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Active energy conserving strategies of the Malaysia Energy Commission diamond building

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Abstract

Energy efficiency in office buildings for the tropical climate has been a subject of much discussion in the building industry. The Malaysia Energy Commission Sustainable Building, also known as the Diamond Building was built as the third Government Energy Efficient building after the Low Energy Office (LEO) and the Green Energy Office (GEO). It is located in Putrajaya, Malaysia which has a hot and humid tropical climate. The cutting-edge design has incorporated the most advanced features available in Malaysia for sustainability and energy efficiency. The aim of this paper is to investigate the design of active energy conserving features for a sustainable office building in the tropical climate and assess the effectiveness of these strategies. In carrying out this study, the methodologies used are non-participant observation conducted through visits to the building and interviews with the designers and users of the building. An analysis is then made on the effectiveness of the various energy conserving strategies implemented. It was found that the implementation of active energy-conserving design strategies are still under experimental investigations in Malaysia and that designers have yet to make compromises in deciding on the energy conserving strategies to be used. Finally, this paper provides a useful reference in the field of sustainable design in the humid tropical climate.

Keywords: Active Energy Conservation; Sustainability; Energy Efficiency

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1. Introduction

The Malaysia Energy Commission Diamond Building is the latest and most advanced example of a government building in Malaysia which integrates a comprehensive list of energy efficient features. It is located at Precinct 2, Putrajaya adjacent to a landscaped garden. This building was conceived as a showcase building which has adopted both passive and active design features in the best way and utilizes the latest technology available in the country as it is a showcase sustainable building. The main objective of this paper is to identify design strategies for energy efficiency in an energy-conserving office building in the tropical climate using the case study of the Malaysia Energy Commission Diamond Building and evaluate the effectiveness of the active and passive design features applied.

2. Energy Efficiency of Buildings

Buildings are among the biggest consumers of energy in countries with a high degree of urbanization and high standards of living. There are many efforts to construct Zero Energy Buildings (ZEB) which eventually lead to Zero Energy Cities Planning [1]. "ZEB is now seen as the future target for the design of buildings. The requirements for the energy efficiency and the accepted renewable energy options are listed as some of the most important issues that should be given special attention"[2].

A majority of the building energy consumptions are from thermal and lighting loads. The air-conditioning accounts for the biggest energy consumption in both office (52%) and hotel (51%) buildings [3]. Architectural design and building's dynamic behaviour as well as energy optimization can result in minimization of thermal and lighting loads [1]

Malaysia is a country with a hot and humid tropical climate; therefore energy is mostly used for the cooling of buildings. A typical Malaysian Office Building consumes about 250 kWh/m^2/year of energy of which about 64% is for air conditioning, 12% lighting and 24% general equipment." [3]. Due to the shortage of natural resources, energy costs are rising. Therefore, energy consumption remains the most important building issue not only because of environmental impacts, but also because of higher energy costs in the future. Environmental sustainability in construction, upkeep and recycling is of primary importance as an ecological criterion, as are the environmental savings which may be expected from large-scale application of the relevant technologies.[4] Application of integrated room automation [5] control simultaneously ventilation, air conditioning as well as lighting levels of building zones to maintain occupant comforts in the Diamond Building. The Diamond Building is an important milestone in Malaysia to showcase how effective design strategies can reduce energy consumption and finally leads to the realization of ZEB.

3. General Descriptions and Functions

The Diamond Building shown in Figure 1 has integrated the most advanced energy efficiency measures available in the nation and low impact on the environment without any compromise on user comfort. This was achieved by a sustainable design concept together with consideration of reduction in fossil fuels, water conservation, sustainable building materials, waste reduction, indoor environmental quality, management of traffic and transport, and a thorough construction and demolition management plan. It was designed to fulfil the criteria of Low Energy Buildings (i.e. BEI of 135kWh/m^2/year or lower) according to the Malaysian Standard MS 1525: 2001 Code of Practice on Energy Efficiency and Use of

Renewable Energy for non-residential Buildings. The building has a targeted Building Energy Index (BEI) of 85kWh/m^2/yr, compared to typical new office buildings in Malaysia and the Southeast Asian region which have energy indices within the range of 200 to 300 kWh/m^2/yr. The Diamond Building has also received the Green Mark certification from Singapore..

The various energy-saving features were incorporated into the design at an extra cost of 6% of the total base building cost, resulting in a simple payback period of 12.3 years. During building use, the energy monitoring adds credibility to the notion that significant energy savings and environmental benefits can be achieved. Figure 1 shows a photo of the Diamond Building.

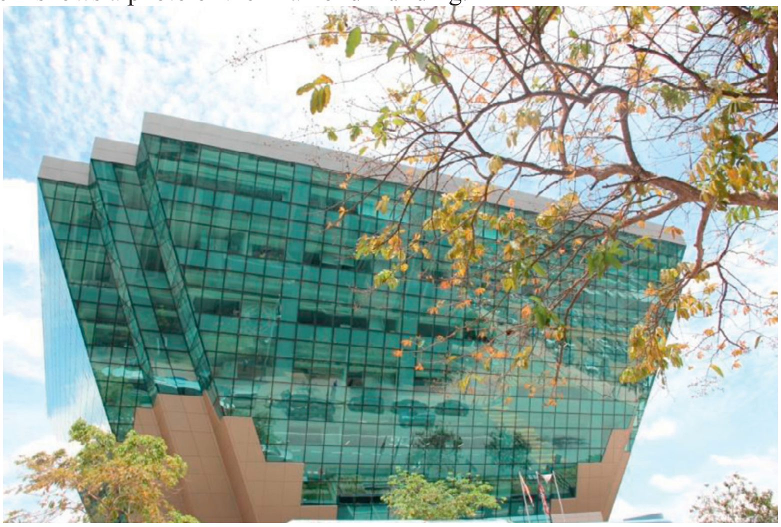

Figure 1. The Diamond Building.

The design concept and philosophy was inspired by the distinctive form of the diamond. It is a prominent and unique form which symbolizes value, quality transparency and durability. It is also an optimum passive design approach to achieve energy efficiency as it is aerodynamic and effective in preventing air infiltration into the building via the tilted facade. Another reason for the tilted façade is that the upper floors shade the lower floors from the Sun’s heat, therefore eliminating the need for sun shading devices and lowering the cooling load.

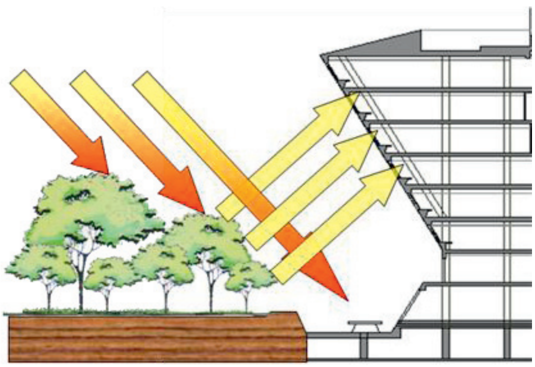

Figure 2. The façade of the Diamond Building was designed for passive solar shading. (Source: Malaysia Energy Commission)

4. The use of daylight

Malaysia is located near the Equator; therefore it experiences a hot and humid climate throughout the year. In such a climate, the average dry bulb temperatures over the year and day fall typically within the range of 27°C and 35°C with 100% relative humidity. As a result the design considerations for the Diamond Building are suited for this climate, with emphasis on cooling and ventilation due to the high temperatures and humidity. The abundant sunlight facilitates daylighting as shown in Figure 3 and solar PV panels are used to generate electricity. It is noted that on the roof of the building, there is a light through oriented in the East-West direction to capture the maximum sunlight. While the sun's path is from east to west, it will sometimes tilt to the north or to the south. The tilt angle is about 25°, so the building's facade is also tilted at 25°. The windows that face the atrium gradually increase in size from the upper floors down to the lower floors where there is less sunlight. Reflective panels (which resemble half a Christmas tree) on the fourth and fifth floors, tilted at 10 degrees, help to reflect light across to the first and second floors [6]. This design strategy minimized impacts by direct sunlight and the building relies mainly on diffused light which is softer and cooler.

The Diamond Building is a massive building with a deep floor plan and eight storeys (Figure 3). It was designed with a glass atrium at the center to maximise the penetration of daylight into each of the floors (Figure 4 and Figure 5). In order to control the amount of light entering the building and ensure optimum lighting levels without glare, the atrium has been equipped with automated blinds. It has six different configurations that change depending on the position of the sun at that particular time. The blinds are made of a material with 30% light transmittance to block direct sunlight and at the same time allow sufficiently diffuse light and prevent glare. They are automatically adjusted every fifteen minutes following three different control strategies for morning, mid-day and evening when the sun angle is different. This ensures stable lighting conditions throughout the day and year in the atrium space. It contributes to energy savings because it prevents excess heat from entering the atrium, at the same time saving on electricity for lighting.

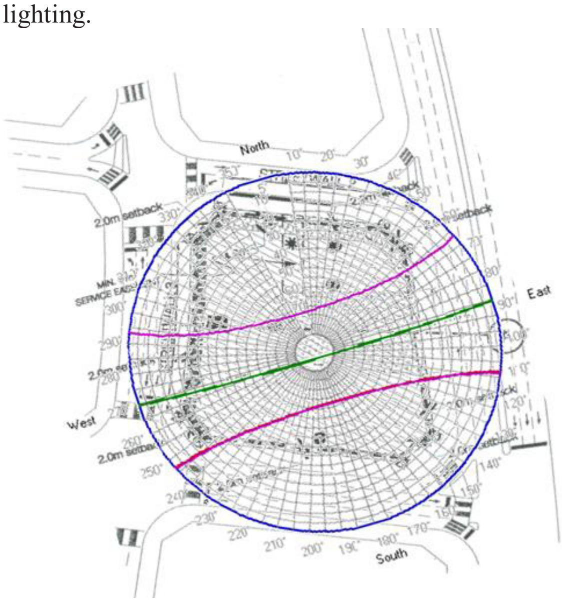

Figure 3: Diagram showing the plan of the Diamond Building which has been designed for the tropical climate by orientating it optimally for daylighting. (Source: Malaysia Energy Commission)

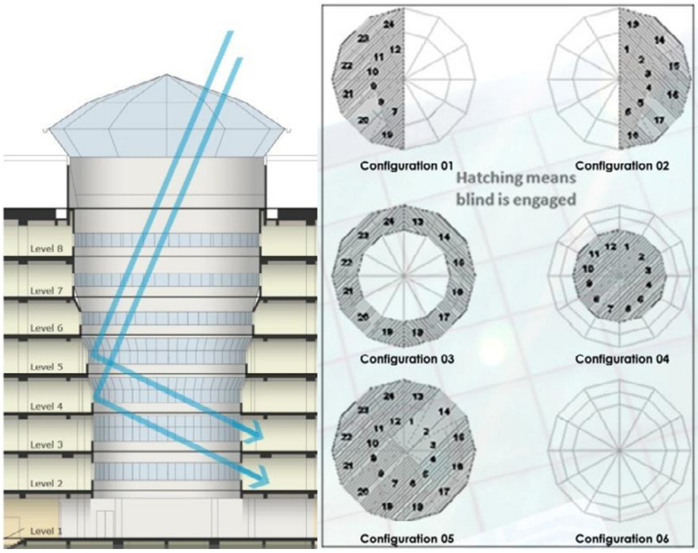

Figure 4: The different configurations of the intelligent shading device at the atrium. (Source: Malaysia Energy Commission)

Figure 5. View of the dome at the atrium in the afternoon with closed blinds.

Figure 6: Lighting conditions in the atrium at 2pm with the automated blinds closed. The lighting is sufficient even when the blinds are permanently closed.

5. Cooling

The Diamond Building uses roof and floor slab cooling as shown in Figure 6. Flexible 22mm PERT chilled water pipes are embedded in the RC floor slabs during construction to function as a thermal storage system in the building (Figure 7). At night, cold water will run through the pipes Thus, the temperature of the floor slabs will decrease to 20^{o}. These will then absorb the heat gain from people, computers, solar gain etc. and radiate cooling to the occupants during daytime. This kind of floor slab cooling not only lowers energy consumption, but it also can reduce the size of AHU (Air-handling Unit) room by about 30% since the cooling task have shifted partially to the slabs. It contributes to energy savings because it reduces the reliance on conventional air-conditioning systems and by reducing the size of the AHU room, less power is needed for air-conditioning. Due to the need to maintain the corporate image and cover the unsightly pipe, a false ceiling has been installed which reduces the efficiency of the cooling system.

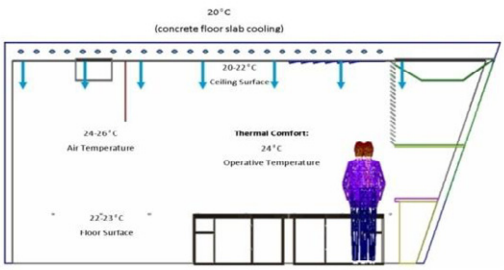

Figure 7. Section showing the floor slab cooling. (Source: Malaysia Energy Commission)

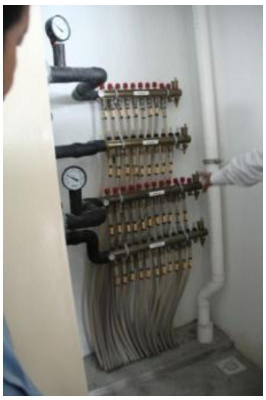

Figure 8. Manifold riser for slab cooling pipes (PERT pipes)

6. Mechanical and Electrical Systems

The mechanical and electrical system is designed based on the intelligent building approach which maximizes the energy efficiency and optimizes comfort of the building occupants. Among the strategies used are:

a) High efficiency lighting systems (CFL, T5 with electronic ballast and LED lights) provide the optimal lighting quality with minimum energy used.

b) Energy Star office equipments, computers and printers to use energy efficiently.

b) Photocells are installed outside the building to detect daylight and adjust the lighting level outside the building and parking lot to the required luminance.

c) The building is equipped with Advanced Demand Control System for lighting and air conditioning control triggered by motion sensors. The motion sensors detect the presence of occupants so that lighting and air conditioning are only provided when required, reducing energy wastage in unoccupied areas.

d) Zone based temperature sensors are installed to adjust the temperature of the designated zone to the set level. This translates to zone based temperature control where only relevant air conditioning units are turned on.

e) The air handlers mix return and outside air so that temperature change between the air drawn into the building and the desired air temperature is minimized. This can save energy by using less chilled water which is available in the Diamond Building's AHUs

f) Variable speed drives are used to control the fan and blowers so that the air volume and air pressure in the rooms of the building are adjusted to the required value.

These measures contribute to energy savings by preventing unnecessary use of energy and using energy in an efficient manner to prevent wastage.

7. Building Integrated Photovoltaics

A 71.4 kilowatts peak (kWp) photovoltaic (PV) rooftop system (Figure 10) has been installed on the Diamond Building. This is a typical example of aesthetic integration of mass-produced PV modules into a rooftop. The shape of the building allows for a bigger area on the ground for greenery, while the larger roof area provides space for solar panels. Solar power supplies about 10% of the energy used in the building [6].Second generation thin film PV panels are used. The thin film solar panels are cheaper compared to the first generation silicon solar panel although the energy efficiency is lower. CIGS (copper indium gallium selenium) is applied to a substance such as foil or glass. CIGS is more stable compared to other forms of thin film materials. Another advantage of thin film solar panels is they are 100 times thinner than the silicon based solar panels. That translates into lightweight, portable and compact architecture design.

The Diamond Building BIPV system is equipped with sensors to measure ambient and module temperature, solar irradiance and wind speed. Data loggers are used to collect performance data to evaluate the effectiveness of the BIPV system installed. PV panels are installed to harvest sun energy from East, West, North and South of the building. The unique design of the Diamond Building also means that modules were placed on all 4 sides, facing North, South, East and West, so that it can be used to gather performance data from all sides of the building. Figure 9 shows a typical thin film solar panel installed on the rooftop of the diamond building. The use of BIPV does not contribute to energy savings in the building. Instead, it is a means of generating more energy for the consumption of the building resulting in a lower BEI.

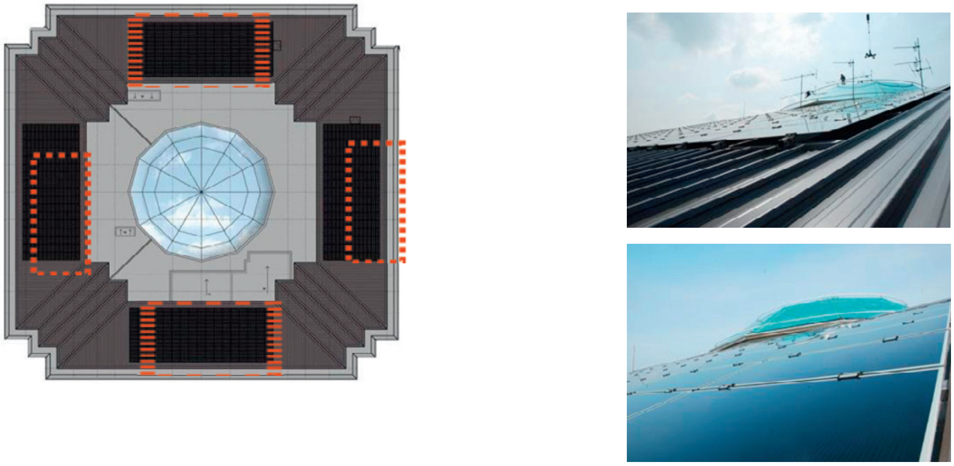

Figure 9. Roof plan (left) showing locations of the BIPV panels; photos (right) showing the BIPV panels on the roof. (Source: Energy Commission)

8. Energy Performance

The Diamond Building has implemented a comprehensive energy management system that controls and monitors the energy usage daily. Table 1 shows that BIPV has contributed significantly to the reduction of BEI of the Diamond Building. From Tables 1, one can see that the Diamond Building has achieved the target BEI even without the use of PV. The existing PV installation contributes to about 9% improvement on BEI.

Mm/yr	**Total energy from the grid (kWh)**	**From PV (kWh)**	**Other energy sources (kWh)**	**BEI (without PV) (kWh/m2/yr)**	**BEI with PV (kWh/m2/yr)**
Oct'10	57,857	7,470	40,775	65.1	59.0
Nov'10	67,647	8,120	41,994	71.5	64.9
Dis'10	71,227	7,456	34,642	67.5	61.4
Jan'11	82,983	7,501	42,004	79.9	73.8
Feb'11	72524	8017	n/a	n/a	n/a
Average	70,448	7,713	39,854	71.0	64.8

Table 1: Effects of PV on the Diamond Building BEI from October 2010 to February 2011. (Source: Malaysia Energy Commission)

From the energy consumption measured, the implementation of both active and passive energy conserving strategies has resulted in an energy saving of 42% for plug loads, 33% for cooling loads, 18% for lighting and 7% for fans. This is because of the energy-efficient IT purchasing policy implemented in the office which requires computers, printers and fax machines to have energy star ratings. According to the US Environment Protection Agency, energy efficient office equipment use up to 74% less energy, depending on the type of device and usage patterns. Energy-efficient IT hardware play a major role in cutting down energy usage since computers are sometimes not shut down for the whole day, causing significant energy consumption if it were not energy efficient. There is also potential for more savings to be made in the cooling energy category. Currently, the energy-efficient purchasing policy is only applied for IT hardware. If this policy were extended to the cooling equipment, significant energy could also be saved for cooling energy.

9. Conclusion

The Diamond Building was designed to avoid direct solar penetration into the building, thus reducing the cooling load which contributes to the bulk of the energy consumption in most tropical buildings. This concept also was done to maximize the passive design strategies of the upper floors shading the lower floors from solar heat gain. However, in making this decision, compromises had to be made. Passive design strategy (sun shading) was used to reduce the cooling load while sacrificing the potential areas for active design strategy (PV panel installation). The tilted façades do not receive much direct sunlight; therefore PV panels were not installed on the facades. Therefore, the shape of the building has contributed greatly to higher BEI.

In the tropics, solar radiation consists of 50% direct sunlight and 50% diffuse sunlight. By tilting the facade, only the direct radiation is shaded whereas diffuse radiation still reaches the interior. Therefore, the reduction in cooling load does not fully justify the tilted facade. Using a straight façade and hence, more PV panels to generate more energy may be a better option for better energy performance and to achieve a lower BEI, although the concept of the diamond would be lost and the building will lose its concept and uniqueness in terms of aesthetic appearance.

The use of PERT chilled water pipes is a common feature of energy efficient buildings in Malaysia. Such a system has effectively reduced the peak electrical load demand by shifting the electrical energy usage to an off-peak interval. It is an important factor that contributes to the reduction in cooling loads. However, the cooling system's efficiency was compromised to maintain the corporate image of the office. Effective building automation system, the installations of energy efficient lights and equipment have also contributed to low energy usage. As a result, the Diamond Building has achieved a BEI well beyond the target value. However, the BEI can still be further improved if more PV panels can be installed and interior design for the corporate image is done by taking into account the cooling system.

Acknowledgment

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