Optimum ESD Facades – Different Cities, Different Solutions

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Keywords

Abstract

Ecologically sustainable development (ESD) requires that building facades should be designed to minimise energy consumption and thus reduce greenhouse gas emission. It is generally recognised that windows can be one of the weak links in the energy efficiency of a building but it is unthinkable to eliminate windows from buildings. Therefore, to reduce energy usage in air-conditioned buildings it is necessary to optimise the façade cladding system design together with the interior building services of air conditioning and lighting. However, the optimum solution in a hot climate may be quite different to the optimum solution for a colder climate and different again in highly humid environments. This paper discusses the features of the façade design, which are applicable to various climates for the purpose of minimising energy consumption while maintaining occupant comfort.

Introduction

In recent years we have become increasingly aware that the world is getting warmer and there is a need to reduce Greenhouse gas emissions. Therefore, energy conservation is even more important, which is not only due to the need to reduce building operating costs. Consequently, more than ever before, building designers, owners and occupiers are concerned to minimise their energy consumption and costs. However, the true cost of occupant comfort is not often considered by building designers and owners.

Occupant comfort is of utmost importance in design of all buildings; both air-conditioned and naturally ventilated. Various studies have shown that comfortable workers are more productive, whereby comfort derives from both thermal and visual conditions. For example, the Commerzbank building in Frankfurt has found an estimated 2% increase in productivity due to the ventilation strategy, while the workers at the Building Research Establishment's "Environmental Building" in the UK believe they work up to 20% harder in summer due to the natural ventilation and natural lighting.

Studies into the effect of daylight in buildings have shown similar results. In retail shopping, it has been found that stores with natural daylight outsell their windowless competitors by up to 40% and in schools it has been found that test scores are up to 20% higher.

Comfort can also be related to cost savings. For example, consider an office building, which rents at $400/m^2 per year. Typical energy costs in Australia are $22/m^2 per year and salary costs are around $4,000/m^2. Thus, if a comfortable building results in 20 fewer sick days per year, that equates to an 8% increase in productivity, or $320/m^2 per year. Compared with the energy cost and the rent it can be seen that improving comfort also has significant cost advantages.

Heating, cooling and lighting are responsible for the main energy demands of buildings. Heat-flows through walls, roofs, floors and windows make up about 80% of energy losses from buildings. This paper presents some of the results of collaborative research, in which the author was involved while employed at Pilkington (Australia). The Lighting Research Unit, School of Architecture, University of New South Wales examined the impact of glazing materials on the energy performance of buildings.

The research used a computer model capable of considering every important factor: climate, orientation, internal partitioning, window area and design, and glass characteristics. The model (DOE 2.1) was developed at the Lawrence Berkely Laboratory, California, USA. Lighting systems for energy conservation are also considered, together with the effects of climate.

Energy Savings with windows

Window design and the choice of glass are critical to energy consumption for lighting, heating and cooling; and to the health, well being and productivity of the building's occupants. Only a few decades ago, the window was seen as a liability in energy conservation. However, it is now evident that windows can make a valuable contribution to energy conservation. This is achieved by using recently developed, high performance window products for insulation and visible transmittance, automatic lighting controls (when daylight provides lighting needs) and passive solar energy technology.

Today, the choice of glazing systems is wider than ever before. Many options are available to extend the degree of thermal and solar control that glass can provide. Glass selection can influence total transmittance, spectral properties and directional properties. With the latest advanced glazing technologies, the transparent components of a building envelope are becoming far more flexible in their response to heat and light. However, the solution is complex involving variable properties and trade-offs between conflicting requirements.

Electric lighting controls, together with technical improvements in daylight-oriented glazing materials, can assist in turning glazing into an energy-efficient asset in perimeter areas by balancing heat gain and loss with daylight admission.

Daylight is not only a source of illumination to enhance the quality and quantity of light in a building but it also reduces electricity consumption and peak electric loads. In one sense, all buildings with windows or skylights are "daylit". In this paper "daylighting" refers specifically to the use of electric lighting controls which automatically turn off or dim the lights when daylight is sufficient, hence achieving energy savings. Daylighting is usually discussed in relation to new buildings but installation during building refurbishment is also possible and will become increasingly important in the future.

A daylit building is more energy-efficient than an identical building without such controls but the degree to which the use of daylight can reduce lighting loads depends on the visible light transmittance of the glass, and the glazing area. Since the glazing materials selected need to have a reasonably high visible transmittance and a relatively low shading coefficient to ensure maximum daylight and minimum heat gain, trade-offs will be required. It is also necessary to avoid the heavy cooling penalties introduced by glazing materials with unfavourable solar optical properties and excessively large sizes with inadequate solar control. These cooling loads can offset the benefits of daylighting.

The other major factor affecting energy consumption of commercial buildings is climate. The effect of climate was studied by considering a typical commercial building, which was located in three Australian cities having quite different climates (Darwin, Sydney and Melbourne).

Case Study: A Typical Multi-Storey Office Building

The study focused on energy conservation, and visual and thermal comfort. The research also considered the effects of varying window size, transmittance and shading coefficient. For the purpose of the case study, the DOE 2.1 computer program was run for on an existing building. This was a 27-storey office tower using double-glazing with a window/wall ratio of 60%. For the case study, the building was hypothetically clad with a variety of glazing types, covering the range of types available. The calculations were carried out for both for daylighting and without daylighting being used. To measure performance over a range of Australian climates, the building was 'located' in Melbourne, Sydney and Darwin.

The glasses selected for this comparison were chosen to cover the range of products available, including the new advanced glazing materials. All the glass types chosen were 6mm thick, in double-glazed units with 12mm air spaces and the selected glazing was as follows.

Type 1 – Clear/clear unit

This consisted of clear outer and inner panes. This is a basic energy conservation unit offering reduced air-to-air heat transfer but minimal solar control. It was chosen to see how much the new glazing technology can improve performance.

Type 2 – Grey/clear unit

This consisted of grey tinted outer pane and clear inner pane. This was the first step in the evolution of 'high performance' glass, which adds some solar control by the addition of a body-tinted outer panel.

Type 3 – Reflective coated/clear unit

This consisted of a reflective coating (TS20) on surface 2 of the clear outer glass and a clear inner glass. This was a major improvement in glazing technology and it was considered a benchmark for comparisons. This is the glass used in the Rialto Building, Melbourne.

Type 4 – Tinted LowE coating on green/clear unit.

This consisted of a tinted low emissivity coating having 54% visible transmittance placed on surface 2 of a green tinted outer glass and a clear inner glass. This unit achieves a very good thermal performance with low reflectivity and high light transmission. This unit is useful where reflective glass is not desirable for aesthetic, glare or regulatory considerations.

Type 5 – Reflective coated/Low E on clear unit

This consisted of a reflective coating (TS30) on surface 2 of the clear outer glass and a clear Low E coating clear on the outdoor surface of the clear inner glass (surface 3 of the unit). This unit gives thermal performance similar to the Type 3 unit but with lower reflectivity and higher light transmission.

Type 6 – Reflective Gold low E coating on green/ clear unit

This consisted of a reflective Low E coating having 55% visible transmittance on surface 2 of a green tinted outer and clear inner.

The results from the case study, in terms of total energy consumption are given in Tables 1 and 2.

Table 1

Glazing Type	Total Energy Use (GW hr) Without Daylighting		
	Melbourne	Sydney	Darwin
1	5.20	5.69	8.83
2	5.25	5.56	8.03
3	5.17	5.37	7.20
4	4.98	5.29	7.33
5	4.98	5.25	7.19
6	4.90	5.21	7.12

Table 2

Glazing Type	Total Energy Use (GW hr) With Daylighting		
	Melbourne	Sydney	Darwin
1	4.82	5.21	8.14
2	4.97	5.19	7.49
3	4.96	5.13	6.86
4	4.67	4.89	6.75
5	4.74	4.94	6.76
6	4.59	4.79	6.54

Conclusions from the Case Study

1. The Type 1 unit has the highest energy consumption in Sydney and Darwin, because of the greater cooling loads in these regions. The problem with clear units in all three locations is direct solar radiation through the windows, leading to extreme discomfort in adjacent areas.

2. The Type 2 unit offers energy savings over the clear unit in all locations, due to improved solar performance. Energy consumption is still relatively high, due to the cooling loads. This is the result of the high shading coefficient (compared with other glasses).

3. The Type 3 unit is a good performer overall, especially in Darwin, where its low shading coefficient minimises cooling load. In cooler areas (Sydney, Melbourne) its higher coefficient of thermal transmittance (U value) compared with Low-E units means heat loss is higher and hence total energy consumption is higher.

4. Energy consumption with the Type 4 unit was lower than with the Type 3 unit in Sydney and Melbourne. The higher shading coefficient of this unit means that total energy usage in Darwin is higher, due to the importance of cooling load. However, this unit offers superior/comparable energy consumption to a traditional high performance unit such as the Type 3, and achieves this with a reflectivity of only 13%.

5. The Type 5 unit has essentially the same aesthetics as the Type 3 unit. It gives comparable performance in Darwin and superior performance in Sydney/Melbourne. It has a marginally higher shading coefficient and a much lower U value. This means that in Darwin, any increases in energy demand due to direct solar radiation are offset by reductions in heat transfer. In Sydney and Melbourne, where heat loss is more significant, the lower U value reduces total energy demand. This unit also has low reflectivity and high light transmission.

6. The Type 6 unit gave the lowest total energy consumption in all situations because of its low shading coefficient and low U value. Cooling loads with this unit are also minimised. This is the optimum performer of the glasses compared due to its high reflectivity and high visible transmittance combined with a Low E coating. It is the best energy conserver, but unfortunately its use may be restricted by reflectivity considerations.

The Benefits of Daylighting

The benefits of daylighting are best illustrated by looking at the total energy use in Darwin, where the performance of the Type 3 unit compared with the Type 5 unit is virtually identical without daylighting. The addition of daylighting to the Type 5 unit reduced energy consumption by 6% due to its higher visible light transmittance. Clearly, the Type 3 unit has very good energy conservation potential, but this can now be matched and even improved on by a unit with a lower reflectivity.

Conclusion

The use of double-glazing is usually employed in colder climates. However, this research has shown that energy saving is possible using double-glazing, even in hot climates and the use of double-glazing with Low E coatings can be justified on economic considerations, not to mention the benefits in reducing Global Warming and the other advantages of double glazing, namely:

(a) The protection given to the reflective coating on the glass to avoid scratching during construction and during the life of the building
(b) The reduced risk of condensation on the glass surfaces
(c) The lower heat radiation from the glass resulting in better comfort and higher occupant satisfaction levels. This is of utmost importance in view of the hidden economic benefit of improved comfort.

The research has also demonstrated that for different climates there can be different solutions for the purpose of minimising energy consumption and thus reducing Greenhouse gas emissions. The availability of advanced software to analyse the complex interaction of data, including local meteorological data for cooling and heating loads, energy and comfort now makes it possible for building designers to achieve ecologically sustainable development.

References

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