ENERGY AND COMFORT ORIENTATED RETROFITTING OF AN OFFICE BUILDING

INSTITUT FÜR GEBÄUDE- UND SOLARTECHNIK (IGS)

TU Braunschweig

Prof. Dr.-Ing. M. N. Fisch, Dipl. Ing. M. Rozynski

Mühlenpfordtstr. 23, 38106 Braunschweig

Tel. +49/531/391-3583 Fax : +49/531/391-8125

1. INTRODUCTION

A comprehensive concept for an energie and comfort orientated retrofitting is realised for an office high rise building „BS 4" (on campus at Braunschweig Technical University). This master plan will take the form of a research and developement projekt; a pilot realisation will be carried out on the 10^{th} floor.

2. RETROFITTING AIMS

Around thirty million squared metres of air-conditioned office space was already built even before 1980 in the Federal Republic of Germany [1]. Considering the situation at large therefore, it would be logical to assume that in future it will be necessary to develop retofitting concepts especially for these buildings. These retrofitting concepts should reduce energy consumption while optimizing user comfort (thermal comfort and workstation lighting) and the effective functioning of the building.

The maintenance of comfortable room conditions is especially important in office buildings because employees' powers of concentration and performance are considerably influenced by the conditions in which they work. Twenty or thirty years ago a high level of energy consumption for air conditioning was required to guarantee comfortable conditions. Characteristic energie units of over 300 kW/m²a for heating and electricity are not uncommon even today in administration buildungs built in the 1960's and 1970's.

New building concepts make it possible to keep the interior conditions comfortable even at summer temperatures without conventional air-conditioning, which in many administration buildings consumes more energy than the heating system. The project should show to what extend the best possible results of an energie efficient retrofitting can be achieved despite working on a low budget.

The pilot project "Energy- and Comfort-orientated Retrofitting", or SAN-IGS for short, starts with the retrofitting of the tenth floor (home to the IGS-Institute) of the high-rise block "BS 4" which is situated on campus at the Technical Universität of Braunschweig. The retrofitting will be carried out in the period between April and July 1998. The project is funded by the "Deutschen Bundestiftung Umwelt" in Osnabrück (German state-funding body for the environment). After the rebuilding has finished, data regarding energy efficiency will be researched and collated in a one-year monitoring phase. On the basis of the results of the rebuilding of the tenth floor this retrofitting concept will be extended to the whole building.

2. OUTLINE OF THE CURRENT SITUATION

The thirteen-storey building, built in 1975/1976, houses the university institute, providing offices and lecture halls but no laboratories or work rooms which might influence energy consumption in an extreme way.

The construction of the building is as follows: a steel and concrete skeleton structure consisting of external pairs of support pillars which are unfixed and which penetrate the facade; sheet concrete ceilings reinforced at the edges (Fig. 1/2/3). The facade consists of an aluminium post-bolt construction which is externally visible.

[1] Source : BINE Informationsdienst, Retrofitting of ventilation and air conditioning, II/97

The present glass is made of sunproof, insulated glass (k$_F$ ca. 3,0 W/m²K), the window breasts are made of moulded glass. It should be noted that the existing glass is gradually outliving it s planned life expectancy 25-30 years and the windows are beginning to glare.
The ground plan with a depth of 25 metres, is overlaid diagonally by a grid 80/80 cm, to which the light fittings are also fixed. The entire technological fittings are functionally non-specific.

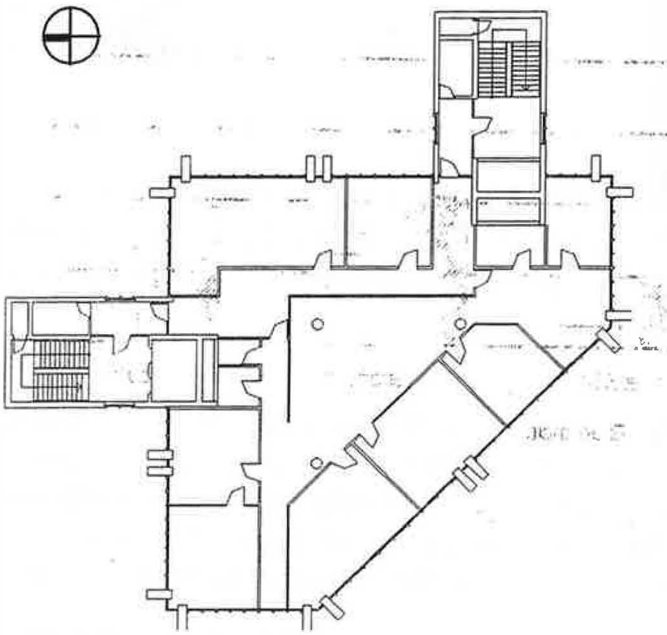


Fig 2 Current Foundations

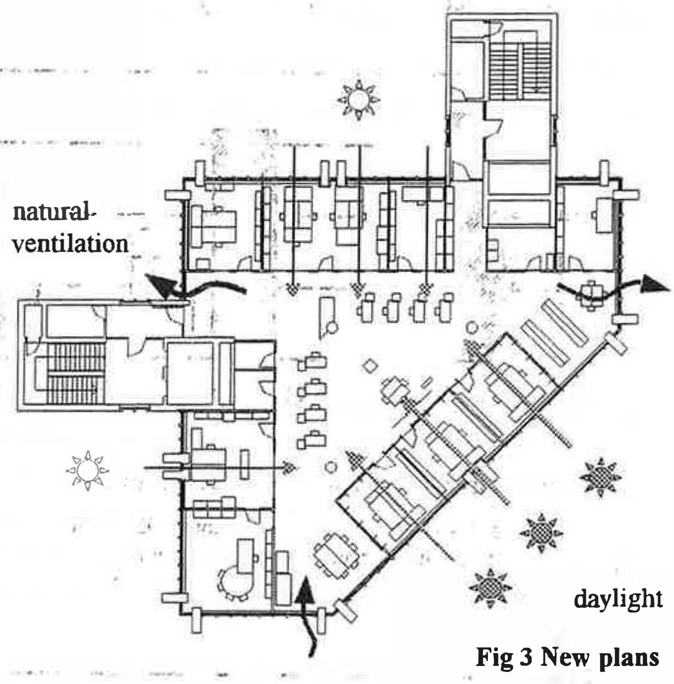
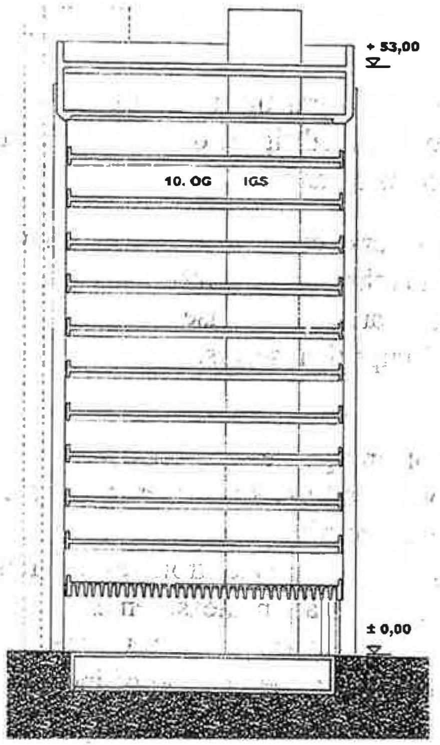


Fig 3 New plans

Heating comes from an external heat source - from a coal power station. Hot water is heated electrically and decentrally. The building is heated by static heating surfaces in the facade area; there is a separate heating circuit for the north and south side and also by preliminary heating of the incoming air by means of a thermostat in a central ventilation unit with heat recuperation facilities. This unit is divided into two ventilation circuits for inner and outer areas. A cooling system was planned, but not installed.



Surface and Volume Statistics for the Building

gross ground plan	: 8.528 m²
heated area (BGF$_E$)	: 5.889 m²
remainig area for office use	: 4.923 m²
cover area A	: 11.477 m²
gross volume V	: 34.600 m³
A/V- ratio :	: 0,33 m^{-1}

Fig 1: Cross-section

4. ANALYSIS OF THE CURRENT SITUATION

The high-rise block shows the typically extreme high levels of energy consumption of a mechanically ventilated administration block. The aim of the planned retrofitting is to reduce by half the consumption of heat energy and electricity while at the same time significantly increasing user comfort. Retrofitting of office blocks should not, according to Swiss standard SIA 380/1, exceed a total of 105 kW/m²a for heating or 63kWm²a for electricity. For modern buildings 70/50kW is recommended. (Fig 4).

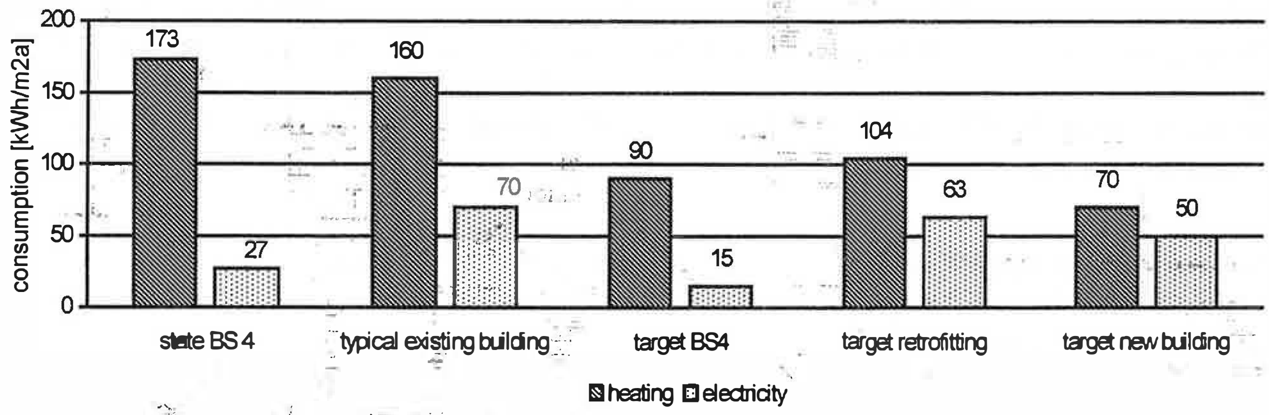


Fig 4 Comparison of characteristic energie units

Current Figures BS 4 : Average Consumption 1992 - 1996, measured on heated area
Typical existing building, target retrofitting, target new building : SIA 380/1

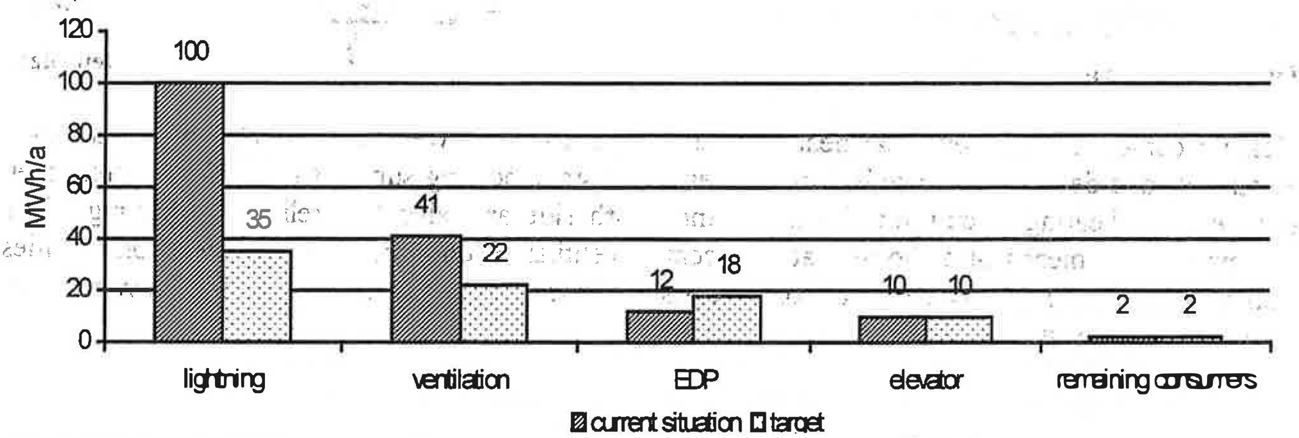


Fig 5 Detailed electricity consumption

If we were to calculate the current energy consumption of the BS4 from the point of the CO_2 emissions caused by the burning of fossil fuels, we would arrive at a total figure of 283 t per year just for this building. The retrofitting would reduce the CO_2 emissions by half.

The estimated cost of the rebuilding is approximately 800 Deutschmark (ca. 400 ECU) per squared metre of working and movement areas; the estimated time needed is three to four months. It should be taken into account that odd structural repairs and maintenance are in any case necessary, for example the glass needs replacing as do the neon lighting and the lamps themselves.

Planning research

A detailed user survey was carried out in the initial stages of the planning research, because a fully-integrated retrofitting plan must be made in close collaboration with end users in order to research comprehensively the current problems and the requirements of the retrofitting.

Exact consumption figures for external heating and electricity were collected from evaluations recorded in minutes of organizational meetings. Temperature and radiation measurements were taken on the roof and on the tenth floor from April 1997 onwards; in addition, as student projects, a detailed lighting study was carried out, the ventilation unit examined and the volume of incoming and outgoing air was measured.

Thermal Comfort:

The working conditions in BS4 are often intolerable even in the transitional period. Especially in rooms which are orientated to the east, south and west facades. The originally planned sunproofing never arrived; the offices therefore quickly become overheated. In sharp contrast the very cold glass facade and the outer concrete surfaces contribute to an uncomfortable room temperature in winter.

Lightning

The building is too deep, so that there is a lack of daylight in the inner areas which must be constantly artificially lighted. The present lamps provide only a completely monotonous level of lighting so that users powers of concentration is hindered. In any case the existing fixed ceiling grids do not allow for any flexibility or adjustment of the lighting. To add to this it is not possible to install a glare-free PC in the outer areas of the building because sun proofing on the outside of the building was planned but not realised.

Natural Ventilation

Natural through ventilation is prevented by the arrangement of the ground plan. The very draughty facade makes for very many uncontrollable changes in air current direction and draughts in the upper storeys are not uncommon.

Ventilation and air conditioning

The functionally non-specific set-up of the ventilation unit does not allow the ventilation to be adjusted to suit individual user needs; the ventilation cannot even be adjusted for a single storey. Lectues are attended by thiry to forty people and the lecture halls become quickly overheated and the ventilation unit over-taxed. (Fig 6).

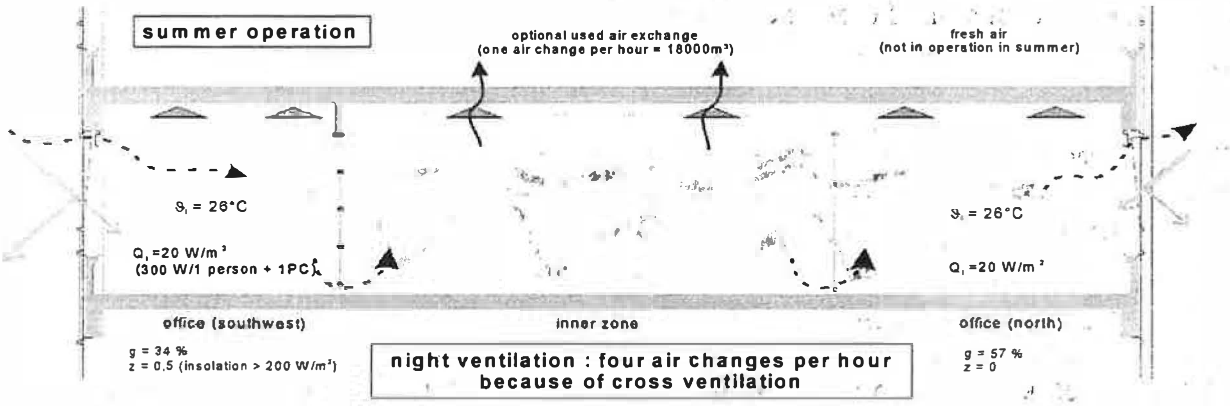


Fig 6 natural Ventilation and air conditioning in Summer

5. PLANNED IMPROVEMENT MEASURES IN DETAIL

The problems caused by the functional, technical and contructional shortcomings described above should be tackled in the following ways:

Ground Plan Layout

The changes in layout in functional and layout terms improve the ratio of areas used to move in the building to work areas with the result that there are now 28 work stations available as opposed to 20 previously. The new layout guarantees in addition by way of glass partitions new adjoining work areas and a considerably improved light in the inner areas of the building. Here portable computer work stations with low daylight requirements are being se up. A through ventilation and activation of storage heating is made possible.

Improvements Made in the Outer Areas of the Building

Thermal simaltion and analysis of „cold-bridge" led to the follwoing porposals:

a) New Glass:

The existing reflective sun-proof glass (kv- 3,0 W/m² K) will be replaced on the east, south and west sides by neutral sun-proofed glass (kv- 1,3 W/m² K). On the north and shodowy east wings the glass will be replaced by heat-resistant glass (kv- 1,3 W/m² K). The eventual k value of the outer shell of the building is thereby reduced from 3,0 W/m²K to 1,5 W/m² K.

b) Fixing of the Supports from the Inside:
A fixing of the pairs of concrete support pillars from the inside is planned.

Just by taking these steps the consumption of heat energy is reduced by approximately a third. A further reduction is possible if the air-tightness is improved. Measures such as the repairing the old insulation are undertaken in practical tests and evaluated in „blower door" tests.

c) Retrofitting of the Facade:
In Simulationen werden Möglichkeiten von Doppelfassaden ausgewertet. Simulation tests are being carried out on different possibilitys of twin face facades

Reducement of Overheating
Overheating can be reduced in the following ways:

- Instllation of a sunscreen
- Reduction in the total heat energy loss through the glass (except on the north face!)
- Regulation of the ventilation unit to be sensitive to external temperatures (exclusion of disturbing elements such as sun glare, room temperature, wind)
- Through ventilation by re-design of the ground plan layout
- Freeing the storage heating units (removing the false ceiling)
- Reduction of internal heat gain by efficient lighting and effective use of daylight
- optimizing the regulation of heating circuits.

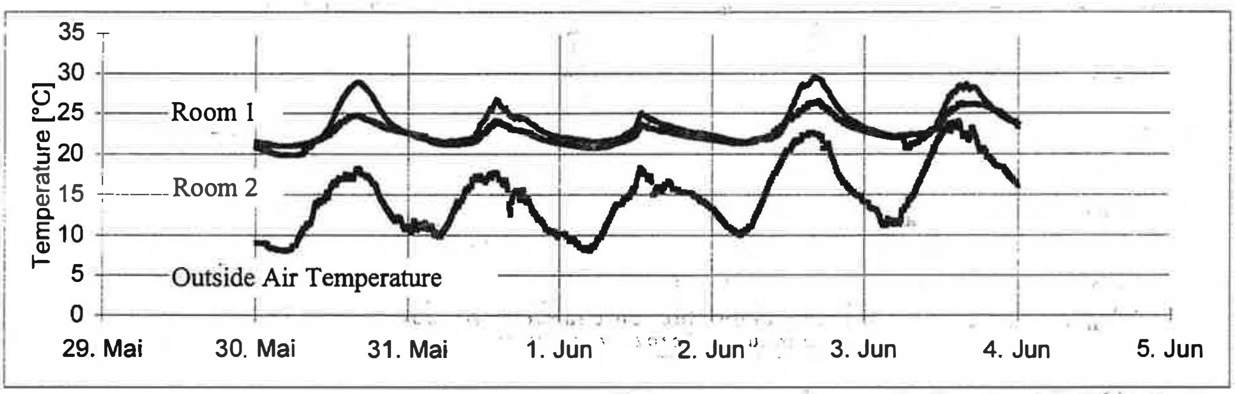


Fig 7:Inside air temperature in two different rooms with different sun proofing;
room 1: curtains, room 2: roller blind with highly efficient reflecting coatings.

Fig 7shows that the room temperature can be reduced in the early afternoon by 3 to 4 Kelvin using the internal roller blind with a special coating..

The time when the room temperature is over 26 centigrade is reduced by at least 90% by freeing heat storage surfaces and simultaneously flushing out the system over night. Sufficient night-time flushing and three to four changes in air direction are required.

Lighting
a) Daylight
An improved level of daylight penetration in the inside areas of the building is achieved by means of transparent partitioning, the use of highly reflective building materials and light-conducting elements such as a segment system or light-shelf

b) Artificial Lighting
A retrofitting of the lighting unit, a new layout of the reflective surfaces and making use of up-to-

date technology saves approximately 55% of electricity costs while giving considerable improvements in comfort). To achieve these reductions it is necessary to combine optimised building materials and efficient lamps in combination with regulation of lighting sensitive to daylight

Ventilation Unit
The improvement of the heat insulation of the outer facade (Replacement of the glass, kv 1,3W/m²K, inside fixing 50mm) would enable the mechanical ventilation unit to be switched off. Calculations show that the current needs of the building can be met by using the storage heating surfaces.

Management of the building:
The local oparating network (LON) is being installed on the tenth floor to increase the effectiveness of the measures taken. This system allows for regulation of individual rooms (heat, light, sun and glare protection) automization of the building (night cooling in summer) as well as data collection.

6. ECONOMIC AND ECOLOGICAL ASSESSMENT

The gross cost of all the retrofitting work is 4 500.000 DM. Per employee a total cost of approximately 13.400 DM is incurred. Final result: approximately 800 DM per squared metre of work and movement areas for the whole building.

	Energy consumption old / new [MWh/a]	Costs old / new [DM/a]	Energy Units old / new [kWh/m² a]
Heat	1016 / 453	81280 / 36240	173 / 77
Electricity	161 / 90	25.700 / 14400	27 / 15
Total	1177 / 543	106980 / 50640	200 / 92

Tab 1: Current Energy Consumption and Costs Incurred

The annual savings of energie costs are approximately 56000 DM. Assuming an annuity of 7.8 %, 700 000 DM (15%) of the total gross cost - which is approximately 120 DM per squared metre of work and movement areas - would pay for itself by the annual savings of energie. It should be taken into account however that the university as a large-scale consumer enjoys extremely favourable conditions for heat and electricity.[2];

Considering that the quest for energy-efficient office buildings is frequently associated with complicated technology, where a high level of manufacture, transportation and assembly is necessary - which in turn involve a further consumption of energy and raw materials - we have set out to prove the contrary, namely that the implementation of simple, passive changes can achieve a great deal. Moreover, our study proves that comprehensive research and planning are essential when retrofitting an office block and emphasizes that the results are applicable to other buildings.

7. LITERATURE

SIA 380/1 und D 080	Energie im Hochbau
SIA 380/4 und D 0131	Energie im Hochbau
ERL 7	Zeitgemäße Lüftungssysteme, VSHL / BEW 1994
DIN 4108, T. 2	Wärmeschutz im Hochbau, Wärmedämmung und Wärmespeicherung, August 1981
WSchV 95	Verordnung über energiesparenden Wärmeschutz bei Gebäuden, August 1994
Rietschel	Raumklimatechnik Band 1, S. 125 bis 175, Mensch und Raumklima, P.O. Fanger, 16. Auflage, Berlin 1994
ISO 7730	Moderate thermal environments - Determination of the PMV and PPD indices, Geneva 1984
ISO 7726	Thermal environments - instruments and methods for measuring physical quantities, 1985
DIN 5035, T.1, T.2	Beleuchtung mit künstlichem Licht, Juni 1990
Fisch, M.N.	Einführung und Zielvorgaben auf dem Seminar „Energie- und komfortgerechte Sanierung des BS 4", Juni 1997
Niehoff, Reimar	Licht und Luft für den BS 4, Studienarbeit am IGS November / 1997
Rohr, David	Beleuchtungskonzept für ein Bürogebäude, Studienarbeit am IGS Dezember / 1997
Baukmann, Volker	Energetische Sanierung der Lüftungsanlage des „BS4", Studienarbeit am IGS Nov. 1997
Groth, Wulf	Energie- und komfortgerechte Sanierung eines Bürogebäudes, Studienarbeit am IGS Dez. 1997
Andreas Lahme	Berechnungen mit dem Wärmebrückenprogramm KoBru, IGS November 97

[2] Current pricing TU : Electricity 16 Pf/kWh, Heat 8,0 Pf/kWh