THE EFFECT OF BUILDING FORM MANIPULATION ON COOLING LOAD PERFORMANCE OF MEDIUM RISE BUILDING

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ABSTRACT High energy consumption correspondingly starts from an inefficient use of energy. The high consumption of energy is an environmental issue that is being faced worldwide due to the increasing number of people and limited resources. Since past decades the standard of living has improved, people tend to expect a better comfort level which they consider the usage of air conditioning system is a must. The design of a building is required to provide comfort and efficient energy usage. This research investigates the development of building form in decreasing the cooling load. The manifestation of different thermal behavior of each form is based on different building form surface is explored. The research methodology explores the base model being compared to the actual building cooling load with the simulated base model and its relation within variables. The study is conducted using Autodesk Ecotect 2011 which is a computer simulation analysis program. The outcome of this research reveals that the compact shape and the lower ratios of surface to volume depicts the same results which influence lower cooling loads in Btu/hr. The experimentation of the base model indicates a surface area plays a huge role in lowering the cooling load. The simulation model analysis result also shows the orientation aspect is less significant towards lowering the cooling load compared to the exposed surface area of the form. This research is significant in helping to accumulate the information regarding building form behavior. Based on the result, the manipulation of the building form will reduce the cooling load.

1. INTRODUCTION

Building surfaces are constantly exposed to solar heat which is the major source of heat generation in tropical climate (Ahmad, Ossen, & Ling, 2004). Most tropical climate countries like Malaysia, Thailand, Singapore, and Indonesia have direct access to solar gain throughout the year. The need for comfort in this location means either installing air conditioning system or ensures better design of a building. If a building is designed in such a way that it enhances energy efficiency and comfort, the building can cool itself. Smaller and fewer air conditioners mean significant less energy consumption and more savings on electricity bills (Suziyana, et al., 2013). People always imagine energy efficiency in terms of its appliances and components such as electrical and lighting appliances, a sensor system, and controlled ventilation. However, these devices can be installed and planned even after the building is constructed and completed. The focus is not just on the installation of the equipment but on how to save the energy during the design process instead. The strategy is in the design process that leads the architects to design a building within the shape and form that contributes to a better design with less energy consumption. This study tries to explore the building form manipulation that can contribute in lowering the cooling load.

An institutional building was chosen as the base model for comparative form and energy studies. The chosen building was based on basic form experimentation in which showed that courtyard form has higher cooling load compared to other basic building forms. The selections of basic form analysis involve the box, circle, oval, L, T, U, I and courtyard shape. Understanding the physical and operational specifications of a building to be modelled is important in developing a reference building. The descriptions of the base model were established so it can be modelled in the building energy simulations. An existing or actual building that has an identical parameter with the building characteristics simulated was chosen. The chosen building can be identified from Google Earth images in Figure 1 (a) and the three-dimensional view and roof plan of the base model are illustrated in Figure 1(b) respectively.

The base model was a 5-storey building with windows, brick wall, and a centralized HVAC system. The floor to floor and window heights were ±4 meters and ±0.950 – 1.5 meters respectively. The total air-conditioned area was

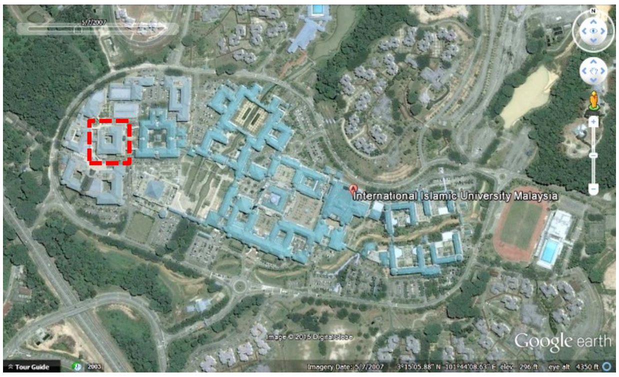

Fig. 1 (a) Google Earth image shows the building choose as the base model

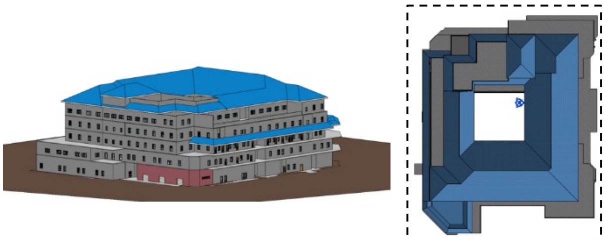

Fig. 1 (b) 3-dimensional view and roof plan of the base model

10434.423 m². The window glazing was a single glazing with aluminium frame. The roof, external wall, and windows U-value were 3, 2.6, and 6 W/m²K respectively. The building characteristics was five-stories and it an educational buildings located in Gombak, Selangor which utilized full air conditioning system. The building form parameter was more or less identical based on the first model analysis simulation of the optimize form. The overall floor area of the building was 12491.937 m². In investigating the shaping effect of a medium size building, this institutional building in hot humid climate was chosen. The selected building material is consisted of common brick walls.

2. MODEL SIMULATIONS

2.1 Methodology

The building properties in the base model was placed equal to the actual building properties. Then, its cooling load was calculated in the software to generate the actual building cooling load before the base model can be manipulated.

2.2 Validation

The validation process is crucial in order for the base model to be experimented and resembled the actual building. The base model study was modelled in Revit and exported to Ecotect Analysis 2011. Before starting the simulation of the base model, the model needs to be drawn and validated to ensure the cooling load calculation is nearly identical to the actual building cooling load. The result of the modelled building in Ecotect should generate ±6 000 000 Btu/hr similarly or nearly equivalent to the existing building cooling load. The cooling load amount data was collected from IIUM Development Division Unit. Once the base model study produced the same or close to the cooling load given, then further analysis simulation was executed.

2.3 Experimentation Steps

Next, the base model study was simulated accordingly based on various variables. The variables help to identify how cooling load reading reacts towards the form manipulation. These variables are shown in Table 2. The following recommended design variables were based on daylight usage manipulation, energy demand reduction on cooling load, peak cooling load reduction, and geometry manipulation.

Table 2 Variables

Independent Variables	Dependent Variables	Constant Value
Split spaces vs one large space (solid and void)	Cooling Load (Btu/hr)	1.Volume 2.Materials 3.Floor to floor height 4.Floor area
Surface to volume ratios (Geometry & Form Manipulation)		
Width to length ratios		
Orientation (NSEW)		
Building surfaces area		

Based on the Ecotect energy analysis, internal gain shows a higher heat gain due to occupancy time, people, and equipment; however, in this study the internal heat gain, infiltration rate, number of people and occupancy was controlled and kept constant. Occupancy and operation also plays a role in building heat gain (Shaharin A. Sulaiman & Ahmad H. Hassan, 2011). The basic result of the building analysis data will be extracted from the software. The base model was created to ensure all parameters were identical to the actual building and have nearly the same cooling load, then the parameters that of building forms will be manipulated.

3. ANALYSIS

3.1 Base Model

The result of the base model analysis was verified and validated as it was purely based on hypothetical form and computer simulation. As the base model was modelled step by step, each element placement was being analysed. Firstly, as a plain model, without the addition of building elements. The second phase of the modelling was the placement of openings, such as windows and doors. The placement of this elements showed a significant impact on the cooling load. Then, the building occupancy and space functions were identified. Lastly, the manipulation of variables take place to identify either the cooling load is increased or lowered. The process is shown in Figure 2.

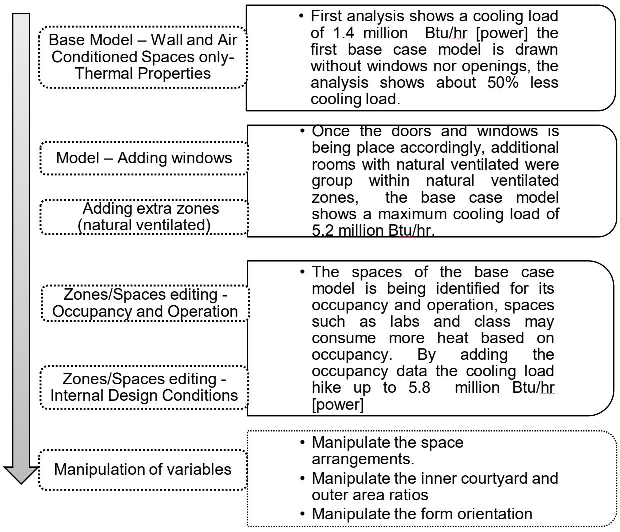

Fig. 2 Process of setting up and variables manipulation of the base model

3.1.1 Placement of building elements

The phases of placing the building elements involved in modelling and analysis showed a trend of how the building form generated its cooling load. The trend can be seen from the graph in Figure 3. The graphs shows that adding window increased the cooling load up to 89% as heat enters mostly from the openings. Another 10% increment was by the occupancy and operation of the base model settings.

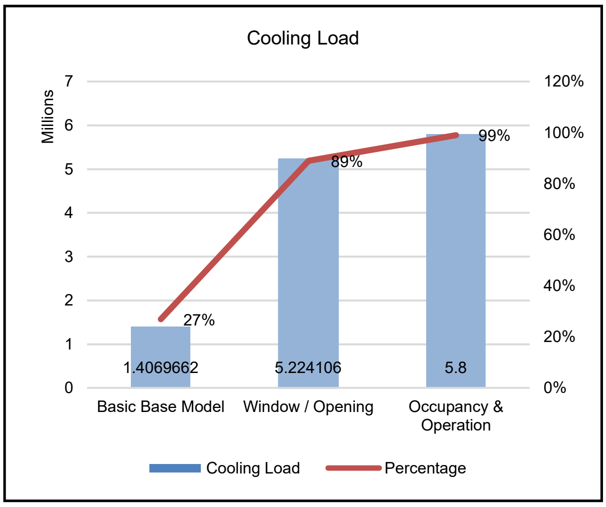

Fig. 3 Cooling load graph

3.1.2 Arrangement of space

The conversion of small scattered spaces into one huge space / rooms did show notable changes of building cooling load calculation. Internal load and properties hesitation as well as other elements were set constant. Figure 4 shows how scattered spaces are rearranged accordingly to ensure all spaces are intact to each other and become one huge space. The actual imagery of the building roof plan shows the building courtyard form. Hence, the new huge space with lower surface to volume ration has lower cooling load but may not be significant enough with only 65631 Btu/hr which is lesser than the base model with 1.1% less cooling load.

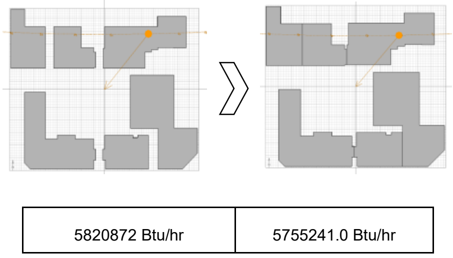

Fig. 4 Scattered spaces are converted into one large space combining the smaller spaces

3.1.3 Building ratios

The inner court and outer area ratio of the base model reflect the same ratios resulted in basic analysis of the courtyard form. The ratios show the lowest cooling load when the inner court is smaller than the outer area, which also indicate less surface of the building forms. This conclude that the base model chosen is having the optimum form. However an interview with the building personnel, the building air conditioning system is utilized at its best yet the building space is not cool enough, the main reason is due to the additional equipment or the internal load that has been added later compared to the calculated cooling load in the early construction of the building. Still the building is at its optimum courtyard form for cooling load.

3.1.4 Orientation

The graphs in Figure 5 illustrate the fluctuated data of building form manipulation over the orientation. The orientation of NSEW showed slight changes in cooling load. Basically, most orientation bear ±5816000 Btu/hr of cooling load. This means that manipulation of orientation will only lower the energy consumption less than 1%. The

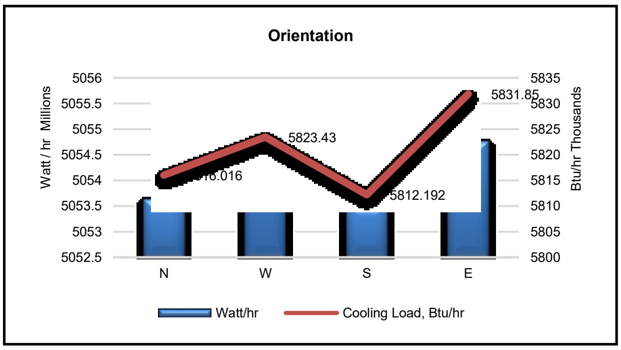

Fig. 5 Base model orientation and cooling load data

difference of orientation shows 0.1% to 0.3% reduction cooling load of the base model. The difference of 0.5% cooling load can be seen from form manipulation experimented on a rectangular form in basic form analysis. The difference of orientation will be more than 1% if the form manipulation is experimented on a rectangular form.

If we combine both manipulations, lower cooling load and its energy consumption can be achieved. The influence of changing the orientation of the cooling load basically depends on other variables too such as materials of the floors and exterior walls and the insulation levels (Hamdani, Bekkouche, Benouaz, Belarbi, & Cherier, 2014).

CONCLUSION

The result, analysis, and findings of the simulation were engaged to determine the behaviour of the building forms on cooling load. The study focused on the courtyard form that produced higher cooling load in basic form analysis. The building form was analysed to investigate the building form behaviour, and to seek the relation of the variables to the building form. There are certain variables that may not be so significant but do cause a bit of a difference in the result. Whenever the S/V ratio decreased, the surface area decreased, and the cooling load of the form also decreased. Due to low S/V ratio, the most compacted form initiated lower cooling load, which signifies less heat gain inside the building forms. Locating the spaces of building or combining smaller spaces to become large space may help in decreasing the cooling load due to less infiltration. Less building infiltration may improvise less heat gain. Locating an air conditioning space enclosed around other spaces helps in ensuring the coolness stays longer in the room. Hence, no specific form could be identified but certain rules can be followed in creating and initiating the optimized form based on hot humid climate. Lowering the cooling load helps in selecting proper air conditioning system. This research believes that building form does affect the cooling load of a building. The studies and the research processes were conducted to satisfy the objectives of the research. This research has fulfilled the first objective, to convey the significance of building forms; and understanding the concept and the influence of building form and geometry in achieving energy efficiency. Moreover, the second objective is to identify the relation of building forms and its variables into improving energy efficiency. It has been identified that optimum and effective form that can influence in decreasing the cooling load depends highly on its surrounding. Basically, the more compact a form, the lower its cooling load. Building surface has a large influence on total heat gain and cooling load. Other factors that affect a building form are the type and the use of a building, planning layout, feasibility, and cost. The main factors that determine the difference result of cooling load are the surface to volume and compactness of the form. While in relation to the orientation, width and length ratio plays the main role. Pertaining courtyard form, the surface to volume ratios are concurrent within the inner width and outer width ratio which define certain courtyard form ratios that can perform better in air conditioning environment. Based on the computer simulation analysis, different types of building shape and its components generate different cooling load data. Analysing building form in relation to the cooling load gives imperative result significantly. This study explored the real case study focused on the relation between extended building geometry of the courtyard and its proportions, ratios, and cooling load. Manipulation of building geometry with these variables was the focus of this study. The changes in the cooling load were the consequence of variations in space placement, orientation and ratios.

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