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ACADEMY MONT-CENIS: PLANNING OF NATURAL VENTILATION AND DAYLIGHTING IN A LARGE MICROCLIMATIC ENVELOPE

authors: Pasquay, T., Müller, H.F.O.

Prof. Dr. Helmut F.O. Müller, Dipl.-Ing. Till Pasquay
University of Dortmund, Chair for Environmental Architecture
Baroper Str. 301, D-44227 Dortmund
Tel.: +49 – 231 – 755 4690
Fax: +49 – 231 – 755 5423
mueller@klima.bauwesen:uni-dortmund.de

ABSTRACT: For the academy Mont Cenis in Herne, Germany, a large microclimatic glass envelope (72m x 180m x 15m) with separate buildings inside the envelope, a concept for the natural ventilation was put up and a program for the control of the motor driven windows in the facades and in the roof was developed. To comprise the influence of wind speed, wind direction and the temperature difference between the envelope and the environment, numerous CFD-calculations were carried out on the base of a wind tunnel test and dynamic thermal calculations. The thermal mass was in taken into account to avoid short switching intervals of the windows. A 10.000 m² PV plant integrated in the roof avoids overheating in summer and the glass envelope leads to moderate temperatures in winter.

KEY WORDS

Microclimatic Envelope, Natural Ventilation, CFD, Photovoltaic, Holographical Optical Elements

THE ACADEMY MONT CENIS

At the former coal mine Mont-Cenis in Sodingen, a quarter of Herne, the academy Mont-Cenis in combination with a quarter centre was built as a part of the International Building Exhibition Emscherpark (architects: Jourda Architects, Paris, Hegger-Hegger-Schleif, Kassel). The building was inaugurated in August 1999.

Central part of the arrangement is a glass microclimatic envelope, in which the buildings of the academy and the quarter centre are placed. The glass hall causes a shift of the climate inside to higher temperatures compared to the climate outside during the cold seasons.

The worlds largest photovoltaic power plant integrated in a building with one megawatt peak output is installed in the roof of the glass hall on 10.000 m². The PV panels are arranged in a cloud imitating form and serve as a sun protection during the summer.

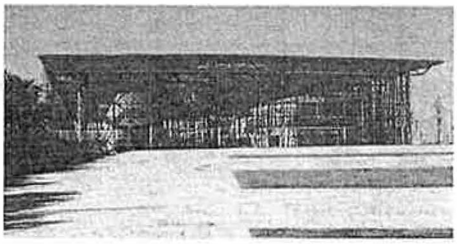

Figure 1: front view

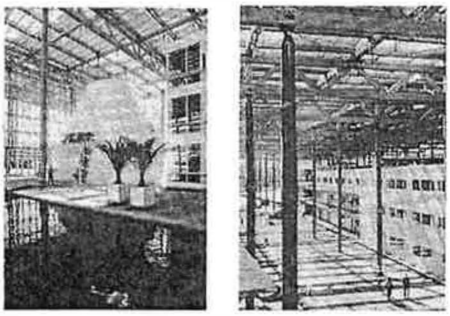

Figure 2: library and hall inside

NATURAL VENTILATION OF THE ENVELOPE

For the microclimatic envelope a concept for natural ventilation was developed together with the consulting engineers Schmidt Reuter Partner in Cologne, using extensive computational fluid dynamics (CFD). On the base of the CFD-studies with the program PHOENICS for the typical seasons the kind and place of ventilation openings was fixed together with the architect.

To maintain a pleasant climate inside the glass hall without the use of mechanical ventilation, a pattern for the opening and closing of separate groups of ventilation openings (windows) was developed, according to the meteorological conditions of sun, wind, and outside and inside temperature.

The input data for the CFD-simulation, such as the temperatures of the surfaces in the hall (PV-cells in the envelope, facades of the buildings, ground) were determined with the dynamic thermal program TRNSYS at the Institute for Light And Building Technique in Cologne. The program calculates the dynamic thermal processes in the hall in hourly steps for the period of one year using the German test reference year for Herne and considers the thermal mass of the construction.

The pressure distribution around the envelope induced by the wind was determined in a wind-tunnel test with about 160 measurement points on the envelope by the Gesellschaft für Aerophysik in Zürich.

The results of the thermal and the CFD simulations depend strongly on the input data. At the same time results of one program (air change per hour) effects the result of the other program (temperatures of the surfaces). In an iterative process of both programs good results were achieved.

On a calm sunny day with 28 °C outside an air change per hour of 6,45 1/h was calculated and the zones of warn air concentrate under the roof with the hot PV-cells (fig. 3 and fig. 4).

VENTILATION OF THE BUILDINGS

All buildings in the hall have mechanical ventilation with heat recovery in order to keep the heating energy demand as small as possible. Fresh air for the buildings is taken either from the hall or from an earth duct. The earth duct is used to precool or preheat the air during very hot or very cold periods (fig. 5). During the intermediate seasons the solar gains of the glass envelope are used to preheat the air, distributed to buildings inside. Independent from the artificial ventilation system, the buildings have windows to the hall, that can be opened at all times.

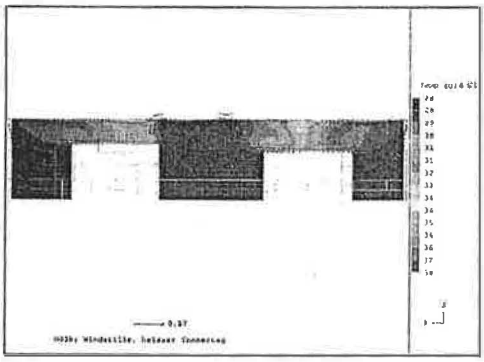

Figure 3: Calm summer day, temperatures

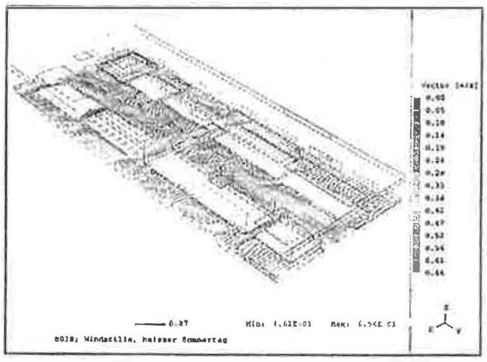

Figure 4: Calm summer day, air velocity

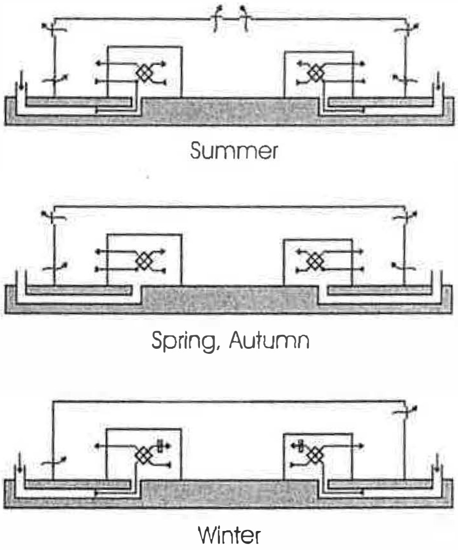

Figure 5: Ventilation concept

STEERING PROGRAM FOR THE WINDOWS

The dynamic behaviour of the hall was determined by an offset reaction triggered by the change the parameters sun, air change per hour, and temperatures with a dynamic thermal simulation. Figure 6 shows the reaction of the hall on a change of the direct radiation from 0 to 400 W/m². The time to reach 70% of the final value was 3 hours. For the control system a period of one hour between two switches was fixed to avoid a permanent opening and closing of the windows.

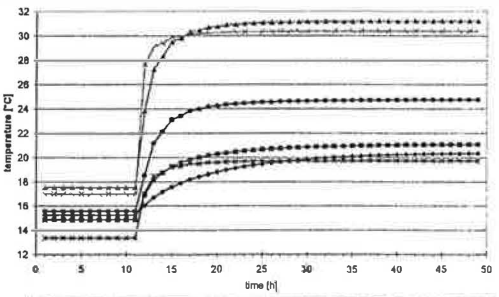

Figure 6: Offset reaction sunshine

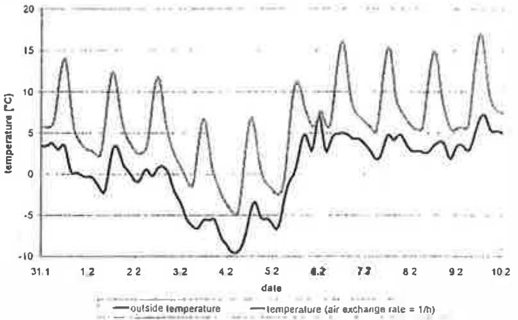

Figure 7: Temperatures in Winter

On the base of simulations for the typical seasons and the transition between the seasons, for different wind speed and directions a pattern of groups of windows to be open and closed was developed in order to receive a certain air change per hour. Table 1 gives an example of temperatures outside, temperatures inside and the air change per hour, that is suited for 6 window combinations. Table 2 gives the percentage of open windows in each facade and in the roof, that fits to the combinations in table 1.

The simulated temperatures inside the envelope during the cold winter at an air change per hour of 1/h illustrates figure 7. At least during the day the temperature inside the hall rises up to 15 °C. During the night the minimal temperature difference between inside and outside is between 3 °C and 5 °C.

Table 1: Opening pattern for windows

Windspeed = 0 bis 2,5 m/s

T_{out} [°C]	T[illegible] [°C] <18	18-22	22-25	>25
>25	ACH=1-2 h^{-1} E	ACH=1-2 h^{-1} C	ACH=2-5 h^{-1} B*	ACH > 5 h^{-1} A*
20-25	ACH=1-2 h^{-1} D	ACH=2-5 h^{-1} B	ACH=2-5 h^{-1} B*	ACH > 5 h^{-1} A*
15-20	ACH=1-2 h^{-1} C	ACH=1-2 h^{-1} C	ACH=2-5 h^{-1} B	ACH=2-5 h^{-1} B
5-10	ACH=0,5-1 h^{-1} F*	ACH=0,5-1 h^{-1} E	ACH=1-2 h^{-1} D	ACH=1-2 h^{-1} D
<5	ACH=0,5-1 h^{-1} F*	ACH=0,5-1 h^{-1} F*	ACH=1-2 h^{-1} E	ACH=1-2 h^{-1} E

* supply air from earth duct

Table 2: Percentage of windows open

part of windows open in the four facades

window combination	upper windows N [-]	O [-]	S [-]	W [-]	lower windows N [-]	O [-]	W [-]	gates N [-]	O [-]	S [-]	W [-]	roof windows roof [-]
A	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
B	1,00	1,00	1,00	1,00	1,00	1,00	1,00					1,00
C	0,50	0,50	0,50	0,50								0,50
D		0,25		0,25								0,25
E		0,25*					0,25**					
F		0,15*					0,15**					

* wind facing
** wind offside

DAYLIGHTING

The integration of the PV-cells was not to affect the use of daylight in the hall and in the buildings inside the hall. With simulation and photorealistic visualisation the distribution of light was optimised for clear and diffuse sky in co-operation with the ILB in Cologne. A full scale use PV-panels turned out to unacceptable. The result of the optimisation process, developed in co-operation with the architects and Pilkington-Solar-International, was a cloud-imitating arrangement of the PV-panels, placed mostly above the buildings (figure 8). It guarantees a sufficient daylight factor inside the hall, and in the buildings. Modules with a different density distribution of PV-cells were used in the roof (86%, 73%, 63%) and the south-west facade (53%).

Holographical optical elements (HOE) elements redirect the direct radiation of the sun as a colourful animation above the reception building of the academy and as white light above the library for daylighting (figure 9). Lightshelves, placed above the parapet, help to use daylight in offices and seminar rooms.

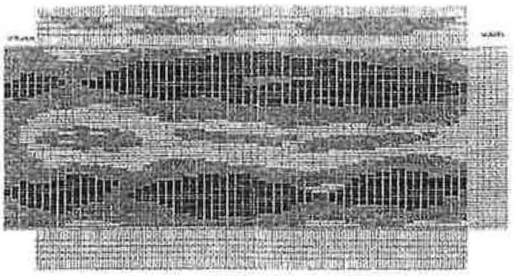

Figure 8: Distribution of PV-panels

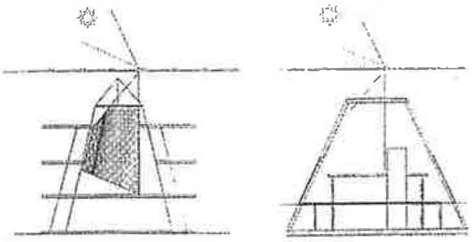

Figure 9: Use of holographical optical elements

CONCLUSION

The planing of natural ventilation on the base of wind-tunnel tests and CFD and thermal simulations is possible and can lead, regardless of the numerous combination of influences like wind-speed, wind-directions and temperature differences, to a reasonable steering concept. The temperatures in the microclimatic envelope with solar panels integrated in the roof are in summer sometimes slightly above the temperatures outside, but are acceptable due to the high possible natural ventilation rate.
During a process of optimisation a daylighting concept was developed, that combines sufficient daylight in the buildings, the prevention of overheating in summer, and a maximal use of PV-cells for electric power generation.

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