Beyond the Intelligent Façade

CIBSE

Friday, 5 February 1999
CIBSE Building Services Engineering Centre

CIBSE Skills Course
CIBSE
Registered Charity No. 278104

Tel: 0181 675 5211
Fax: 0181 675 6554
Email: info@cibse.org

Beyond the Intelligent Façade

Programme

09.30 ***Registration and Coffee***

10.00 **Chairman's Introduction**
Paul Langford - *Colt International*

10.15 **Photo Voltaics: An Architectural Feature**
David Lloyd Jones - *Studio E Architects*

10.45 **The Intelligent Building Skin: A Case Study Review**
Jude Harris - *Jestico + Whiles Architects*

11.15 ***Coffee***

11.35 **Automated Shading Devices: Control Issues**
Mark Skelly - *Centre for Window and Cladding Technology*

12.05 **Transparent Solar Shading**
Robert Buck - *Colt International*

12.35 ***Lunch***

13.30 **Air-Lit -PV: A European Research Programme on Intelligent Façade Development**
Paul Langford - *Colt International*

14.00 **Electro-Chromic Glazing for Improved Indoor Comfort**
Michael Hutchins - *Oxford Brookes University*

14.30 **Photo Voltaics for the Next Millennium**
Paul Baker - *BRE Scotlab*

15.00 ***Tea***

15.20 **Beyond the Intelligent Façade: An Open Discussion**

16.00 ***Close***

Beyond the Intelligent Façade Seminar

Photovoltaics: An Architectural Feature

David Lloyd Jones
of Studio E Architects

PHOTOVOLTAICS: AN ARCHITECTURAL FEATURE

David Lloyd Jones AA Dip RIBA FRSA

Studio E Architects Palace Wharf Rainville Road London W6 9HN UK
Tel: +44 171 385 7126 Fax: +44 171 381 4995 e-mail: studioearchitects@btinternet.com

With photovoltaics (PV) architects are not quite sure what they have got hold of. Is it a building component (or an assembly thereof)? Is it a building system? Is it a tool for social change? Or is it a force for architectural expression? This uncertainty becomes clear when one looks at recently constructed buildings that incorporate photovoltaics.

One thing is evident; with the step change in corporate investment and the hike in government backing, photovoltaics will, at some point, become a viable building integrated energy source in the same way that stand alone systems are now an every day and unremarked upon feature in the landscape of both developed and developing countries.

Building integration of photovoltaics is promoted on the basis that some of the costs of the installation can be offset against costs of materials and components it replaces in the building envelope. This may be the case in retrofit situations,but, in new build these savings have yet to be demonstrated. The force for integration is, in fact, not an economic but an architectural one. Designers, in the past, have taken on board new technologies and, once they have been proven, have been absorbed into the prevailing architectural vernacular. In this way the steel frame dematerialised the perimeter wall, the elevator permitted the skyscraper, and air conditioning allowed the deep plan. These technologies are part and parcel of building design. They cannot exist otherwise. It is clear that PV has the potential to make a similar impact on building; and, in order to create buildings that are effective both in function and form, it will be deployed by architects as any other construction element: as an integral part of the overall design.

The impact of PV on building design is not just its physical incorporation into the building envelope, it effects the whole process:

- Urban design
- Massing and layout
- Building fabric
- Building systems
- Internal comfort
- Mood and feeling

The presentation will explore these aspects of PV integration.

Beyond the Intelligent Façade Seminar

The Intelligent Building Skin: A Case Study Review

Jude Harris
of Jestico + Whiles Architects

The Intelligent Building Skin: A Case Study Review

Jude Harris BSc BArch

Jestico + Whiles Architects, 1 Cobourg Street, London NW1 2HP
tel: 0171 380 0382 fax: 0171 380 0511
e mail: jude@swone.clara.co.uk/j+w@jesticowhiles.co.uk

ABSTRACT

The idea of the 'Intelligent Building' has achieved a certain currency in the last few decades. With concepts such as 'smart materials' it represents the introduction into design principles of self-adjustment and response. Not all the applications of such terminology have equal legitimacy, and there are as many uses that are based on marketing as are based on a true application of the labels used.

In this paper it is assumed that the Intelligent Building is based on a very different paradigm to that which is conventionally understood. There is a much closer comparison with the biological notion of intelligence and response, such as is seen in the natural intelligence of the human body, and the science of Artificial Intelligence.

A redefinition of the term acknowledges a closer kinship with natural biomorphic systems, such as the thermo-regulatory powers of the human skin, the seasonal changes of coat in many mammals, and the opening and closing of flowers in response to sunlight. As such, it is defined as a building with the ability to know its configuration, anticipate the optimum dynamic response to prevailing environmental stimuli, and actuate the appropriate physical reaction in a predictable manner. It is expected that the system will strive to exploit the use of natural forces and minimise the need to import energy from non-renewable sources. The truly Intelligent Building is therefore endowed with some of the human characteristics that give it the ability to learn, adjust and respond instinctively to its immediate environment in order to provide comfortable internal conditions and use energy more efficiently.

The emphasis is on the 'active' control of the functions that the building façade performs. This is very different to the conventional architectural approach that seems to have prevailed in the environmental design of buildings, which in the past has adopted a solely 'passive' approach. More 'active' design features are required to reverse the inertia of buildings, by giving them the capacity to respond dynamically to the variations of climate, occupancy and use.

Buildings are static, inanimate objects that move only slightly in response to structural and thermal stresses. Climatic conditions vary between morning and afternoon, between day and night and between the seasons. Yet one of their primary functions is to protect occupants from the extremes of climate, and as such provide the interface between internal and external conditions. There are also marked differences in climate between different locations around the globe, and these may become more pronounced as a result of global warming. It was Darwin who held that the capacity to survive depends on the ability to adapt to a changing environment.

The case study examines a selection of buildings that have employed such 'active' and responsive controls to reduce energy consumption, increase user control, optimise internal comfort and generate electricity. This work is part of an ongoing research programme at the

University of Plymouth School of Architecture, which is attempting to establish the criteria, mechanisms and design methods related to the Intelligent Façade (Wigginton, 1995).
It is not anticipated that any of the buildings presented in this early stage in the evolutionary process of the Intelligent Building can be regarded as *truly* intelligent. Instead, the buildings in the Case Study provide clues as to what might be called the 'genetics' of this new generation of buildings. The purpose of the case studies is to describe the range and variations of intelligent technologies employed to moderate energy flows through the building envelope, demonstrating how such dynamic response mechanisms have been incorporated into the design and construction of a number of buildings in the past 20 years.

The 'Intelligent Façade' is an intrinsic constituent of the Intelligent Building, and concerns the design and construction of the element that is the single greatest potential controller of its interior environment. The façade can account for between 15% and 40% of the total building budget (Hall, 1997), and may be a significant contributor to the cost of up to 30% more in its impact on the cost of building services. Applying the biological metaphor of the human skin, it seems more appropriate to describe this enveloping membrane as the 'Intelligent Skin', emphasising its close relationship with the natural responsiveness of the epidermis.

The work presented in this paper is predicated on the assumption that the impact of the Intelligent Skin, complementing less complex mechanical and electrical environmental systems, may result in a legitimate redeployment of a building's budget into a more sophisticated and responsive fabric. In addition, reduced capital plant and operating costs, and maybe increased worker productivity can theoretically balance additional costs associated with the use of intelligent technologies.

A measure of the amount of investment needed to maintain internal comfort, even in our own comparatively temperate climate, is seen in the fact that up to 50% of the UK's energy is used in buildings (Shorrock and Henderson, 1990). The amount of energy expended on such systems is enough to have prompted the numerous initiatives into energy saving now current, and more recently underwritten by global imperatives.

The case for the Intelligent Skin is further reinforced by opportunities for increased user control, more precise and predictive maintenance programmes, the optimisation of energy use, and automatic control of increasingly complex building systems. Most significantly intelligence can be used to improve the performance of the building fabric to work much harder in reducing the need for imported energy for heating, cooling, lighting and ventilation.

It is well established that building occupants should be offered maximum personal control over their immediate environment. The variable building fabric can still be effective with manual control, eg curtains and venetian blinds. Unfortunately, this places unsustainable demands on the predictive capability of occupants, and requires their continuous or very frequent presence. The Intelligent Building resolves this difficulty, because it looks after itself, but it can also facilitate (supervised) user control.

With high-technology (moving) parts comes a resultant need for increased maintenance and a greater susceptibility to breakdown. However, this may actually result in the building stock being better cared for. It might bring about improved maintenance and hence longer life to buildings that are notoriously neglected in the current situation. As the Intelligent Building evolves, buildings may be serviced more like cars, and perhaps even match their reliability.

The Intelligent Skin is described as a composition of multi-functional construction elements confined to the outer, weather-protecting zone of a building, which perform active functions that can be individually or cumulatively adjusted to respond predictably to environmental variations. The adaptability of the façade elements is actuated instinctively through self-regulated adjustments to their configuration. Energy flows through the building fabric (in both directions) are autonomically controlled for maximum gain, and minimal reliance on imported energy. The intelligent building fabric offers additional functionality, becoming a flexible, adaptive and dynamic membrane manipulating the external elements for maximum gain, rather than a statically inert envelope that merely permits the flow of energy, often unchecked.

An element of Intelligent Design is assumed as a prerequisite when describing the truly intelligent building, where human designers produce an architecture which is itself intelligent, rather than just an assembly of intelligent components (Kroner, 1997). The idea is to restore the basic priorities of 'Bioclimatic Design' by working in alliance with environmental engineers to achieve interior comfort through responsive climatic design. What the Intelligent Building provides is building morphologies which, both by the shaping of the form, and the application of ingenuity to its fabric reduce the need for importing energy for cooling, lighting or heating.

The Case Study of 23 buildings identified a range of features that constitute built examples of the Intelligent Skin. They provide a depiction of the 'genetic characteristics', which might make up the Intelligent Skin in its fully evolved form.

1. Daylight adjustment	maximise daylight through responsive manipulation
2. Intelligent lighting	artificial lighting responsive to prevailing natural light
3. Controlling the sun	control, moderate and mitigate against (glare) the sun
4. Electrical self-sufficiency	electrical autonomy through self-generation
5. Heating	reduced space/water heating - controlled passive gain
6. Ventilation	automatic regulation for increased effectiveness
7. Cooling	passive cooling, mixed mode and night time ventilation
8. Building management systems	the brain determining the appropriate control response
9. Learning ability	learn thermal characteristics and effective solutions
10. Occupant control	intelligent technologies provide maximum user control

No longer should building 'exclosures' (after Perry) be designed in the same way from America to Zimbabwe, safe in the knowledge that building engineering can battle to overcome the climate. Instead we should 'design with nature', regarding it 'as an ally and a friend' (McHarg). We can learn a great deal from the responsive and adaptive examples that we see in nature and produce intelligently designed 'enclosural' building morphologies, which can reduce the need to import energy.

The ecological goal in building design should be to strive for a reduction in the total primary energy needs to a minimum, and ideally down to zero, by using only renewable resources and incidental heat gains to 'drive' a building's comfort system. By utilising the building fabric itself (the skin), artificial heating, cooling, lighting and other energy intensive systems can be minimised, or avoided altogether. We cannot win a contest with nature, but instead we should learn from its inherent efficiencies and resilient ability to survive millennia.

A Case Study of the Intelligent Skin

First Draft

Jude Harris

and

Michael Wigginton

Intelligent Buildings Research Programme
School of Architecture
University of Plymouth

August 1998

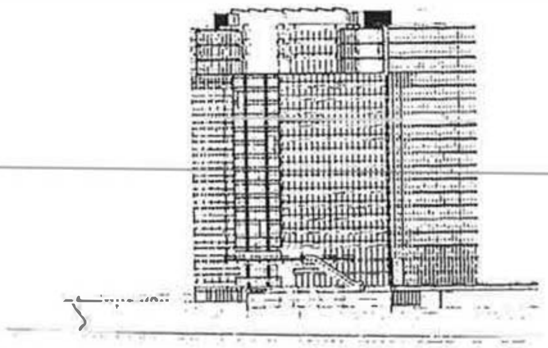
Contents

Stadttor (City Gate) 2

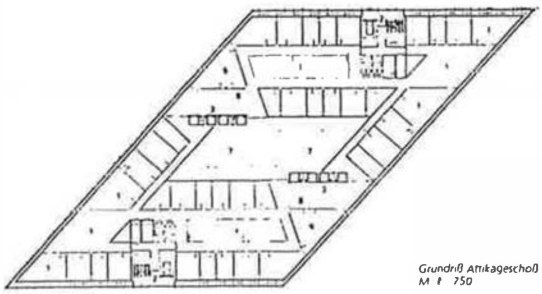
Speculative office development
Düsseldorf
Germany
Petzinka Pink und Partner Architect
DS-Plan Energy Consultant
Engel (developer) Client
1991-1997 Dates
51.29°N Latitude
99°N Primary Axis of Orientation

Intelligent Features

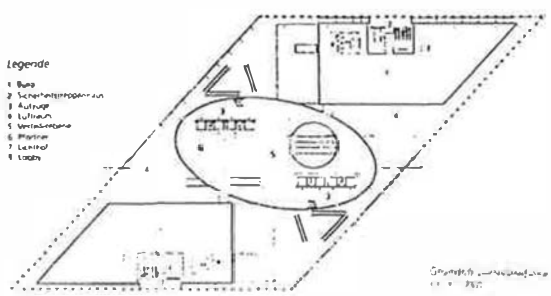
Building Management System	■
Learning facility	
Weather data	■
Responsive lights	
Sun tracking facility	
Occupant override	■
Self generation - CHP/PV/Wind	
Night cooling	■
Solar water heating	



Querschnitt M. 1 : 750



Grundriß Attikageschoß M 1 750



Introduction

A competition was launched in 1991 to explore the possibility of designing a high rise building on top of a new road tunnel, which brings traffic into the centre of Düsseldorf. The competition was won by Ingenhoven Overdiek Petzinka und Partner and built by the re-formed practice of Petzinka Pink und Partner. The new building was to be part of a new 'creative' mile that is proposed for the old harbour with offices, studios, media and advertising developments.

The Intelligence Factor

The building is controlled by a building management system, which determines natural ventilation or mechanical ventilation modes automatically. Natural ventilation is achieved through computer control of ventilation flaps within the depth of the building envelope. Ventetian blinds within the cavity are lowered and raised automatically according to light and insolation levels, and the need for nighttime insulation.

Brief

The Stadttor project is an office building that is designed to give a good quality of light, individual spaces and an attractive working environment. It has been speculatively developed.

Accommodation

The building is composed of two separate rhomboid towers, connected at the top with three bridging levels, defining the top of a huge atrium void, 50 metres high. The top three office floors have their own inner atrium that is lit from a roof light. These were the first floors to be let. The 20-storey building is supported by two vertical triangular trusses, which are connected by the top three floors of office accommodation, forming a structural bridge. The whole building is supported on the subterranean tunnel. A double skin cavity up to 1.4m in depth provides an enclosed balcony for all offices. The office floors are to speculatively let to multiple tenants.

Energy Strategy

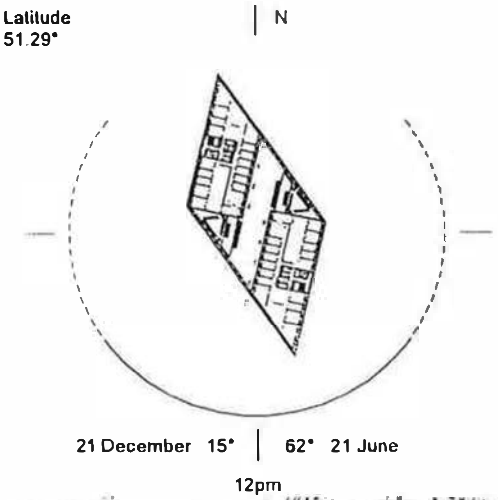
The building is predominantly naturally ventilated through computer controlled ventilation flaps, which run in horizontal bands at each floor level. The building management system has sensors for wind, temperature, rain and sun to exercise optimum control strategies for heating, cooling and fresh air supply. The ventilated double skin limits the required cooling loads, by ventilating away the solar heat build up in the cavity.

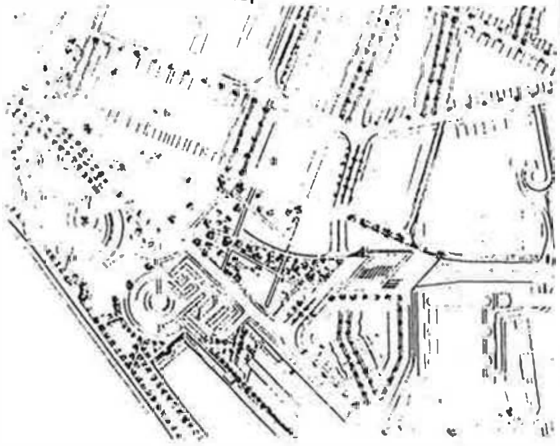
Site and Climate

The tower occupies a rhomboidal site and is split into two parallel towers with an atrium space between, which affords maximum views

2 Stadtlor, Germany, 1997, Petzinka Pink und Partner/DS-Plan

Sunpath



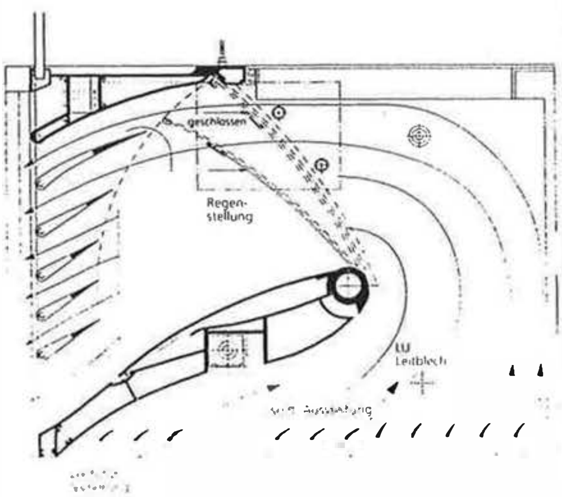


Façade Transparency

North	100%
East	100%
South	100%
West	100%
Roof	22%

U-Values

Double skin (vents open)	1.2 W/m²K
Double skin (vents closed)	1.0 W/m²K
Slab	0.4 W/m²K
Roof	0.1 W/m²K



2 Stadtlor, Germany, 1997, Pelzinka Pink und Partner/DS-Plan

of the city and the river Rhine, which is close to the Stadttor. The site is very exposed, and experiences strong wind speeds.

Construction

The structural frame consists of steel columns filled with reinforced concrete, and composite floors. The outer face of the building is entirely clad with planar glazing panels between horizontal bands of aluminium ventilation boxes.

Glazing

A double skin cavity envelops the three sides of the office floors, creating a ventilated perimeter zone, varying between 1.4m and 0.9m in depth. The outer face of the double skin is 15mm toughened planar glazing. It is a low iron 'opti-white' glass for maximum transparency. The inner skin is made from vertically pivoted high performance timber windows. The full-height double glazing has a low-e coating. The overall energy transmission equates to 50%, without the blinds, and 10% with the blinds lowered. Light transmission through the envelope is 68%. The vertical atrium walls are single glazed with planar glass.

Heating

Heating is provided by a low temperature hot water system, which is fed by a district heating system that uses waste heat from a power station, and is supplied to the building at 100-120°C in winter and 70°C in summer. LTHW is distributed at about 40°C to radiant ceiling panels (metal ceiling tiles with coils behind) and underfloor heating in some areas. The atrium is not heated except for localised underfloor heating in occupied areas.

If the mechanical ventilation is operational (approximately 25% of the time in heating mode), the supply air is pre-heated by a heater battery in the air handling units, which is also fed by the district heating system.

Domestic hot water is heated electrically at point of use.

Cooling

Cool water is supplied from groundwater sources at 8-10°C, which is heat exchanged, stored and filtered in eight tanks in the basement. The water is distributed to radiant ceiling panels at about 17°C.

If the mechanical ventilation is in operation (approximately 5% of the time in cooling mode), the air can be pre-cooled by 'sorptive cooling'. This involves cooling the air with the heat supplied by the district heating network, which would otherwise be waste heat in the summer. Outgoing air is deliberately humidified and heated to condition the incoming air by heat and humidity exchange. Incoming air gives up its heat by heat exchange to the humidification process. There is no active cooling in the form of chillers, condensers or towers.

The regulation of building temperature and humidity levels is assisted through the use of automatically controlled blinds in the double skin cavity.

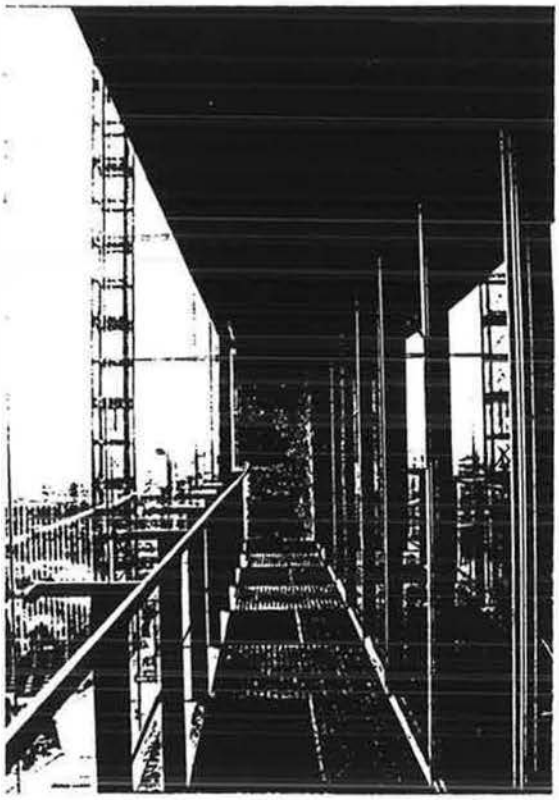
A nighttime cooling facility is available if required. The ventilation flaps are automatically opened and the users leave the inner windows open.

Ventilation

It has been predicted that natural ventilation will be achievable for 70% of the year, when temperatures should be between 5°C and 22°C. For 25% of the year, temperatures are likely to be below 5°C, and pre-heated mechanical ventilation will be used. For the remaining 5%, temperatures are likely to be above 22°C, and pre-cooled mechanical ventilation is needed. Mechanically distributed air

Intelligent Control

	Passive	Manual	Automatic
Daylight adjustment - reflection/protection			
Glare control - blinds/louvres/fixed		●	●
Responsive artificial lighting control		●	
Heating control		●	●
Heat recovery - warmth/coolth			●
Cooling control		●	●
Ventilation control		●	●
Fabric control - windows/dampers/doors			●
Insulation - night/solar			●



2. Stadttor, Germany, 1997, Petzinka Pink und Partner/DS-Plan

is supplied pre-conditioned as described above through ceiling diffuser slots. it is also extracted through the ceiling.

Ventilation boxes at each floor level are integrated into the depth of the façade, with an automatically controlled damper. Alternate boxes act as inlet and outlet vents, with grilles into the cavity from the top and bottom of the box respectively. The flaps can be completely closed or completely open. If it is raining or wind speeds are high, then the flaps are only opened by 10%. After closure, the flaps first open by 10%, and then by the full 100%. In all, there are 3.3 linear kilometres of ventilation boxes in the façade of this building.

For natural ventilation, it is necessary for the users to open their inner windows manually. The ventilation flaps in the outer façade, which admit air into the cavity, are automatically controlled. Outer offices are side ventilated from the double skin cavity, and inner offices secondarily from the atrium.

A red light on the room 'switching' panel notifies users when the mechanical ventilation is in operation, and good practice would result in them closing the inner windows (may need education).

The atrium is naturally ventilated. Four areas of glass louvres provide 40m² of openings in the two end walls. One bank of louvres is situated at the bottom of the glazed wall, and the other at the top. Various control strategies can provide 25%, 75%, and 100% opening. The glass louvres are controlled according to wind speed and direction. In windy conditions, one side can be closed to avoid wind travelling through the building.

Corridors, toilets and conference rooms in the centre of the plan are mechanically ventilated in line with German regulations.

Daylighting

Full-height glazing ensures maximum exposure to daylight, and views over the city. Inner offices are secondarily lit from the atrium, which has fully glazed walls at each end. The top three office floors have their own central atrium, lit from above.

Artificial Lighting

The artificial lighting is not responsive to daylight conditions. Users are responsible for turning lights off when daylight is sufficient. However, there is automatic provision for sweeped shut-down at the end of the working day. A highly efficient light fitting was specially developed, utilising fluorescent tubes to provide both uplighting and downlighting.

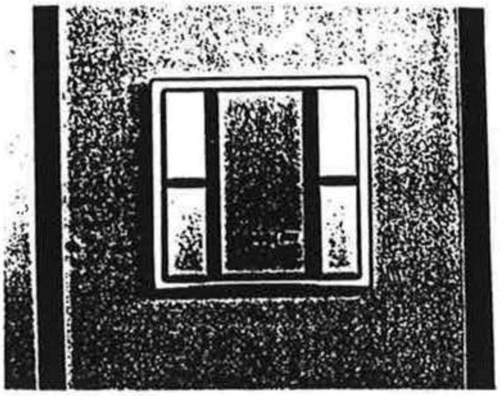
Solar Control

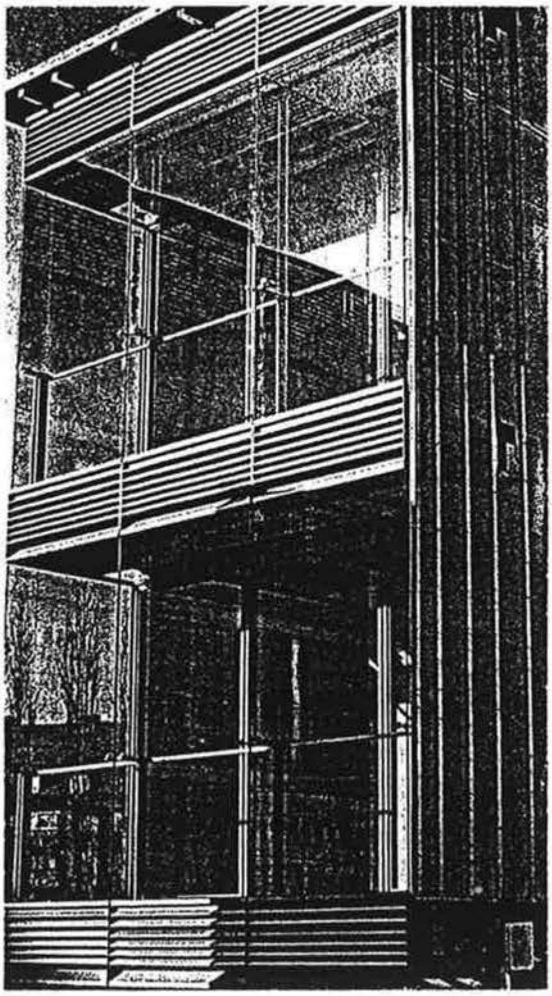
Ventetian blinds are situated 200mm behind the outer face of the building, within the double skin cavity. The blinds are automatically lowered in response to photocell detectors on each façade, which indicate if the sun is shining on a particular building face. Once they are lowered, a second impulse adjusts their tilt to 45°, which still allows daylight into the building, but reduces glare. If the sun is not directly shining on a particular façade, then the blinds are raised. The blinds have three tilting positions, which can be adjusted by the user's light 'switch': completely closed, 45° tilt, and horizontal for the reflection of high summer sun. Users also have the facility to override whether the blinds are up or down through the same switch.

The 1.4m depth of the cavity also provides a degree of solar protection in ensuring that most (high angle) direct sunlight is prevented from entering the inhabited zone.

Controls

A building management system controls the atrium vents, the ventilation flaps, the blinds, lights, mechanical ventilation, heating and cooling, fire and security. A European installations Bus connects the





Building Data

Contract Value	150m GDM
Area m²	40,000m²
Typical Floorplate	16.5m
Number of Storeys	20+B
Price per m²	~£1250/m²
Annual Energy Use	n/a
Typical Energy Use for Building Type	n/a
Annual CO_2 Output	n/a
Number of Sensors	40+
Visited by Authors	✓
Monitored by Others	✓

2. Stadttor, Germany, 1997, Petzinka Pink und Partner/DS-Plan

control system for the lighting and blinds. A separate Bus system is used to control the heating, cooling and ventilating plant.

There are sensors for wind speed and direction, outside temperature, cavity temperatures, outside humidity, global insolation and photocells outside light levels.

The ventilation boxes are controlled according to pressure differentials across the office floors. Pressure difference is limited to 50 Pascals, so that doors are not difficult to open. Air tubes from the façade and atrium connect to a special monitoring facility on the 15th floor. The differential pressure is measured for each side of the building, and the ventilation flaps adjusted accordingly.

User Control

User have a special 'switch' panel by the door, which enables them to turn lights on and off, and adjust the cavity blinds. Room temperature can be varied by ±4 degrees Kelvin by a separate turntable dial. A 'How to ...' booklet provides users with information about the building's operating strategy.

Operating Modes

In winter, mechanical ventilation will operate when temperatures fall below 5°C. The flaps in the ventilation boxes are closed when the mechanical ventilation is in operation. The atrium will be opened periodically to avoid condensation, automatically activated by humidity levels. The atrium vents are only opened at the top, to avoid cold downdraughts. The radiant heating panels will be charged between 6am and 9am, with heating provided by occupancy gains during the remainder of the day. The cavity blinds will operate automatically according to insolation.

At night in the winter, all ventilation flaps are closed, and the cavity blinds can be lowered for additional insulation.

On a normal day, all ventilation flaps are opened unless wind speeds exceed 9m/s. If this threshold is reached, the flaps are damped to the 10% position. If the pressure differential exceeds 50Pa, the flaps are closed. Inner windows are opened according to user desires. If the ventilation flaps are closed a red indicator light notifies users that mechanical ventilation is in operation, and that inner windows should be closed. There is unlikely to be any demand for heating, which will be satisfied by incident gains.

If the outside temperature exceeds 22°C, pre-cooled mechanical ventilation takes over from the natural ventilation. However, the ventilation flaps are kept open to prevent the blinds in the cavity from overheating.

On summer nights, all ventilation flaps are opened for night time cooling of the building structure. Users are asked to leave the inner windows open overnight.

Performance

Monitoring is being performed by DS-Plan. In particular, the performance of the façade is being closely monitored. Tests have shown that air leaving the cavity is 6°C hotter than incoming air, suggesting that it is performing a useful cooling effect on the blinds. Air coming into the offices is only 1°C or 2°C hotter than outside air.

Delivered Energy Consumption

Delivered energy consumption figures are not yet available, as the building is not fully occupied (first tenants moved in February 1998). During the design phase, heating was simulated at 30kWh/m² per year.

Credits

Architect: Petzinka in Overdiek, Petzinka & Partner, Ingenhoven Overdiek Petzinka & Partner, and now Petzinka Pink und Partner
Energy Consultants , Building Physiscists and Energy Monitoring: DS-Plan
Service Engineer: Jaeger, Mornhinweg Partner
Structural Engineer: Ove Arup - Lavis Stahlbau, Drees & Sommer AG
Façade: Josef Gartner & Co, Steiner Infratec
Project Manager: Dress & Sommer
Controls Installor: Johnson Controls International

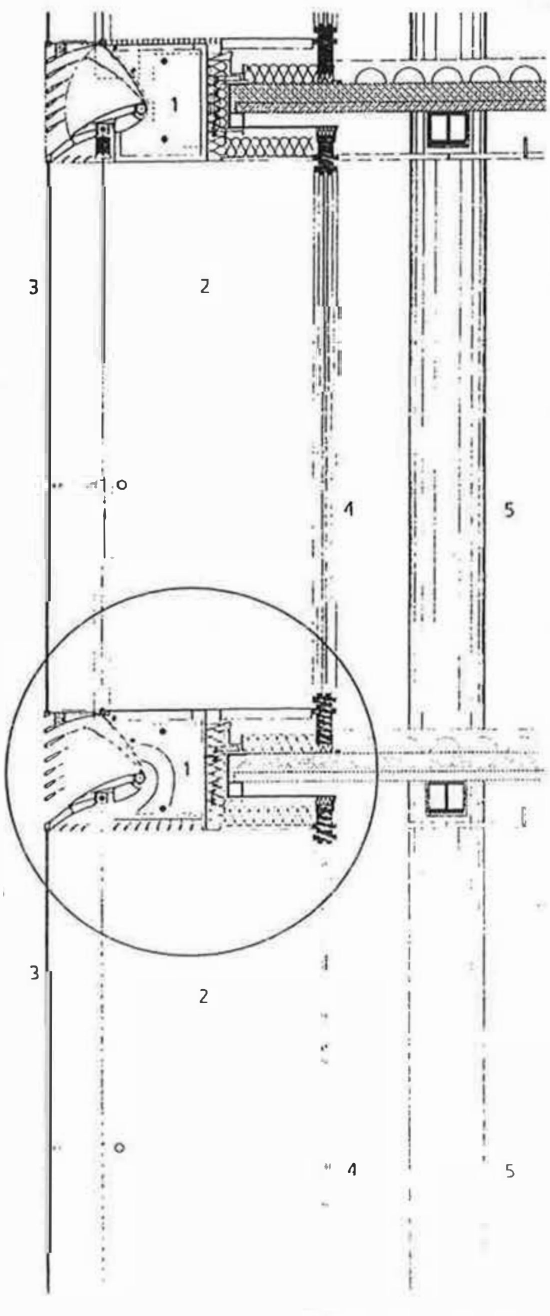
References

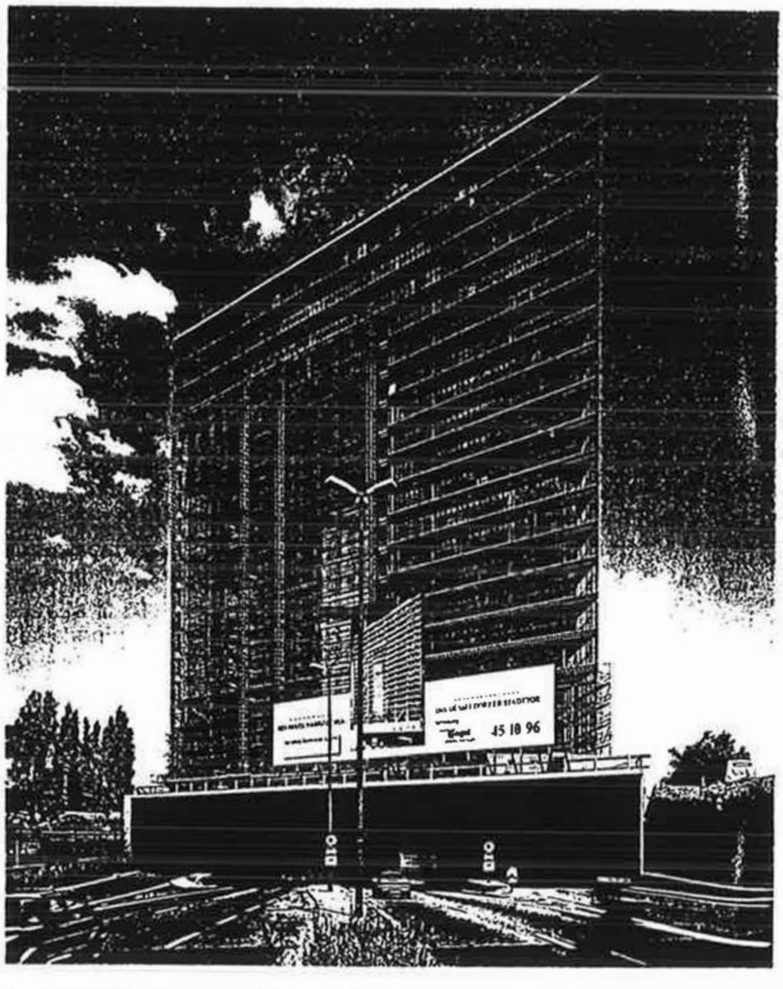
Architectural Design, Vol 66 No 7/8, July/August 1996, 'Architecture on the Horizon', pp36-39
l'ARCA, The International Magazine of Architecture, Design and Visual Communication, June 1993, No 72, 'A Tunnel High Rise', pp40-45, Paolo Righetti
AIT Spezial: Intelligente Architektur 12, February 1998
Prof Dipl Ing Karl-Heinz Petzinka/Thomas Pink/Karl-Martin Selz, Petzinka Pink und Partner
Mr Rolf Lieb, DS-Plan Ingenieurgessellschaft für ganzheitliche Bauberatung-u Planung mbH

Design Process

There were many simulations performed during the design stage, particularly on the ventilation boxes. Thermal simulations were done using 'DS-therm' and computational fluid dynamic simulations were made of the ventilation boxes and the double skin cavities.

Tests were also conducted in the wind tunnel A test cell was constructed by Gartner as a mock-up of the façade. They also performed acoustic tests on the ventilation boxes.





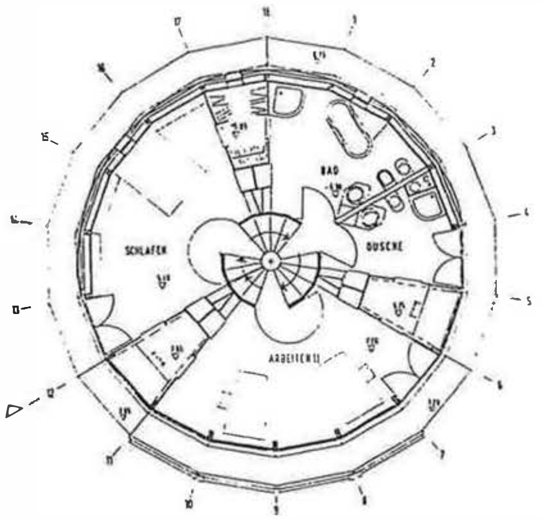
2 Stadtlor, Germany, 1997, Petzinka Pink und Partner/DS-Plan

HELIOTROP® 11

Residential/studio office
Ziegelweg 28
Freiburg-im-Breisgau
Germany (D-79100)
Prof Rolf Disch Architekt Architect
Krebser & Freyler Energy Consultant
Prof Rolf Disch Client
Completed 1994 Dates
48°N Latitude
Variable°N Primary Axis of Orientation

Intelligent Features

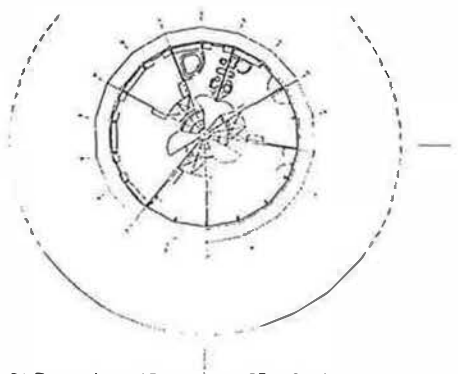
Building Management System	■
Learning facility	
Weather data	■
Responsive lights	
Sun tracking facility	■
Occupant override	■
Self generation - CHP/PV/Wind	■
Night cooling	■
Solar water heating	■



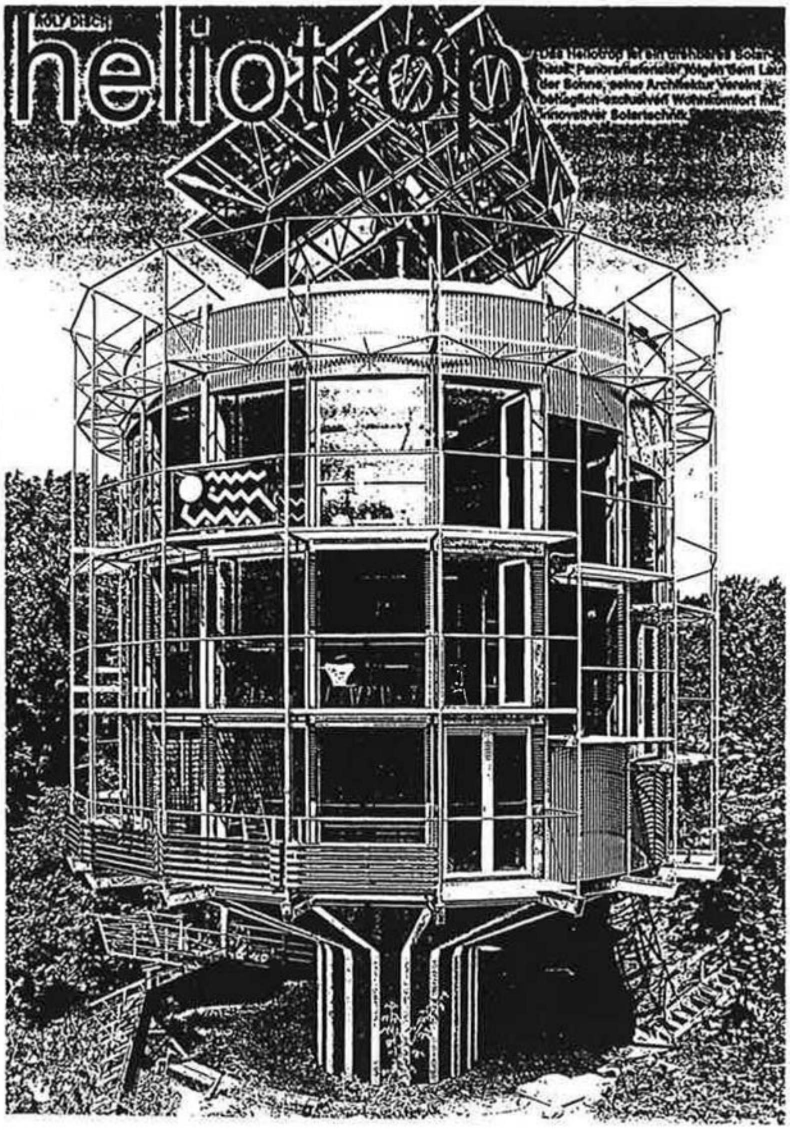
Sunpath

Latitude
48.00°

N



21 December 19° 65° 21 June
12pm



Introduction

This lightweight 'tree house' has been named after the word heliotropism, which refers plants that grow in response to the stimulus of the sun. The wooden structure is cantilevered from a central stair shaft which can revolve the 100 ton house to track the sun, maximising passive solar gains to the indoor spaces and active gains to the evacuated solar collectors mounted on the balustrades. Independent of the main house is a tracking photovoltaic array, which is mounted on the roof. This house was a prototype and there are now others that have been built to similar designs. The Disch office developed the energy concept and architectural planning, and Professor Disch funded the project.

The Intelligence Factor

This is the only case study that is able to vary its orientation in response to the position of the sun. Other features include solar water heating, photovoltaics and an earth heat exchanger. The ventilation and heating input to each room is determined by an 'occupancy switch', which tells the BMS that the room is in use.

Accommodation

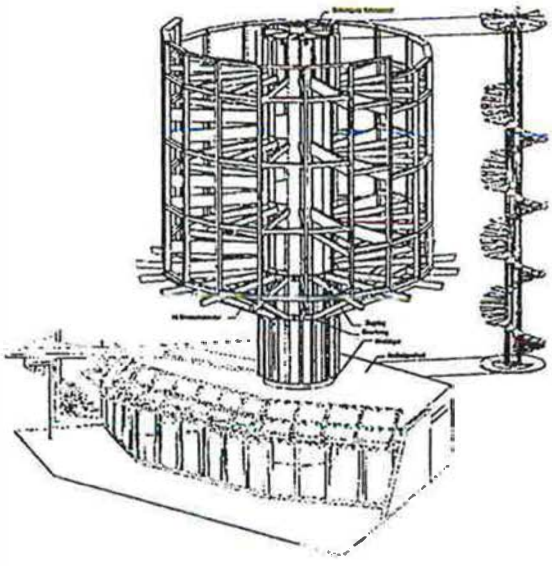
The office area is built into a steeply sloping bank, providing earth-sheltered accommodation at the semi-basement level. The cylindrical timber stair shaft rises from the plant room in the basement, creating a sheltered entry with the main living accommodation towering 14.5 metres above. The principal living spaces are arranged around the central 'trunk' within the 10.5 metre diameter, spiralling up the building to a roof garden at the top. One half of the revolving living

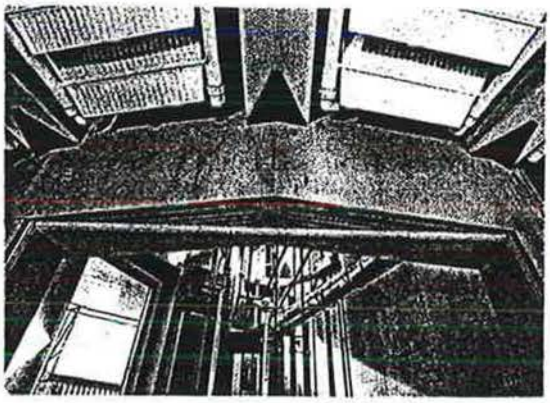
Façade Transparency

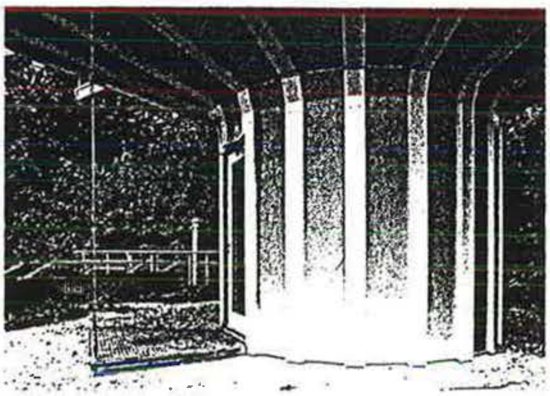
North	20%
South	100%
Roof	0%

U-Values

Walls	0.13 W/m²K
Slab	0.20 W/m²K
Roof	0.13 W/m²K
Windows	0.50 W/m²K







11 HELIOTROP®, Germany, 1994, Prof Rolf Disch Architekt

tower is highly glazed, and the other is well insulated with few window openings. The architect designed the house for himself and his wife, and he has an office in the earth-sheltered basement.

Energy Strategy

The energy strategy aimed to win all of the energy for the house from the sun. It is able to adjust its position according to the need for maximum solar gain, or to turn itself out of the sun for protection. The building has a rotation capability of 400° (+20° either side). The building is programmed to follow the sun by rotating approximately 15° each hour. It stops rotating at sunset, and returns to the sunrise position at 3am each morning. A full 400° revolution takes about one hour. The electric motor that turns the house uses about 120W (at maximum speed), equating to a yearly power consumption of between 20kWh and 40kWh.

Site and Climate

Freiburg is situated at the bottom of the upper Rhine valley and lies on the edge of the Black Forest. It is the hottest place in Germany, with average temperatures of 10.3°C and 4.8 average daily sunshine hours. The typical climate is hot and moist summers and cold fogs in winter. The mean yearly global radiation on the horizontal plane is 1180kWh/m²/a. The degree days are 3400 Kd.

The steeply sloping site had previously been regarded as unusable, and the new tower utilises the site effectively, giving beautiful views over vineyards towards south.

Construction

The timber framework is insulated with 300mm of mineral wool insulation and the opaque elements are covered with corrugated metal cladding. The 2.6m diameter central column was prefabricated, and is made from a faceted array of 18 sheets of laminated timber panels, 111mm thick. The laminated panels are joined together with an epoxy resin and steel ties.

Glazing

Different types of glazing were used in the building for experimentation. The predominant glazing is triple glazing with krypton filled cavities, low-e coatings and insulating blinds.

Heating

Evacuated tube collectors installed on the balustrade of the perimeter balcony provide hot water and part of the heating energy demand. The solar-heated water is fed into tanks in the basement, with up to 1200 litres of storage capacity. Underfloor heating has been laid into the 65mm screed, and is distributed at about 33°C, a temperature which can easily be achieved by the solar-heating plant in the winter. The slow response of the underfloor system can be supplemented by radiant ceiling panels of metal fins, distributing hot water at 45°C, which is also suitable for combination with solar-heated water. A back-up system for the water heating is provided by an electric heating element which is due to be replaced with a wood burning stove. Fresh air supplied mechanically to the space can be warmed in winter by the earth heat exchanger in the basement. Heating is only required between November and February.

Cooling

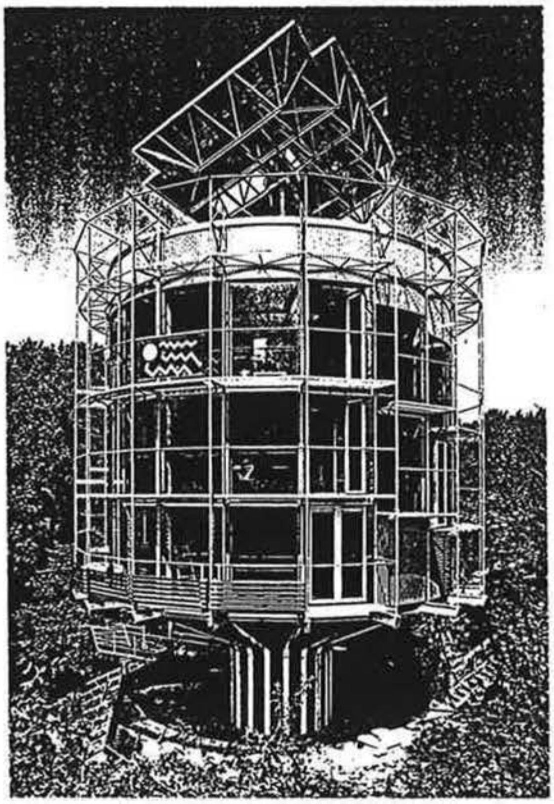
Ventilation air can be pre-cooled by passing it through the earth heat exchanger that is buried into the bank. The glazed side of the building can be turned away from the sun, or programmed to offset its revolution by 180° to prevent unwanted solar gain.

Ventilation

Both the basement and the top of the house can be mechanically ventilated with low level inlets and a high level extract. An earth heat

Intelligent Control

	Passive	Manual	Automatic
Daylight adjustment - reflection/protection	•		
Glare control - blinds/louvres/fixed		•	
Responsive artificial lighting control		•	
Heating control			•
Heat recovery - warmth/coolth			•
Cooling control			
Ventilation control			•
Fabric control - windows/dampers/doors			
Insulation - night/solar		•	



11 HELIOTROP®, Germany, 1994, Prof Rolf Disch Architekt

exchanger in the basement that maintains year-round temperatures in the range of 8°C, ensures that the air is pre-heated or pre-cooled depending on the season. In the winter, air is heated further by passing through heat exchangers containing solar-heated water. Outgoing air is also passed over a heat exchanger for recycling of waste heat. In summer, opening windows can be used for ventilation.

Electricity Generation

A photovoltaic array on the roof is also programmed to follow the sun on a two axis tracking system (in response to azimuth and elevation), which operates independently of the house. Unlike the main living areas, the photovoltaic panels should always be positioned for maximum exposure to the sun (except during maintenance). The tracking facility is predicted to allow efficiency improvements of 30-40% over a fixed system. The $54m^2$ array of mono-crystalline silicone cells has a peak output of 6.6 kilowatts, giving an estimated annual output of 9000kWh. This is five times the building's calculated electrical consumption, but this is largely offset by the increased consumption of the monitoring equipment, producing no overall net gain. Any excess electricity is sold to the grid at the same price at which it is purchased, making the grid an effective storage device instead of heavy-metal batteries. The measured annual electricity output of the PV system in 1997 was 8300kWh [Gereon Kamps].

Daylighting

All perimeter rooms are provided with windows for natural light and views. Rooms that are notionally on the south side have full-height glazing.

Solar Control

Metal balconies which spiral around the perimeter of the tower allowing maintenance access and fire escape, also double as external sunshades. Internally, aluminsed fabric blinds can be raised from floor level to reduce unwanted solar gain. The U-value of the triple-glazed windows is improved to 0.46 W/m^2K when the blinds are closed.

Controls

The building is programmed to turn every ten minutes according to a calculation that determines the azimuth and elevation of the sun. Each room is fitted with a temperature sensor and an occupancy switch (activated manually) which help the computer to determine the room inputs in terms of heat and air.

User Control

The rotation of the building can be manually overridden. For instance it may be desired to rotate the dining room to overlook the vineyards during a dinner party, or the building may need to be turned out of the sun when the occupants are on holiday. A manually activated occupancy switch is used to tell the computer which spaces are occupied, and the temperature of vacant rooms is kept lower.

Operating Modes

In the summer, the house can be turned away from the sun to prevent overheating. By rotating the house to face northeast and opening the windows at night, room temperatures can be maintained at 25°C. In the peak of summer, the house can track the sun with an offset of 180° to avoid solar penetration to the glazed living areas.

For the remainder of the year the house is rotated to take maximum advantage of passive solar gain and active solar water heating.

Performance

Continuous measurements of the house began in late 1995. In July 1996, with thermally non-optimal positioning and ventilation, the

Building Data

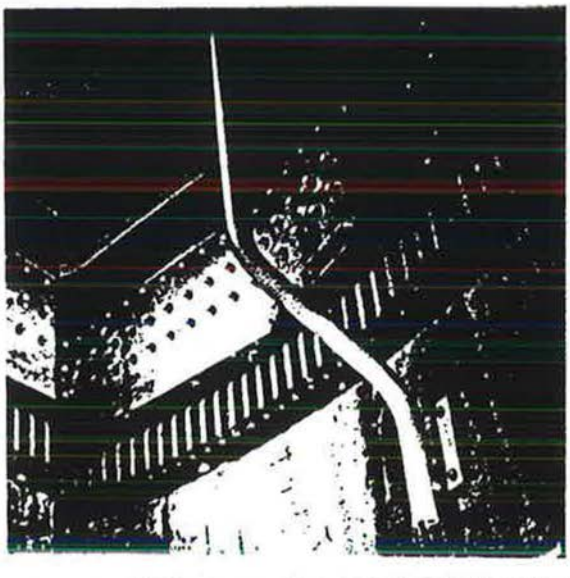
Contract Value	3.2m GDM
Area m²	285m²
Typical Floorplate	4.2m
Number of Storeys	3+B
Price per m²	~£3800/m²
Annual Energy Use	25.3kWh/m²
Typical Energy Use for Building Type	200kWh/m²
Annual CO_2 Output	nagative (PVs)
Number of Sensors	100
Visited by Authors	✓
Monitored by Others	✓

Credits

Client: Prof Rolf Disch
Architects: Prof Rolf Disch Architekt and his team
Services Engineer: Krebser & Freyler, Teningen
Structural Engineer: Andreas Wirth, Freiburg
Timber construction: Blumer AG, Waldstatt, CH

References

AIT Intelligent Architecture 1
Der Architekt (BDA), No 1, January 1995
Deutsche Bauzeitung, Vol 129, No 6, June 1995
Deutsches Architektenblatt, Vol 127, No 5, 1 May 1995
Baumeister, October 1994
Rotatable Solar House HELIOTROP: The experience of living rotating completely around the sun, Architectural Office Rolf Disch
Energy Characterisation of the Rotatable Solar House HELIOTROP® in Freiburg Germany, First Results, Klaus Rohlffs, Andreas Gerber, Fraunhofer, Gereon Kamps, Rolf Disch, Architectural Office Rolf Disch, EuroSun 96



measured air temperature in the living zone lay between 21.5°C and 30.1°C, with a mean temperature of 25.5°C, and with 30°C only being exceeded once. The average ambient temperature was 18.7°C. Temperatures rose above 26°C due to absence (windows not opened). There was no ventilation or subterranean heat exchange, and no delayed tracking of the house to minimise solar gain during this test period as the occupants found the conditions agreeable.

It is intended to increase the storage capacity of the solar heated water by a further 6000 litres to survive longer spells of poor weather.

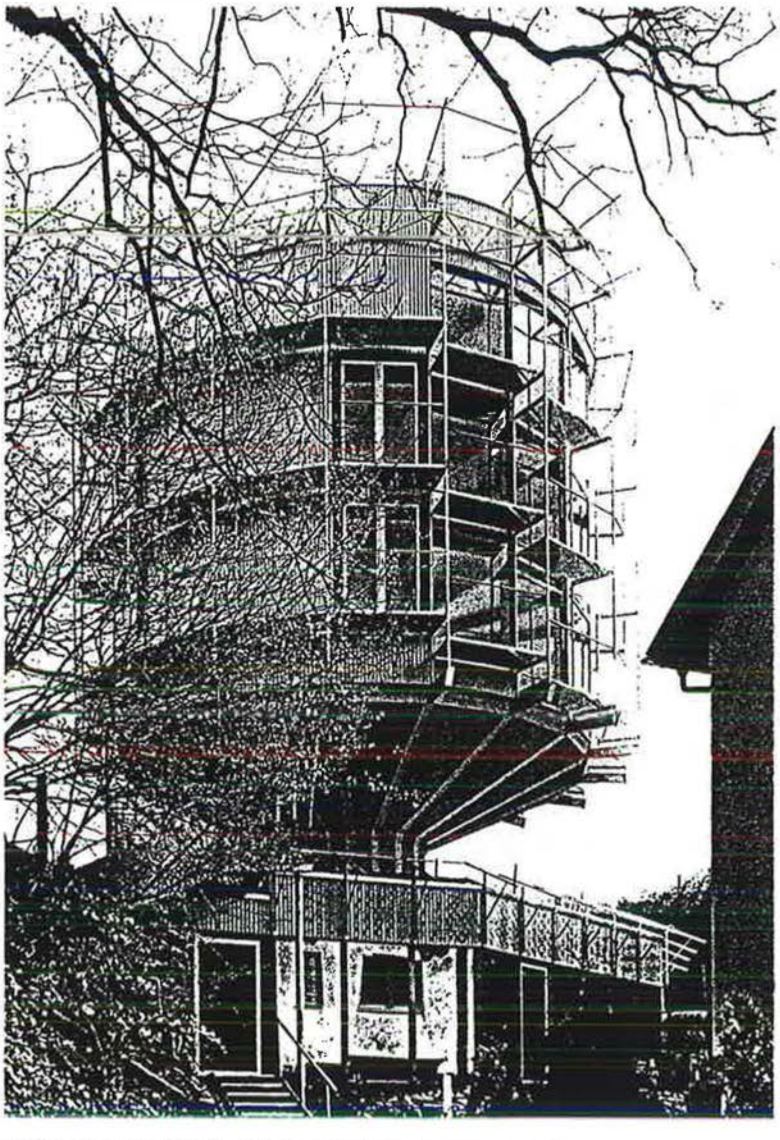
Delivered Energy Consumption

Mesurements have shown that the actual heating energy demand of the Heliotrop lies close to the heating energy demand of 27kWh/m²/a predicted by TRNSYS simulations during the design stage. A measured heating load of 25.3kWh/m²/a has been recorded for the tower.

The typical heating energy use for domestic buildings in Germany is 200kWh/m² per annum. Since 1995, by law, the calculated heating energy demand of new domestic buildings has to be lower than 100kWh/m² (the precise value is a function of the relation between outer surface and volume of the building).

Design Process

Dynamic computer simulations calculated energy lost by heat loss and infiltration, and the heat gained from internal sources and the sun. The TRNSYS simulation showed a heating energy demand of only 21kWh/m² for the top house and 47kWh/m² for the basement.



11 HELIOTROP®, Germany, 1994, Prof Rolf Disch Architekt

Beyond the Intelligent Façade Seminar

Automated Shading Devices: Control Issues

Mark Skelly
of Centre for Window and Cladding Technology

AUTOMATED SHADING DEVICES: CONTROL ISSUES

CENTRE FOR WINDOW AND CLADDING TECHNOLOGY

Presented at the CIBSE seminar:
***"Beyond the Intelligent Façade"*, Balham, 5/2/99**

by

Mark Skelly
Centre for Window and Cladding Technology, University of Bath, Calverton Down BA2 7AY

SUMMARY

In recent years, the design of the modern office building has developed to encompass renewed concerns over energy efficiency and occupant comfort. One by-product of this evolution is that designers are now beginning to rediscover and re-emphasize the importance of the building facade and its influence upon the indoor climate. By integrating traditional principles of vernacular architecture with the use of modern building materials and controls, building skins have emerged that possess the ability to act as climate filters or moderators, by accepting and rejecting free energy from the external environment depending on seasonal and diurnal variations. This paper will provide a brief overview of some of the important issues related to one aspect of 'Intelligent Façade' design: The control of automated façade devices.

An 'intelligent façade' design must respond to many variables. These variables can be divided into three categories:

(i) *Weather* - no two days are the same, in fact temperatures and solar radiation levels can vary significantly from hour to hour and from minute to minute;
(ii) *Context* - no two sites are the same, and even on the same site the micro-climate and obstructions imposed on one facade can be dramatically different from those imposed on another;
(iii) *Occupants* - no two individuals are alike, each has different preferences depending on past experience and various other psychological factors.

In addition, the interactions within and between these three factors are inherently:

(i) *Dynamic* - many parameters change over time and at different rates;
(ii) *Non-linear* - some parameters exhibit different types of behaviour in different regions;
(iii) *Stochastic* - some parameters are subject to large unpredictable/chaotic environmental disturbances;
(iv) *Multi-dimensional* - many different mechanisms interact in a complex manner;
(v) *Unmeasurable* - some variables are difficult to measure, have unknown relationships, or are expensive to evaluate in real time, such as occupant satisfaction and future cloud cover.

If we wish to take into account most of these complexities, we find that control system design becomes less amenable to direct mathematical modelling based on physical laws and flexible adaptive/intelligent control systems seem preferable to a traditionally fixed control system.

However, despite their name the majority of existing 'intelligent facades' do not incorporate basic intelligent control theory within their control logic, i.e. they do not have the ability to adapt, reason and learn about processes and disturbances. The term is simply applied to a facade that employs the latest innovative technologies, for example: movable shading devices, automatic ventilation openings and switchable glazing.

Research on the traditional manually operated venetian blind, demonstrates the reasons behind automated facade development. The use of venetian blinds can lead to considerable energy savings, if controlled correctly and adjusted several times a day (Newsham, 1994). Unfortunately, field studies show that occupants rarely manually adjust blinds and identify overheating and glare as the principal parameters that stimulate occupants to manually operate window blinds (Rubin and Collins, 1978). The studies also show that after having made an adjustment, occupants very rarely re-adjust the blinds for the rest of the day, which can result in the unnecessary use of artificial lighting. This stimulated the development of automated photoelectric controls for lighting and shading systems. However, recent occupant surveys show that the advancement of the humble venetian blind to an 'intelligent facade' device has largely neglected the needs of the user (Stevens, 1998).

The primary goal of most building systems and of any individual within those systems, is the attainment of 'comfort'. The term 'comfort' has a broad definition: when related to the built environment it refers to a state of mind that expresses an indifference to the environment; in other words the absence of discomfort, where discomfort is alleviated by making various adjustments (Humphreys, 1993). We can categorise the mechanisms people use alleviate discomfort into three classes:

(i) *Behavioural* - moving to another environment;
(ii) *Physiological* - adapting to the environment, e.g. dilation of skin pores, etc.;
(iii) *Artificial* - changing the environment, the creation of tolerable or comfortable conditions where none previously existed, e.g. the use of shading devices, etc.

There is broad agreement among researchers that individual comfort and satisfaction can be attained universally by providing individual control of the local environment (Bordass *et al*, 1995; Slater, 1995). When giving the occupant this form of personal control, we are providing them with three different forms of individual control (Averill, 1973):

(i) *Decisional control* - this is the opportunity to make various adjustments;
(ii) *Cognitive control* - this is the perception of control; it represents the way in which an event is interpreted and appraised;
(iii) *Behavioural control* - this is when an occupant makes an adjustment to avoid a threatening event, such as overheating.

The availability of decisional control (e.g. thermostats, window blinds etc.) and the perception of control, both contribute to user satisfaction; however the exercise of control (behavioural control) decreases occupant satisfaction (Veitch and Gifford, 1996). Therefore even by providing a user over-ride on a control system, occupants may still become frustrated if they have to constantly over-ride the system, and this can affect occupant comfort and productivity.

The Centre for Window and Cladding technology are currently carrying out research to design future intelligent control systems that gradually learn individual preferences and site characteristics by relating patterns in user over-rides and building performance to patterns in the environmental variables. The challenge lies in integrating the users' priorities with energy efficient control, to produce a smooth, transparent, comfortable, energy efficient control strategy. The system must be robust enough to cope with the stochastic noise associated with real-time data whilst providing comfortable internal conditions.

References

Averill J.R., 1973, Personal control over aversive stimuli and its relationship to stress, *Psychological Bulletin*, **80**, 286-303.

Bordass W.T., Bromley A.K.R. and Leaman A.J., 1995, Comfort, control and energy efficiency in offices, BRE Information Paper, IP3/95.

Humphreys M.A., 1993, Field studies and climate chamber experiments in thermal comfort research, *Proc. Conf. Thermal Comfort: Past, Present and Future*, ed. N.A. Oseland and M.A. Humphreys, Building Research Establishment, Garston, 9-10 June 1993, BRE264, pp52-69.

Newsham G.R., 1994, Manual control of window blinds and electric lighting: Implications for comfort and energy consumption, *Indoor Environment*, **3**, pp135-144.

Rubin A.I. and Collins B.L., 1978, *Window blinds as a potential energy saver: A case study*, NBS Building Science Series No.112, Washington.

Slater A., 1995, Occupant use of lighting controls in offices, *CIBSE Journal*, **17**(8), pp43.

Stevens S., 1998, Occupants reactions to automated glass facades, Unpublished poster paper presented at Conf. Intelligent Buildings: Realising the Benefits, 6-8 October 1998 at BRE, Watford, UK.

Veitch J.A. and Gifford R., 1996, Choice, perceived control, and performance decrements in the physical environment, *Journal of Environmental Psychology*, **16**, pp268-276.

Automated Shading Devices: Control Issues

Mark Skelly

Centre for Window and Cladding Technology

Overview

- Why use shading devices?
- Why automate shading devices?
- What factors should we consider when designing a control strategy for such a system?
- What techniques are currently used?
- What does the future hold?

Why use Shading Devices?

To provide occupants with comfortable conditions

- *What is Comfort* ? Comfort is the absence of discomfort; Discomfort is alleviated by making various adjustments

To provide occupants with comfortable conditions

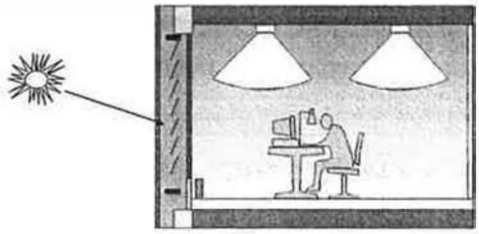
- *Thermal comfort* - limiting overheating by direct sunlight
- *Visual comfort* - limiting glare from external environment
- *Privacy* - limiting views from outside to inside

To manage solar energy exchange through the facade

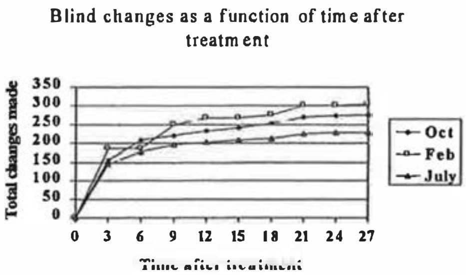
- *Heat* - balance solar heat gains with seasonal needs
- *Light* - balance the natural light entering the space

Why automate shading devices?

For significant energy savings, shading devices must be adjusted several times a day



People rarely adjust their blinds



They animate the building façade and can give a building a high-tech appearance

What factors should we consider?

Impact on the Occupants

- Perception of control - Occupant over-ride

Impact on the Occupants

- Perception of control - Occupant over-ride
- View - choose a solution that allows views out
- Distractions - from noise and motion

Shading type used

- Degree of solar heat control

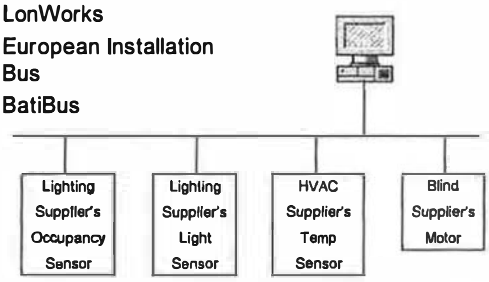
  Blind type: external, mid-pane or internal? Blind properties: reflectivity, transmissivity and absorptivity
- Degree of daylight control

  Blind type: louvre or roller, vertical or horizontal (tilt and raise)?

  Blind properties: reflectivity and transmissivity

Interoperability with other control systems

- LonWorks
- European Installation Bus
- BatiBus



Variables

- *Weather* - no two days are the same
  - Solar radiation
  - Sky illuminance
  - Air temperatures
  - Wind speed
  - Wind direction

Variables

- *Weather* - no two days are the same
- *Context* - no two sites are the same
  - Surrounding topology
  - Obstructions
  - Deciduous plantlife
  - External reflections

Variables

- *Weather* - no two days are the same
- *Context* - no two sites are the same
- *Occupants* - no two people are the same
  - Individual comfort
  - Occupancy patterns
  - Tasks performed
  - Spatial use
  - Psychological factors

Variables

- *Weather* - no two days are the same
- *Context* - no two sites are the same
- *Occupants* - no two people are the same

The interactions between and within these three factors are inherently:

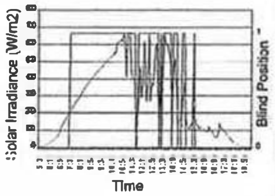
- *Dynamic*
- *Non-linear*
- *Stochastic*
- *Multi-dimensional*
- *Unmeasureable*

What techniques are currently used?

Control strategies

- Threshold

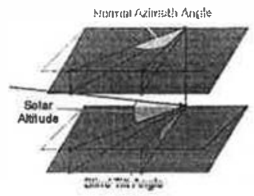
- Operates when threshold passed or after time delay



Control strategies

- Threshold
- Sun tracking

- Algorithm or Sensor Driven



Control strategies

- Threshold
- Sun tracking
- Scene control

- Daylight and Blinds used in harmony to create a series of pre-set lighting scenes

Control strategies

- Threshold
- Sun tracking
- Scene control
- Performance

- Predicted energy performance used to control blind position

Shortcomings

Either
- Too simple
  - Often based on simplistic engineering models
  - Inflexible and unadaptable

Shortcomings

Either
- Too simple

or
- Too complex
  - Large amounts of project specific data is integrated into the controls during design and commissioning
  - Difficult to change and adapt once installed

Shortcomings

Either
- Too simple

or
- Too complex
- Little user-centered design
  - energy performance often takes preference to occupant's needs
  - views are sometimes poor

Shortcomings

Either
- Too simple

or
- Too complex
- Little user-centered design
- Little interoperability
  - Systems tend to be supplied as stand-alone

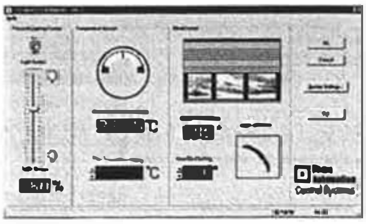
What does the future hold?

'The Intelligent Façade'

- Automated shading devices should develop to encompass intelligent control strategies
  - have the ability to adapt and learn about processes, disturbances and operating conditions
  - acquire knowledge and store it in such a way that it can be used or retrieved
  - autonomously improve upon its performance as experience is gathered

Better user interfaces

- Occupant used as additional sensor.



Better use of sensors

- Interoperability will bring about more sensor data for the utilization in shading control strategies

Smart materials

- Advanced glazings will be increasing used in shading and façade systems
  - electrochromics
  - photochromlcs
  - thermochromics
  - liquid crystals

Summary

An automated shading control system should be:

- Comfortable
- Energy efficient
- Transparent
- Flexible and adaptable
- Interoperable

Beyond the Intelligent Façade Seminar

Glass louvres & shadovoltaics

Robert Buck
of Colt International Ltd

Glass louvres & shadovoltaics

Robert Buck, BSc, Colt International Ltd

The increased use of glass for cladding commercial buildings has been one of the most significant advances in building design. This presentation examines existing methods of shading buildings from solar heat gain and looks at shadovoltaics, a relatively recent development that combines shading, natural light and photovoltaic power generation.

Solar heat gain

Left unchecked, solar gain has an undesirable impact on a building's cooling load, either increasing the air conditioning capacity required or making natural ventilation ineffective. With this having obvious cost implications there can be a demonstrable benefit of installing some form of solar shading. The principle is relatively simple: intercept direct solar radiation before it reaches the internal environment and either reflects it absorb it and re-radiate it.

Established systems

Shading has generally been achieved in one of four ways: internal blinds, blinds between the panes in double glazing, solar control glass or external shading. Each has its own particular characteristic. Internal blinds allow solar energy to enter the building before treatment. Absorbed energy is re-radiated within the building skin. Manual blinds, though, are rarely optimally operated which results in reduced levels of natural light inside the building and, as a result, an increase in artificial light.

Glass Louvres

External shading aims to prevent the solar radiation from falling on the window and, in so doing eliminates the problem of heat gain. Fixed shading is usually horizontal and is positioned above the window. However, fixed louvre systems can not be programmed according to the prevailing weather conditions or seasonal variations in the angle of the sun. This means that it will shade when no shading is required which, in turn, can cause a reduction in levels of natural light inside the building. This can be solved either with a translucent external shading system and /or with a movable system. Glass can be coated or laminated with a number of shading mediums to provide the optimum characteristic of solar heat gain reduction, maximising daylighting levels and allowing vision though.

Photovoltaic power generation

Movable external shading systems utilise horizontally or vertically configured louvres which can pivot, so presenting the maximum surface area to the sun when required. One of the more innovative of these is Shadovoltaic louvre system, which combines solar shading, natural lighting and electricity generating functions. Electricity is generated by photovoltaic cells that are mounted on the panels. A computer models the movement of the sun, and the position of the panels is automatically adjusted so that maximum power generation is achieved. Producing in some instances a 1/3 of the energy recuirements.

Beyond the Intelligent Façade Seminar

AIRLIT-PV

Johnny Kronvall
of J & W Consulting Engineers, Sweden

ABSTRACT PL971275

AIRLIT-PV

Development of a prototype facade unit integrating natural ventilation, daylighting, solar protection, intelligent local control and photovoltaic power

Objectives of the project

The objectives of this project are:

- to develop, design, build and test a prototype of a pre-packaged and application-specific building facade unit integrating natural ventilation, daylighting and solar protection under intelligent local control and with photovoltaic power,
- to deliver an industrial controller, based on artificial intelligent techniques, to optimise the interactive operation and, when required, integrate with the energy system of the building, and
- to work out a comprehensive plan for the exploitation of the facade unit and the industrial controller.

Technical approach

The principal technical issue to overcome is the integration of the different elements to be used. Combining natural ventilation, solar protection and daylighting in an optimum way will require the development of new intelligent control algorithms. In addition this will need to be integrated into any other energy or environmental systems in the building.

This issue will be addressed by two main parallel but inter-linked work packages. One will involve the immediate production of a prototype system, and subsequent physical improvements. The other will involve testing and modelling to optimise the design, and to work on the control mechanisms. After these, a smaller but important work package will address the final exploitation of the developments produced by the other two work packages.

Expected achievements

The main outcome of the project will be prototypes of pre-packaged and application-specific building facade units integrating natural ventilation, daylighting and solar protection under intelligent local control and with photovoltaic power. The prototypes are intended for both new buildings and major retrofitting. It is estimated that even a modest 2 % take-up of these facade units could save directly 1 million tonnes of oil equivalent in five years, and contribute to the potential annual saving of 7 million tonnes of oil equivalent within the EU by using natural ventilation and daylighting.

Beyond the Intelligent Façade Seminar

Electrochromic glazing for improved indoor comfort

Prof Michael G Hutchins
of Oxford Brookes University

BEYOND THE INTELLIGENT FAÇADE

CIBSE Natural Ventilation Group Meeting, London, 5 February 1999

Electrochromic glazing for improved indoor comfort

Professor Michael G Hutchins
Solar Energy Materials Research Laboratory,
School of Engineering, Oxford Brookes University,
Gipsy Lane Campus, Headington, Oxford OX3 0BP
Tel: 01865 483681: Fax 01865 484263; email: mhutchins@brookes.ac.uk

SUMMARY

In both heating- and cooling-dominated climates energy consumption in buildings represents a major proportion of total energy use. In many countries the demands for heating, cooling and lighting in residential and commercial buildings comprise the largest single sector of total energy use. Reduction of energy consumption, the improvement of visual and thermal comfort and the lessening of adverse environmental impacts are important considerations for the design and operation of "better" buildings. As such, the window plays a critical role in determining the performance of the building envelope. The annual energy performance of buildings employing advanced glazing is highly climate-dependent and is a complex function of trade-offs between solar heat gain and thermal insulation.

In recent years many significant advances have been made to improve the sophistication of coated glass products and to extend the range of choice available to the architect and the building design engineer. Transparent spectrally selective low emittance coatings represent the state-of-the-art of advanced glazing materials for window applications. Such coatings may be designed to transmit only the visible part of the incident solar radiation to reduce overheating by direct solar gain.

Dynamic variable transmission "smart" windows, such as electrochromic devices offer ability to alter in situ the transmittance of a glazing in response to the needs of the internal environment, a concept which has long appeared an attractive option for optimising the thermal performance of a building and which offers opportunities for new forms of architecture.

The attraction of glass as a building material leads to the construction of many commercial buildings with heavily glazed facades. In many climates this can result in excessive solar gain with consequent demands for additional air conditioning adding to the cooling load. The conventional means for reducing solar gain in such circumstances is to use tinted or coated glass.

Materials whose optical properties vary in response to an external stimulus are termed "chromogenic". Most widely known are the photochromic materials which darken in response to the intensity of light incident on the material. The optical properties of thermochromic materials alter with temperature. Electrochromic materials change colour in response to an externally applied electric field. The past

decade has witnessed a rapid growth in research activities in both academic and industrial laboratories in pursuit of the development of smart windows (1). Many possibilities have been investigated and the potential of a wide range of chromogenic classes of materials have been assessed. For building applications attention has centred on the electrochromic properties of inorganic transition metal oxides and, in particular, the properties of tungsten oxide, nickel oxide and vanadium oxide.

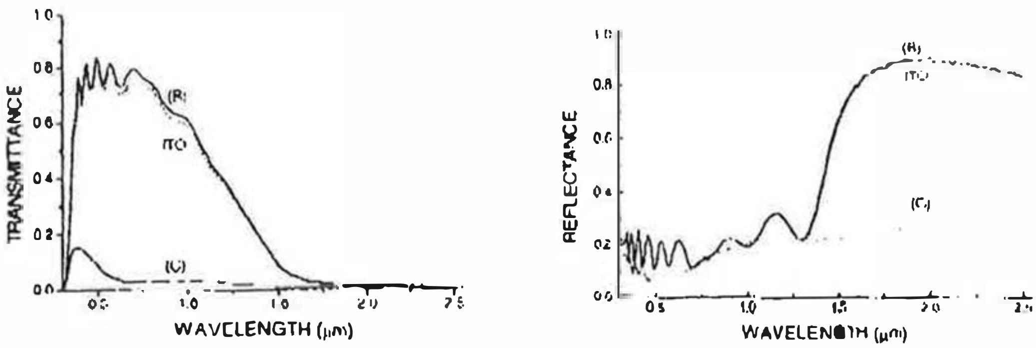


Figure 1 Spectral transmittance and reflectance of electrochromic tungsten oxide devices in the bleached (B) and coloured (C) states.

In parallel with materials science R&D, design engineers have employed building energy analysis tools to simulate the performance of variable transmission windows in order to identify the most promising applications, predict energy and environmental impacts and test possible control strategies.

This paper presents a review of recent materials advances in the development and performance of smart windows and associated studies addressing their potential use in residential and commercial buildings. The paper concentrates particularly on the electrochromic window which has emerged as the most likely candidate for initial use in buildings. There is much evidence to indicate that smart windows are close to commercialisation and will soon be available in large areas for building applications.

with local transmittance adjustable from 50% to 10% of clear window of 80.

Beyond the Intelligent Façade Seminar

Fitness for purpose of Building Integrated PV Systems

Paul Baker
of BRE Scotlab

Fitness for purpose of Building Integrated PV Systems

Paul Baker, BRE Scotlab

In order that BIPV may have a significant impact on the market, confidence in these innovative building systems must be engendered. Technical approval, where a defined set of requirements is met by the product or system, may aid the general acceptance of PV in buildings. But what are these requirements?

The EC JOULE PV-Hybrid-PAS project has developed an assessment methodology for the electrical, thermal and visual performances of "hybrid" PV systems such as ventilated double skin facades. However, the building envelope may need to fulfil other performance requirements in order to meet the specifications of the client, designer and legislation; e.g. buildability, maintenance, durability, impact on internal environment, safety, aesthetics, environmental impact, etc.

The JOULE PRESCRIPT project is currently assessing the applicability of existing European building and electrical codes to BIPV, to identify areas where the codes fall short, and consequently elaborate appropriate pre-normative testing procedures for BIPV products.

This paper identifies some of the (non-electrical) issues that should be considered for building integrated PV systems.