WALL ENVELOPES IN OFFICE BUILDINGS: DESIGN TREND AND IMPLICATIONS ON COOLING LOAD OF BUILDINGS

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ABSTRACT

The wall envelope is a vital element of a building especially to a high rise building where its wall to building volume ratio is higher compared to other building forms. As well as a means of architectural expression, the wall envelope protects and regulates the indoor environment. In recent years there have been many applications of glass products and cladding systems in high-rise buildings built in Kuala Lumpur. This paper describes a recent research and survey on wall envelope designs adopted in 33 high-rise office buildings built in the central business district of Kuala Lumpur since 1990. This research adopts component design analysis to identify dominant trends on wall envelope design for the surveyed buildings. The paper seeks to discourse the implications of this design trend on energy consumption of high-rise office buildings in the country.

Keywords: wall envelope; energy consumption; window-wall-ratio (WWR); envelope design criteria, Overall Thermal Transfer Value (OTTV)

Introduction

The last ten years of the 20th century saw rife speculation that subsequently created demand for high-rise office spaces in Kuala Lumpur. New projects as well as those differed during the economic down turn of the late 1980s were hastily constructed to meet the new millennium. Many more high-rise towers dotted the Kuala Lumpur map when the economy recovered soon after.

The wall envelope is a very important element of a building. It protects the internal spaces from rain, sun and wind. It can be likened to an environmental filter as it sieves and intermediates with the external climate to create comfortable internal climate. Apart from acting as an environmental filter, wall envelope is a manifestation and expression of architectural thoughts, aspiration and ideas.

This paper reports on a recent study conducted on envelope walls adopted in high-rise office buildings in Malaysia. The study particularly looked at buildings within the central business district of Kuala Lumpur. Buildings selected are those completed since 1990 during which there were two main factors likely to influence the selection of wall envelopes. First is the introduction of more sophisticated glass products and envelope systems in the local market, and secondly the growing efforts by the government to control energy consumption in commercial buildings. The research adopted a building component analysis method where data on case studies were gathered, described and interpreted to reveal trends and effects of design solutions. The focus of this paper is on the energy implications of the research findings.

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Background of High-Rise In Malaysia And Its Energy Use Patterns

The high-rise building form was first introduced in Malaysia in the 1950s. Early examples of high-rise buildings are the EPF Building (1952) and the Chartered Bank Headquarters (1964). The surge of high rise buildings in the country however started between late 1970s and at the beginning of 1980s. High rise development was imminent in response to the immediate need for more office space within a concentrated urban area.

The EPF Building, one of the early high-rise examples, attempted to address the local climate by incorporating sunshading elements as an integral part of its envelope system. Some feel that generally, with exception of a few isolated efforts, high-rises built in the 1980s had little consideration to the local climatic conditions (Yeang 1992) instead they resemble high-rise building solutions of the modern Western countries. Outcome of such approach were glass cladded buildings without any form of sunshading means, for example Bangunan Pernas and Wisma Hamzah. The widespread use of air conditioning, and new development in cladding technologies brought in from the West enticed local architect to adopt these solutions. Yeang (1992) suggests that in the 1990s, there was a shift of local architects' concern and sensitivity towards environmental responsive architecture. Early evidence of this trend was the Menara Mesiniaga which was designed based on bioclimatic considerations (Powell & Yeang 1999).

High-rise is regarded as a highly energy intensive building form (Yeang 1999). This is due to the fact that it consumes a lot of energy to meet its purpose. Under the Malaysian climate, energy used in this building is mainly for air-conditioning and lighting, accounting for a breakdown average of 51.8% and 42.5% respectively of the total building load (Ramatha 1994).

Wall Envelope and Its Purpose

Essentially a wall envelope would comprise of an opaque wall such as masonry, metal cladding and a proprietary envelope systems and sunshading devices (Nashed 1995). The building envelope is sometimes referred to as an environmental filter. It plays a vital role in protecting and regulating the indoor environment of buildings. Further to this, it is a means for the architectural expression of the building.

In the West, there have been many technological advances and innovations on the wall envelope. Much of them were relevant to the Western climatic conditions and technological environment. Some of these products were brought into Malaysia by local traders especially on prestigious and large scale projects.

Wall envelope and energy load

Wall envelope design significantly influences energy use patterns in buildings. A highly opaque wall envelope with minimal openings will proportionally reduce heat transmission into the building, thus reduces the cooling load. Allowing natural daylight into buildings will minimise dependency on artificial lighting. These two aspects can at times be paradoxical in that kerbing heat can also reduce lighting levels. The challenge is to seek for the perfect balance between the two.

Parameters that influence the thermal performance of wall envelopes are window-to-gross exterior wall area ratio for the orientation under consideration (WWR), solar absorptivity of opaque wall (α), thermal transmittance of opaque wall (U_w), solar correction factor (CF) and shading coefficient of the fenestration system (SC) (Department of Standards 2001). Put together, these variables form a measure of heat transfer from outside to the indoor environment through the external envelope of a building. This concept is called the Overall Thermal Transfer Value (OTTV). This concept was first introduced in ASHRAE Standard 90A-1980 and Malaysia is currently in the process of adopting it as a design control measure, setting the limit at a maximum of 45 W/m^2. The premise of the OTTV is that a building with a higher OTTV will admit more heat through its shell which in turn will have to be removed by its air conditioning system. In other words, a smaller OTTV reflects less energy needs for cooling.

The OTTV equation adopted for Malaysia as stipulated in *the Code of Practice on Energy Efficiency and Use of Renewable for Non-Residential Buildings* (MS 1525:2001) is as follows:

$$OTTV_i = 19.1\ \alpha\ (1\text{-}WWR)\ U_w + (194 \times CF \times WWR \times SC) \qquad (1)$$

where WWR= window to gross exterior wall area ratio for the orientation under consideration, α = solar absorptivity of opaque wall, U_w = thermal transmittance of opaque wall (W/m^2 K), CF = solar correction factor and SC = shading coefficient of the fenestration system multiplied by other permanent shading provisions such as canopies and balconies of significant depth.

Wall envelope and the architectural expression

The wall envelope is essentially the architectural expression of the building. It is more defined and deliberate especially for corporate offices and prestigious government buildings. The fenestration and design reflects the identity and aspiration of the proprietor. From the wall envelope one can sense the environmental awareness, technological inclination and aspirations of the time. The wall envelope embodies valuable information prevalent of the time it was conceived and this can be regarded as a very important historical landmark.

Results On Design Characteristics

Design element analysis was conducted to establish the characteristics of wall envelopes adopted in the surveyed buildings.

The survey identified *material choice* and *articulation approach* of wall envelopes. This in turn would reveal the prevailing thought process of those involved in designing the buildings, namely the architects, engineers and clients.

With regards to material choice, there appears to be a fair amount of stereotyping in terms of material choice appropriate for high-rise buildings. It was discovered that there were a few materials that were frequently used as claddings. These materials are perceived as high profile materials, namely glass, granite, and metal (aluminium and stainless steel). Granite is commonly associated with corporate ness and imparts the perception of reliability, strength and stability. Aluminium and glass for example are perceived as dynamism, visionary, transparent and high technology.

Very few of the buildings actually used sophisticated solar glass perhaps due to its high cost (2 out of the 33 surveyed buildings). Many opt simply for tinted or coloured glass which solar coefficient (SC) is in the range of 0.87 to 0.6, depending on the glass thickness and tint quality.

From the survey, only 21.2% of the subjects (7 cases) deployed external shading devices. This means the remaining 78.8% do not have any form of effective shadings to protect their facades. External shading devices are introduced either selectively (28.6%) or extensively (remaining 71.4%). The ratio of the depth of shading projection over length of projection was estimated to be in the range of 0.4 and 1.0, which results in shading coefficient (SC) in the range of 0.5 and 0.8.

Results also showed that window sizes for these envelopes tended to be large with window-wall-ratio (WWR) for fenestrated walls estimated to be between the range of 0.25 and 0.75, with tendency to be on the higher limit.

The manner in which the wall envelope materials are combined and manipulated represent the overall articulation approach adopted for the building.

Generally the envelopes adopted in the surveyed buildings can be categorised into four articulation approaches;

streamlined facade with selective external shadings

The wall envelope is predominantly glass with aluminium. It primarily relies on the fenestration system to provide solar shading, coupled with external shades introduced selectively on building facades that face more severe solar orientation, namely the east and west. The building service core is located on the peripheral wall as a form of thermal buffer.

streamlined facade with no external sunshading

Wall envelopes under this classification were assembled predominantly with glass, constructed using curtain wall system. The window openings were mostly large with window-wall-ratio (WWR) in the range of 0.5 and 0.75. Visually, this resulted in a homogenous flushed appearance, emphasising on the building transparent streamlined form.

extensively shaded / rugged facade

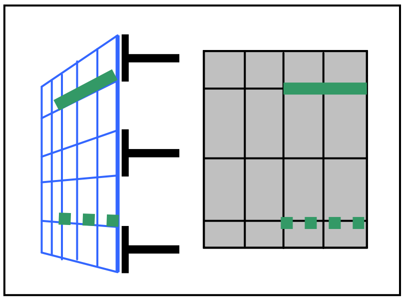
This envelope type integrates extensively external sunshading devices. The sunshading devices provide a strong character for the envelope system, which on the overall appears rugged and tropical. These are expressed as architectural features in the form of balconies, terraces, canopies, fins and egg crate metal framework. Glass used is slightly tinted, which improve daylighting transmission into the interior space.

multiple windows configuration

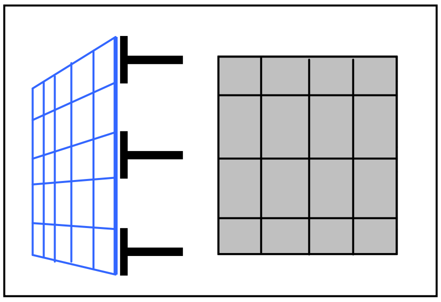
This approach tries to balance the area of transparent and solid materials through the use of recessed windows, tinted or reflective glass and fins projections. These means however do not contribute effectively to the solar shadings. WWR were in the range of 0.2 and 0.6.

Group two is most likely to cause high thermal gain, which in turn increase cooling load requirement for the building. Total reliance on glass with window-to-wall ratio in the range of 0.5 and 0.75 would not be able to combat heat gain. 27.27% of the surveyed buildings fall within this category.

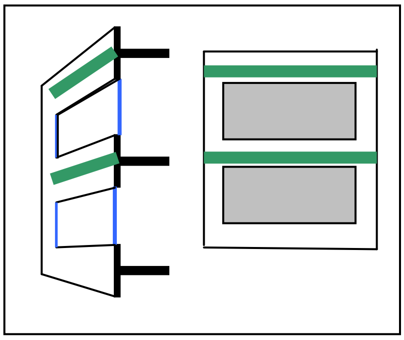
Among the four groups, the third group is most likely to achieve better energy performance evident by the extensive use of sunshading devices through out the buildings. Deep overhang with full glazed windows, provide increased opportunity to tap good daylight potentials. This solution is likely to reduce glare and heat gain. Seven cases fall under this classification.



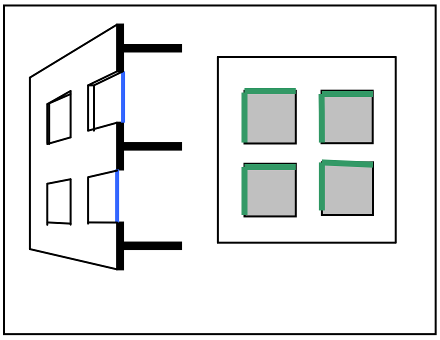
1. Streamlined facade with selective shading



2. Streamlined facade, no shades



3. Extensively shaded / rugged facade



4. Multiple window facade

Figure1: Diagrammatic layout of envelope design classification

Results on OTTV Calculations of Two Cases

OTTV calculations were performed on two office buildings, each representing the extreme categories, group two and three of the above classification. This exercise serves to demonstrate the thermal transfer performance of these envelope systems. High OTTV indicates poor heat reduction performance of the envelope design, which results in higher air conditioning and electricity consumption for the building.

The OTTV calculations were based on schematic drawings obtained from the local authority (Case one) and the architectural firm (Case two). For the purpose of calculating the OTTV, the wall profile for both buildings is assumed to be 250mm thick, comprised of 4mm composite cladding on the exterior, 150mm brick wall lining on the interior, complete with 50mm insulation.

Case One

This is a 34 storey office building with a 4 storey podium. The office tower built up comprises of air-conditioned space that exceeds 25,000 m2. The building is well orientated in the sense that its service core is positioned to the west. The building is extensively cladded with composite aluminium panel and 6 mm thick tinted glass, with no external shades.

U value for the opaque wall component of the building range between 0.53 and 1.53 W/m^2K. The SC of the 6mm tinted glass fenestration is taken to be 0.67 (from manufacturer's recommendation).

The OTTV results show that the OTTV for each façade range between 52.2 W/m^2 and 91.0 W/m^2. The east façade has highest value. On the overall, the OTTV for the building is 65.6 W/m^2, which exceeds the country's limit of 45 W/m^2 by 45.7%.

Case two

Completed in 1999, this building has 19 floors of office space. External shading devices in the form of horizontal wire mesh sunscreen and balconies are incorporated extensively on three main facades of the building.

U value of the opaque wall used in the building range between 0.53 W/m^2 and 2.88 W/m^2. The OTTV for each façade range between 32.4 W/m^2 and 48.2 W/m^2. The overall OTTV is 43.1 W/m^2, which is in compliance with the country's OTTV requirement.

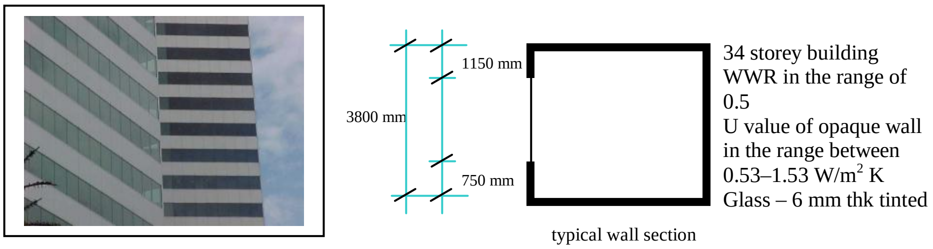


Figure 2: Illustrations of Case 1

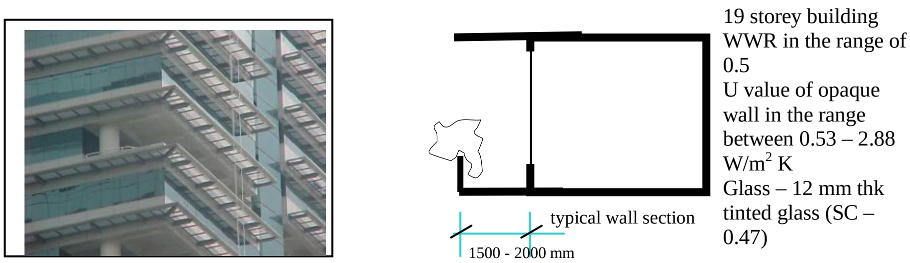


Figure 3: Illustrations of Case 2

Table 1: Comparative analysis of OTTV and WWR of Case studies with standards

	Envelope Attribute	Mean	Min.	Max.	% difference of mean from standard
Case 1	**OTTV (W/m^2)**	65.6	52.2	91.0	+45.7% exceed limit
	WWR (%)	45.0	45.0	45.0	within limit
Case 2	**OTTV (W/m^2)**	43.1	32.4	48.2	-4.2% within limit
	WWR (%)	45.0	33.0	47.0	within limit
Malaysian Standard **MS 1525:2001** not yet enforced	**OTTV (W/m^2)**	45.0	-	-	-
KL City Hall building department's requirement - already enforced	**WWR (%)**	-	40	50	-

Conclusion

It is evident from this study that the choice of envelope design affects energy usage in office buildings. It was found that many solutions currently being employed do not contribute to energy efficiency design and relied heavily on air-conditioning to achieve the desired comfort levels. In general the study supports the government's recent move to control envelope designs, with the aim of reducing heat gain into buildings and thus help minimise air conditioning and electricity usage.

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