A Retrofit for Energy Conservation using Transparent Insulation: The Paul-Robeson-School in Leipzig, Germany

D3

1 Photos

Figure 1: *Left:* The south façade of the school after the retrofit.
Right: before the retrofit.

2 Project summary

The Paul-Robeson-School represents one type of the so-called "typical schools" built with a modular concept (Plattenbauweise) in the former German Democratic Republic from the 60's until the middle of the 80's. From 1991 - 1993 this building has been retrofitted as a representative example for this type of school, in order to show the energy saving potentials. One of the main retrofit features was the use and assessment of transparent insulation in comparison to the use of standard insulation material.

3 Site

The Paul-Robeson-School is located in the northern area of the city of Leipzig, in the state of Saxony, in the Eastern part of Germany at Lat. 51.4° north, Long. 12.4° east. The monthly average outdoor temperatures are close to 0°C (D:0.4°, J:–1.2°, F:–0.7°, M:3.2°) in winter and near 17°C (J:16.5, J:18.1, A:17.8, S:14.4) in summer. The daylighting of the building is unobstructed.

4 Building description /typology

4.1 Typology / Age

Typology/Age	Pre 1910	1910–1930	1930–1950	1950–1970	1970–
The multi-storey school				●	
The side corridor school				●	

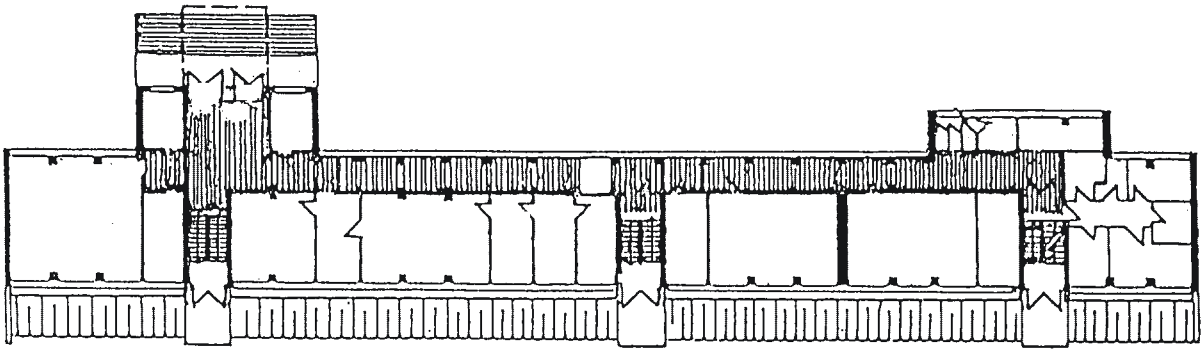
The building was erected in the seventies as a typical side corridor school with classrooms oriented to the south. It is used as a primary and a secondary school.

4.2 General information

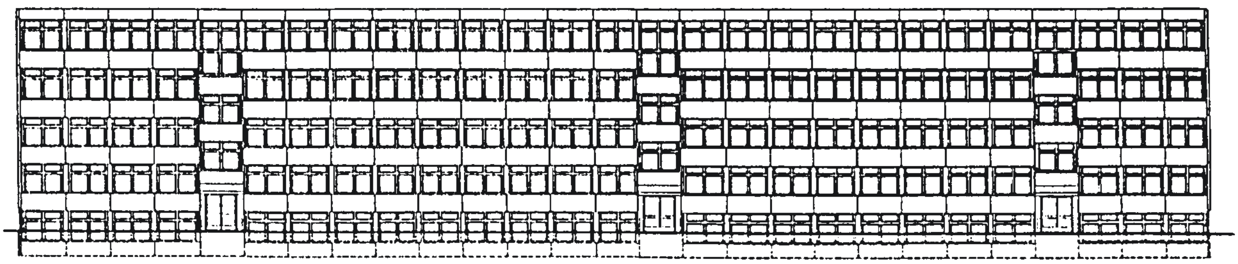
The building is a single 4 storey block, 81 m in length. It has been retrofitted from 1991 – 1993. The total floor area of 4100 m^2 includes classrooms, staircases, corridors and practical rooms. There are 24 classrooms: 11 typical ones with a floor area of 54 m^2, 6 practical rooms and 7 larger classrooms with a floor area of 81 m^2. The window area is 60% of the south façade. About 400 schools of this type have been built in the eastern part of Germany.

4.3 Architectural drawings

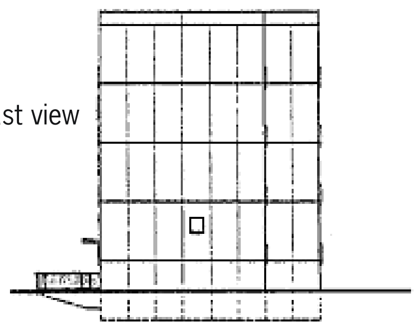
ground floor



south view



east view



west view

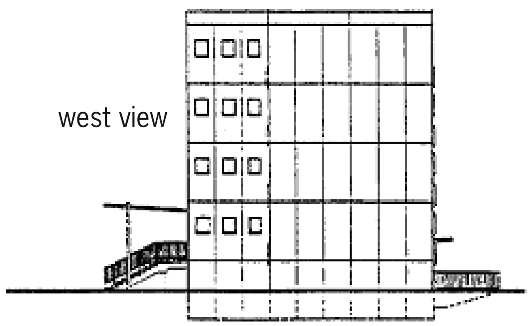


Figure 2: Ground floor plan, south, east and west view of the building.

5 Previous heating, ventilation, cooling and lighting systems

Heating:
The heating system ran on local town gas. The system with its boilers was installed in 1978. The nominal heating power was 1.4 MW. The system temperature depends on the outdoor temperature. It had been manually controlled by the caretaker since the control system broke down.

Ventilation:
Ventilation worked by natural cross-ventilation through the classrooms. From

the outside through opened windows to the classrooms then through ventilation shafts at the wall adjacent to the corridor. Besides this, the façade was not airtight. Overheating was reduced by ventilation.

Lighting:
Lighting was manually controlled by the users. Shading was provided by fixed blinds.

6 Retrofit energy saving features

6.1 Energy saving concept

The heating energy demand before retrofitting amounted to 225 kWh/m^{2}a. The concept aimed at a reduction of at least 50%. Beside standard measures like improving the thermal insulation of the roof and the façades, the use of low-E coated glazing, renewal of the boiler controls and the control of the heating circuits, the retrofitting process mainly concentrated on the use of transparent insulation material. 300 m^2 of transparent insulation material (PMMA) was integrated in a wooden frame curtain wall façade. To reduce the summertime risk of overheating, a movable shading system was attached both in front of the transparent insulation system and in front of the south oriented windows a year later, following overheating in the first year.

6.2 Building

Measure (U-value)	**U-Values [W/m^{2}K]** Before Retrofit	After Retrofit
Wall (opaque)	1.4/2.6	0.38
Wall (transparent insulation)	2.6	0.55
Roof	0.65	0.18
Cellar Ceiling	3.7	0.46
Window	2.8	1.5

Table 1: U-Values of walls, windows, roof and cellar ceiling before and after retrofit.

To reduce the energy demand by at least 50%, it was necessary to replace the windows and improve the thermal insulation of the roof and the façades. The new windows were made of low-E coated glazing in wooden/aluminium frames. The exterior walls of lightweight concrete were insulated with 8 cm of mineral wool. The roof and the cellar ceiling were insulated with polystyrene foam. On the south side, the retrofit concentrated on using transparent insulation material. This material (PMMA) was integrated in a wooden frame and put up to the façade as a curtain wall façade. In front of the 80 mm PMMA, a pane was attached. A shading system in front of the transparent insulation was unavoidable in order to achieve comfortable internal temperatures in the summer.

6.3 Heating

The renewal of the heating control system was important to minimize the heating energy consumption. The rooms now have individual room control. The local gas supply was changed to natural gas in November 1993. The existing system was oversized. The separate pairs of boilers are coupled in a row and activated when required. The caretaker's heating system was separated from the school's one.

6.4 Ventilation

Because of the retrofitting (thermal insulation, transparent insulation curtain wall façade) the façade became much more airtight than before. Therefore ventilation slots (they can be open or shut, as required) were installed in the window frames and fans were added to provide draft. The two-speed fans are manually controlled.

6.5 Lighting

Lighting was not part of the energy concept.

7 Resulting Energy Savings

A simulation program to predict energy consumption considering characteristic building values, worked out an energy consumption for the existing building of 128.5 kWh/m^{2}a, however the measured value was about 225 kWh/m^{2}a.
The estimation of the heating energy demand derived from the use of natural gas showed a reduction of about 61% and 75% for the two monitored winter periods compared to the situation before retrofitting. The energy consumption in the second period was significantly higher than in the first because the first heating period benefitted from mild weather conditions.

Table 2: Heating energy consumption before retrofitting and the values monitored in the two heating periods after retrofitting, compared to the heating energy demand according to the energy concept obtained by simulation.

Heating energy consumption [kWh/m^{2}a]			
Before Retrofitting	Calculated (Energy Concept)	Monitored '94 / '95	'95 / '96
225	57	58	89

For the transparent insulation system the time shift between radiation and emission of the warmth into the room is 7 hours. Therefore a more constant and higher room temperature can be expected but the solar gains are shifted to the unoccupied period of the day. The temperature on the inside of the walls with transparent insulation lay between 21 K above and 1 K below the room temperature during the heating period. The average of the inside of these walls was approximately 0.5 K above the room temperature. Usable heat gains from the transparent insulation could not be measured.

8 User evaluation

The original concept without a shading device led to complaints about overheating. The users did not fully accept the ventilation strategy and kept the air inlets closed and opened the windows manually. A higher temperature level in winter is favoured by the users and can be supported by the transparent insulation system.

9 Renovation costs

No detailed cost information is available.

10 Experiences/Lessons learned

10.1 Energy use

Reduction of the heating energy demand of 67% as a mean value was realized. The concept with the transparent insulation proved to be strongly climate dependent (50% higher heating energy demand in cold winters).

10.2 Impact on indoor climate

Because of the reduced ventilation, the risk of overheating increased. A shading device was attached after the first monitored period in 1994. As immediate action the users had to open fanlights and the fans had to start

running at 4 o'clock in the morning to reduce overheating.
The user-dependent ventilation could be improved by a visual indication of CO_2 concentrations.

10.3 Economics

No detailed information is available, but most of the technologies used were not cost effective.

10.4 Practical experiences of interest for a broader audience

When using transparent insulation systems you have to consider that they have no regular fire permission. Allowances for special fire tests added 6 months to the planning phase of the project. Using transparent insulation without shading devices led to overheating. The intention to use local craftsmen cost time because the technology was unknown to them.

10.5 Resulting design guidance

- Transparent insulation systems have to be planned carefully (shading, fire, costs, etc). Experience is needed.
- Innovative ventilation systems including continuous air intakes have to be planned carefully to avoid uncomfortable cold air streams. Otherwise the users will shut down the system and will keep opening the windows as before.
- To increase the user acceptance, mechanical ventilation systems should be used only as support to the natural ventilation (hybrid system).

11 General data

11.1 Address of project

Paul-Robeson-Schule, Jungmannstr. 5, 04159 Leipzig

11.2 Existing or new case study

Project initiation: 1990
Design completed: 1991
Renovation construction completed: 1993
Monitoring and evaluation completed: 1996

11.3 Date of report / revision no.

July 2002, no. 6

12 Acknowledgements

Authors: Silke Leiß, Heike Kluttig, IBP
The retrofitting of the school was funded by the German Ministry of Research.
Building Physics and Monitoring: Fraunhofer-Institut für Solare Energiesysteme, Freiburg, Germany

13 References

[1] Fraunhofer-ISE: Energetische Sanierung einer Schule unter Verwendung transparenter Wärmedämmung – Modellvorhaben "Paul-Robeson-Schule" Leipzig, Schlußbericht zum Fördervorhaben 0329224D, Februar 1997.