Building refurbishment – Waste disposal operation

- Heating energy consumption of 60 kWh/m² p.a.
- High level of satisfaction with thermal comfort achieved by passive cooling
- Lack of air-tightness of building envelope is a critical factor in systematic night ventilation during summer
- Differing construction types affect the thermal behaviour of the individual storeys

The refurbishment of complex buildings that serve various functions presents a particular challenge. This project involves a building that was built in 1968 and has been in use since then by the local authorities and public companies of the city of Remscheid. However, one consequence of a reform of the city’s administration was that the existing facilities were only to be used by Remscheid’s waste disposal services, including their vehicle fleet and administrative departments. This changeover presented an opportunity to refurbish the building, which had begun to show signs of its age. Alongside the rectification of structural defects, the client’s wishes also included significant improvements to the functionality and appearance of the building. Satisfied users have become an important quality criterion for office buildings.

There were significant problems with the building. These were particularly evident on the facades and roof and with the building services equipment and fire protection, meaning that economically viable building operation was no longer possible. In addition, there were structural defects. Accessibility features for disabled persons such as a lift were lacking, and this was no longer acceptable for a municipal building open to the general public. The clearance height in the staircase was only two metres in places. A feasibility study showed that refurbishment was more economical than demolishing the building and rebuilding it, even in the light of the numerous problem areas. The additional costs for a new building were estimated to be around 40%, as the disposal of the reinforced concrete skeleton structure would have led to high costs.

One of the goals of the planned measures was to reduce the primary energy requirement from around 440 kWh/m² p.a. to approximately 136 kWh/m² p.a., which would in turn also significantly reduce the operating costs for the building. The heating requirement of over 370 kWh/m² p.a. was well above the requirements of today’s German Energy Saving Ordinance. The high energy consumption was caused by the very poor structural condition of the building, the high hot water requirement all year round for showers, and errors with the control system.

The energy and indoor environment balances of the building were monitored for two years after refurbishment. This work was supported by the German Federal Ministry of Economics and Technology as part of its “Energy-Optimised Construction” (EnOB) research initiative. User surveys were also conducted in order to investigate levels of workplace comfort. In advance of the EnOB project, an economic and ecological evaluation of various facade structures was supported by funds from the Deutsche Bundesstiftung Umwelt (DBU).
The building

The four-storey building has a reinforced concrete skeleton, and had a typical 1960s facade consisting of precast concrete elements. Lightweight construction had to be used for structural reasons when a further storey was being added at the time of building. The two lower levels serve as a depot for refuse collection vehicles. Thanks to the slope of the overall site, it is effectively possible for vehicles to drive directly into each of these levels. The upper storeys house the common facilities with showers, the drying area and offices that required artificial lighting because of the depth of the rooms present.

Refurbishment concept

The main entrance was moved from the south-facing front to the westerly side end of the building. Part of the vehicle depot behind this was converted into a small foyer that provides access to a customer centre. A new staircase with a lift was added to the existing building. The floor plan of the two upper floors was altered in order to reduce the depth of the office rooms, which previously had a depth of 8 m, and to allow for a better supply of daylight. Areas for photocopi­ers, kitchenettes and sanitary facilities were created in the middle (Fig. 3).

The necessary thermal insulation is provided by a new, prefabricated lightweight wooden­en construction facade consisting of large panels (5 x 8 m) with integrated insulation and translucent multi-layer panels made of polycarbonate that offer weather protection, windows with insulating glass, and additional insulation on the flat roof and the ceiling of the unheated vehicle depot.

Energy concept

The building is split into three areas for functional reasons: the vehicle depot which is not actively heated, the common area, and the administrative area with offices. This results in particular challenges for the energy concept as regards room temperature and the possible means of providing ventilation for the various zones. The concept includes heating for the office and common zones using radiators in the facade area. Passive outdoor air inlets and a mechanical exhaust air system provide ventilation. The building is heated using a central gas condensing boiler.

Ventilation

Supply air enters the building in a distrib­uted manner through outdoor air inlets that are controlled depending on the weather, thus ensuring a sufficient air change rate in the offices. The flaps on the outdoor air inlets can be adjusted and closed, and are half-open during working hours. The exhaust air system is switched off outside of working hours and the ventilation inlets are closed. The inlets can be completely opened at night during the summer if the outdoor temperature is appropriate. Automatic closing outside of usage periods is necessary during winter operation in order to avoid ventilation heat losses.

Before the exhaust air leaves the insulated envelope, it passes through heat ex­changers where it heats up the supply air to the ground-floor offices and the sanitary and hall areas. The mechanical ventilation is intended to prevent unclean air caused by the vehicle exhaust fumes from entering the offices. Exhaust air from the office block is fed to the vehicle depot as necessary, thus keeping this area free of frost. This means that it is not necessary to install any heating in the depot area.

Passive cooling

Passive cooling of the building using night ventilation was one focus of this project. A prerequisite here is that the thermal loads are reduced as much as possible in summer and that the thermal mass of the building structure can be exploited.

Sun protection fitted externally on the south­facing windows and solar control glazing on the northerly facade help to ensure low solar loads in summer. The design of the sun protection provides for a sufficient supply of daylight and allows the building occupants to look outside even when the sun protection is closed. Artificial lighting is controlled depending on the daylight situation and on presence detection. This reduces internal loads.

The solid building structure offers sufficient thermal mass. Latent heat storage (PCM) elements in the plaster and in the suspended ceiling provide increased thermal capacity in the second floor, which has a lightweight construction. A pleasant indoor atmosphere in summer can be achieved in the building thanks to the automated night ventilation.
Measurement equipment was installed in early 2007 in order to evaluate the building while in service. Measurements of energy performance and indoor environment were carried out, and user satisfaction was also evaluated.

Initial results revealed that heating energy consumption was above the planned value and that there was high power consumption for ventilation in the offices and in the common area. Break rooms, showers and drying rooms for work clothes are located in this area. The extraction of humid room air is a significant factor in achieving good air quality here, meaning that high air change rates are necessary. Initially, the air change rates were not linked with usage periods. This was corrected as required. The air change rate in the office rooms was also reduced from 1 h\(^{-1}\) to 0.6 h\(^{-1}\). As a result, the power consumption of the fans dropped significantly. Measurements of the CO\(_2\) concentration confirmed that good air quality was being achieved.

**Comfort during the summer**

Despite difficulties with night ventilation, the thermal insulation strategy that was implemented for summer periods proved to be effective. Evaluations of the measurement data and the results of user surveys confirmed that good levels of comfort were present. However, the potential offered by night ventilation could not be fully exploited as the planned volumetric flow rate of air of 160 m\(^3\)/h through the outdoor air inlets was not being achieved. Blower door measurements revealed problems such as a lack of airtightness around the fire doors to the unheated staircase and the equipment ducts. This meant that the negative pressure of 22 Pa in the office rooms relative to the exterior – the appropriate amounts of air must be extracted and sufficient negative pressure must be created in the office rooms. Supply air may only be drawn in through the outdoor air inlets. An air change rate of 1 h\(^{-1}\) is provided for during daytime operation, with air change rate of 2 h\(^{-1}\) in the case of night ventilation.

**Comfort criteria**

The limit values in DIN 1946-2, which was still valid in 2005, were used as the comfort criteria when designing the passive cooling. These criteria define a given “comfort zone” depending on the outdoor temperature. The European standard EN 15251, which was introduced in 2007, was used as the benchmark for the evaluation of the thermal comfort when evaluating the measurement data. A floating average value was used as a reference outdoor temperature here. This approach assumes that no active cooling takes place, that users can directly influence the ventilation and sun protection at their workplace and that they adapt their clothing to the temperatures to a certain extent. Three comfort classes are defined which indicate the level of user acceptance for the room temperatures present as a function of the outdoor temperature.

The effects of the light construction method can be observed for the second floor. The PCM elements have to release the heat stored during the day at night again. Otherwise there will be insufficient buffer capacity for the following day and the indoor temperatures quickly rise again. The results from 2008 show that no problems with excessive indoor temperatures occurred apart from a few exceptional cases. Admittedly, there were only a few periods of high outdoor temperatures during the summer of 2008.
The building in Remscheid has been improved in terms of both architecture and function as a result of the refurbishment. Intensive planning and the involvement of clients and planners contributed to the implementation of a holistic refurbishment project with a justifiable level of costs. The characteristic energy values achieved represent good results when compared with the high values before refurbishment. However, there is also room for improvement in the light of the targeted values.

The planning of an administration building with an integrated common area, shower facilities and drying rooms presented particular challenges with regard to the energy balance. A building such as that in Remscheid cannot yet be treated using the standard methods in DIN V 18599. For this reason, certain additional calculations were necessary to take the particular circumstances into account. This underlines the need for planning tools that go beyond standardised calculation procedures when implementing innovative projects.

Once the building went back into service, it became evident that the planned air change rate of 1 h⁻¹ for the offices was too high. Users also expressed their dissatisfaction with the dry air in the winter. Measurements indicated higher humidity values once the air change rate had been modified. The CO₂ concentrations that were recorded demonstrated that the air quality was sufficient even with an air change rate of 0.6 h⁻¹. In total, the power consumption for fans was too high for the building. It transpired that the shower and drying areas were subject to an air change rate of 15 h⁻¹, even outside of usage periods. By adapting operation in line with working periods, the power consumption of fans was reduced by around 70% between 2008 and 2009. This type of potential for savings can only be exploited by monitoring operation in a systematic manner.

Once the building went back into service, it became evident that the planned air change rate of 1 h⁻¹ for the offices was too high. Users also expressed their dissatisfaction with the dry air in the winter. Measurements indicated higher humidity values once the air change rate had been modified. The CO₂ concentrations that were recorded demonstrated that the air quality was sufficient even with an air change rate of 0.6 h⁻¹. In total, the power consumption for fans was too high for the building. It transpired that the shower and drying areas were subject to an air change rate of 15 h⁻¹, even outside of usage periods. By adapting operation in line with working periods, the power consumption of fans was reduced by around 70% between 2008 and 2009. This type of potential for savings can only be exploited by monitoring operation in a systematic manner.

The principle of passive cooling based on outdoor air inlets has proved itself here. Savings can only be exploited by monitoring operation in a systematic manner. However, the prerequisite for this is careful attention be paid to the air-tightness of the building as well as air-tightness between the individual zones in the building. Air-tightness is necessary if the volumetric flow rates at the air inlets specified in planning are to be actually achieved in service. Consideration is often not given to the fact that fire doors are not automatically air-tight and that air can be drawn in from other parts of the building instead of from the exterior. The pressure difference between the office and exterior that is necessary during night ventilation has not yet been achieved. It is also important that the outdoor air inlets close automatically in an air-tight manner in winter outside of operating periods.

Once the building went back into service, it became evident that the planned air change rate of 1 h⁻¹ for the offices was too high. Users also expressed their dissatisfaction with the dry air in the winter. Measurements indicated higher humidity values once the air change rate had been modified. The CO₂ concentrations that were recorded demonstrated that the air quality was sufficient even with an air change rate of 0.6 h⁻¹. In total, the power consumption for fans was too high for the building. It transpired that the shower and drying areas were subject to an air change rate of 15 h⁻¹, even outside of usage periods. By adapting operation in line with working periods, the power consumption of fans was reduced by around 70% between 2008 and 2009. This type of potential for savings can only be exploited by monitoring operation in a systematic manner.

The principle of passive cooling based on outdoor air inlets has proved itself here. Savings can only be exploited by monitoring operation in a systematic manner. However, the prerequisite for this is careful attention be paid to the air-tightness of the building as well as air-tightness between the individual zones in the building. Air-tightness is necessary if the volumetric flow rates at the air inlets specified in planning are to be actually achieved in service. Consideration is often not given to the fact that fire doors are not automatically air-tight and that air can be drawn in from other parts of the building instead of from the exterior. The pressure difference between the office and exterior that is necessary during night ventilation has not yet been achieved. It is also important that the outdoor air inlets close automatically in an air-tight manner in winter outside of operating periods.