Retrofit of the Library Building of the University of Bremen

D6

1 Photo

Figure 1: Left: Entrance area of the Bremen University and State Library
Figure 2: Above: Interior view of the library

2 Project summary

The building of the Bremen State and University library has been in operation since 1975. The building has deep plan spaces and is fully air conditioned. The primary energy consumption of 820 kWh/m^{2}a is high when compared to new constructions of similar use. The university is supplied by district heating from a waste incineration plant. Because new consumers have been connected to the grid the maximum capacity of the plant has been reached. Therefore it was decided to retrofit the university library, one of the main consumers of energy on the campus.
The main goals of retrofitting were to reduce the energy consumption by more than 50% and to improve the indoor climate and user acceptance. A monitoring program of energy use and indoor climate before and after refurbishment served to optimise the planning process and to control the efficiency of the refurbishment.

Retrofit features

The retrofit includes measures to the building envelope as well as the intended building systems. Originally heating and cooling were provided exclusively by supply air. The HVAC system was retrofitted to allow separated heating and cooling. The air change rate varies according to the requirements of indoor air quality. Perimeter offices have been equipped with operable windows to allow natural ventilation. All facades have been equipped with new glazing. New repositioned luminaires have been installed in the library. In daylighting zones daylight responsive controls have been installed. Some book shelve areas have been converted to open access areas.

3 Site

Bremen is located on the river Weser in the north of Germany close to the North Sea. The University is located in the northern part of Bremen on a flat site only a few meters above sea level. Latitude: 53°N. Longitude: 8.5°E. Altitude: 5 m above sea level. Mean annual temperature: 9°C. Mean winter temperature: 3.6 °C. Climate description: cloudy, temperate. Essen Test Reference Year (TRY)

4 Building description /typology

4.1 Typology / Age

The campus of the Bremen University was planned since 1965, the library then was constructed from 1971 until 1974. It is an open access library with lending department. US-Campus libraries served as a model. The building has a concrete skeleton structure consisting of posts, beams and slabs. The facade as well as interior partitions have no load bearing function. The library is fully air-conditioned. The building can be assigned to the megastructure university building type.

4.2 General information

Architect:	University of Bremen Construction Department
Year of foundation:	1660
Type of library:	open access library with lending department
Inventory:	approximately 3.1 Million volumes (2000)
Building volume:	125,253 m^3
Year of construction:	1974
Year of renovation:	2002 – 2003
Total floor area (gross):	28 124 m^2
Usable floor space:	19049 m^2
Number of pupils:	26,000 students as users + staff of 1,900

4.3 Architectural drawings

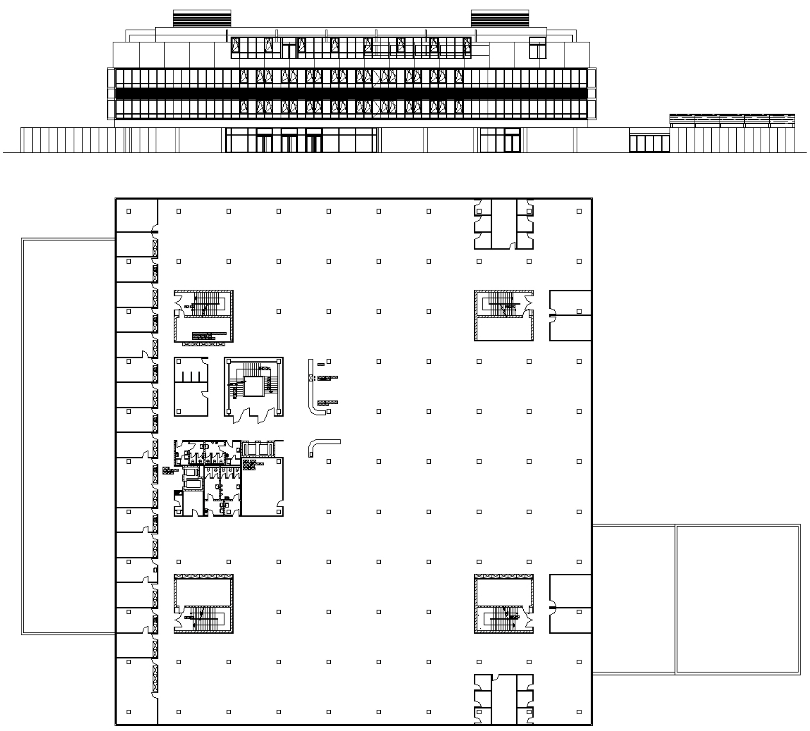

Figure 3: South façade and floor plan of level 2

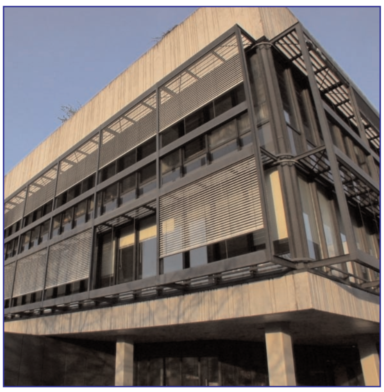

Figure 4: Facade detail showing the shading systems

4.4 Building construction before retrofit

The building of the Bremen State and University library is a concrete skeleton structure with a curtain wall facade. An exterior metal frame construction includes fixed and movable louvre blinds. In some areas concrete cladding had been applied without any additional insulation. Window frames had some thermal insulation, the original glazing had a U-value of 2.8 W/m^{2}K.
Interior partitions were lightweight constructions tiled with coated chipboard. Suspended ceilings had slats of coated sheet metal.
The superposition of different floor plans results in several roof areas and ceiling soffits. These areas had been insulated using expanded polystyrene. While the U-value of the roof garden was only 0.84 W/m^{2}K other roof areas had a U-value of 0.48 W/m^{2}K.
The building had a surface to volume ratio of 0.2 m^2.

Figure 4: Interior view of the window area

5 Previous heating, ventilation, cooling and lighting systems

The building was fully air-conditioned without operable windows. Heating, cooling and humidification were exclusively provided by supply air. The building had 10 air handling units with maximum loads from 4,000 to 91,000 m^3/h. Exhaust fans were typically separated from these plants. Heat recovery was not installed. The heating load was 5,000 kW, the cooling load 3,200 kW. In the perimeter area 2 pipe induction units were used, additionally an air-curtain was installed at the windows. Some of the plant allowed vitiated air to be recirculated. Humidification was done by steam-injection. The air flows before retrofitting significantly deviated from the design values.
Ceiling mounted luminaires mostly equipped with two 38 W fluorescent lamps and magnetic ballasts had been installed. A few incandescent lamps were still in use. The installed specific lighting load was 20 W/m^2.

Figure 5: Air curtain outlet at bottom of window

5.1 Problems, Damage

Generally the building was in a good state of repair. The main problems were high energy consumption and user acceptance on a conceptual level. Heating, cooling and humidification could only be provided by the ventilation system, the air change rate was significantly higher than necessary. This resulted in high energy consumption. The pneumatic control system did not allow optimisation of the operation of the HVAC-system. The individual HVAC systems included no possibility to monitor the energy consumption of the individual systems. Users complained that private offices had no operable windows.
In some areas the lighting level was too low and the space appeared dull although the specific electric lighting load was high. In window areas glare could not be controlled efficiently.

Figure 7: Exterior view of offices on the roof terrace

5.2 Retrofit concept

The main area of the retrofit is the design of a new HVAC System. A detailed survey of the existing plant including monitoring and simulation was the basis

Table 2: Specific transmission losses before and after retrofit

Surface	Area [m^2]	Specific Transmission Losses [W/K]	
		Before Retrofit	After Retrofit
Exterior Wall	3.964	5.877	5.877
Roof	7.805	4.695	2.411
Base Floor	7.805	11.212	11.212
Windows	2.954	10.413	5.227
Total	**22.582**	**32.196**	**24.726**

of planning the retrofitting strategy. Experiments established the link between the ventilation rate and indoor air quality. Further the air conditioned area could be reduced by about 10% by installing operable windows in perimeter offices. Retrofitting the facades improved thermal and visual comfort. Formerly inaccessible depot areas were converted into open access areas.

5.3 Building construction

Although the energy profile of the building is core dependent, the energy saving potential of retrofitting the facades is significant, and improves indoor climate. The installation of operable windows in perimeter offices was accompanied by the application of new glazing with a lower U-Value energy transmission coefficient of 0,38. The ground plate with a U-value of 1.44 W/m^{2}K could not be retrofitted as a cost effective and practicable solution was not found. In roof areas additional insulation was applied.

Table 3: U-value of building components

Surface	Area [m^2]	U-value [W/m^{2}K]	
		Before Retrofit	After Retrofit
Exterior Wall	3.964	1,48	1,48
Roof	7.805	0,6	0,31
Base Floor	7.805	1,44	1,44
Windows	2.954	3,53	1,77

5.4 Heating / Ventilation / Cooling and Lighting system

Originally heating and cooling were delivered exclusively by supply air. The installation of separate radiators at the facades and decentralised cooling units in the core of the building allows heating and cooling to be provided independently from the ventilation system and hence the mechanical ventilation can be turned off outside opening hours. A variable air change rate and the installation of heat recovery further contributes to energy savings. The air curtain in the window area could be completely abandoned as the U-Value of the gazing was improved. In offices with operable windows the radiators are automatically locked when the window is open.

The electric lighting system plays an important role in the retrofitting strategy because of the large number of operating hours and the relatively small fraction of daylit zones. New efficient luminaires with T5 lamps and electronic ballasts have been installed. The suspended ceiling of louvres was replaced plasterboard ceilings in order to allow an optimised placing of luminaires with respect to the position of bookshelves. The design illuminance was increased to optimise visual comfort. In daylit areas daylight responsive controls have been installed. The furniture was repositioned in order to increase daylight penetration. A new control strategy was applied to the motorised louvre blinds.

6 Resulting Energy Savings

6.1. Heating

Since the heating of the State and University library is provided by district heating, there was no need to retrofit any heat generation plant in the building. The heating load of 5000 kW was significantly be reduced by the retrofit actions. Heating energy savings mainly result from the redesign of the HVAC System and from the improvement of the thermal characteristics of the building envelope. The specific heating consumption before retrofitting averaged around 290 kWh/m^{2}a. The predicted consumption after retrofitting is 96 kWh/m^{2}a, thus about 2/3 of the heating consumption could be saved.

5.2. Electrical Energy

The redesign of the HVAC-System and the electric lighting installations leads to a reduction of the electric consumption close to 50%. Before retrofitting the specific consumption was 189 kWh/m^{2}a, after retrofitting the consumption is predicted to be 94,7 kWh/m^{2}a. Before retrofitting the air handling units were the main consumers of electricity followed by the electric lighting. The separation of heating and cooling from the ventilation system and the variable control of the air flow results in a predicted saving of more than 70% of the electric consumption for ventilation. The installation of energy efficient luminaires combined with a better positioning of the luminaires with respect to the bookshelves and an enhancement of daylight use results in savings of about 50% of the electric lighting consumption. These considerable electric lighting savings could be achieved although the lighting level was increased as part of the retrofitting activities. After refurbishment electric lighting will be the main user of electricity. Since the building is connected to a local grid of district cooling, the savings on cooling consumption do not decrease the electricity consumption. However, the specific average cooling consumption of 42 kWh/m^{2}a before retrofitting is predicted to decrease to 30,4 kWh/m^{2}a.

Heating consumption [kWh/m_a]			
before retrofitting		*after retrofitting*	
measured performance	predicted performance	measured performance	predicted performance
290	367,2	-	96,2
Cooling consumption [kWh/m_a]			
before retrofitting		*after retrofitting*	
measured performance	predicted performance	measured performance	predicted performance
42	50,1	-	30,4
Electric consumption [kWh/m_a]			
before retrofitting		*after retrofitting*	
measured performance	predicted performance	measured performance	predicted performance
189	191,4	-	94,7

Table 3: Energy consumption before and after retrofit

8 User evaluation

Before refurbishment employees regularly complained about the air quality in their work spaces. Some measures such as the installation of operable windows in private offices specifically focus on the improvement of the user acceptance. After refurbishment surveys among users will be conducted to evaluate the perceived comfort.

9 Renovation costs

The costs of energy related measures and the costs of other measures to adapt the library to today's requirements are provided by different funds. The cost volume of the project is about 7,2 Million EUR. 5,6 Million EUR have been spent on the different retrofitting measures. These costs are mainly covered by the ZIP, a federal program for sustainable development. The University of Bremen raised a loan to cover the remaining costs. The loan is expected to be paid back by energy cost savings.
About two thirds of the retrofitting costs are linked to measures on the building's internal systems. About 16% of the costs have been spent on measures to the facade.

Table 6: Renovation Costs

Site facilities	4.9%
Dismounting	6.1%
Metal construction and glazing	14.0%
Shading systems	2.3%
Dismounting and replacing suspended ceilings	6.2%
Electrical installations and lighting	25.1%
Building management system	7.5%
Ventilation system	17.4%
Heating, Cooling and Steam supply systems	11.6%
Insulation of pipes and ducts	5.0%
Total budget	**5.6 Million EUR**

10 Experiences/Lessons learned

A final evaluation of the project will be made when the refurbishment is completed and monitoring results are available.
Generally refurbishment activities are accompanied by uncertainties about the existing construction. Although the state of maintenance of the State and University Library was good, a large number of interventions in the existing HVAC Systems had affected the efficiency of the ventilation system. These interventions had not been documented. For example when employees complained about a draft usually a piece of sheet metal was installed locally in an air outlet to limit the air flow. So a detailed survey of building systems was necessary in order to understand the operation of the building.
Asbestos already had been removed from the building some years before retrofitting for energy savings. Therefore asbestos was not expected to be a problem. The construction activities showed that within the air ducts there was still some asbestos installed which then had to be sealed.

11 General data

11.1 Address of project

Staats- und Universitätsbibliothek Bremen Bibliothekstraße, 28359 Bremen, Germany

11.2 Date of report / revision no.

12 Acknowledgements

Project Co-ordination:	University of Bremen
Research Team:	University of Bremerhaven
	Schiller Engineering
	Bremen University of Applied Sciences
Monitoring:	TTZ Bremerhaven
National Support Programme:	German Ministry of Economy and Technology
	Projekttraeger Juelich (PTJ)

13 References

Schiller Heiko, Schnaars Ursula; Energetische Gesamtoptimierung der Staats- und Universitätsbibliothek Bremen; Proceedings „Rückblick – Querschnitte – Ausblicke“, Symposium zum Förderkonzept Energetische Verbesserung der Bausubstanz, 3. – 4. July 2002 in Stuttgart

Project homepage: http://www.gosub.uni-bremen.de/
University of Bremen: http://www.uni-bremen.de/
Schiller Engineering: http://www.ib-schiller.de/
Bremerhaven University of applied science: http://www.hs-bremerhaven.de/
Bremen University of applied science: http://www.hs-bremen.de
Research program on retrofitting buildings: http://www.ensan.de/