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COMFORT AND ENERGY CONCEPT POST TOWER, BONN

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Abstract

The paper describes the balanced air flow through the different facade layers and spaces in the new Post Tower in Bonn. This new type of high-rise building with an absolute consequently integrated comfort and energy concept is occupied by the Deutsche Post AG. This building, developed by a design team behind Murphy/Jahn including Werner Sobek Engineers and Transsolar Energietechnik, is not using the well known double facade concept as an add-on but the whole comfort and energy concept relies on this. The building is not only 70% but 100% of the year ventilated by the double facade, which excludes an additional central mechanical system that other examples of well known double facade buildings have installed. The typical office floor uses the double facade as the intake air distribution and the inner sky gardens as exhaust collection, which allows to skip all vertical air distribution shafts, a major point in respect to the building's efficiency. In addition one mechanical floor was saved by this ventilation concept, using decentralized air intake units in the standard under floor convectors. All these savings could be used for covering the additional costs in the facade construction.

Figure 1 Views of the building. Source: Anja Thierfelder, 2003.

Building Data Deutsche Post AG, Bonn:

Height:	162,50 m	floor below grade:	5
Length:	ca. 82 m	work places:	ca. 2 000
Width:	ca. 41 m	BGF Tower:	ca 60 000 m²
Floor above ground:	40	BGF Base building:	ca 6 400 m²

1. Introduction

For their new headquarter building in Bonn, Germany, the Deutsche Post AG decided to go for building concept which ensures on one side a very high comfort and working space quality for each employee and approaches this with the lowest energy input. The building site is in a river bank park of the Rhine, which is open to the public. Already the decision for a highrise building solution in the architectural competition tried to minimized the footprint of the building, which is by fare the highest building in the region. The footprint of the building is like an ellipsoid, cut through the middle axis with a shift and an offset to create 9 story high sky gardens. To allow in all floors of the building to open the windows during all times and to ensure the function of a good external shading device, the building concept included a double facade. The facade cavity is open all along the building side and as well for 9 stories to allow a “breathing” of the plenum with the wind, instead of adapting the external pressure differences. The wind and weather protected shading device behind the outer single glass shell allows to keep all glass as transparent as possible, using low iron glass and a neutral low-e coating for the inner double glazing with argon filling. By this reduction of external loads and a minimizing of internal loads through a daylight controlled artificial lighting, the space conditioning can be limited to a building integrated heating and cooling system by a plastic piping in the open concrete ceilings. This piping is via a heat exchanger connected to a ground water well providing natural cooling without using a chiller.

2. Climate Concept – Breathing in the Wind

’Breathing in the Wind’ best describes the airflow through the various facade skins and the interior of the new Deutsche Post head office in Bonn. The project, which is completed and has been in use since the beginning of the year 2002, strives to consistently integrate comfort and energy concepts into the architectural aspect. This relies, without ‘braces and belt’, on the airflow through the double skin facade, in total realization that extreme supply air temperatures are drawn from there. This was the only way to avoid the need for a backup ventilation and cooling system for the extreme seasons, which is the case with a lot of other projects involving a double skin facade. As a result, increased investment in the facade was compensated for by savings in the HVAC budget. Regardless of the season or the exterior temperature, the facade of the Post Tower serves to provide and distribute supply air, the corridors are exhaust air collectors and the skygarden zones act as an air extraction chimney. Consequently, neither vertical supply air nor extractor shafts are required to ventilate the normal offices along the outer facade, which can mean considerable savings in a high-rise building with a number of floors. Furthermore, due to the ventilation units and the exhaust air collection, an entire floor that would otherwise have been needed for the technical equipment, could now be used as office space.

2.1 How it all began

The client requirements as stated in the competition brief for the new Deutsche Post AG head office in Bonn included the following: a high level of workplace comfort for the employees, a user-friendly building with louvers and limited individual access to heating and cooling controls, a minimum energy requirement for heating (25% below WSVO 95/german energy conservation code) and the integration of natural energy sources. The minimization of running costs for heating, cooling and ventilation was also to be taken into consideration. In this respect, the aims had already been set very high and when we on the planning team then opted for a high-rise solution, the challenge was perfect.

2.2 Our objective

Our aim at Transsolar was to create a working environment in which each individual employee could regulate his/her required level of comfort without being limited to a pre-determined heating temperature. It should also be possible to open the windows in the skyscraper at all times, to select the room cooling temperature and to a certain extent to be able to set the quantity of pre-warmed or pre-cooled supply air in the working zones. Fanger’s criteria for comfort served us here as a basic indicator. According to Fanger, interior heating and cooling is considerably more pleasant if it is mainly radiation-based as opposed to being conditioned purely with air. The provision of a pleasant level of brightness guarantees individual access to sunshade control and to the level of artificial light in each room.

2.3 The basic concept – the house as an air channel

’Breathing in the wind’ was the starting point for the climatic concept solution, to the proposed full glass facade for the 40-storey building. However, a high level of transparency, particularly from the exterior, can only be achieved if coated sun protection glazing can be avoided. This requires consequently a high-energy use for the room cooling system or an exterior shading device. As the cooling system is, for the most part, dependent on the natural cooling source of two ground water wells, the cooling requirement had to be reduced to a minimum. The shading device had to be extremely stable or needed additional protection in order for it to function properly, even on a fine but windy summer's day at a height of 140 m. This was done by adding to the inner facade of gas-filled insulating glass a highly transparent single glazing, thus creating a vertical and horizontal open facade. This cavity can buffer extreme exterior temperatures in winter with a minimum of ventilation by means of controlled facade openings and can use solar gains to pre-warm the supply air. In the summer, the fully opened louvers allow for maximum ventilation and extraction of heat from the solar gains that have mainly been absorbed on the shading device. The facade cavity also ensures that the windows can be opened even in windy conditions.

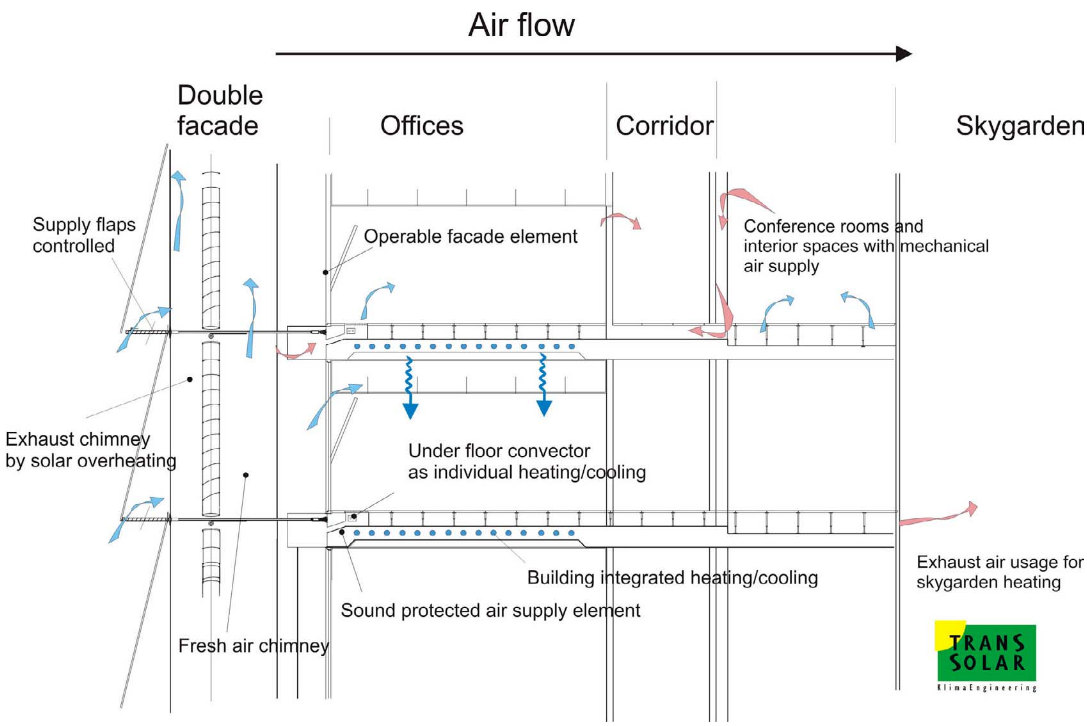

Figure 2 The basic concept.

If one considers the pressure pattern around the skyscraper, for example, in a prevailing West wind, one will see considerable differences in pressure levels along the facade of one of the towers, from built-up pressure in the flow area right up to a high suction effect due to the increase in air velocity along the facade. The double-skin feature of the building is tasked with reducing this difference in pressure to the extent that doors and windows can be opened in a south-west or south-east facing office without the risk of doors slamming or desks being blown clear of papers. This has as well solved the problem of door opening forces that are too high due to the relocation of the pressure differences into the building.

In addition, the supply air for the offices is distributed through the facade cavity, whereby one must also be aware of the fact that depending on ventilation, the position of the sun and prevailing exterior conditions, temperatures may occur that are considerably above room temperature. Nonetheless, the building draws its entire supply air from there and eliminates the need for a second auxiliary supply air system. It was, of course, evident that each room would have its own individually controlled heater. Together with John Durbrow of Murphy/Jahn, the idea was proposed to develop the heater to the extent that it could also carry out the basic ventilation of the room. Due to the open facade cavity, the windows can be used as a source of fresh air, provided an acoustic connection with neighbouring offices is not a problem. The heater, additionally defined as a sound-insulated supply air element, can also assume the pre-cooling of supply air. In combination with an individual airflow control it will allow for a certain individual cooling temperature regulation in the room, the basic cooling of which is covered the building cooling system in the open concrete ceiling.

3. Concept development and detailed assessment – Theory and reality

The above approaches were analyzed, examined, expanded and adapted during the planning phase by all the planning partners, as sometimes the actual realization of a lovely idea does have its problems. When detailing the supply air convectors, for example, during intense discussions with Professor Rakoczy based on fluid dynamic simulation and wind canal measurements, we realized that a mechanical support for the air displacement was necessary. The team managed to convince the technical consultants at Deutsche Post of this innovative idea although it had not yet been realized consistently in any reference project. While the consultants representing our client examined all approaches critically, they were more than prepared to accept new ideas once they had been provided with sufficient evidence of the validity of the idea. This is one of the requirements for innovation and indeed our most successful projects to date are the result of close collaboration with clients who are open to new ideas and prepared to tread new paths.

The pressure conditions in the double-skin facade in a prevailing wind were re-created in parallel by Transsolar using computational fluid dynamics and by the Institute of Industrial Aerodynamics (IFI) at the Institute of Technology, Aachen, in a wind canal. This allowed us to calibrate the two ensuing models by means of the building airflow. The correspondence between the two models was good in the case of open louvers, whereby the external pressure conditions on the inner facade were reflected as slightly reduced. The theoretical approach of pressure equalizing in an open, that is a double skin facade without horizontal or vertical separations, is based on the principle of the main drop in pressure at the louvers in the exterior facade and the cross flow in the facade cavity along the facade. The important background to this is that the pressure level can hardly be reduced through the louvers in a closed double facade system: after a certain time the full compression or suction effect is evident on the inner facade and/or the door leading to the corridor. However, due to the cross flow in the facade cavity the pressure differences behind the louvers are reduced, which means that the incoming air flow rate at the louvers is limited. We developed this principle for the project DLZ Neckarsulm, a 20-storey high-rise building with a floor by floor continuous double skin facade, and tested it in practice.

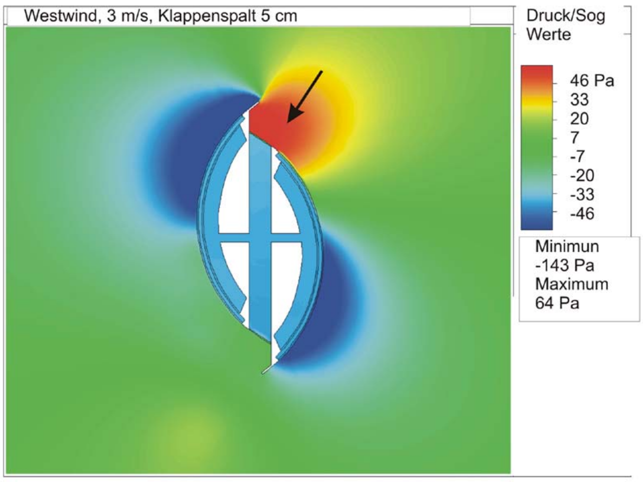

Figure 3 Wind caused pressure distribution.

The first measurements in the wind tunnel showed, in contradiction to the results from the flow calculations, no reduction of the inner facade pressure when the area of the facade openings was reduced. Intense consultation with Professor Gerhardt from the Institute of Industrial Aerodynamics in Aachen about possible differences between the models provided the explanation. In the wind tunnel model, the facade louvers were represented by holes in the outer facade cladding. In the case of the closed facade louvers, except for 20 percent opening, the team had simply left every fifth hole open and had covered over the holes in between. With that, however, a reduction in pressure did not materialize behind these relatively large openings, and therefore there was no reduction in the pressure profile from the exterior to the interior. The correct model with a reduced number of holes along the entire facade brought the expected correspondence between the wind tunnel and the CFD (computational fluid dynamics) models.

The ventilation of the facade cavity by means of pure stock effect was measured and confirmed parallel with the simulation with a dynamic building model on TRNSYS and flow simulation on a 1:30 model. It showed that while the nine open facade storeys did lead to an increase in air temperature in the facade, a greater chimney effect was created due to the greater height, which as a consequence led to a decrease in temperature difference towards the outside.

Bringing the plan to fruition – from prototype development to tests during the planning phase of the project, there was no decentral under floor air equipment on the market. The company that came the nearest to developing the equipment we required was FSL in Mannheim, a small but incredibly creative firm that has been trying for years to push the issue of decentral ventilation on the market. The first prototype was developed and tested in detail together with Josef Ormai from FSL. It must be said that our requirements of max. 29 dBA at 90 m³/h supply air flow, combined with the limited space in the raised floor, involved considerable development work. Of course, the equipment on the one hand should not permit a return flow from the building into the double skin facade and, on the other hand, should be capable of displacing the required level of fresh air even at areas of reduced facade pressure.

Figure 4 Concept evaluation by mockup tests (Displacement ventilation)

Real scale mock-up tests were carried out at the testing station for outer facades at the University of Stuttgart with a real testing area with heat source, building cooling system and the decentral supply air equipment. The tests confirmed the ventilation efficiency of the intended displacement ventilation, the maximum room temperature of 27 °C at an exterior temperature of 32 °C and the robustness of the equipment in respect of condensation. The presence of condensation was only then ascertained in the under floor convector when the water inlet temperature was far below dew point of the exterior conditions. On the other hand, it was shown that a supply air temperature of 16 °C could be realized at floor level without a reduction in comfort. This is due to the fact that already a sufficient turbulency is created at the supply air filter at a low airflow rate – the user can request maximum 120 m³/h – in order to fulfil the criteria for comfort even at a distance of one meter.

4. From prototype to production, how to maintain the system?

Almost 2,000 individual ventilation units have been installed in the Post Tower for the decentralized system. This involved, initially, a considerable level of development work on the part of the manufacturer, Trox/FSL. Each appliance has, in addition to the conventional convector, through which fresh air passes, a fresh air filter, a flap valve with a magnetic lock, patented by the developers from Mannheim, and a three-stage ventilator. It was necessary to be able to clean and maintain the system in a very short space of time, in order to minimize maintenance costs. The convector was, therefore, connected flexibly to the 4-pipe air-conditioning system with wire-armoured pipes and carried sideways on a track. In this way, it is easy to lift the convector when the grill is lifted, to clean it and the convector shaft. The supply air filter, which can be removed when the floor covering is lifted, should be changed once or twice a year. All other mechanical components such as ventilator or flap valve are on a type of sled, which is secured with one screw and which can be easily removed. Therefore, tedious repair work at the scene can be avoided. If there are problems, the sled is simply removed and replaced, the cables reinserted and that’s it! The annual equipment service, which begins with a visual examination, is also carried out in this manner, thus reducing the time required to a minimum. Experience with other systems has shown that the replacement rate is very low with high-quality ventilators and that the annual maintenance and service costs are in the region of one to two percent of the overall investment costs.

5. Lessons learnt from the project 'Deutsche Post'

Approximately six months of operation and an adjustment phase was required to achieve optimal control of the facade and the individual appliances. After the year 2003, the first year of the building behaviour could be analyzed (see Figure 5 and Figure 6). We will discuss if the long-term expectations of the building are fulfilled looking at the energy demands and the thermal behavior of the building.

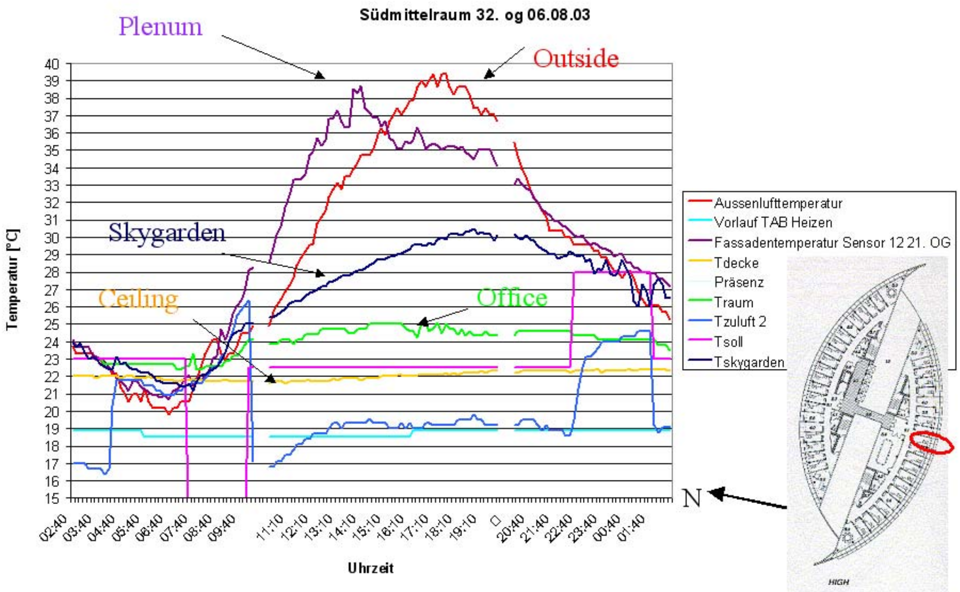

Figure 5 Real test under extreme conditions - July-August 2003

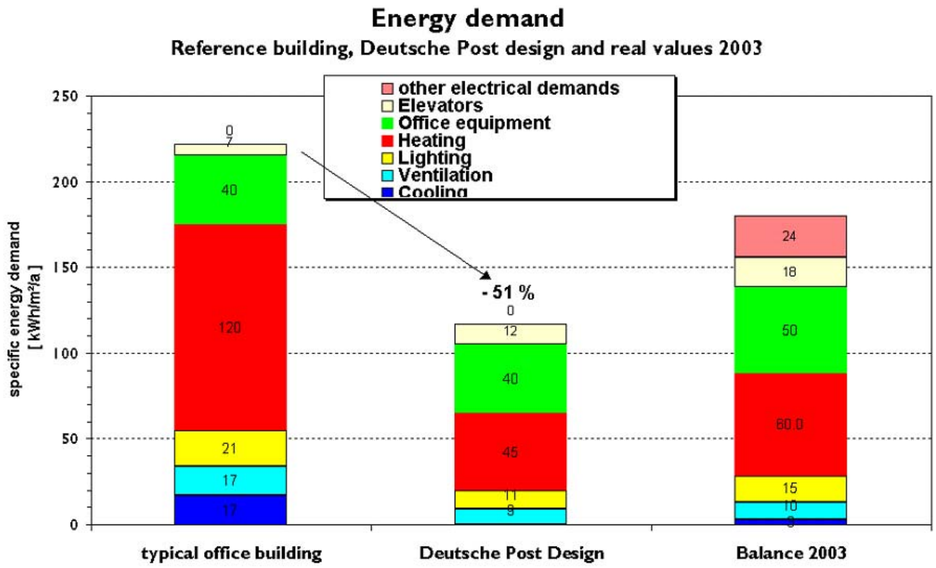

Figure 6 Energy demand for 2003

References

Editor Anja Thierfelder. 2003. Transsolar ClimateEngineering. Birkhaeuser Basel, ISBN 3-7643-0751-X.