MODELLING THE THERMAL PERFORMANCE OF GLAZED FACADES

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ABSTRACT:

Thermal comfort and energy use in modern office type spaces is closely related to the thermal performance of the glazed façade. The ability to provide shading and thermal insulation can influence the type of environmental system for heating/cooling and ventilation. This paper will describe the use of computer modelling to predict glazing performance in relation to modern office environments. A combination of dynamic thermal modelling and spatial airflow modelling has been used in the design of a range of glazed facades. The paper will draw on experience of real façade design projects based on new and existing offices in Switzerland, involving different combinations of glazing treatments and internal environmental systems.

INTRODUCTION

In recent years there have been interesting developments in façade design. This has largely been in response to the design of ‘climate selecting’ or ‘passive’ buildings that can provide comfort conditions with the efficient use of energy. Many such buildings have highly glazed facades to provide daylit spaces, visual contact between inside and outside, and to provide aesthetically pleasing elevations. Glazing systems can now have relatively high levels of thermal insulation. For office type spaces the heat loss in winter is less of a problem after the initial morning warm-up period, due to the increasing levels of internal heat gains which have to be exhausted. If the building is naturally ventilated then the façade must also provide suitable openings, while if the building is mechanically ventilated the façade is often itself ventilated to exhaust heat gains collected in the glazing system. The façade is therefore a major component of environmental design and its performance needs to be carefully assessed during design in relation to the heating and cooling loads on the space and the associated systems.

In Switzerland there is a tight control over the use of air-conditioning, and in most cases it is restricted to mechanical ventilation with some comfort cooling. Air conditioning is only allowed if the design can demonstrate that the solar gains are minimised. Sometimes additional cooling may be provided through active cooled surfaces, such as chilled beams and ceilings.

The problem of controlling solar gains has been addressed through innovative shading, often of a dynamic nature, moving into position only when the sun is incident on the
façade. However, even for facades with low g-values (that is, total solar transmission), there have been problems associated with excessive heat gains and high internal glass surface temperatures (greater than 40°C), making the internal glazing effectively a ‘low temperature’ radiator.

Therefore to ensure the successful design of glazed facades, predictive tools are needed to predict the façade performance and how it is integrated with the overall building environmental system. This paper describes the use of such design tools with reference to real design situations.

THERMAL DESIGN OF FACADES

The aim of the thermal design of facades is to control heat gain and heat loss. The heat gain is mainly from direct and diffuse solar radiation, although in hot weather there will also be some transmission heat gains, especially if the space is mechanically cooled. The problem of controlling solar heat gains is usually worst in summer when the outside temperature is also high. This is especially the case for west and sometimes east facades when the sun angle is low. However, even in winter the gains can be problematic, especially as the solar altitude is lower during mid-day making shading difficult.

In Switzerland, there is usually a requirement that the internal air temperature does not exceed 26°C in summer and the internal glass surface temperature should be within 5°C of the space air temperature. Regulations restrict mechanical cooling. Glazing g-values have to be less than 0.15 and there must be a mass greater than 350kgm⁻² of floor area. Then, only if temperatures exceed 28°C for more than 35 hours per year is cooling allowed. Therefore in order to avoid overheating in summer, the façade has to be carefully designed to minimise solar heat gains, not only to the space but also to the glazing system and avoiding high glass temperatures.

If large areas of glazing are to be used, some form of shading is required. This can be located (see figure 1):

- On the external façade, sometimes moving into position only when the sun is on the façade. This is usually considered the best approach, as the solar heat gains are kept external to the space and glazing system.

- In the middle, within the glazing system. If the system is sealed then the solar heat gains can be trapped within the glazing system and can result in high internal glass temperatures. If the glazing system is ventilated then the heat gains can be exhausted to outside, but still the glazing system is subject to some gains which can give high temperatures, especially if the ventilated glazing extends for a number of floors (for example, a ventilated double skin).

- On the inside, This is the worst case to control as the heat gains are allowed to enter the space. Although some are reflected back and absorbed by the shading system.
most of the heat will be contained in the space either as convective gains or long wave radiant gains.

The accurate predictions of these systems are needed for design. The glazing system performance must also be integrated with other environmental aspects, such as passive or active cooled surfaces and displacement ventilation.

Figure 1 Illustration of different glazing shading strategies indicating convective and radiant heat exchange for, a) external shading, b) middle sealed shading, c) middle ventilated shading, and d) internal shading.

PREDICTION TOOLS

There is therefore a need to be able to predict the time varying performance of facades under varying external conditions of temperature and solar radiation. This can be achieved using a dynamic energy model. The model HTB2 used in the work described here was developed at the Welsh School of Architecture (Alexander 1997) and is in use in a number of academic and industrial organisations. It can be used to predict internal space and glass surface temperatures (Lang et al 2000). It models the system as a set of
nodes, each node associated with a space temperature or a surface (or ‘finite difference’
temperature within a construction). The only assumed information is the ventilation
rate of the space and this has to be input to the model. Figure 2 presents the nodal
description of a simple space with a blind on the inside.

Figure 2 A nodal representation of an office space with an internal blind. The gap
between the blind and the glazing is modelled as a separate space.

The ventilation rates associated with individual spaces and the spatial variation of
temperatures and air movement can be predicted using an airflow model. The most
widely used airflow models are now generally computational fluid dynamics (CFD)
models. They can predict the spatial variation of temperatures and air movement.
Airflow models are generally used to predict conditions at a point in time, often using
surface temperature boundary conditions generated by dynamic models, which can
account for thermal mass effects (Jones and Kippenburg 2000). Figure 3 presents an
example of an airflow model predicting the airflow and internal temperatures for an
internal blind system.

Figure 3 A vertical section through a space with an internal blind and displacement
ventilation, showing the temperature contours and air velocity vectors.

APPLICATION TO SHADED GLAZED FACADES

The above tools have been used to predict the performance of the glazing systems
shown in figure 1. In each case the system was approximated to a system of nodes, with
the inside shading option shown in figure 2. The ventilation rates associated with the
three ventilated shading systems (cases 1a, 1c, and 1d in figure 1) were estimated from
airflow prediction (similar to figure 3). The results are presented in figure 4 (a to d).
Figure 4a Internal blind.

Figure 4b Middle blind in sealed glazing system.

Figure 4c Middle blind in ventilated glazing system

Figure 4d External blind.
The results of the simulated blind performance indicate the internal glass (or blind in figure 4a) temperature for the different systems. With the internal blind and middle sealed blind the internal glass surface temperature is relatively high, peaking at 36.5°C and 43.5°C respectively, which is well above the 5°C limit above the internal space temperature. The peak cooling load for each case is presented in figure 5. There is about a 10:1 difference between the best and worst case.

![Graph showing relative peak cooling loads for four cases.](image)

Figure 5 Relative peak cooling loads for the four cases.

When considering these results it should be noted that they relate to specific window systems, with particular blind and glazing properties. They are therefore only indicative of the performance of these types of systems.

![Double skin façade on five floors.](image)

Figure 6 Double skin façade on five floors.
In some cases the blind system will extend over the whole façade and it will be necessary to predict the façade performance at this scale. In such cases the airflow model can be applied to predict peak or typical conditions. Figure 6 shows an example of a simulation of a double skin façade indicating the rise in air temperature with height, imposing an increasing cooling load and internal glass surface temperature on floors at higher level.

**CONCLUSION**

The modelling of facades is important in relation to the control of solar gains. There is potentially a wide range in performance for different glazing shading systems. The main aspect of a successful design is to exhaust the solar heat gains trapped by the glazing system. This is especially problematic for internal and sealed glazing blind systems.

Very often it is the indirect heat gains through high internal glass surface temperatures that is the main problem. These will have convective and radiant components.

A combination of dynamic thermal modelling and CFD airflow modelling provides a means of predicting system performance and integrating the glazing system with other environmental systems, for example, thermal mass and ventilation. Currently, the use of the two models is carried out in an iterative way. However, in future it should be possible to combine the dynamic and spatial models into one general tool.

**REFERENCES**


