Implementation of triple layer facade in Singapore

Haico Schepers[a,*], Russell Cole[b], Neil Johnson[c]

[a]*Arup Group, Sydney, Australia;* [b]*Arup Singapore Pte Ltd., Singapore;* [c]*Land Transport Authority, Singapore*

ABSTRACT
During the construction of Dhoby Ghaut Station on the MRT North-East line a 10-storey commercial development was completed. The facade is a vented cavity of a triple glazed construction comprising of an Insulated Glazed Unit, cavity blind with natural ventilation, and a single internal operable glazed layer. This type of facade technology has been used in Europe; however, its relevance in tropical climates where buildings are cooling-dominated needs to be carefully considered. This paper discusses how the system is optimized to improve thermal comfort adjacent to the facade whilst maintaining energy efficiency in the tropics. Ventilating the cavity reduces the surface temperature of the internal pane of glass by relieving the heat absorbed by the surfaces. Theoretically it is possible to achieve the recommended radiant asymmetry criteria recommended by ISO7730 by ventilating the cavity for the glass construction. Subsequent to the facade's construction testing has been performed to understand and identify actual levels of improvement in thermal comfort and efficiency. This paper discusses the findings of these tests.

INDEX TERMS
Triple layer facade; Insulated glazed unit; Singapore

IMPLEMENTATION OF TRIPLE LAYER FACADE IN SINGAPORE
Dhoby Ghaut Station is a 10-storey building on the North East MRT line. The facade is of a triple glazed construction comprising a Low E double glazed unit (DGU) cavity blind and a single internal operable glazed layer. The facade is a vented cavity of a triple glazed construction comprising of an Insulated Glazed Unit, cavity blind with natural ventilation and a single internal operable glazed layer. This type of facade technology has been used in Europe; however, its relevance in tropical climates where buildings are cooling-dominated needs to be carefully considered. Object of report is to report on the actual performance of the innovative-vented cavity facade.

Of key importance when designing the facade were:

- occupant comfort,
- energy implications,
- maintenance issues.

The use of ventilated cavity facades is a new and innovative technology that is now being more frequently used in Europe. The application of this technology in a tropical climate requires some consideration to understand its overall performance in terms of occupant comfort, energy efficiency and maintenance. The design of these type systems leads to various modifications compared to the European designs:

- the facade is internally ventilated as external ventilation in Singapore has little benefit due to high external air temperatures;
- the cavity is naturally ventilated and connected only to the room plenum as there is little use in ducting the warm air for use as a reheat source;

* Corresponding author.

- the internal skin is hung against the facade as access to the cavity is only required infrequently.

Facade Construction

The vented cavity design proposal is shown on current tendered drawings. This study investigates the vented cavity curtain wall as detailed below:

- The typical curtain wall is all glass. It is split into two zones:
  - *Vision zone*: the glass is intended to have light transmitting approximately 50% with a gentle green tint.
  - *A spandrel zone*: the spandrel panel is proposed to have the same glass and be of spandrel box form. Within the cavity a fixed louvre blade is proposed.
- The glass types used were:
  - AFGD Low E Green 8-12-8 IGU externally.
  - Silver Venetian cavity Blind.
  - Removable 8.76 mm Clear glass internally.
- There are two continuous blades that protrude 600 mm at +2.1 and +3.1 all around the building.
- An internal 'Venetian style' blind can be raised or lowered by the occupant. The blade's inclination may be adjusted to control glare and local thermal comfort.

Performance

Various issues were considered in the detailed design of the ventilated cavity wall. The following performance targets were made based on theoretical facade performance analysis:

- *Comfort*: maximum glass surface temperature 28°C.
- *Energy*: performance is better than Standard Green DGU.
- *Maintenance*: recommended cleaning frequency of 12 months or more; ease of maintenance should be considered (a way of filtering the inlet air may need to be developed to achieve this maintenance requirement).

Subsequent to the finished design and installation of this facade, the designers have returned to the operational building to understand the actual performance of this innovative technology and how it relates to the tropical climate of Singapore. The results of this testing are still being finalized and will be issued as an addendum to this paper prior to the conference.

OCCUPANT COMFORT

General

Occupant comfort plays a significant role in the perceived quality and productivity of an office space. Three significant factors in occupant comfort are:

- visual comfort,
- acoustic privacy,
- thermal comfort.

The following measures where taken at design stage to improve occupant comfort:

Visual Comfort

Daylight is a significant source of joy for the occupant. The challenge is to introduce daylight without causing visual discomfort. The glazing light transmission for Dhoby Ghaut Station was optimized to 50% to reduce visual discomfort. The internal cavity blind offers further opportunity to control this glare.

Thermal Comfort

Thermal comfort is result of the interaction between:

- ambient temperature,
- relative humidity,
- air velocity and
- radiant temperatures.

A typical air-conditioned building is designed to control the first three of these effects to achieve a recommended comfort index, Percentage People Dissatisfied (PPD), of not more than 10%. At a building's perimeter, however, the effects of radiant temperatures become dominant as shown in the comfort plot below. The standard on comfort, ISO 7730, specifies a maximum asymmetry of 10° for windows. Good practice is to limit the radiation asymmetry to 5° above ambient.

Theoretical analysis indicated that naturally ventilating the cavity reduced the surface temperature of the internal pane of glass to less that 5° by reliving the heat absorbed by the surfaces. This is highly dependent on actual ventilation rates. The ventilation rates are dependent on the inlet and exit losses, the height of the air column and the resistance of the blind and possible air leakage through the sides. The theoretical estimated vent rates associated with Natural Ventilation is 0.1 m/s.

Actual Performance

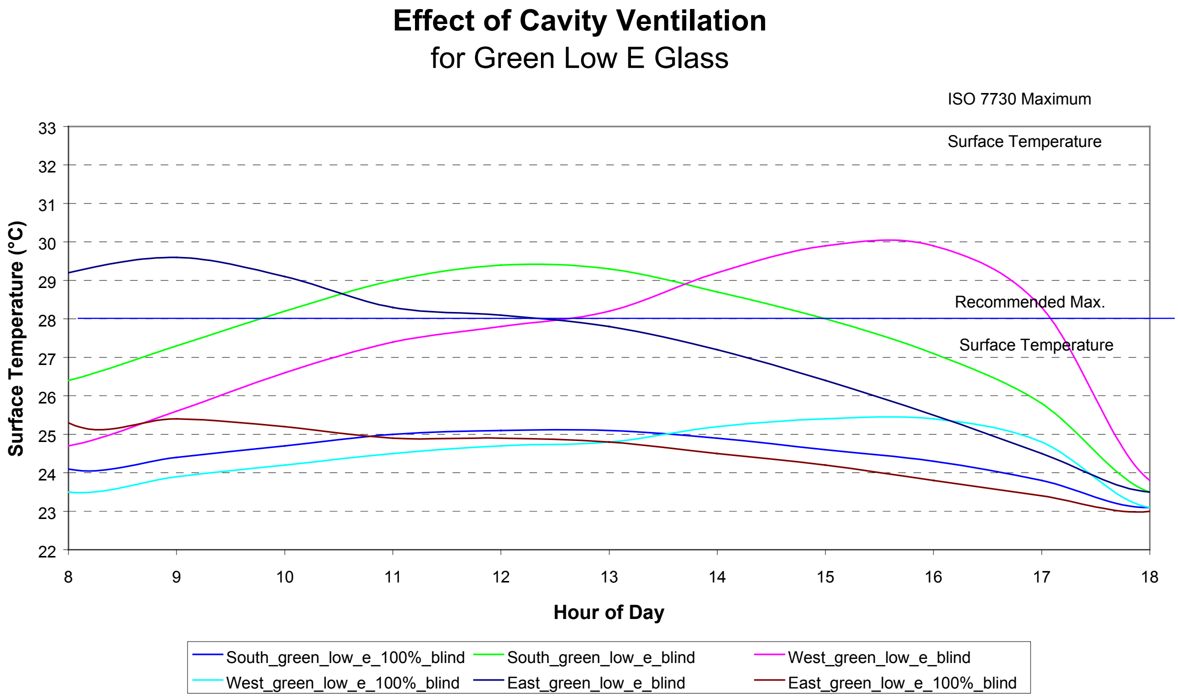
Testing of overall occupant comfort

To take a measure of these issues and identify the relative perceived performance major areas contributing to office productivity, a survey was developed. The occupants were asked to describe their subjective feelings of comfort relating to issues of thermal comfort for heating, cooling, visual comfort, acoustic distraction due to outside noise, controllability and overall perception of the internal environment. They rated their response from 1 to 5, 1 being important/uncomfortable and 5 being not important/comfortable.

The full results of the occupant survey are still being collated and will be issued as an addendum to the paper.

Energy

The use of a ventilated cavity can improve energy efficiency if the air in the cavity is discharged from the building. In this case the warm cavity air is returned to the air handling unit with the rest of the return air and re-conditioned, thus both the internal blinds and internally ventilated cavity may be considered as irrelevant to the OTTV and energy usage calculations. It should be noted however that this system is a more efficient method of picking up perimeter heat flow before it impacts on the occupants in the room. This efficiency may lead to a reduced load on the room side HVAC system allowing the cooling plant to run more efficiently to meet peak loads. The cavity opening size plays a large role in determining airflow rate and thus energy efficiency. The smaller the opening size the closer the system comes to a triple glazed facade in energy efficiency. In reality the OTTV value is somewhere in between a double glazed facade and a triple glazed facade.



Actual Performance

Testing

Testing is currently underway at the site.

MAINTENANCE ISSUES

One of the most demanding issues associated with ventilated cavity designs is the ability to access and clean the cavity space. There are many mechanisms in the market that allow access to the cavity including tilt and turn, slide and sash systems. Each of these systems has implications on interior partition layout, visual appearance and ease of maintenance. This particular system requires two men to lift the lower, 1.4 × 2.1 m internal pane of glass off the mullion, removing it temporarily in order to clean the cavity. This was considered the most cost-effective system that had least impact on the internal layout or space usage. Typically internal facades are cleaned every 6 months. In this case, however, due to the use of relatively clean internal air for ventilation and the low pressures associated with natural ventilation, it was estimated that the cavity required internal cleaning only annually.

Testing

Currently the cavity is only cleaned on an annual basis. The removal of the internal pane of glass has proved to be a relatively straightforward exercise and the cleaning could be done less frequently.

CONCLUSION

The design of a ventilated cavity in Singapore presented many challenges. These challenges were overcome by using various sophisticated analytical tools. This paper aims to consider the key issues of occupant comfort, energy efficiency and ongoing maintenance and cleaning costs of this system as installed and operated. The building has been in operation for about a year at the time of writing but full details of the operational testing have not yet been completed. These will be issued as an addendum to the report prior to the conference.