ADVANCED FACADES AND ENVIRONMENTAL SYSTEMS:
INTEGRATED DESIGN SOLUTIONS

Massimo Colombari and Marc Zobec
Permasteelisa R&E, via Mattei, 21/23 - 31029 Vittorio Veneto (TV) – Italy
Tel. +39-0438/505255
Fax +39-0438/505375

ABSTRACT
Low energy architecture is a central issue in the current building construction debate, due to the new building regulation restrictions undergoing in many countries. In the last few years the development of new advanced façade solutions integrated with plants has been growing considerably to combine architectural features and trends (transparent buildings) with new regulations to reduce carbon emissions. As a response to these problems and as a means of realising smooth external surface, ventilated double skin façades represent a most valid technology, which is becoming increasingly common and diffused. Whereas external shading devices are the most efficient in terms of solar control they pose a series of problems, especially for high rise buildings. The present paper describes, through examples of realised buildings, different advanced double skin façades and their possible integration with smart systems, to control and monitor the different building functionalities.

The integrated design approach target is considering the building envelope and the environmental systems as synergetic parts of one overall solution. Especially when designing transparent buildings, the aim is to allow transparency without compromising occupant thermal and visual comfort and energy consumption.

In order to validate and test different combinations of façade technologies and environmental systems using advanced building automation devices, fourteen test rooms are equipped with advanced Building Management System solutions (BMS). They represent an efficient full-scale tool for detailed analysis of different building integration strategies, combining shading device management with heating and cooling systems, natural and artificial lighting distribution and glare control. They are currently monitored in terms of ambient conditions and energy consumption.

A brief preliminary analysis of pay-back time of BMS installation cost is discussed.

Figure 1 – 1 Peking Road, high rise double skin façade building (Hong Kong)

1. INTRODUCTION
The integrated approach when designing building envelopes and plants is becoming increasingly important since the trend of construction company strategies on the market is providing a whole building technology, and not selling façades or building components only. Moreover, due to the new building regulation restrictions undergoing in many countries, low energy architecture is a central issue in the whole building construction debate. Therefore the energy strategies for heating and cooling, for shading device management, façade ventilation and artificial lighting control represent the chance to get the optimum solution to reduce energy consumption and running/maintenance costs.

The present paper describes, through examples of realised buildings, different advanced double skin façades and the possible integration with smart systems, to control and monitor the different building functionalities. In this context, the testing activity on real scale is an essential mean of performance assessment, which aims to test combinations of different possible technologies and assess integrated solution benefits, such as an improved thermal and visual comfort, lower energy consumption and maintenance cost reductions.
2. FACADE TYPOLOGIES

In the last few years the development of new advanced façade solutions integrated with plants has been growing considerably in Europe to combine architectural features and trends (transparent buildings) with new regulations to reduce carbon emissions. As a response to these problems and as a means of realising smooth external surface, double skin façades represent a most valid technology, which is becoming increasingly common and diffused. Whereas external shading devices are the most efficient in terms of solar control they pose a series of problems related to wind resistance as well as costly installation and maintenance, especially for high rise buildings. The principle of ventilated double skin façade is to position the shading devices between two layers of glazing (the “double skin”), capturing the energy trapped in the cavity. The energy can be expelled in periods with high solar gains and cooling demands, or recovered in periods with heating demands. Four façade categories are briefly described:

- **Conventional (fully glazed) façade:** this base case incorporates insulating glazing units and either external or internal shading devices. Coated glass is used to modify thermal and solar glazing performance.

- **Naturally ventilated façade:** the glazing configuration is composed of an external single layer of glass and an internal insulating glazing unit. The cavity between the two skins is naturally ventilated with outdoor air, which comes up through the base of the glazing and returns to the outside at the top.

- **Active Wall façade (figure 2 - left):** the glazing system is composed of an external insulating glazing unit and an internal single layer of glass. The cavity between the two skins is ventilated with return room air, which is extracted from the room at the base of the glazing and returned to the air-handling unit at the top.

- **Interactive Wall façade (figure 2 - right):** in this case the glazing configuration is composed of an external single layer of glass and an internal insulating glazing unit. The cavity between the two skins is ventilated with outdoor air, which is introduced at the base of the glazing and returned to the outside at the top by means of temperature-regulated radial fans located in the upper part of the façade.

![Figure 2 – Simplified scheme of mechanically ventilated double skin facades (Active Wall – left, Interactive Wall – right).](image)

The integration between double skin façades and environmental systems mainly results in a reduction of installed power both for heating and cooling, due to a reduced U-value, a lower solar factor when needed (SHGC) and a potential heat recovery (Colombari, De Carli, 2003). The system performance depends on numerous design parameters (glass types, blind type/setting, airflow rates and panel geometry), nevertheless, in order to allow a rough comparison, a set of indicative performance parameters is given in the following table. (Zobec et al., 2002).
### Tab. 1 - Overall indicative performances of different façade typology

<table>
<thead>
<tr>
<th>Facade typology</th>
<th>Light transmission</th>
<th>Solar Factor</th>
<th>Thermal transmittance</th>
<th>Acoustic insulation¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully glazed conventional façade (high performance glazing)</td>
<td>( \tau_{\text{vis}} )</td>
<td>( \text{SHGC}^2 )</td>
<td>( U )-value</td>
<td>( R_w )</td>
</tr>
<tr>
<td></td>
<td>[( - )]</td>
<td>[-]</td>
<td>[W/(m(^2)K)]</td>
<td>[dB]</td>
</tr>
<tr>
<td>Fully glazed conventional façade</td>
<td>0.50 - 0.60</td>
<td>0.30 – 0.40</td>
<td>2.0</td>
<td>32-36</td>
</tr>
<tr>
<td>Externally shaded</td>
<td>0.50 – 0.70</td>
<td>0.05 – 0.25</td>
<td>2.0</td>
<td>32-36</td>
</tr>
<tr>
<td>Naturally ventilated</td>
<td>0.60 – 0.70</td>
<td>0.10 – 0.20</td>
<td>1.4</td>
<td>38-44</td>
</tr>
<tr>
<td>Active Wall</td>
<td>0.60 – 0.70</td>
<td>0.15 – 0.25</td>
<td>1.0</td>
<td>38-44</td>
</tr>
<tr>
<td>Interactive Wall</td>
<td>0.60 – 0.70</td>
<td>0.10 – 0.20</td>
<td>1.3</td>
<td>38-44</td>
</tr>
</tbody>
</table>

### 3. EXAMPLES OF BUILDINGS REALIZED WITH DOUBLE SKIN FAÇADE SYSTEMS

More than 50 projects worldwide have been already realised with a wide range of building geometries and double skin façade solutions. Often the advanced façade solutions are realised in conjunction with innovative HVAC concepts as shown in the following examples (Architectural envelopes, Permasteelisa Group, 2003).

**Moor House, 119 London Wall – London (U.K.)**

*Architect: Foster and Partners - Engineer: Ove Arup and Partners*

The 19-storey high office building is placed on a prominent site at the corner of London Wall and Moorgate in the City of London. The east façade is a sloped Active Wall from level 9 to 16, which is characterized by a strong architectural inclined/curved gutter all height long, as shown in figure 3.

![Figure 3 – Active Wall facade of Moor House in London (Foster and partners).](image)

¹ The sound insulation mainly depends on glass thickness, air space of insulating units, pvb typology, façade dimensions and all specific project design details.

² Solar Heat Gain Coefficient.
Manulife Financial – Boston, MA (U.S.A.)
Architect: Skidmore, Owings & Merrill, LLP - Engineer: Skidmore, Owings & Merrill, LLP

The building comprises 4 levels of subgrade parking with 15 levels of office floors and a mechanical penthouse above grade. The total gross area is 440,000 m². The design for the exterior skin of the building is 19500 m² Active Wall, which utilises the false ceiling as an exhaust air plenum. Specific testing have been carried out to assess the feasibility of the overall integration of façade and air handling unit. The project will be registered with the United States Green Building Council (USGBC) to be a Leadership in Energy and Environmental Design (LEED) Certified Building.

Levine Hall – Philadelphia, PA (U.S.A.)
Architect: KieranTimberlake Associates LLP - Engineer: CVM Engineers, Vanderweil Engineers, Arup

The exterior of Levine Hall has been designed in response to existing site conditions and context, while establishing an appropriate character for the University of Pennsylvania’s School of Engineering. Whereas adjacent structures are clad primarily in red brick, Levine Hall is articulated as a glazed pavilion, presenting luminous façades to the University campus and an adjacent courtyard. These façades were constructed using Active Wall curtain wall system in a composition of transparent and translucent glass with golden section derived proportions. Levine Hall provides approximately 4,500 m² of new space, housing offices, labs and conference facilities for the Computer and Information Science Department as well as a 150-seat auditorium.
Jiu Shi Headquarters – Shanghai (P.R. of China)

The large tower on the historic Bund in Shanghai adopts an Active Wall technology, thus representing one of the most important examples of high rise double skin façade technology in Asia. The building is equipped with 1300 blind motor controllers on LonWorks communication protocol technology.

1 Peking Road, Commercial & Office Building – Hong Kong (P.R. of China)
Architect: Rocco Design Limited - Engineer: WMKY Architects – Engineers Limited

The project is located in the heart of Tsim Sha Tsui on Kowloon peninsula – one of the most famous touristic places in Hong Kong. This complex comprises 4 levels of shopping malls, 8 levels of restaurants and 14 levels of office floors. The project is a computerised-controlled Active Wall building (23,000 m²). It incorporates a range of environmental features such as solar shading, light reflectors and ventilated façade system that ensures maximum user comfort and energy efficiency. Curtain wall is fitted with light and thermal sensors to activate the venetian blinds. The south façade terminates at the rooftop with a series of elegantly designed photovoltaic glass panels for auxiliary power generation.

The building is orientated to maximize harbour view with minimal east and west facing façades. Most effective shading device for west/east facing façade are realized with horizontal sunbrakers with internal perforated blind, while maintaining maximum view. Active façade system utilization allows clear glass to achieve maximum transparency and solar control. Light shelves/shading device configured to allow better daylight distribution into rooms.
Many Active Wall façades have been realised also in Italy (below two images of Italian projects in Vicenza (left) and Udine (right), where climatic conditions are particularly hard in terms of solar gains.

**Figure 8 – Active Wall façade of Maier Research HQ in Vicenza (left) and RIF building in Udine (right).**

**STMicroelectronics – Geneva (Switzerland)**  
*Architect: A.M.A. Group - Engineer: A.M.A. Group*

A&M architects have designed for STMicroelectronics (ST) – one of the largest semiconductor companies in the world - a new European headquarters sensitive to sustainability issues. The building was developed adopting the *Interactive Wall* technology (15,000 m²) that allows a high level of transparency without compromising the occupant comfort and the energy consumption (The Plan, 2003). Acoustic measurement on site have demonstrated high level of sound insulation ($D_{nT,w}=50$ dB), due to the double skin effect.

**Figure 9 – Interactive Wall facade of ST Microelectronics - Geneva (AM Architects- Rome).**

Many other Interactive Wall buildings are under construction also in Italy, such as the new Electrolux headquarters in Pordenone, the new Permasteelisa headquarters in Vittorio Veneto (TV), and the new Vicenza Business Tower (VI). All these mentioned buildings adopt BMS standard technologies.
4. BUILDING AUTOMATION CHALLENGE
As previously mentioned double skin and other advanced facades can guarantee an improved energy and occupant comfort performance. In order to get a considerable benefit of the potential function of an advanced façade, the mechanical ventilation, the lighting control and the heating/cooling systems need an integrated design. In practice the real overall performance depends very much on each subcomponent status during the operational time of the building (i.e. blinds up or down, blind orientation, ventilation on/off, etc.). One way of achieving this synergy is by using a Building Management System (BMS). One of the most important advantages of adopting a BMS is that the building adapts to different operating scenarios, according to the required functions, for example:
- comfort user mode, where the priority is thermal comfort and glare automatic control;
- energy saving mode, for free heating in winter and solar protection in summer;
- Combined, high performance mode, operating with both previous modes, in relation to the presence of occupants in the building (occupancy sensor dependence).

Therefore a BMS can contribute significantly to an optimisation of energy, thermal, lighting and glare comfort, integrating also other different building functionalities, such as fire alarms, access control, internal video cameras, etc. Everything is integrated and supervised within the same system, with simple BUS line network. Each component (controller, motor, switch, PC, etc.) represents a node, has a proper ID code and is running within the BUS line. In order to be able to connect on the same network different components, a standard communication protocol is necessary, because many different signal types move and exchange information, such as temperatures, switch status ON/OFF, operation input, etc. The nodes can be temperature sensors, actuators or intelligent self-decision devices. The supervision can be made by means of a PC with specific “bridge” component between LAN and BUS networks. Different architectures of the network are possible, such as star, loop, etc., depending on the BMS firmware choice and specific project characteristics. There are two main protocols available on the market, which are the American LONWorks (Local Operating Network) and the European EIB (European Installation Bus). The differences between these systems consist mainly in the number of possible nodes on the network and communication speed. These differences result in having LON or EIB according to the different project dimensions. In USA market BMS technologies are mainly addressed to HVAC system whilst in Europe are also involved in many other applications. When designing bus line networks, a general remark is that it is often very difficult to obtain full compatibility of different systems, even if each of them is declared standard protocol compatible. The reason of this not full compatibility can be found in component supplier market strategies on one hand and in insufficient standardization of “LON/EIB certified” component requirements on the other hand.
In order to test different technological combinations and communication protocols of facades/systems and their consequent benefits, fourteen full-scale test rooms located in San Vendemiano (TV, Italy) are currently monitored in terms of energy consumption, ambient temperatures and humidity as well as surface temperatures across the façade and transmitted solar radiation. A meteorological station on the roof of the building records the climatic conditions. Hence, energy measurements are produced in conjunction with an assessment of occupant thermal and visual comfort. A description of these facilities is available in (Zobec et al., 2002) together with the acquisition system details and the measurement techniques. The test rooms are equipped with advanced BMS solutions thus representing an efficient full-scale tool for detailed analysis of different building integration strategies, combining shading device management with heating and cooling systems, natural and artificial lighting distribution and glare control. The aim is to investigate and monitor the difference between BMS and not BMS buildings.

![Figure 11 – External view of the two new test rooms 05 (left) and 12 (right) at Permasteelisa Campus.](image)

In particular the research activity is now focusing on the two test rooms recently realized: test room 05 (figure 11) is equipped with an Interactive façade, a radiant plasterboard ceiling (Messana, 2003), automatic blind control and dimmered lighting. Test room 12 adopts a HVAC system which consists of dynamic beams with separate control for façade and core zone and EIB protocol blind control. The undergoing activity in the new test rooms (beyond the scope of this paper) is to analyse and develop new strategies and technologies combining energy efficiency issues and occupant comfort requirements. In order to evaluate the convenience of adopting a BMS, as preliminary case study, the payback time of the BMS cost investment (approx. 200,000 Euro) has been analysed for the new Permasteelisa Headquarters in Vittorio Veneto (TV – Italy). As general approach, the different savings adopting the BMS have been quantified as percentage of the initial and running cost, as follows 3:

1. Longer life-cycle of the HVAC systems (5 years longer due to improved maintenance);
2. Energy saving due to external conditions dependent control parameters and system general optimisation (10% yearly reduction);
3. Energy consumption reduction due to an improved use of natural light, which results both in electric energy saving and in cooling demand reduction due to lower internal gains (the 10% saving rate considered in this analysis is still to be validated by the new test room results, together with software simulations);
4. Maintenance cost reductions, both in terms of materials (4%) and in terms of working hours (11%). In fact the possibility of monitoring the different building components like HVAC, blind motors, façade fans, etc. allow programmed and efficient maintenance. For example rain sensors and wind speed anemometers allow intelligent use of external shadings to prevent resistance problems and guarantee longer life-cycles.

---

3 Assumed discount rate 5%.
In Figure 12, it is possible to see how the investment is rescued in less than 5 years (dotted curve). An other important consideration is that the increased productivity due to a better environment and a higher thermal and visual comfort results in higher concentration at work, time saving for end-users and it is an important issue under analysis by several scientific centres (Wyon, 1996, 2001). If an increased productivity of 0.5% of the employees is taken into account, the pay-back time is even less than two years.

Next future research issues are the development of intelligent control systems which learns from the occupants interactions with the controls of façade and HVAC settings. Nevertheless, many other building automation technologies are already available on the market such as vocal controls, radio connections and meteorological dependence HVAC operation (for example external temperature control and modulation of supply hot/cold water); moreover, remote control and alarming, sun sensors for solar control and sun-tracking with variable setting blind adaptation, internal light sensors, infrared local control, occupancy sensors, etc.

7. CONCLUSION
Different advanced façade systems have been introduced in this paper and the current research activity is discussed with particular attention to double skin facades and their integration with environmental systems. Particularly high-performance advanced façades may lead to reductions in required mechanical plant capacity and potential application of alternative solutions, such as ‘soft cooling/heating’. A performance comparison has been shown between advanced and conventional façade solutions.

Some examples of buildings realised with transparent ventilated double skin facades have been described with the different possible integration with environmental systems. Moreover, fourteen full-scale test rooms have been set in Vittorio Veneto (TV – Italy) to test different technological combinations and are here introduced. The goal of these testing facilities is validating BMS communication protocols both in terms of hardware and software, and quantify the benefits of occupant visual and thermal comfort and energy savings.

---

The increased productivity has been estimated as percentage of the overall employees cost per year: 600 employees, 1750 hours/year per employee, 20 Euro/hour.
As preliminary analysis some consideration have been assumed to evaluate a possible pay-back time for a BMS cost investment.

Decision-makers should therefore be aware that the whole life costing of the building service need to be taken into account. The purchase decision has to move away from the lowest tendered costs with the focus being more on the cost in use benefits whoever the tenant is going to be. This issue is particularly relevant but difficult to achieve especially if the building is to be sold thereafter.

As final remark, it must be observed that energy-efficient building and office design offers the possibility of significantly increased worker productivity, which is a key factor to evaluate the overall impact of advanced building technology and BMS strategies.

AKNOLEDGMENTS
The help of Lorenzo Zanardo is greatly acknowledged, as well as the contribution of Jean-Pierre Peillon and Philippe Deloison (SOMFY – France).

REFERENCES


BIBLIOGRAPHY

www.permesteelisa.com