EXPERIENCES WITH HIGH TECH BUILDINGS

W. Braun
Geilinger Ltd
CH-8401 Winterthur, Switzerland

ABSTRACT

A conventional type office building in Winterthur, Switzerland, has been extended by two floors with a High Insulation Technology (HIT) envelope, equipped with a source-dominated displacement ventilation. This paper reports some of the results of two years of detailed investigations, including readings of the energy consumption, measurements of the thermal performance and monitoring of the mechanical ventilation and its control-system. Results of computer simulations are also presented.

One of the most impressing features is the extremely low total energy consumption of the new part of the observed building (360 MJ/m^2a), which is far below the average value for Switzerland (825 MJ/m^2a).

1. INTRODUCTION

During the last few years it has become widely accepted, that new ways for energy saving in building management must be found. Many people do automatically associate this requirement with a decrease of the user comfort. In this paper it will be shown that the contrary can be achieved.

A new concept, based on a high insulated building envelope and a low momentum mechanical ventilation, leads to a higher user comfort and at the same time reduces the energy consumption. Following this concept, several office buildings have already been constructed with a newly developped window system, which is called High Insulation Technology (HIT). Glazing-U-values of 0.65 W/m^2K are typical. Comfort and energy measurements have been made [1] and have been compared to dynamical computer simulations. One case is presented on the next pages.

2. TWO YEARS OF REGULAR PERFORMANCE OF A HIT-PROJECT

2.1. Extension of a Conventional Building

Detailed investigations were made in 1988/89 at an office building in Winterthur, Switzerland. Up to the fourth floor, the building has a conventional facade with insulated double glazing windows, natural ventilation and radiator heaters. On top of this building, two floors were erected in 1987 based on the HIT concept: high insulation windows, mechanical ventilation with source dominated displacement flow [2,3,4], roomindividual control, no radiator heaters. All windows can be opened and effective sun shades can be lowered individually.

The ventilation system of the HIT-part of the building operates with temperature demand controlled variable air volumes of 1.0 ... 5.0 air changes per hour. The outside air is heated up to 19°C by heat recuperation and - if necessary - by a water heater (connected to the central heating system of the older part of the building). On top of this, the air can be heated by a room individual electrical unit, if desired by the occupant.

Since the ventilation system is not equipped with a cooling unit, the mechanical ventilation is turned off at outside temperatures over 22°C in order to prevent unwanted heating. Users are then recommended to make a reasonable use of the openable windows. During summer nights, the excess heat is removed by free cooling.

2.2. Measurements

For two years, the energy consumption was investigated by regular readings of different meters for electricity, heat supply and operating hours.

Further, two campaigns were conducted during winter 1987/88 and summer 1988. The observations included a conventional room for comparison. 30 parameters were recorded at time intervalls of 10 minutes. The objectives were:

- user comfort: temperature distribution (time and space)
- efficiency of free cooling
- suitability of the control concept of the ventilation system
- monitoring of the mechanical ventilation

2.3. Computer Simulations

HIT-KOMFORT is a software package for the dynamical simulation of the thermal behavior of an office room. Important features are the inclusion of the

- behavior of the occupant
- heat production of machines and lights
- heat load of the sun (with or without sun protection)
- transmission losses to the outside
- heat flux into massive storage (floor)
- heat flux into light storage (walls and furniture)
- convective and radiative heat exchange between the different heat capacities
- different HVAC and control systems (also window opening)
- real weather data

The time step is 6 minutes (which is less than the time constant of the room air-capacity). The simulation time can be selected: one year or a few days. The model has been validated with measurements of real buildings.

3. THERMAL PERFORMANCE

3.1. Seasonal Aspects

Present office work is characterized by relatively high internal heat loads from equipment (computers, copying-devices) and lights. Typical values range from 10 to 40 W/m². Different aspects are of importance during winter and summer, respectively.

With a high insulated facade the transmission losses in winter are covered by the internal heat load, which signifies optimum energy efficiency. Regarding comfort conditions it is to say, that the inner surface of super insulated windows is only a few degrees below the room temperature. Consequently, the thermal radiation field is well-balanced and downdraft does not develop.

With moderate weather conditions, a well insulated office room normally needs passive cooling: the outdoor air is only warmed up to 19°C and can therefore remove a part of the excess heat. A large amount of the heat gain is stored in the masses and removed at night. This mechanism is of special interest during hot summer weather, when free cooling can be applied.

3.2. Room Air Temperatures

In summer 1988 several distinct warm weather periods occurred in the region of the investigated building. A reasonable use of sun protection and window opening could be stated in both rooms under observation. The internal heat loads were also comparable.

At all times the room air temperature in the HIT-room was lower than in the other one. Figure 1 shows the statistical distribution of the room

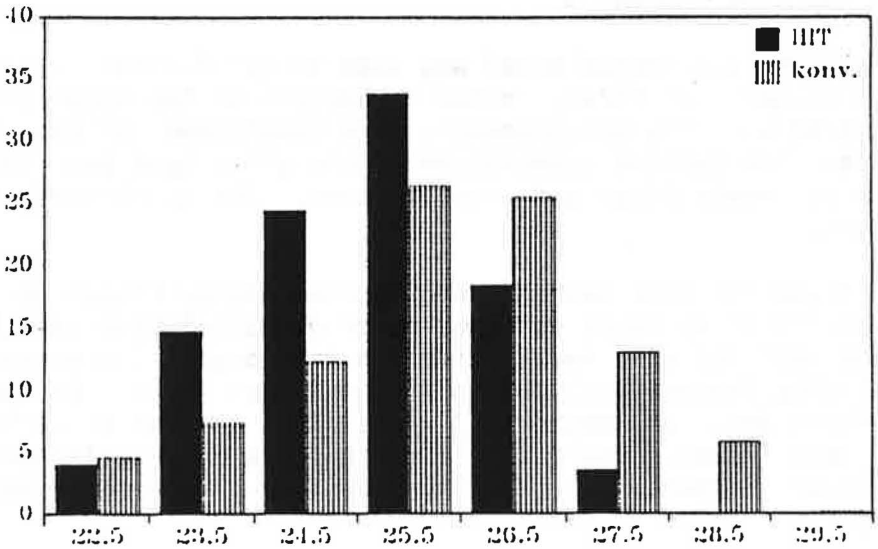

FIGURE 1. Statistical distribution of the room air temperatures of 12 summer weeks during working hours: a comparison of a HIT-room and a conventional room in the reported building. Vertical scale: percentage.

air temperatures of the HIT-room and the conventional room, respectively. The statistics includes a periode of 12 summer weeks (530 working hours). The time average doesnot give much information, but the number of hours with "high" room temperatures ($t_i > 27°C$) is a measure of the user comfort: 19 hours in the HIT-room, 111 hours in the conventional room.

On hot days, it could be observed, that shortly after the end of the working time, the room air temperature of the HIT-room began to drop, although the outside air temperature still remained higher. This is due to the effect of the thermal mass (floor, walls, furniture). Contrary, the conventional room is strongly influenced by the course of the outside air temperature and can, therefore, only cool down if the temperature of the outside lies below.

3.3. Free Cooling

A mechanical ventilation system offers the opportunity to run a free cooling mode during summer nights: the excess heat, which has been accumulated in the thermal masses during the day, is being removed by the cold nocturnal air.

For a typical case (1./2.9.88), the extracted energy has been investigated. The calculation was based on the measurements of:

- air temperatures and velocity in the air ducts (energy transport by free cooling)
- air temperatures in the rooms and outside (transmission)

A total amount of 10860 kJ was removed from the HIT-room: 9100 kJ by free cooling and 1760 kJ by transmission. Naturally, transmission is much more effective for the conventional room (7370 kJ), but it is still below the amount removed by free cooling. In this case, the ventilators consumed 6000 kJ electricity (related to the office room). This amount should be seen as part of the yearly total energy consumption, which is extremely low (see chapter 4).

The HIT-KOMFORT simulation model was used to get further insight into the energy fluxes. At first, three parameters of the model calculation were compared with the measurements: the development of the room air temperature, the surface temperature of the glass pane and the energy extraction by ventilation and transmission. The quantitativ agreement is excellent.

Figure 2 shows the time development of three energy fluxes to the room over a period of 48 hours (the period of precalculation was 7 days). Persons and machines were heat sources on both days. Sun energy (first day) and lights (second day) were additional heat loads. In the morning of the first day, the mechanical ventilation removed a part of the internal heat loads. Apart 1.00 p.m. there is no ventilation at all (high outdoor temperature). During the night, free cooling was in operation.

All heat input, which was not removed immediately, was stored in massive materials (floor, walls, furniture) with a thermal capacity of around 20 MJ/K and room air with a capacity of somewhat less than 0.1 MJ/K. (Clearly, the air is unimportant as a heat capacity). During

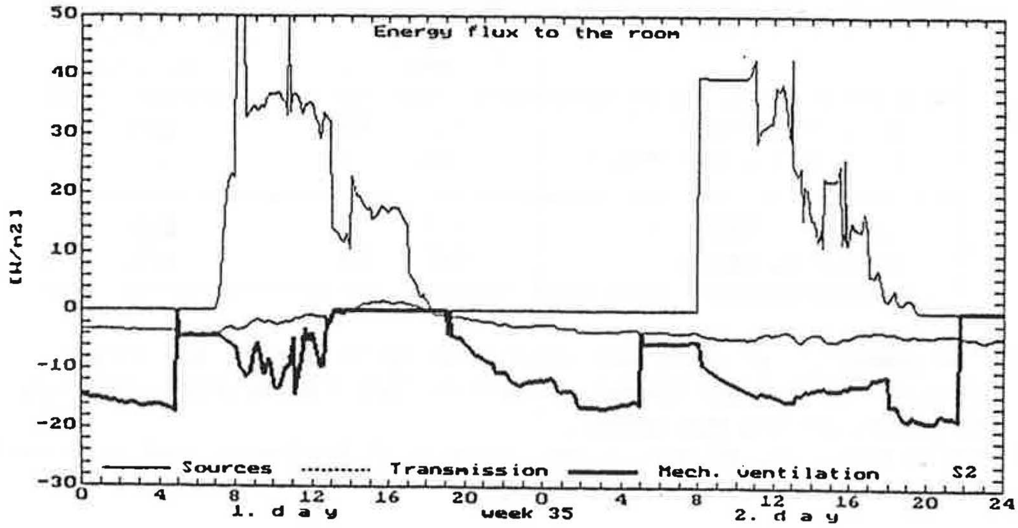

FIGURE 2. Energy fluxes [W/m² floor area] to the room over 48 hours from the sources (sun, lights, machines, persons), the transmission and the mechanical ventilation.

the working time of the first day, the larger part (0.75 MJ/m²) of the internally produced heat energy is stored in the massive capacities. Running in the free cooling mode (until 5.00 a.m.), the mechanical ventilation (and to a small extent the transmission) removes 0.53 MJ/m². At 8.00 a.m. of the second day the surplus amount of 0.15 MJ/m² is still present.

If free cooling would be out of operation, the transmission would remove only 0.10 MJ/m² until 5.00 a.m. (instead of 0.53 MJ/m²). As a consequence, the room air temperatures would be approximately 0.5 K higher during the next day. During a hot weather periode, this would result in a quite unpleasant heat accumulation. (This theoretical result was obsereved in reality: Due to an error, the free cooling was not in operation during a few summer days.)

4. ENERGY SAVING

4.1. Two Years of Observation

The most impressing feature is the extremely low total energy consumption of the HIT-part of the observed building (see table). Since the 6th floor has transmission losses also to the roof, more heat energy was consumed than at the 5th floor. Although conditions for the extension of the building were not optimum (certain heat leaks such as outside columns could not be avoided), the energy consumption is far below the nominal value for Switzerland.

At the 5th floor, 45% of the total enery was consumed for lights and machines, and 35% for heat. Compared to the swiss average this is only a small fraction. Most of the heat energy has been used for central air pre-conditioning. In other words: heat is not needed to cover the transmission losses, but for the fresh air supply of the occupants.

	heat MJ/m²a	%	total energy MJ/m²a
HIT, 5th floor	110	35	320
HIT, 5th + 6th floor	160	45	360
average 1988 (*)	575	70	825
proposed value (**)	240	58	415

TABLE. Consumption of heat and total energy of office buildings
(*) Existing office buildings in Switzerland (buildings with heavy deficiencies are excluded), [5].
(**) recommendations of the Swiss Society of Engineers and Architects (SIA), [5].

4.2. Results of Dynamical Simulations

Comparisons of real buildings have the inherent deficiency that they differ in too many parameters. For this reason, some results of a parametric study are added to this report. The above mentioned dynamical simulation code HIT-KOMFORT was used. (Once again, the calculated energy comsumptions fit very well to the observations.)

A model office room was defined with the same dimensions as the observed one. The room is supposed to bee air tight. The HVAC system consists of a combined water-air-system with radiators at the ceiling for effective cooling. The U-values of the facade were varied from 0.4 ... 2.0 W/m^2K. The specific power of the machines ranged up to 50 W/m^2 (which is far beyond typical values).

Figure 3 shows the total energy consumption as a function of the consumption for lights and machines. For a highly insulated building, this is a linear dependance, and besides, practically independant of the climate. In the common region of internal heat loads, the total energy consumption gets more and more independent of the consumption for electricity (but becomes very sensitive to climate). These calculated energy amounts are clearly underestimating the cases of conventional buildings, since there, additional heaters are in operation simply to prevent downdraft. Besides, this building type normaly is not air tight at all (which has a large effect on the energy consumption).

5. CONCLUSION

Investigations on real buildings demonstrate that it is possible to provide a high comfort level and at the same time to reduce the total energy consumption drastically form todays averages. One solution is to combine a high insulation building envelope with a mechanical ventilation based on the displacement principle, which is equipped with an adequate control system. In cases of very high internal loads, a supplementary water system for radiative cooling can be recommended.

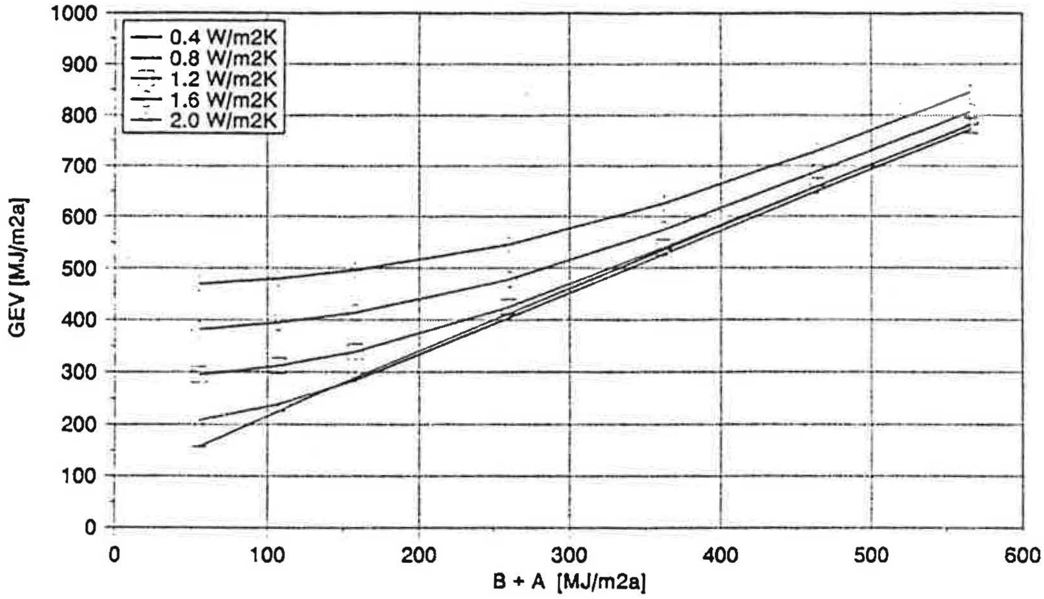

FIGURE 3. Results of a parametric study: total energy consumption as a function of consumption for lights and machines dependant of the U-value of the facade.

REFERENCES

(1) Braun, W., Keller, B., Resultate von Energieverbrauchsmessungen bei hochisolierten Bürogebäuden. 5. Schweizerisches Status-Seminar "Energieforschung im Hochbau", Zürich, September 1988

(2) Skåret, E., Displacement ventilation. ROOMVENT 87, Stockholm, 1987

(3) Mathisen, H.M., Skåret, E., Ventilation efficiency - part 4: displacement ventilation in small rooms. SINTEF-Report Nr. STF15 A84047, Norvegian Institute of Technology, 23.5.1983

(4) Hesthag, B.H., Ventilation and thermal climate in an office equipped with HIT-window and low momentum displacement ventilation. SINTEF-Report Nr. STF15 F85023, Norvegian Institute of Technology, 16.4.85

(5) Swiss Society of Engineers and Architects (SIA). SIA-Empfehlung 380/1, Energie im Hochbau, 1988