect performances of building envelope energy might design variables (e.g., configuration of the exterior wall) or given inputs, which is imposed by the project's context (e.g., outdoor temperature of the site) together with this fact there are some remedies including repairing or changing components [6]. Optimum thickness of wall, floor, roof and ceiling insulation maintains minimized energy loss with optimal thickness for each sector.

Building Information Modeling (BIM) solutions help having sustainable design by providing the opportunity to the architects and engineers to accurately analyze, simulate and visualize the performance of buildings formerly in the design process. To analyze different systems such as systems for manufacturing, the construction process and analyzing the energy simulation is a practical way [7, 8]. Revit and other applications made for BIM help designers design, simulate, visualize and collaborate in order to capitalize on the advantages of the interconnected data within a BIM model and also, Ecotect, Energy Plus and Transys are common Software of BIM that used to simulate building and easy energy analysis [9, 10, 11].

In the previous years, more emphasis has been put on the need to reduce both the natural resources exploitation and energy use; nevertheless, not enough attention is given to environmental issues and sustainability. Sustainability issues have not been measured distinctly; rather than, they have usually been incorporated with selection of energy consumption or materials [12, 13, 14].

Sadeghifam *et al*. (2015) states that the most influential way to reduce the consumption of energy in tropical regions particularly residential buildings are to change the ceiling heights and its materials; furthermore, inside temperatures and wall materials were in the following stages of important factors correspondingly [15]. Sabouri *et al*. (2011) was focused on the influence of various kinds of materials for floors, roof and walls on the amount of energy, which was used in a normal low-density bungalow house. Energy Plus and Design Builder software are employed to simulate and analyze energy. The researchers changed the heavy walls (Cement sand render (1.3 cm), Concrete block (Medium) (11 cm), Gypsum plastering (1.3 cm)) with light weighted walls (Lightweight metallic cladding (6 mm), air gap (5 cm), gypsum plastering (1.3 cm)) and the results showed that using of this material wall saved 16% of energy. Using white painted steels instead of concrete roof tiles saved 5.8% of energy. Through suitable materials selection for floor 9.4% of energy was saved in this study [16].

Considering several studies, which have been done before, to compare several details of walls, floors, windows, roofs and ceiling based on their energy performance a critical analysis could be used. In most of the researches conducted before considering this topic each research group checked particular buildings parts. However, reaching higher maintenance and better options of the building parts can be gained through more research [17]. Furthermore, more accurate and practical results can be obtained through using different software applications.

Garg and Singh (2009) investigated the influence of the thermal transmittance characteristics of floor, roofs walls and zones of buildings on entire energy savings by using different windows. They established an equation to calculate the total energy saved by a window. It was shown that the window's capacity to save energy is dependent on the type of window, building dimensions, climatic conditions, window orientation and thermal transmittance of the wall and roof. Among these factors, the last two contribute the most energy savings [18].

The main aim of any air conditioning system is to provide us an acceptable temperature and comfortable indoor condition. Malaysia as a tropical country is hot and humid and consequently enormous amount of energy has been used by the cooling system in the public buildings. Most problems in these buildings are wasting energy that related to a cooling system that most of time user of these buildings is not satisfied with the level of temperature. Since sustainable buildings have been developing and applying BIM tools in a new concept in Malaysia and due to lack of awareness among client, consultant and contractors, few building projects implement the guidelines provided by BIM tools in their development. In this research, we used monthly cooling load to compare data. By having this information it is feasible to deduct the amount of cooling which are needed to provide thermal comfort band for any building. On the other hand, the usage of energy relies on the efficiency of devices, which are selected to cool these places, and clearly, other devices with varied efficiencies lead to different amount of energy consumption. Furthermore, we used more precise Building Information Modelling (BIM) applications, which differentiate our project from former studies. More precise view is possible by using the cooling load as the basis of comparison for knowing the effect which wall materials has one of the most optimized on energy usage in building. This study concentrates on analysing the performance of 8 various of wall element regarding total amount of cooling load which are saved in tropical climate during one year.

2.0 METHODOLOGY

The methodology used in this study was based on the comparison of the alteration of the physical specifications of building wall component and model simulated by Building Information Modeling software and finally model energy analyzed by BIM Application. To limit the scope of this study it was assumed that the base model represented a public building made with wall materials commonly used in Malaysia.

In first step, some practical and accurate measures like the number of users at each level; temperature, humidity and airflow should be measured and recorded that needed for simulation. In the next step, the selected case study modeled and simulated through BIM application. The selected case is a four-story library located on UTM Johor campus. The CAD drawing of this case imported to the Revit Architecture software, which is well known for being one of the simulation tools with high accuracy and practicality among BIM software, simulated there by parametric design principles. In the next step, In order to analyze the energy consumption of the building used as a case study, a model was created in Revit Architecture should be the pioneer energy analysis application of BIM. The specifications were re-assigned to Ecotect and a final sketch-up analyzed by Ecotect software as BIM application for analysis energy. In the last step, in order for optimizing the energy usages of the case, some variables of wall materials tested the trend of variations recorded. Then, by analyzing the obtained data, then identified most optimized wall materials for Malaysia that most common wall materials in Malaysia were chosen.

3.0 RESULTS AND DISCUSSION

This paper focuses on analyzing the data collected from the literature review and field measurement then simulating of case study and preparing for analysis in the energy analysis software. Consequently to find most optimize wall materials by consideration the energy usages of the case, variety of wall material tested the trend of variations recorded. Then, by analyzing the obtained data, most optimized of wall material identified for using in the public buildings in tropical countries.

3.1 Case Study

A case study is conducted on the library building of University Technology Malaysia (UTM) Johor campus and its floor area is around 20000 meter square. This building is selected based on the use of the building as a research center and it consumes high electric load every day. The library is a 4 story building consisting an underground floor (level 2), ground floor (level 3), level 4 and 5, with a capacity of 3,422 users and it has a total of 179 operational staff. The building's structure was reinforced concrete and the roofs of the building were pitched and covered with clay tile without roof and wall insulations. The facade of the building was covered with cement sand render and the main material of exterior walls was plaster and brick. Figure 2 shows the view of the selected building for the energy analysis.

Figure 2 View of the library building

Johor Bahru, a city which is located in the south part of the Malaysia, is positioned at latitude 1.48° N and longitude 103.73° E, most of the year this part experiences consistently relative humidity and high air temperatures. The average mean dry-bulb temperature ranges from 21.9°C to 32.8°C. The relative humidity (RH) varies between 82% and 86%. The average monthly precipitation is 196 mm. Over the course of the year typical wind speeds fluctuate from 0 m/s to 5 m/s (calm to moderate breeze), seldom exceeding 7 m/s (Table 1).

Table 1 Climate data for Johor Bahru

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average High °C	31.0	32.0	32.5	32.8	32.5	32.1	31.5	31.5	31.5	31.8	31.3	30.6	31.8
Average Low °C	21.9	22.0	22.4	22.9	23.1	22.9	22.4	22.4	22,4	22.6	22.7	22.4	22.5
Average rainfall mm(inches)	162.6	139.8	203.4	232.8	215.3	148.1	177.0	186.9	190.8	217.7	237.6	244.5	2355.5
Average rainy days (≥ 1.0mm)	11	9	13	15	15	12	13	13	13	16	17	15	162

3.2 Experimental Method

Field measurements applied while occupants conducted their normal daily activities and each levels and zones had a particular air conditioning system in operation. Digital devices (Fluke 922 Airflow Meter) were positioned in the center of each zone 1.5 meters above the floor to measure temperature and humidity and airflow. Experiments were undertaken during sunny days in February. In duration of one month, temperature, humidity and airflow measured at various zones were continuously recorded every 1-hour for full 24 hour period. The result of the Figure 3 Shows that the temperature in the morning is higher than evening and the temperature decreases gradually.

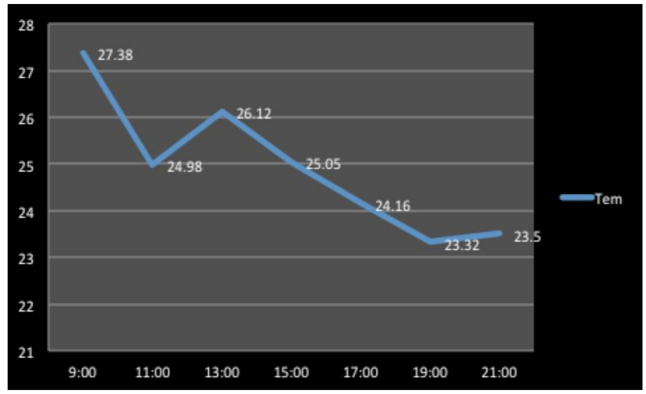


Figure 3 Average temperature fluctuations in levels

3.3 Simulation Model Development

At first, Revit Architecture software was used to simulate the building in our case study. The CAD drawings of the building were modeled in Revit Architecture and by means of principles for parametric design. The output of the Revit Architecture with scaled dimensions and its particular details are presents in Figure 4.

Figure 4 Simulated building in this software

3.4 Model Energy Analysis

After the building modeled in Revit Architecture it is saved as gbXml file and then imported simulated building in Autodesk Ecotect software for analysis energy according the Figure 5.

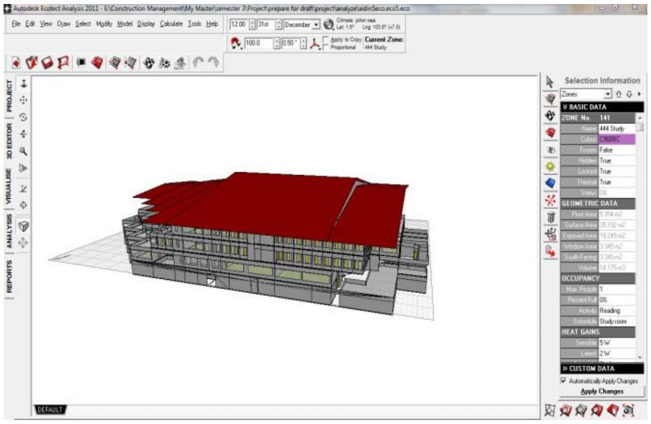


Figure 5 Visualizes of building in the Autodesk Ecotect

By inputting details such as temperature, user number, working hours of user, type of activities, cooling system and operation hours of system. By using the measured and recorded data the current situation of the building energy usage for cooling load as shown in Table 2. This table shows that a cooling load for a total area of the library is 2,678,691 kWh and 138.7236 kWh per M² for 1 year.

Table 2 Energy usage of case study for 1 year

MONTHLY HEATING/COOLING LOADS			
MONTH	**Heating (kWh)**	**Cooling (kWh)**	**Total (kWh)**
Jan	0	207295.3812	207295.3812
Feb	0	2126567.0857	2126567.0857
Mar	0	260832.0021	260832.0021
Apr	0	259413.3792	259413.3792
May	0	240611.904	240611.904
Jun	0	224859.008	224859.008
Jul	0	224343.1484	224343.1484
Aug	0	206502.1192	206502.1192
Sep	0	227411.1467	227411.1467
Oct	0	225358.4578	225358.4578
Nov	0	200495.2768	200495.2768
Dec	0	188916.0506	188916.0506
Total Area	0	2,678,691	2,678,691
PER M²	0	138.7236	138.7236

3.5 Modification of Wall Materials

The tropical climate of Malaysia does have very fluctuation, but because the buildings are highly exposed to the radiation of the sun, sensible lads have a significant influence on heating the interior parts of the building. Consequently, appropriate measures like adequate insulation of walls must be provided in order to diminish the heat flow into a building that has been air-conditioned. If the insulation materials have higher thermal conductivity, it means that the thermal resistance is at a lower level. Thus, for getting a most advantageous thermal insulation, it is necessary to use those of higher thickness. The output of the energy analysis software revealed the monthly cooling load for the base model. The outcomes of this step revealed the most effective energy saving building wall materials. To optimize the energy, various analyses were done. We were set up the kind of wall materials for the component so that the energy consumption of the case could be optimized. Later, the acquired data was analyzed which led to preparation of practical suggestions and answers to optimize the consumption of energy in public constructions. Eight different types of wall material that are used typically in Malaysian buildings in was chosen for comparison purposes were selected from the available in manufacture and there were tested in the Ecotect software to find the most optimize one material. Figure 6 shows the result of energy analysis of different type of wall component used in this study.

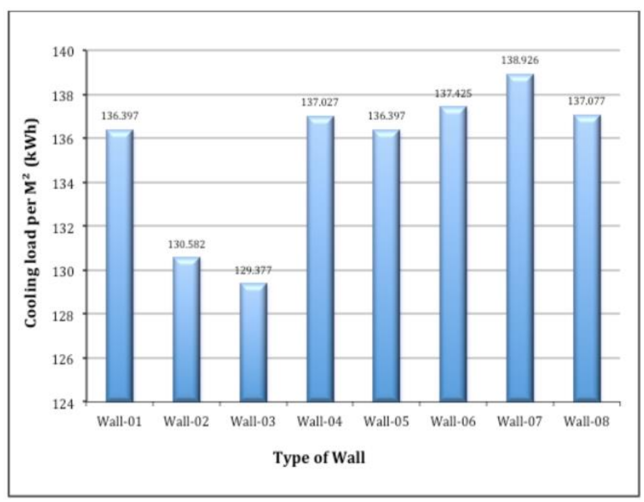


Figure 6 Impacts of wall different types on cooling load

Result of experimental temperature recording and input to Ecotect software 2011showed that by changing wall materials in simulated building decreased electrical energy usage by 8 %. Moreover, by testing in the Ecotect software with 8 different types of wall material to find most optimize one. Results indicated that wall type 03 (ReverseBrickVeneer_R20) was the best option with 8% savings in cooling load and energy (Table 3).

Table 3 Amount of energy saving for different types of wall

Types of Wall	Name of Wall	Energy Saving	Rating of Energy Saving
Wall-01	Double Brick Cavity Render	2%	3
Wall-02	Reverse Brick Venner R15	7%	2
Wall-03	Reverse Brick Venner R20	8%	1
Wall-04	Double Brick Cavity plaster	1.5%	6
Wall-05	Brick Conc Block Plaster	1.1%	7
Wall-06	Brick Cavity Conc Block Plaster	1.7%	5
Wall-07	Brick Conc plaster	0.5%	8
Wall-08	Double Brick Solid Plaster	1.8%	4

There are several factors to consider in selection of wall material type. U-Value, admittance and thickness are the main variables, which were considered in this analysis. Using wall-05 with a U-value of 0.39 W/m².k, admittance of 5.00 W/m².k, solar absorption of 0.545 and 200 mm thickness obtained the highest level of energy saving (Table4).

Table 4 Properties of simulated wall type 3

Type	Name of Wall	U-Value (W/m2.k)	Admittance	Solar Absorption	Thickness (mm)
Wall-03	Reverse Brick Veneer_R20	0.390	5.00	0.545	200

This practical and implementable way can be applied for most of public buildings such as a library, which we simulated in this study. Due to saving energy we can claim that we promoted the way, which decreases harm to natural resources for generating energy.

4.0 CONCLUSION

In this research with the aid of BIM Application and measurement one of the practical ways has been found to optimize energy usage in the library. The modification in type of wall materials input in Ecotect software helped to approach saving in electrical energy by 8%. In this manner if the decrease amount in energy usage determines one-year result a big saving for society will be resulted. Furthermore, the environmental benefits of using less energy will result in having a green campus with less damage to nature. Practical and sustainable ways including modifying materials results in energy saving and thermal comfort. In this paper, rating of wall materials were introduced to the performance of materials that was used for wall by considering their cooling loads in public buildings in tropical countries. To progress in this rating for the building components optimization that was mentioned earlier and their influence to save cooling loads was considered. This research did not consider the materials life cycle and their costs.

The outcome of this research shows that when a suitable material is chosen for buildings with bioclimatic design and optimized energy consumption, the designers are supposed to pay more attention to crucial elements like U Value, admittance, solar absorption and the thickness of wall materials. Providing succinct information regarding the performance of building elements and environmental considerations is intended to stimulate awareness of energy efficient factors and encourage the integration of these factors into the design and construction of new buildings.

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