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Monitoring of a residential building retrofitted with TIM at Sonnenäckerweg/Freiburg

J. Vahldiek and E. Bollin

Fraunhofer Institut für Solare Energiesysteme

Oltmannsstrasse 22, D-7800 Freiburg, Germany

Abstract

The application of transparent insulation materials (TIM) for space heating in existing buildings is demonstrated in the project "Sonnenäckerweg / Freiburg, FRG".

A two-storey residential building, which was originally built at the end of the fifties, was renovated with TIM. This building consists of 8 apartments and has a floor area of 400 m^2.

The retrofit involved the installation of TI elements on the south-east and the south-west facades. The elements include roller blinds for heat control. The north-east and the north-west facade, as well as the basement ceiling and attic floor, were covered with high-quality opaque insulation.

The windows were replaced by double glazed windows with integrated roller blinds for solar and thermal protection. For the heating system, decentralized electric and gas room heaters were selected.

Another identical building in the neighbourhood was also retrofitted, but in another way. This building is equipped with a central heating system combined with a heat recovery ventilation system and the same quality of opaque insulation, but no TIM is installed.

Since Dec.'89 the building has been occupied and extensive measurements have been made in both houses.

The results from 1990 will be reported. In comparison to conventional insulation, TIM buildings were able to save 50% of the annual energy needs for space heating.

1. Retrofitting of existing Residential Buildings in Freiburg

As part of a modernisation programme by the City of Freiburg, several identical blocks of flats in a residential area were renovated. In general, the measures undertaken include the opaque insulation of the outer surfaces of the building, replacement of the windows by thermally insulating glazing and the installation of modern heating systems, as well as various improvements to the building interior. Several houses in the Sonnenäckerweg were thermally insulated with different materials, according to different standards.

The Freiburger housing company, Stadtbau GmbH, the Freiburger energy and water utility (FEW), and the Fraunhofer-Institute for Solar Energy Systems (FhG-ISE) cooperated to retrofit one of these buildings with TIM and with opaque insulation of higher quality than is called for by the usual renovation standard. Another neighbouring block of flats was also fitted out with high-quality opaque insulation and equipped with a heat recovery ventilation system.

To assess the effect of these changes, the thermal properties of the buildings and meteorological data were measured by FhG-ISE over two complete heating periods.

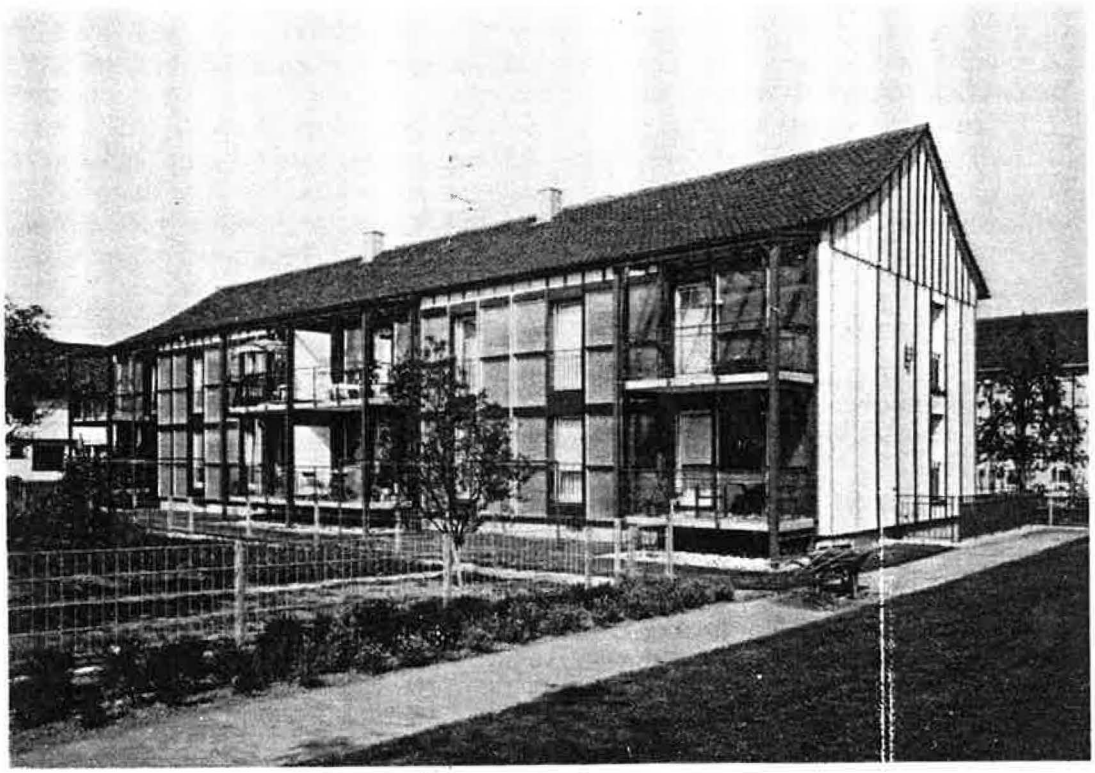

Fig. 1: TIM-project building at Sonnenäckerweg/Freiburg (south-east facade)

2. The TIM Project Building

The two-storey building consists of eight apartments and has a total living area of approx. 400 m^2.
The renovation of the TIM project building included the following measures:

- installation of TIM elements on the south-east and south-west walls (a total area of 120 m^2) with roller blinds for shading
- replacement of the original windows with integrated double glazing units containing photovoltaically powered roller blinds for thermal and solar protection
- opaque insulation of the north-east and north-west walls with 10 cm hard polyurethane foam
- opaque insulation of the basement ceiling and the attic floor
- total U-value for the outer surfaces of the building of appr. 0.4 W/m^2K.

The outer walls of the project building are constructed of 30 cm thick light hollow masonry (south-east); the south-west wall is made of 30 cm brickwork.

The TIM elements containing honeycomb material 10 cm thick, extend over the total height of the wall and were constructed completely before being mounted on the walls (Fig. 2).

The building is heated with individual gas and electric room heaters. This means that a central heating system did not have to be installed, and also allows the heating consumption to be determined in more detail.

3. The Comparison Building

The neighbouring building, which was renovated for low energy consumption, corresponds to the TIM building in its floor plan, construction and materials. The individual measures applied here were the following:

- opaque insulation of all walls with 10 cm thick hard polyurethane foam
- opaque insulation of the basement ceiling and the attic floor
- installation of low-e insulating glazing
- total U-value for the outer surface of the building of approx. 0.3 W/m^2K
- installation of gas central heating with a heat recovery ventilation system.

4. Results

As the flats were occupied and measurements were started in January, 1990, it is now possible to present results from the calendar year 1990.

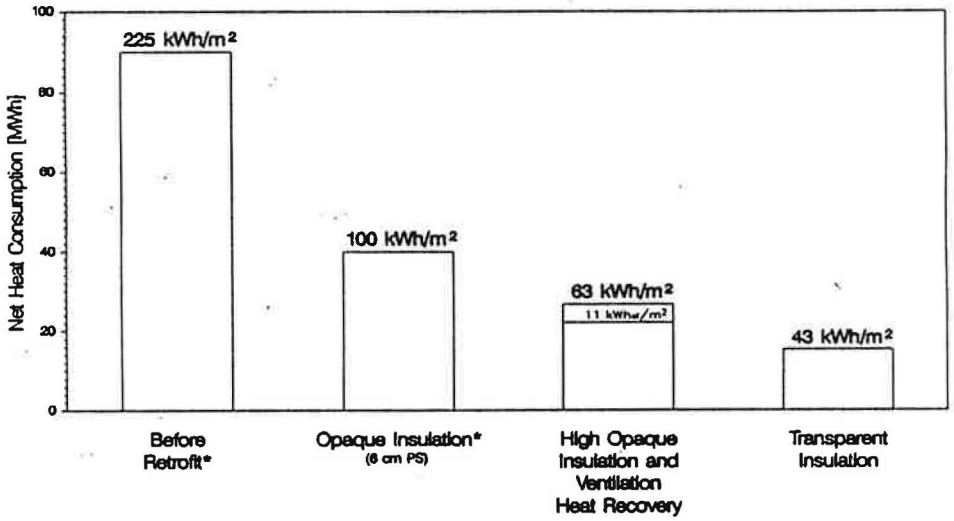

Fig. 2: Comparison of the Net Heat Consumption

The total annual energy consumption (heating energy after subtracting losses, without taking internal heat sources and solar energy gains through the windows and TIM elements into account) of the TIM project building in 1990 was about 39 kWh per m^2 heated living area. Relative to the average number of degree days for Freiburg, this corresponds to an annual energy consuption of 43 kWh/m^2. These values also corresponds to earlier simulations.
For the comparison building with the heat recovery ventilation system, a total annual energy consumption of 56 kWh/m^2 (or respectively 63 kWh/m^2) was calculated from the data for 1990. The amount of electrical energy needed to operate the system not taking the efficiency value of the powerstation into account was about 4500 kWh electrical Energy (11 kWh_{el}/m^2).

As a comparison, results from simulation calculations can be used (fig.2), which give a value of approx. 225 kWh/m^2a for the conditions existing before the renovation, and 100 kWh/m^2a for an assumed renovation with 6 cm thick opaque thermal insulation (Storofoam).

The energy flux through the TIM wall area is determined separately on the south-east and south-west walls. For the test areas, an energy input of 73 kWh per m^2 of wall area was determined on the south-west wall for the whole year, and on the south-east wall the equivalent value was 27 kWh/m^2. These values only include those energy inputs which were measured on days having average air temperature lower than 15 °C. The monthly energy balances of the SE and SW walls can be seen in fig.3. The difference between the SE and SW walls is due to their different masonry materials, solar

irradiation values and the position of the test areas. Compared to a non-insulated wall, the SW facade shows an energy gain of 165 kWh/m^2 (tab.1).

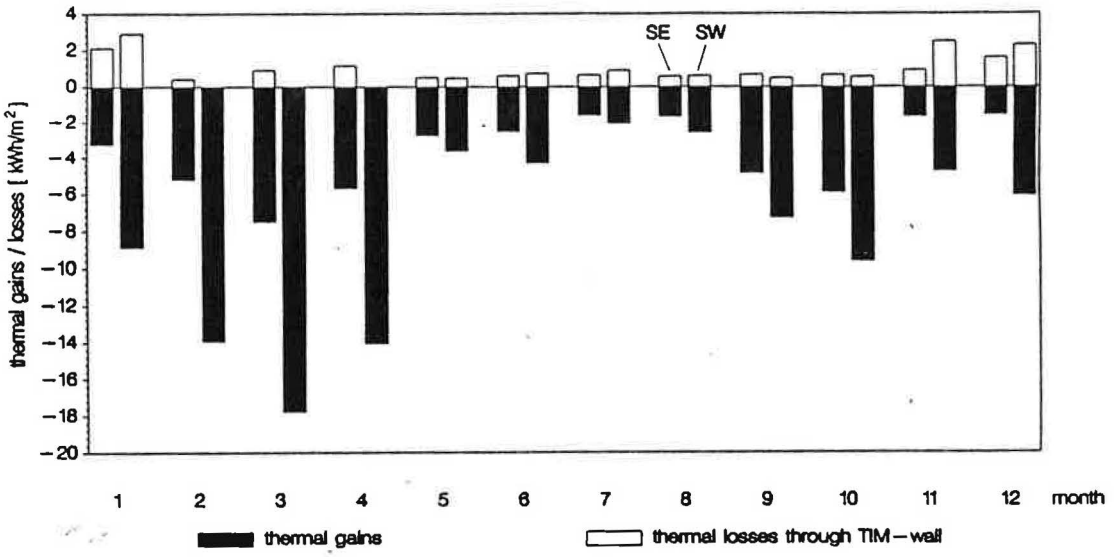

Fig. 3: Energy balance of the TI-wall/monthly thermal gains/losses 1990

	U-Value W/m^2 K		annual spec. energy balance kWh/m^2	
	SE	SW	SE	SW
1. non-insulated masonry	1,10	1,29	-78	-92
Complete construction with:				
2. TI wall without solar gains (corresponding to app. 5 cm PS hard foam)	0,45	0,49	-32	-35
3. opaque insulation corresponding to 10 cm PS hard foam	0,29	0,30	-21	-21
4. TI wall with solar gains (measured values)	-	-	27	73
total solar gains difference between 1. and 4.			105	165

Tab.1: Total energy gains of the TIM test areas compared to different insulations (per m^2 TIM area)

Altogether, the inhabitants responded positively to the measures taken in the TIM building. The heat radiated from the TIM wall into the room was perceived as pleasant. The roller blind shading system prevented overheating, even with high solar irradiation. Transparent insulation was valued as a simple system for using solar energy; only the roller blinds require a certain amount of attention in operation.