



CONTROLLED NATURAL VENTILATION IN A LARGE MICROCLIMATIC ENVELOPE

Authors: Dipl.-Ing. Till Pasquay, Prof. Dr. Helmut F.O. Müller

University of Dortmund, Chair for Environmental Architecture
Baroper Str. 301, D-44227 Dortmund, Germany
Phone: 0049 - 231 - 755 4690
Fax: 0049 - 231 - 755 5423
e-mail: Klimagerechte-Architektur@.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 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.

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The academy Mont Cenis

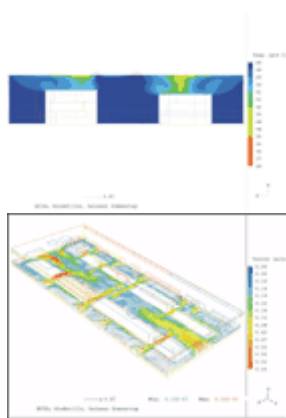


At the former coal mine Mont-Cenis in Sodingen, a quarter of Herne, the academy Mont-Cenis in combination with a quarter centre was built as a part of the International Building Exhibition Emscherpark (architects: Jourda Architects, Paris, Hegger-Hegger-Schleif, Kassel). The building was inaugurated 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 world's largest building integrated photovoltaic power plant with one megawatt peak output is integrated in the roof of the glass hall on 10.000 m². The PV panels are arranged in clouds and serve as a sun protection during the summer.

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.

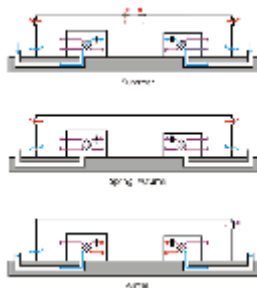
The input data for the CFD-simulation, such as the temperatures of the surfaces in the hall (PV-cells in the envelope, facades of the buildings, ground) were determined with the dynamic thermal program TRNSYS at the Institute for Light And Building Technique in Cologne. The program calculates the dynamic 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 brought up.

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 warm air concentrate under the roof with the hot PV-cells.

Natural Ventilation of the envelope

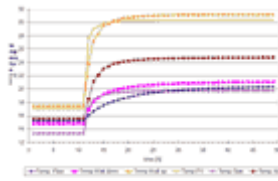


All buildings in the hall have mechanical ventilation with heat recovery in order to keep the heating energy demand as small as possible.

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. 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.

Steering program for the windows

The dynamic behaviour of the hall was determined by an offset reaction to the change the parameters sun, air change per hour, and temperatures with a dynamic thermal simulation.



The left figure 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.

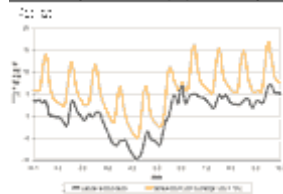
Windgeschw. = 8 bis 2,5 m/s

T _{ext} [°C]	15,12	15,12	21,21	21,21
7/8	22,0-11,0 °C	AC=1-2 °C	AC=1-2 °C	22,0-11,0 °C
3/3/3	E	G	B'	A'
18/28	D	E	B'	A'
5/3	G	G	B	B
1/8	A	B	D	D

per Facade: 1-4 (1-4) (1-4) (1-4)

Wind	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0

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 the left figure. 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.

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 envilope with solar panels integrated in the roof are in summer sometimes slightly a the temperatures outside, but are acceptable due to the high possible natural ventilation rate.

References

[1] U v. Bohlen, M. Kischkoweit Lopin, M. Müller, T. Pasquay: Fortbildungsakademie Mont Cenis - Planung der natürlichen Lüftung und Beleuchtung, Symposium Energiefassaden, Deutsche Gesellschaft für Solarenergie, ISBN 3-9805738-2-6, 1998.