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greenTEG

gSKIN® application note: Measurement vs. Calculation

In this case study the theoretical U-value based on a calculation model is compared with a U-value based on a heat flux measurement with greenTEG's gSKIN sensor. An office wall at Technopark, a business and meeting centre in Zürich, has been assessed. The building is built in 1990 according to the highest energy standards and therefore reached excellent thermal characteristics for that time. The goal of this case study is to find out to what extent the U-value calculated with the construction data deviates from today's measured value.

Buildings have not only become more and more energy efficient over time but also the documentation of data on the construction details and materials has improved. For many buildings constructed in the last decades this data is available which allows a precise theoretical calculation of the thermal properties such as the U-value. The problem with these calculations is that the value in practice might be way different. Certain kinds of foam insulation, widely applied in the first insulated buildings, tend to deteriorate due to displacement of gas or infiltration of moisture. Also the U-value of newer buildings insulated with mineral wool might be worse in reality due to damage, increase of moisture or poor installation methods.

Assessment of the building envelope

A wall of an office within the Technopark has been assessed . The building has not been renovated since its erection in 1990. The wall is a multi-layered structure (figure 1) built up from inside to outside of concrete (180 mm; 1), mineral wool insulation (100 mm; 2), vented cavity (40 mm; 3) and a gypsum fibreboard (10 mm; 4).

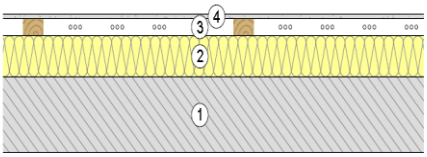

Figure 1: wall structure, including all layers

Calculation method

The theoretical U-value is calculated with the online model of u-wert.net using the materials and thicknesses of the wall as described above. This results in a theoretical U-value of 0.31 W/m²K.

Measurement characteristics

The wall faces the West and is blocked from solar radiation by buildings nearby. The room in which the measurement is conducted is occupied during office hours. The measurement period has been roughly 72 hours to be in compliance with ISO 9869 and to reduce the effect of a daily temperature pattern within the room.

The heat flux sensor has been attached to the inside of the wall. The inside temperature sensor is placed next to it, approximately 3-4 cm from the wall. The outside temperature sensor is also attached 3-4 cm away from the wall (and not influenced by direct sunlight).

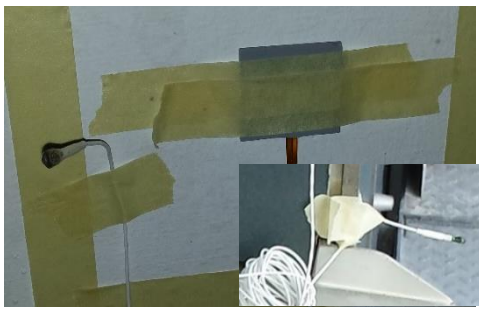

Figure 2: Above: Measurement set-up; heat flux sensor with inside temperature sensor, Bottom right: outside temperature sensor

Results of measurement

Results of the U-value measurement are shown in the following figure.
The graph includes the heat flux, the inside temperature, the outside temperature and the U-value.

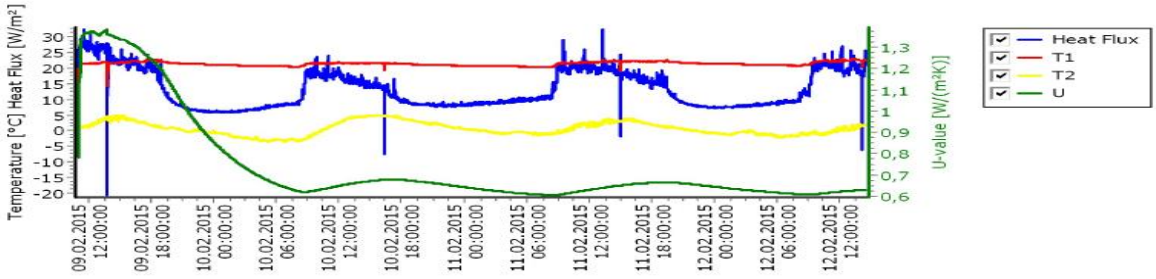

Figure 3: Results of U-value measurement in line with ISO 9869 (Report on basis of greenTEG Software v1.00.03, 2015)

In Figure 3 the heat flux clearly shows a daily pattern due to the thermal capacity of the wall and the temperature changes within the room. Every morning the heating system is turned on and the temperature in the room slightly rises which cause an increase in the measured heat flux. During the night the heat flux is relatively low as a reversed effect. The measurement shows that it is crucial to measure roughly 72 hours or another multiple of 24 hours (ISO conform) when assessing a wall with a large thermal capacity and daily (inside) temperature patterns to get an accurate U-value. Besides these fluctuations, it can be seen that every day a window was opened for a few minutes in order to ventilate the room and the sensor was placed close to this window. The standard deviation of the last 24 hours was only 2.65% which makes this measurement in line with ISO 9869. The U-value of this wall according to the heat flux measurement is 0.63 W/m^{2}K.

Comparison

The following table compares the calculated U-value, the measured U-value and the minimum required U-value for a Minergie refurbishment. Besides these U-values, it shows the corresponding heat loss per m^2, the heating costs per m^2 wall surface and the total heating costs associated with the wall. In order to calculate the heat losses the average number of heat days of the last two years in the north of Switzerland are taken into account. For calculating the heating costs a heating price of € 0,10/kWh is used. A wall surface of 400 m^2 is assumed to calculate the total heating costs associated with the walls for an average Technopark company.

	U-value (W/m^{2}K)	Heat loss[1] (kWh/m^{2}yr)	heating costs (€/m^{2}yr)	Total heating costs (€/year)
Calculation	0.31	25.69	~ € 2.60	€ 1,030.-
Measurement	0.63	53.20	~ € 5.30	€ 2,090.-
Minergie Ref.	0.25	20.72	~ € 2.10	€ 830.-

[1] Data degree days: Location: Zürich-Kloten; Base temperature: 19 °C; www.degreedays.net

Analysis

The in-situ measured U-value is more as twice as high as the calculated U-value. The insulation of this wall is way worse than could be expected from the construction data. This results in a difference in the energy costs of € 2,70 per m^2 each year. If is assumed that the measured value is representative for all walls of the office, the energy bill of the office tenant is roughly €1000,- higher than it is supposed to be. A Minergie refurbishment would in this case save the office tenant around €1200,- per year in heating costs. In order to evaluate the overall insulation quality of all offices, it should be investigated if the measured spot is indeed representative for the whole wall surface. The homogeneousness of the wall can either be determined by additional heat flux measurements or by a thermographic survey. An insulation company should then be able to evaluate if replacing or improving the insulation would be possible and economically interesting.

It is hard to determine why the U-value is so much higher than expected. The insulation quality of mineral glass wool is hardly influenced by aging effects. However, an increase of the moisture content could lead to a significant deterioration of the thermal performance. Another explanation could be that some mistakes have been made in the initial installation of the insulation. Lastly, the data used in the calculations is based on hand-drawings from the facility manager of the Technopark. The material mentioned by the facility manager had to be matched to the materials listed in the U.wert.net database. Also during these processes errors or inaccuracies might have occurred. A thorough analysis is required to find out what the exact reason is for the higher than estimated U-value.

Conclusion

A successful measurement has been conducted in line with the ISO 9869. The outcome of the measurement can therefore be considered as reliable. Although material characteristics of the wall were available the measured in-situ value appeared to be twice as high as the calculated value. It indicates that by just relying on building characteristics, one could get a wrong understanding of the thermal performance of a building and the heating costs the office tenant is facing. Further investigations are required to review if a refurbishment could be an interesting option for the Technopark.