Paper presented at **The whole-life performance of facades**
University of Bath, CWCT, 18/19 April 2001, Bath, UK

Monitoring of Advanced Facades and Environmental Systems

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ABSTRACT

Transparency in architecture is desirable for many reasons. In order to build transparent buildings with high levels of occupant comfort without compromising energy performance, facade technology and integration of facade and environmental systems become still more advanced. The present paper deals with the performance of facade and environmental system combinations. A case study is presented, illustrating potential benefits of careful application of the available technologies adopting an integrated approach from the early design phases. Moreover, the paper gives an introduction to Permasteelisa's efforts to test and demonstrate the performance of various facade and environmental system combinations. A series of full-scale test rooms are being continuously controlled and monitored in terms of energy consumption and indoor environment.

INTEGRATED BUILDING ENVELOPE AND ENVIRONMENTAL SYSTEM DESIGN

Transparent building envelopes

Transparency in architecture has always been desirable and the problem has always been to realise a transparent building envelope without compromising energy performance and indoor climate. For years the development of advanced facade and environmental systems has aimed at creating fully glazed buildings with low energy consumption and high levels of occupant comfort. Ventilated double skin facades reducing solar gains in summer and providing thermal insulation in winter is an example of a technology, which is becoming still more common.

Permasteelisa R&D

Permasteelisa is a worldwide leader in design, fabrication and installation of custom made architectural envelopes. The group of companies has realised hundreds of prestigious buildings all over the world – typically 'tailoring' the envelope to meet the architectural intentions.

Permasteelisa is continuously striving to improve the performance of the solutions. Development of ventilated double skin facades is part of this process. In recognition of a series of problems with the naturally ventilated facade – especially in hot climates - Permasteelisa has developed a compact, unitised double skin facade system, which is integrated with the mechanical system of the building and ventilated with room air. The Active Wall has been used with great success for more than 40 large scale, prestigious buildings all over Europe.

Furthermore, over the past couple of years, Permasteelisa's research department has successfully developed the Interactive Wall - another member of the family of mechanically ventilated double skin facades. This unique type of facade is mechanically ventilated with outdoor air and needs no integration with the mechanical system of the building. Due to its excellent solar performance, the Interactive Wall is recommended when cooling is a major concern (a solar factor as low as 8% is realised without use of external solar shading).

Integrated design

Intelligent application of advanced facade technology in conjunction with innovative environmental systems results in significant energy savings and – at the same time – improvement of indoor comfort. It has been shown that, when designed carefully, innovative systems do not represent additional initial costs, running costs are lower and energy costs can be reduced by approximately 30% compared with conventional solutions.

> *Successful application of these systems depends closely on the adoption of an integral design approach from the early, schematic phases of a given project*

Too often the facade design is developed when fundamental decisions, for instance pertaining to the layout of the ventilation system, have already been taken. At this point it can be too late to benefit fully from application of advanced facade solutions. If facade and environmental system are engineered as two parts of the same solution, not only will the performance most likely be superior – both initial and running costs may moreover be reduced significantly.

To this end, there is a need for a change of approach bringing together facade- and M&E engineers during the early design phases. Moreover – and this is a problem we experience frequently these days – there is a pronounced need for a common language in order to characterise and communicate the performance of innovative systems such as the mechanically ventilated facades. For instance, quantities such as U-value and solar factor are not readily applicable when the facade interacts with the ventilation system, and traditional ways of designing HVAC systems may not be adequate when assessing possible application of innovative solutions such as soft-cooling.

> *There is a pronounced need for a common language in order to characterise and communicate the performance of innovative systems such as the mechanically ventilated facades*

www.BuildingEnvelopes.org

Apart from a continuous effort to communicate various system properties to other parties of the construction process, Permasteelisa has set up a series of full-scale test rooms in order to test and demonstrate the performance of different combinations of facades and environmental systems. In collaboration with the Graduate School of Design at Harvard and MIT, Permasteelisa has moreover taken the initiative to an Internet portal dedicated to Building Envelopes and Environmental Systems. The portal will be realised by a consortium consisting of leading companies in the construction industry, architects, consultants as well as universities and other research entities. The objective is to create a knowledge base and facilitate the integral, cross-disciplinary approach when conceiving architectural projects, in turn leading to sustainable architecture with high levels of occupant comfort without increasing initial and running costs.

CASE STUDY: UCB CENTER, BRUSSELS

Double skin facade in conjunction with chilled ceiling

The following case study has been selected to illustrate the potential benefits of careful combination of advanced facade and HVAC technology. This particular case study describes the ‘happy marriage’ between a mechanically ventilated double skin facade and chilled ceilings as realised in the UCB Center by the architects Assar (Brussels) with the mechanical and structural engineers Tractebel. At a conference in the UCB Center, May 2000, the owner reported the performance and the analyses prior to the realisation of the project were presented.

Originally there was no intention to use double skin facades and chilled ceilings for the UCB Center. The project was proposed with conventional fancoil units. The directors of the UCB (Union Chimique Belge) wished to have transparent facades. Initially the chilled ceiling concept was considered, but rejected because of its limited capacity (soft-cooling) and the south exposure of the glazed main facade. Even with fancoil units, the thermal balance of the system would be at the limit. The architect's wish to increase the glazed area could not be met without introducing external solar shading, which would be in conflict with the whole design philosophy. These considerations lead to the idea of the double skin facade with solar shading positioned in the facade cavity. This type of facade posed an ideal compromise offering a smooth, glazed external surface and, at the same time, providing the necessary solar protection. Mechanical ventilation was required in order to extract the solar heat from the facade cavity, but this was not a difficult problem to solve. Because of the solar protection provided by the ventilated double skin facade, the chilled ceiling (soft cooling) technology now became possible. A comparative cost analysis of the alternative solutions was carried out [Marcq & Roba, 2000]. Both initial costs and expected running costs were compared. The conclusion of the study was that the solution with double skin/chilled ceiling resulted in better comfort and did not result in higher initial costs, compared with a solution based on conventional facade and fancoil units. The building has been in use for two years, and the expected advantages have all been confirmed [Vervaeck, 2000]:

- Transparency, better view to the exterior, which is particularly appreciable because of the nature surrounding the building.
- Thermal comfort, summer and winter, without draughts and fancoil noise.
- Virtually non-existing maintenance of the chilled ceilings.
- Reduction of energy consumption.

Technical details and performance

The double skin facade (Active Wall) of the UCB Center is composed of an external double glazed unit with a U-value of 1.3W/m²K, a 143mm deep, mechanically ventilated cavity and a clear single layer internal glazing. Motorised blinds are positioned in the ventilated cavity and controlled depending on the solar irradiance. The airflow rate is 40m^3/h per module (width 1.5m) corresponding to 27m^3/hm.

Heating is provided by the supply air, which results in lower installation costs, and means that the glazing can be continued down to floor level (no fancoil units). The ventilation air is re-circulated when the building is not occupied. The temperature of the inlet air is regulated depending on the solar irradiance.

Cooling is provided by means of chilled ceilings operating with water at temperatures between 15°C and 17°C(!). The chilled ceiling is a capillary type in polypropylene, incorporating thermal insulation. The acoustic barrier is horizontal. In order to avoid condensation problems, the ventilation air is dehumidified.

> *Energy savings have been significant. Up to 30% savings on gas, and up to 44% savings on electricity.*

Energy Savings. Gas: BEF 88/m² per year. The normal level for an air-conditioned office lies between BEF 100 and BEF 126/m² per year according to Sogesmaint. The savings amount to between 12 and 30%. Electricity: BEF 357/m² per year. The normal level for an air-conditioned office lies between BEF 580 and BEF 641/m² per year according to Sogesmaint. The savings therefore amount to between 39 and 44% [Caudron, 2000].

The chilled ceiling technology is reducing air movement and increasing occupant comfort. The absence of fancoil units at the facade increases the usable floor area. Utilisation of a static system such as the chilled ceiling leads to better acoustic performance than the dynamic fancoils. Furthermore, the acoustic insulation of the facade is improved due to the extra layer of glazing.

It is important to note that the ‘soft-cooling’ technology, which leads to energy savings, is enabled by the thermal and solar performance of the ventilated facade. The performance is due to the successful combination of these two elements. If the chilled ceiling is to maintain a comfortable indoor environment, the cooling load cannot exceed 70W per m² floor area. In zones with higher cooling loads, such as conference rooms, additional cooling capacity is required.

PERMASTEELISA’S TEST ACTIVITIES

Test room monitoring

At Permasteelisa’s Headquarters in Italy, a series of advanced facade solutions have been realised in conjunction with innovative environmental systems. Currently, a total of 10 full-scale test rooms are being continuously monitored in terms of energy consumption and indoor environment and another 4 rooms are in progress. The measurements will enable a direct comparison between different solutions exposed to identical climatic conditions and provide a basis for validation of both simplified and detailed engineering tools.

The building envelope configurations comprise double skin walls (naturally ventilated, mechanically ventilated indoor-indoor and outdoor-outdoor) demonstrating stand-alone systems as well as integration between facade and environmental system. The environmental systems comprise variations of radiant systems as well as displacement ventilation.

For comparison, the innovative systems are installed side-by-side with conventional systems adopting high performance glazing and fancoil cooling/heating.

Measured parameters

Generally speaking, all of the rooms are continuously monitored in terms of energy consumption, ambient temperatures and humidity as well as surface temperatures across the facade (and cavity air temperatures when applicable) and solar radiation transmitted through the facade. Moreover, daylight measurements can be carried out in one room at a time. A meteorological station records the climatic conditions from the roof of the building.

Measurements in each room

- Room ambient temperatures (3 heights, 3 distances from facade)
- Facade surface temperatures (3 heights on the different layers of the facade)
- Facade cavity temperatures, when applicable (3 heights)
- Room ambient humidity
- Transmitted solar radiation through facade
- Outlet/inlet airflow rate and temperature
- Outlet/inlet water flow rate and temperature (hot and cold water)

Outdoor climate

- Total solar irradiance (on vertical)
- Long wave irradiance (on vertical)
- Illuminance (on vertical)
- Drybulb temperature
- Relative humidity
- Wind speed and direction

Mobile measurements

- Indoor illuminance (3 positions)
- Room ambient temperatures (3 positions)

Apart from providing a basis for assessment of system performance and direct comparison between different solutions exposed to identical climatic conditions, the measurements will yield a basis for validation of simulation tools. The data will prove useful for validation of both existing and future software tools.

Publication of results

The monitoring/control system has been operating since the summer of year 2000. Preliminary results yield trends, while the system is continuously being modified and improved in terms of both control and monitoring. Since the seasonal variations play an important part in the assessment of facade/HVAC performance, long-term measurement is essential. However, already now, studies of specific climatic situations and pertinent system performance are being carried out in collaboration with the MIT and the results will be published. Apart from publications in journals and at conferences and seminars, the results will be published through the architectural Internet portal www.BuildingEnvelopes.org, which is dedicated to building envelopes and environmental systems.

THE TEST ROOMS

Different combinations of facade and environmental system

Initially the test rooms are not occupied and no internal loads are simulated. They are all kept at the same set point temperature and ventilation air is supplied at a rate corresponding to 2 air changes per hour. The rooms, which have radiant systems are being conditioned mainly by means of these, but the air volume can be increased if the capacity of the radiant systems is not adequate, for example during peak load periods.

It is important to note that the objective is to monitor combinations of facade and environmental system technology rather than one of the two.

Room 1: Active Wall and radiant beams

- Double skin facade, ventilated with return room air.
- A transparent roller blind acts as internal skin.
- Radiant beams are installed above the false ceiling.
- A radiant panel provides additional perimeter cooling/heating.

Room 2: Interactive Wall and chilled ceiling

- Double skin facade, ventilated from outside to outside by means of micro fans.
- The fans control the cavity ventilation and switch on when reduction of solar gains is required.
- Chilled ceiling.
- PV-cells are incorporated in the spandrel area.

Room 3: Shading Wall incorporating perimeter air conditioning and PV-louvres

- Naturally ventilated double skin facade.
- Inlet and outlet are controlled according to temperature conditions.
- Ventilation across facade, incorporating local heat exchangers and fancoils for backup (cooling/heating).
- In the facade cavity PV-covered louvres provide solar screening in addition to that provided by computer controlled Venetian blinds.
- Radiant floor.
- The façade-integrated system provides air conditioning for the perimeter zone, whereas the core of the building is set up with conventional air conditioning and radiant floor.

Room 4: Bioclimatic Wall and radiant internal partitions

- Triple layer glazing units.
- External roller blinds.
- On the balcony green plants provide organic shading.
- Cooling/heating is provided by means of radiant internal partitions.

Room 7: Conventional brick wall with windows and fancoil units

- Windows with high performance glazing
- Internal Venetian blinds.
- Traditional fancoils units are situated below the windows.

Room 8: Active Wall and dynamic beams

- Double skin facade ventilated with return room air.
- Venetian blinds are positioned in the ventilated facade cavity.
- Dynamic beams provide cooling/heating by radiation and convection.
- Additional perimeter cooling is provided by means of a radiant panel.
- Artificial lighting is incorporated in the dynamic beams.

Room 9: Interactive Wall and dynamic beams

- Double skin facade ventilated from outside to outside by means of micro fans.
- The fans control the cavity ventilation and switch on when reduction of solar gains is required.
- Venetian blinds are positioned in the ventilated facade cavity.
- Dynamic beams are incorporated in the false ceiling.

Room 10: Shading Wall with roller blinds, incorporating perimeter air conditioning

- Naturally ventilated double skin facade.
- Inlet and outlet are controlled according to temperature conditions.
- Ventilation across facade, incorporating local heat exchangers and fancoils for backup (cooling/heating).
- Solar shading is provided by a roller blind in the facade cavity.
- Radiant floor.
- The façade-integrated system provides air conditioning for the perimeter zone, whereas the core of the building is set up with conventional air conditioning and radiant floor.

Room 11: Bioclimatic Wall, displacement ventilation and radiant ceiling

- High performance glazing
- Wide, external Venetian blinds.
- On the balcony green plants provide organic shading.
- Raised floor and displacement ventilation.
- Radiant ceiling (micro tubes embedded in ceiling).
- Pipes on top of the floor slab under the raised floor cool/heat the concrete, utilising the thermal mass.

Room 14: Conventional, fully glazed curtain wall and fancoil units

- High performance glazing.
- Internal roller blinds.
- Conventional fancoil units are situated in the perimeter zone.

Technological Campus, mock-up display

Apart from the test rooms, the technological campus comprises a collection of more than 30 full-scale visual mock-ups, all realised and tested by Permasteelisa. After testing in Permasteelisa's own test-rig, the most spectacular examples are put on display.

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