THE CASE FOR VENTILATED FACADES – LATEST DEVELOPMENTS TO PREVENT SOLAR OVERHEATING OF HIGHLY GLAZED BUILDINGS.

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ABSTRACT

Architects love to design highly glazed facades, providing continuity from the outside world into the building interior, and providing light, airy spaces in which the occupants can work and live. However, energy considerations – particularly in relation to use of air conditioning – have provided significant challenges for the design of such buildings.

Put in a nutshell, building occupants want thermally and visually comfortable buildings. As one possible approach, ventilated or so called “double facades” have been developed as an approach to provide energy efficient façades with both high thermal insulation values and good solar control, and allowing large areas of glazing to the façade. Different configurations can be employed, and each has a range of features and benefits that must be evaluated to ensure the appropriate solution is selected for a given project. In addition to the usual concerns in regard to the façade itself such as design aesthetics, buildability and weather tightness, the thermal façade performance must be determined together with the building as a system.

This paper discusses some basic questions of double façade design and presents some recently built double façade constructions. Levels of (thermal) performance that are achieved by each are outlined.

INTRODUCTION

Highly glazed façades provide visual continuity from the outside world into the building interior. They provide light, airy spaces in which the occupants can work and live. Notwithstanding their current popularity with architects, such highly glazed facades have been much discussed, e.g. [Gertis99] and are often damned [Schulz04]. Energy considerations – particularly in relation to necessary air conditioning – provide significant challenges for the design of buildings with highly glazed façades [Saelens03].

Of course, such façades can and should not be considered by themselves at any time in the design process when crucial design decisions in respect to thermal building performance are made. The whole building – including its proposed usage in terms of internal loads, its construction in terms of thermal masses available and its control in terms of HVAC system – must be viewed in an integrated way. Such detailed performance evaluation may often lead to the result that energy considerations are not in favour of a ‘static’ double skin façade (that is to say, a double skin façade e.g. with unchanging ventilation openings over the seasons). Of course, there are other reasons to choose a double skin façade, for example the protection of the solar shading device from wind forces in high rise buildings or the possibility of night time natural ventilation.

In order to correctly evaluate the energy efficiency of a given façade design, an annual energy simulation focussing on both heating and cooling load is necessary [Saelens03]. Apart from the above mentioned factors, the simulation model used should possibly take the building site – especially any shading by adjacent buildings – into account. A detailed model of a building will also take the environmental situations for different façade orientations into account (open country, adjacent building, concrete plaza). Oversimplified models, e.g. models that disregard
the performance of solar shading devices for diffuse radiation will lead to wrong – possibly quite wrong – results for heating and cooling loads.

As façade contractor that is generally involved in a stage of the overall building process when most basic parameters have already been fixed, we must assume that the specifications given for the façade design have been drawn out taking all the above mentioned parameters into consideration. However, specification documents often seem to tell differently. More often than not, the approach to façade modelling is very simplistic, ‘centre of’ U-values and area percentages (that need not correspond to the architectural design, as design evolves and corresponding simulations are not necessarily updated) are used to describe thermal properties. Shading schedules and/or control strategies are often rough. Sometimes it may be a good idea to involve a façade contractor at an earlier stage of the design process to avoid unnecessary mistakes.

FAÇADE TYPES

Basically, two double façade configurations are being used most often:

a) External curtain glass – gap – internal IGU and
b) External IGU – gap – internal curtain glass.

In this paper, configuration a) is called “external natural ventilated façade” and configuration b) is called “extract mechanical ventilation façade”.

Of course, a wide range of variations in regard to “macroscopic” geometric details of these two basic configurations is used – e.g. box type window, band type façade, the gap spanning more than one storey, various gap widths etc. Furthermore, the ventilation rate may vary in a wide range. For the external natural ventilated façade, the ventilation rate depends mainly on the size of openings available. Figure 1 shows above mentioned basic façade configurations with their main elements.

*Figure 1:* Typical basic double façade configurations. External natural ventilation (left) and extract mechanical (right).
Often, the architect does not wish to exhibit “functional” openings such as the ventilation openings of an external natural ventilated façade. Then, only the necessary (or possibly slightly enlarged) movement joints between façade elements remain for ventilation opening cross section. Subtract from this any insect mesh or the like which is inserted into the openings and the resulting free ventilation opening area is quite small. To achieve low g-values, high quality coatings in the IGU will be necessary, here.

Taking the next step in this procedure and omitting air outlets at the top of the façade gap leads to a pressure equalised system. That is, a system in which there is no ventilation, but simply a pressure equalisation between the façade gap and the ambient.

The frequency and duration of interstitial condensation – mainly on the outside and inside face of the curtain glass – will generally increase with the reduction of ventilation. However, if (or when) this condensation poses a problem is a question of taste, mainly.

One interesting aspect of the extract mechanical ventilation façade is the internal surface temperature (the temperature of the internal face of the curtain glass). This surface temperature will always be somewhat higher than for an external natural ventilation system due to the highest system temperature generally being the closed blind.

PERFORMANCE PARAMETERS

General
For overall façade design, at least the following general parameters should be considered:

- Architectural requirements / restrictions
- Thermal performance to be achieved (U-value, g-value, layer temperatures)
- Flexibility (adjustable performance)
- Interaction strategy with HVAC systems (extract rate, natural ventilation).

Apart from these parameters of a more general nature, the following more specific parameters may prove to have significant impact on possible design and, therefore, thermal façade performance:

- Loads
- Maintenance (inside or outside?)
- Elements module sizes (e.g. 1.5 vs. 3.0 m)
- Availability of local goods
- Investment vs. running costs (integrated view)

In the following, however, we will focus on the two main thermal performance parameters ‘U-value’ and ‘g-value’ from a façade contractors point of view. Typically, these values are given in the project specifications. However, in the case of double façades we are dealing with here, there are quite a few uncertainties in regard to compliance confirmation due to a lack of clear definitions in relevant standards.

U-value
In general, U-value calculation is based on detailed two-dimensional thermal simulation for all frames, panels and glazing edges involved in a given façade system. The calculation procedure is described in [ISO10077-1, ISO10077-2] for framing elements and in [prEN13947] for façade systems. Still, uncertainties in various definitions / procedures for specific constructions abound.
E.g., how to treat façades with projections – incidentally, experience shows that this is another general area of uncertainty in early stage thermal modelling, or how to treat the façade air gap has been a matter of lengthy discussions. According to [EN6946], any ventilated air gaps are disregarded for U-value calculation. This is the approach to take for ventilated double façades. However, for external natural ventilated systems, the external heat transfer coefficient $h_{se}$ can be reduced due to the additional radiation barrier and reduced convection on the external surface of the internal IGU (and frames and panels, of course).

In more than one project featuring an internal extract mechanical ventilated system, the specification clearly assumed that the heat balance of the air going through the façade gap should be taken into account. To our knowledge, there is no standardised procedure to do this, though. Yet, clarification of calculation methods is usually quite difficult in context of a project. One is asked to confirm performance, end of story. It must be kept in mind, however, that at this point the façade contractor is being asked to ‘mess around’ with parts of the HVAC of a building.

**g-value**

For practical purposes, the calculation of g-values for double façade systems is even less defined, than U-value calculation. Just to name a few possible points of discussion, calculating the g-value according to [EN410] does not allow for ventilated air gaps or solar shading devices. Moreover, the g-value is defined for normal incidence of solar radiation only and is evaluated with temperature equilibrium between inside and outside. This standardised g-value gives a value for ‘direct-diffuse’ radiation (direct radiation as ‘input’, diffuse radiation as ‘output’). All these assumptions and restrictions lead to a value which is not very realistic for the assessment of the performance of a façade in regard to solar radiation.

The international draft standard [ISO15099] gives algorithms for a much more detailed evaluation of the thermal behaviour of windows including shading devices and ventilated gaps. However, this standard does not define a ‘g-value’ as such. It does define a ‘total solar energy transmittance’ which could be viewed as an ‘effective g-value’, that is to say, a g-value that takes ventilated layers and temperature differences between inside and outside into account as well as non-normal incidence angles of the solar radiation. For double façades, we generally use this approach.

Typically, in addition to the specification of the g-value of the IGU, a g-value for ‘blind down and closed’ is specified for double façades. However, in the early stages of a given project, more often than not no detailed information on the shading (colour, surface finish, possible perforation) is available. Additionally, detailed information about the glazing – especially any coatings used – is difficult to come by. Therefore, a ‘similar’ product must be used for the assessment. With luck, such a ‘similar’ product can be found e.g. in [IGDB]. If this is the case, the calculation results themselves can be viewed as quite accurate, as comparison with measurement results show. However, as for example the blind colour does have an impact on resulting g-values, the question remains how the building performance was evaluated without defining the shading system in detail.

Measurement of system g-values for double façades including shading devices usually does not take ventilation into account. Such measurements can be viewed as a ‘worst case’ scenario for ventilated systems. As measurements show, insulating glazing units of modern build allow the achievement of very low g-values even for unventilated systems.
Miscellaneous

For external natural ventilated façades, condensation on the curtain glass (both on the internal and external surface) is often an issue. In general, such condensation can never be completely avoided. However, given a reasonable ventilation of the façade gap the frequency of occurrence during daylight hours will usually be acceptable. Of course, design variations can be checked in this respect, as well.

A further question being brought up in more and more cases is that of ‘thermal breakage’. As façade contractor, we usually put this question through to the glass supplier. However, agreed upon procedures (what is the ‘worst case scenario’?) and decision criteria (Which local temperature gradient is too high? What time scale is to be regarded?) would be very welcome for improved planning possibilities.

EXAMPLES

Recently built double façades give an impression of the wide variety of possible visual and performance solutions. Figures 2 through 5 each show a building overview and a detailed view of the façade of a recent Schmidlin project. The achieved performance for each of the façades is given below the figures. Hereby, U-value is the system (winter) U-value and the g-value is for blind down and closed (without temperature difference). Table 1 summarises the performance parameters of these façades and for comparison the performance data of a double façade for which the g-value was measured as well as a simple “box window” type façade.

Figure 2: ADIA, Abu Dhabi. Internal extract mechanical ventilation, gap width approx. 0.2 m. U-value 1.7 W/(m² K), g-value 0.18 ± 0.02 (air extract rate 8.5 l/(s m)). The vision glass area is ≈ 90% of the façade area.
Figure 3: Swiss Re, London. Extract mechanical ventilation, gap width approx. 1.0 – 1.5 m. U-value 1.3 W/(m² K), g-value 0.17 ± 0.02. The vision glass area is ≈ 85 % of the façade area.

Figure 4: RZVK, Köln. Externally naturally ventilated façade, gap width approx. 0.7 m. U-value 1.5 W/(m² K), g-value 0.09 ± 0.02. The vision glass area is ≈ 90 % of the façade area.
Figure 5: Gemeindezentrum Reinach. Externally naturally ventilated façade, gap width approx. 0.15 m. U-value 1.2 W/(m² K), g-value 0.11 ± 0.02. The vision glass area is ≈ 90% of the façade area.

Table 1: Typical U-values and g-values for some double façade systems. Values given are taken from Schmidlin projects. IGU g-values correspond to [EN410]. System g-values given are ‘effective g-values’ according to [ISO15099] calculated without temperature difference between inside and outside, however.

<table>
<thead>
<tr>
<th>System type</th>
<th>IGU U [W/(m² K)]</th>
<th>IGU g [-]</th>
<th>low-ε [-]</th>
<th>Blind type</th>
<th>System Ucw [W/(m² K)]</th>
<th>System geff [-]</th>
<th>Vision area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ext. nat.</td>
<td>1.1</td>
<td>0.55</td>
<td>0.02</td>
<td>Venetian, light colour</td>
<td>1.5</td>
<td>0.09 ± 0.02</td>
<td>≈ 90</td>
</tr>
<tr>
<td>ext. nat.</td>
<td>1.0</td>
<td>0.56</td>
<td>0.02</td>
<td>Venetian, light beige</td>
<td>1.2</td>
<td>0.11 ± 0.02</td>
<td>≈ 90</td>
</tr>
<tr>
<td>extract mech.</td>
<td>1.4</td>
<td>0.48</td>
<td>0.08</td>
<td>Venetian, light colour</td>
<td>1.7²)</td>
<td>0.18 ± 0.02</td>
<td>≈ 90</td>
</tr>
<tr>
<td>extract mech.</td>
<td>1.4</td>
<td>0.40</td>
<td>0.03</td>
<td>Venetian, light colour</td>
<td>1.3³)</td>
<td>0.17 ± 0.02</td>
<td>≈ 85</td>
</tr>
<tr>
<td>pressure equalised</td>
<td>1.9¹)</td>
<td>0.51</td>
<td>0.16</td>
<td>Venetian, light grey</td>
<td>1.5</td>
<td>0.16 ± 0.02</td>
<td>≈ 42</td>
</tr>
<tr>
<td>unventilated</td>
<td>1.2</td>
<td>0.54</td>
<td>0.04</td>
<td>Venetian, silver grey</td>
<td>1.1</td>
<td>0.12²) ± 0.02</td>
<td>≈ 80</td>
</tr>
</tbody>
</table>

¹) Box type window with two single panes, low-ε hard coating on pos. 3.
²) Design extract flow rate 8.5 l/(s m), taking extract air into account for U-value calculation gives $U_{CW} = 0.89$ W/(m² K).
³) Design extract flow rate 14 l/(s m).
⁴) Measurement result.
RESULTS AND DISCUSSION

System U-values of $1.1 \text{ W/(m}^2\text{ K)}$ and $g$-values of below 0.1 can be achieved using IGUs with modern glazing coatings. Highly glazed thermally comfortable buildings without excessive CO$_2$ emission values due to heating/cooling loads should be feasible. However, realisation of such buildings will usually require close cooperation between HVAC, building automation and façade contractor; preferably from a very early phase of the building design process.

It is shown, that even unventilated double façades can achieve very good performance in regard to solar control. This has become possible with modern high quality coatings for glass products.

A literature review shows that deciding on a ‘static’ double façade in most cases can not be based on energy efficiency considerations. Other design aspects will be paramount.

As façade contractor, we must assume that the early design process has taken all aspects of the building as a system into account. As long as we are not involved at an earlier stage of the design process, we can do no more than design an actual façade that complies with specifications given.

In actual fact, though, we could do a lot more, given the chance.

REFERENCES


