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Performance of electricity usage at residential college buildings in the University of Malaya campus

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ABSTRACT

A critical analysis of characteristic and building design was done through scaled drawing and observation from a site visit of twelve residential college buildings in the University of Malaya campus. The elements of passive mode were implemented as matrixes or criteria for the recent practice of bioclimatic design strategies. The performance of electricity usage was audited based on the Energy Efficiency Index (EEI) in kWh/m^2/year unit of each residential college building for the duration of nine years. As a result, the average electricity usage varied from 24 to 120 kWh/m^2/year. The residential colleges that have appropriate practices of passive mode particularly internal courtyard and balconies that encourage daylighting and natural ventilation were found to achieve a desired efficient use of electricity, in the range of 24 to 34 kWh/m^2/year.

Introduction

The sun, heat and high humidity of the climate are key elements to be considered in designing buildings in Malaysia (Ahmad, 2008). The proposed built form must respond to the climate of the locality to keeps the internal conditions favourable and comfortable throughout most of the year without having to use any mechanical devices (Nugroho et al., 2007). The way we design our building will reflect on how much energy that is required to run the building.

In the equatorial region, there are three main elements related to building services that become an energy liability; conditioning for thermal comfort, lighting for visual comfort and ventilation for indoor air quality (Omer, 2008). Poor building design could lead to higher electricity usage than necessary for lighting and cooling in order to obtain the ideal comfort level in buildings (Lechner, 2009). Holistically, the efficiency of energy usage should start from the beginning or the source itself; which is the building's design, as the service design and occupant behaviour are not easy to be controlled and maintained (Al-Mofleh et al., 2009). This is in line with Haase and Amato (2006) who introduced the Energy Triangle Approach, as shown in Fig. 1.

As depicted in Fig. 1, the energy conservation is stated as the first approach, in which with proper planning at early stages, it will incur no cost and passive design building can be developed appropriately (Haase and Amato, 2006). According to Davis et al. (2006), the lifetime energy saving of the building can equate the original construction cost. The second approach is an increase of efficiency through the use of the latest energy efficiency devices and components. This approach will increase the construction cost of the building of up to 15% higher than conventional designs.

However, it can help to reduce 13% of the total energy consumption and 48% of electricity consumption in the commercial and residential sectors (Al-Mofleh et al., 2009). The utilisation of renewable energy becomes the last approach due to its high cost of installation when coupled with the building design. In most cases, the energy production depends heavily on specific characteristics of the building. As an example, 15 m deep building has a better potential than deeper buildings while a high rise building which has more than five floors has low potential for electricity production due to the lower solar exposure on the horizontal surfaces (Haase and Amato, 2006).

Bioclimatic design strategies were first introduced in the 1950s and they have gone out of fashion being overshadowed by recent ‘green building’ concepts. Although the literal meaning of the terms is different, their aims are similar in promoting efficient use of natural resources especially energy and water to create healthier environment. These design approaches which involve the disciplines of human physiology, climatology and building physics can significantly reduce or even eliminate negative environmental impacts and improve existing unsustainable designs, constructions and operation practices (Olgyay, 1963; Tiyok, 2009). The bioclimatic design optimises all the passive mode strategies to ensure an effective passive low-energy design (Yeang, 2008). This includes the built-form configuration and orientation, enclosure and façade design, solar-control devices, passive daylight concepts, wind or natural ventilation and landscaping. According to Mazloomi (2010) and Cândido et al. (2010), natural ventilation and daylighting are among the most suitable solutions to

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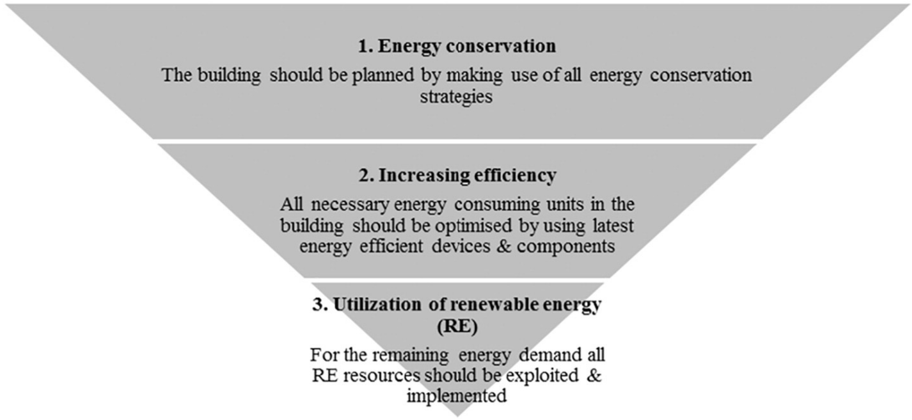

Fig. 1. Energy Triangle Approach.

achieve a more efficient building in terms of energy use especially in the equatorial climate region. The pressure difference that comes from air movement by the difference in temperature or by wind in and around the building generates natural ventilation, while daylighting is a technique to bring natural light into a building through openings (Omer, 2008; Fontoynont et al. 2004). Natural ventilation is highly variable and dynamic when the effectiveness of this approach is reliant on three principal factors, which are site and local landscaping features, building form and building envelope, and internal planning and room design (Aynsley, 2007). The dynamic of daylighting is clearly shown from three possible processes that can take place when light falls onto a surface or a layer; absorption, reflection and transmission (Baker and Steemers, 2002). Nowadays, there are generally two daylight systems implemented in the buildings, which are the shading systems that are primarily used to block direct sun and admit diffuse light, and optical systems, that redirect daylight to area further from the windows or skylight (Kischkoweit-Lopin, 2002).

As reported by Li et al. (2002), the annual electricity consumption can be reduced substantially by 13% through the applications of daylighting. In warm humid climates, about 50% of the energy used for ventilation in buildings can be conserved and by making the right decision in determining the building's characteristics; including the building length, depth and height, the efficient use of electricity can be improved in the buildings (Haase and Amato, 2006). Approximately,

Table 1
The characteristic and building design of all residential colleges.

Characteristic	Residential colleges											
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
Year established	1959	1958	1962	1963	1966	1967	1975	1985	1995	1997	1997	2002
Form of building	LR	LR	LR	LR	LR	LR	LR	LR	LR	LR	LR	HR
Floor level	4	4	4	4	4	4	4	4	4	4	4	10
Building layout & arrangement	L	L	L	L	C	L	L	L	L,OC	L	C, B	L, B
Orientation to sun path & window location	N-S	N-S	NE-SW, NW-SE	N-S, NW-SE, NE-SW	N-S	N-S, W-E	NW-SE, NE-SW	N-S, NW-SE, NE-SW	N-S	N-S, NW-SE	N-S, W-E	N-S
Shape of the building's floor plan	R	R	R	R	R	R	R	R	R	R	LS	R
Wind direction of the locality	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
Total area (m^2)	26,152.49	41,014.10	18,740.60	22,199.00	43,185.06	29,121.64	19,263.41	32,806.00	36,858.00	24,751.08	26,766.14	46,415.84
Total built up area (m^2)	12,530.88	7499.98	4196.08	10,599.03	16,971.02	12,822.28	11,786.98	9213.63	17,451.85	7224.38	11,250.44	30,724.87
Total floor area (m^2)	12,727.44	11,224.71	7159.92	11,427.67	18,212.51	21,989.87	12,989.87	11,274.23	22,288.14	15,217.02	34,305.32	89,545.91
Capacity (no. of residents)	802	700	740	700	847	895	807	921	900	750	1164	2990
Density (no. of residents/m^2)	0.063	0.062	0.103	0.061	0.047	0.041	0.062	0.082	0.040	0.049	0.034	0.022
Occupant load (m^2/no. of residents)	15.9	16.0	9.7	16.3	21.5	24.6	16.1	12.2	24.8	20.3	29.5	29.9
Room's floor area (m^2)[a]	16.5	17.5	17.59	16.43	17.0	16.92	15.5	15.51	16.1	13.16	20.0	15.0
Room volume (m^3)[a]	42.9	50.75	50.32	41.09	47.09	50.76	46.5	49.33	46.86	39.47	57.4	45.0
Window design	Lv, Cs	Lv	Lv, Cs	Lv	CP, Aw	Lv	Cs, Aw	Lv	Lv	Lv	Cs, TW	Lv
Window area (m^2)[b]	2.6	4.31	5.76	2.6	6.46	2.27	4.68	1.53	0.82	2.52	4.12	2.9
Window to wall ratio	0.3	0.42	0.53	0.32	0.69	0.19	0.33	0.08	0.07	0.26	0.36	0.32
Operable window area (m^2)[b]	2.6	2.39	5.76	2.6	4.07	2.27	4.18	1.53	0.82	2.52	2.75	0.95
Operable window to wall ratio	0.3	0.24	0.53	0.32	0.43	0.19	0.29	0.08	0.07	0.26	0.24	0.11

Abbreviations: Form of building – LR: Low-rise, HR: High-rise; Building layout & arrangement – L: Linear, C: Courtyard, OC: Open corridor (in the middle of building at each level), B: Balcony; Orientation to sun path & window location – N: North, E: East, S: South, W:West, NW: Northwest, NE: Northeast, SE: Southeast, SW: Southwest; Shape of the building's floor plate – R: Rectangle, LS: L-Shape; Wind direction of the locality – SW: Southwest; Window design – Lv: Louver, Cs: Casement, CP: Centre pivot, Aw: Awning, TW: Turn window.

[a] Referring to the typical room.

[b] Referring to each typical room.