



Efficient office building with flexible room concept

Fig. 1



- ▶ Heating consumption only 36 kWh/m² p.a.
- ▶ Primary energy characteristic value for heating, ventilation, cooling and lighting: 89 kWh/m² p.a.
- ▶ Control strategy of the concrete core temperature control continuously optimised
- ▶ Flexible room layout possible due to integration of heating, cooling and ventilation elements in concrete ceiling
- ▶ A clear technology and architecture concept enables transferability

The new office building lies on the edge of a "solar housing estate" in the German town of Aachen and follows the energy specifications for the residential buildings of the estate.

Nowadays, the question of heating costs for new residential buildings is often a central matter. For office buildings, high quality of the workplace is normally of main importance, along with the consideration of cooling the building. This does not mean, however, that the construction costs and follow-up have to be high. For office buildings too, energy-optimisation does not just lead to low operating costs but also provides a high level of interior comfort.

In Aachen, the concept of a "solar housing estate" induced its planners to fulfil the same energy requirements for their own new neighbouring office building. In addition, the building was supposed to be particularly economical to create and run. In the concept phase, the costs that are expected over the entire construction and usage period were broken down completely, evaluated and optimised. The more expensive planning process beforehand is paying off – low follow up costs and highly flexible usage promise to secure the investment in the long term. Since, in this case, the contractors planned and are also now using the building themselves, they all acted in concert. The integral planning approach, a basic requirement for a sustainable, energy-

efficient concept, was considerably easier to perform compared to other projects.

The spacious floor plan without load-bearing interior walls allow the building to be sub-divided variably into different units and various office shapes. The energy concept which relies primarily on the use of geothermal heat or cooling in conjunction with a heat pump is kept simple. The integration of the building services equipment into the ceiling or floor offers much flexibility for how to use the interior space. From the very beginning, the office building in Aachen was meant to be more than a one-off experiment. The concept is to be converted into a "product series" so that planning costs are reduced and the experience gained previously can be benefited from.

The office has been in use since summer 2002. A subsequent monitoring process was sponsored by the German Federal Ministry of Economics and Technology in the scope of the key research area, EnOB – "Energy-Optimised Construction". Evaluating several hundred measurement points over a five-year period has played a decisive role in ensuring that the building can now produce such good characteristic value. The evaluation will therefore be continued.

► Building concept

The compact, four-storey office building without cellar has a north-south orientation. The staircase protrudes on the north side of the building. This is where the sanitary facilities can be found on each floor. The large-surfaced floor plan without load-bearing interior walls allows a flexible subdivision. The depth of the building of 16 m makes it possible for adjoining rooms to be accommodated in the central zone. Five parties currently use the building with approx. 100 workplaces in total. In theory, up to eight units would be possible per floor.

Fig. 3: Standard storey floor plan



The reinforced concrete skeleton construction with load-bearing precast concrete facades was, for the most part, prefabricated. The building shell was therefore finished within 8 weeks and the whole building within 9 months. The high standard of insulation is in line with the construction method of a passive house but only reaches an average U-value of 0.48 W/m²K. This is, among other things, a result of the glazing in the slightly-heated staircase which, however, is located inside the insulated envelope, with a U-value of 1.6 W/m²K. The outer walls are insulated with 20 cm mineral wool and faced with square tiles ventilated at rear. The windows in the office zones consist of triple glazing in thermally separated aluminium frames ($U_w=0.80$ W/m²K). The windows account for 41% of the facade surface area. Because of the glazing's comparatively low g-value of approx. 50% and cooling using concrete core temperature control, exterior shading was not installed.

Fig. 2: Building summary

Overall planning	Balanced Office Building GmbH: Hahn Helten und Assoziierte Architekten GmbH VKA Ingenieur GmbH B. Walter Ingenieurgesellschaft mbH
Location	Aachen, Germany
Planning and construction timeframe	1/2001 – 6/2002
Structural design	Reinforced concrete skeleton construction with load-bearing facade made of precast concrete units
Net floor area (NFA)	2,151 m ²
Net floor area (NFA), heated	2,076 m ²
Average room height (NV/NFA)	2.70 m
Gross volume (GV)	7,675 m ³
A/V ratio	0.37 m ⁻¹

With an annual heating requirement calculated at 39 kWh/m² p.a., the office building falls below the then permitted value of the Heat Conservation Ordinance 95 (WSVO) by almost 40%. The air-tightness test of the building envelope produced an n₅₀-value of 0.3 h⁻¹.

Thermal mass and acoustics

Concrete core temperature control as well as other measures for passive climate control require open room ceilings as building elements which can act as thermal stores. Suspended ceilings or other sound absorbers would be counter-productive here because they almost always have a heat-insulating effect as well – a special situation for optimisation of the room acoustics.

As part of a study two rooms of the office building in Aachen were investigated because 17% of those questioned in a user survey were “unhappy” or “very unhappy” with the acoustic situation.

The materials which make up the rooms such as the exposed concrete surfaces and unclad ceilings are reverberant. Needle-punched carpet largely alleviates the sound situation. Measurements and simulations resulted in acceptable reverberation times which were close to the recommended value of the German Industry Standard (DIN) 18041 for a two-person office. Additional open filing or book cases and panel absorbers on the side walls could produce further improvements.

In a room, approx. 50 m² in size, which is used for meetings as well as presentations, measurements confirmed the users' comments which described the room as being “far too echoey”. Low-frequency acoustic insulation is primarily needed here. According to simulations, conventional panel absorbers on the side walls and the front wall, which can also be used as pinboards or projection surfaces, would be a suitable solution.

Fig. 4: One of the meeting rooms without measures to improve room acoustics



Overall the study showed that effective solutions for the acoustics of a room were possible for meeting rooms with a reverberant ceiling. Simulations and measurements should aid the acoustic planning for rooms where the acoustic characteristics are of particular importance for the quality of use, such as conference and presentation rooms or classrooms.

► Heating and ventilation

A heat pump together with 28 borehole heat exchangers is responsible for heat generation. The pump supplies a buffer storage tank which feeds the concrete core temperature control (CCTC). The CCTC is divided into two control circuits (north and south) on each floor. In summer, the heat is extracted from the rooms via CCTC and released into the earth by means of the borehole heat exchangers. The heat pump is not in operation. The energy requirements for cooling and heating balance each other out – the temperatures in the soil therefore do not build up during the course of the year. Fresh air is supplied on each floor via a central

ventilation device with heat recovery. This allows the individual systems to be operated at an optimum and be adapted to the individual usage period. Outside air is drawn in via the roof and fed into the offices via concrete-enclosed ventilation pipes through ceiling outlets. The air from the offices flows through the door leaves into the central zone which is used as an exhaust air section. The exhaust air returns to the outside via the heat exchanger in the ventilation device. The meeting rooms are equipped with hermetic doors and receive larger quantities of supply air. Here, the exhaust air is extracted by suction directly through ducts. The bore-

hole heat exchangers' water circuit can also be used for cooling and heating the supply air by means of an additional heat exchanger. In consideration of the staff being present at the same time, the air renewal rate is reduced to the hygienically-necessary requirement of 20 m³/h per person.

The pipes for CCTC and ventilation were cast into the concrete ceiling together with the welded wire mesh. This is how the air ducts are also used for heat or cold recovery. At the same time, individual areas can be separated spatially and in a flexible manner.

► Daylight and lighting

The office rooms are usually 4 m in depth with the windows providing sufficient daylight. The lower section of the internal blinds provides glare protection; the upper section directs the light via the ceiling, which is partially plastered in white, into the room. Despite the deep floor plan of the building, the inner glass walls allow the central zone to be partially lit with daylight.

On average, 7.5 W/m² electrically connected load of the lighting system is installed for each storey, excluding desk lighting. The workplaces can thus be illuminated by up to 500 lux. The profile system of the lights contains uplights for indirect lighting and specular louvres as downlights. The lights are all equipped with dimmable electronic ballasts. A control unit with a central sensor on the roof and light meters under the ceiling either dims the artificial light or switches it off completely, depending on the daylight. It is also possible to adjust the blinds and the lighting locally. In rooms without daylight, for example, a lavatory or technical room, there is a presence detector.

► Measurement results

During the first years of operation, the building was monitored closely. This allowed energy consumption and factors affecting it to be observed precisely and attention was also drawn to incorrect settings and difficulties with control technology. At first, e.g. the ventilation devices ran with high supply air temperatures, unnoticed by staff. Prompt evaluation of the measurement data discovered the increased energy consumption.

The annual coefficient of performance of the heat pump was approx. 3.1 in 2003. Regulation via reference rooms led to uneven temperature distribution and unnecessary pump running times due to unexpected staff absences or larger numbers of people working in the reference rooms. At the end of 2004, the system was switched over to demand-oriented control. At the same time, the supply temperature was lowered. Now, the pump is turned on and off depending on ΔT between supply and return temperature. The energy requirement control system was developed especially for this building was difficult to adjust, especially in the beginning. The best time periods for measuring had to be determined empirically. Today, the control system is mature and there is a relatively large time period when no heating or cooling is demanded, i.e. when the heat pump is switched off. The supply temperatures were also reduced further. The annual coefficient

► Energy concept: System components

System	Components	Details
Heating/Cooling	Borehole heat exchangers	28 exchangers, drilling depth: 42 m thermal output 56 kW; refrigeration capacity 54 kW
	Heat pump	Compression heat pump, operated monovalently Power consumption 12.9 kW Heat output 56 kW
	Buffer storage tank	900 l
	Concrete core temperature control	Supply temperatures: winter max. 28°C/summer min. 18°C Heating threshold temperature approx. 8°C, cooling threshold temperature approx. 16°C
	Air/water heat exchanger	Connection to borehole heat exchangers for additional heating or cooling of supply air
Water heating	Decentralised electric continuous-flow heaters	1 unit per floor (sanitary facilities without hot water connection)
Ventilation/Cooling	Mechanical ventilation	4 central ventilation devices with heat recovery (75%) Air renewal rate: 20 m ³ /h per person Heat exchanger with borehole heat exchangers (see above)
	Control	Timer switch
	Lighting	Natural lighting
Lighting	Glare protection	internal, two-section blinds
	Artificial lighting	Lamps with uplights and specular louvres as downlights with dimmable electronic ballasts Daylight-dependent control or presence detector; user intervention possible
	Control	Central building management system

Fig. 5: Energy characteristic relating to heated NFA

	Planning (as per WSVO 95) [kWh/m ² p.a.]	Year of operation 2004 [kWh/m ² p.a.]	Year of operation 2005 [kWh/m ² p.a.]	Year of operation 2006 [kWh/m ² p.a.]
Heating (support initiative specification: < 40 kWh/m ² p.a.)	39.7	30.6	26.3	36.3
Final energy: Heating	13.0	8.4	6.6	8.8
Cooling	3.3	3.6	3.5	3.0
Air conveyance	2.0	3.9	4.3	4.3
Lighting	10.0	12.5	10.8	10.8
Auxiliary energy	3.3	3.5	2.7	2.8
Total final energy (support initiative specification: < 70 kWh/m ² p.a.)	31.6	31.9	27.9	29.7
Primary energy (support initiative specification: < 100 kWh/m ² p.a.)	94.8	95.7	83.7	89.1

of performance thus improved to 4.3 (2007). The decision concerning the ventilation to only let in low amount of fresh air has proved to be practicable. Measurements showed that the CO₂ concentration remains considerably below the maximum amount recommended for the workplace. Even with very low or high outside temperatures, longer window ventilation also had little effect on thermal comfort. The ventilation system's heat exchanger reaches an efficiency of up to 75%. Since the air ducts are not insulated and run partly within the CCTC ceiling, the supply air also adopts the temperature of the room or ceiling. Therefore the additional temperature control function of the supply air with the borehole heat exchangers was shut down. Specific electricity consumption for the ventilation constantly rose for all floors but by different amounts. On the one hand, due to high numbers of staff present at the same time and frequent occupancy in some offices the amounts of air required are larger than expected. On the

other hand, the ventilation is often adjusted "by hand" and not changed back later.

Despite there being solely internal shading without any solar protection glass, according to statements of the users, the interior climate was satisfactory even in the extremely hot summer of 2003. Effective cooling by the CCTC no doubt contributed to this. Measurements in south-facing offices established that there were up to 214 hours with air temperatures above 26°C during working hours in 2006.

Electricity consumption for lighting (without table lights) was close to the planned value of 10 kWh/m² p.a. Dark floors, less transparent interior walls, workplaces located away from the windows or shade from neighbouring buildings constituted the reason for the increased consumption in individual office units. Initially in 2005, daylight control was only used on the 2nd floor and extended to the whole building in 2006.

► Economic viability

When constructing the building, high-quality, durable materials were used and importance was also attached to the comfort of cooling and mechanical ventilation – not necessarily the norm in offices. Nevertheless, with a net figure of 1,125 €/m² NFA (cost groups 300 & 400), the investment costs are below the average costs according to the building cost index. This was reached because additional costs, e.g. arising from the use of geothermal energy, were compensated for by savings in other areas such as exterior sun protection. Prefabricated elements also reduced construction costs.

Monthly energy costs for heating, cooling, air conveyance, lighting, water heating and the lifts were amounted to 0.21 €/m² for 2005. In comparable new office buildings these costs are between 0.80 €/m² and 1.50 €/m².

► Conclusion

The planners' idea was a success. The building is both economically viable and energy-efficient to run. At 89 kWh/m² p.a., the primary energy characteristic value is below the target value in the support initiative of 100 kWh/m² p.a. The heat pump system can reach a high coefficient of performance because the temperature difference between the heat source and the supply is small, even with low outside temperatures. The energy equilibrium in the soil from the removal of heat in winter and the depositing of heat in summer also has a positive effect. However, some time and an exact observation of the energy characteristic values was necessary to find the best control concept for operating the heat pump efficiently. For this, the accompanying EnOB monitoring was extremely important. That is why relevant characteristic values continue to be ascertained.

User satisfaction in the building is very high. It must be kept in mind, however, that today's users were both the contractors and the planners. On the other hand, this has the advantage that they have first-hand experience of the problems occurring in the operation of the building and can optimise control parameters without great dispute about responsibility or financing and without having to schedule a lot of meetings. The idea of the building going into "series production" is today being put into practice. The same building is currently being constructed in France. A variation on the design is planned for further locations.

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Literature

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Images

- Fig. 1, 4: Jörg Hempel, Aachen
- Fig. 3: Hahn Helten, Aachen

Internet

- www.bob-x.de
- www.enob.info
- www.energie-projekte.de

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- Additional information in German is available from BINE Information Service or online at www.bine.info (Service/InfoPlus)

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