Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Determining the U-value of building envelopes with the gSKIN® U-Value KIT of greenTEG AG

Dr. Zoltán Nagy, Architecture and Building Systems, ETH Zürich
http://systems.arch.ethz.ch | nagy@arch.ethz.ch | +41 44 633 29 26

Introduction

Defining the U-values of building elements is necessary to determine the transmission heat losses of a specific element. The U-value is the inverse of the R-value, the thermal resistance, and can be calculated according to the following formula [1]:

$$U = \frac{1}{R_{is} + \sum_i \frac{d_i}{\lambda_i} + R_{os}}$$

where λ_i is the thermal conductivity [W/mK] and d_i [m] the thickness of a certain layer. R_{is} and R_{os} stand for the inside surface resistance and the outside surface resistance [m^{2}K/W] respectively. A precise calculation of the formula above requires the exact thermal conductivity and thickness for every layer of a wall. For R_{is} and R_{os} standard values are chosen most of the time. For example, for a perpendicular, non-ventilated wall a value of $R_{si} + R_{os} = 0.17$m^{2}K/W is often used [1].

For older and partially retrofitted buildings, the exact characteristics of the existing wall layers are usually not available. This means that these characteristics and the corresponding U-values must be estimated based on experience. This in turn can lead to substantial failures and as a result, large errors in the calculation of the heat loss.

In this study it will be demonstrated how the greenTEG U-Value KIT can be used to determine the U-values of buildings elements with unknown

thermal characteristics. These U-value measurements are based on the heat flux method, which uses data of a heat flux sensor and two temperature sensors.

Measured building

The considered object is an apartment building from 1960 that has been renovated multiple times. The last renovation included the replacement of the windows and the insulation of the outer wall. The property owner could not provide details about these retrofitting activities.

Figure 1: Heat flux measurements for determining U-value. (Top) Meas. object – arrow marks the measurement area (Bottom) Left: Inside meas. / Right: Outside meas.

Measurement setup

An outer wall at the north side of the building has been measured. The heat flux sensor has been attached to the inside of this 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 protected from direct sunlight.

The measurement periods were at least 72 hours, so that the required period according to the ISO 9869 norm would not be violated. For the measurements in which the inside conditions vary, the measurement time has been extended, to emphasize the importance of constant conditions according to the ISO norm. The measurements were evaluated with the included greenTEG Software (V0.01.07).

Results

Figure 2: Measurement 1, at constant conditions (one air circulation during a few minutes on 29.12.2014).

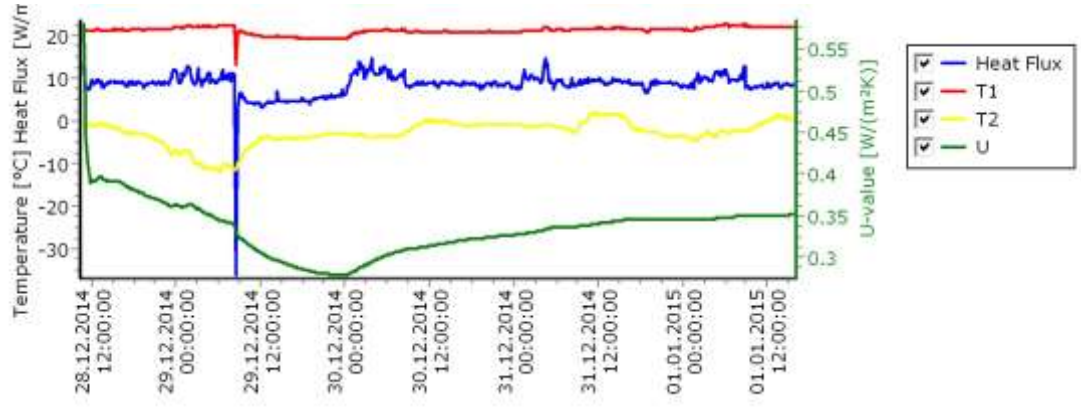

Figure 2: Results at constant conditions according to ISO 9869 (Report obtained from greenTEG Software v0.01.07, 2014)

Figure 3: Measurement 2, with open windows (heavy air circulation) and switch-off the heating during the measurement time.

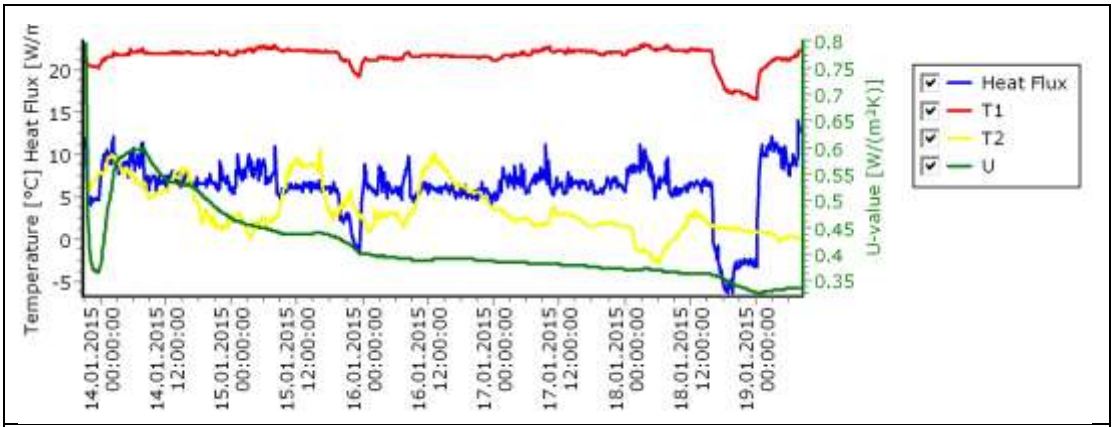

Figure 3: Results with varying conditions, not according to ISO 9869 (Report auf Basis greenTEG Software v0.01.07, 2014)

As seen in the graph of measurement 2, it can be observed that the requirements of the ISO norm (e.g. constant inside temperature, no direct sunlight at the temperature sensors) are important for a reliable U-value measurement. The following table summarizes the results:

Measurement	U-value [W/(m²K)]	Meas. time [h]	Std.dev.U [%]	dU24 [%]	In line with ISO 9869
1. Measurement	0.35	100.67	3.2	1.76	Yes
2. Measurement	0.34	130.50	6.9	9.10	No

Conclusion

The average U-value of the wall is around 0.35 W/(m²K) and is in line with the ISO 9869 norm. It is a typical value for a renovated building, however still above the norm set by Minergie of 0.15 W/(m²K).

Based on the results shown in figure 3 it is clear that constant conditions are important during the measurement period The opening of the window or the switching off the heater rendered a U-value measurement according to ISO norms no longer possible. Due to these varying conditions the reported U-values from 24 hours prior the end of the measurement period

varied too much and were therefore not anymore complying with the strict ISO norm 9869.

Interestingly, the U-value not in line with the ISO norm does only slightly deviate (0.01 W/m^{2}K) from the U-value according to the ISO norm, and for most practitioners both values would be treated as the same. However, due to the difference in the deviation during the last 24 hours (more than 5%, in that case 9.1%), measurement 2 is not in line with ISO 9869.

References

[1] U-Wert-Berechnung und Bauteilekatalog, Neubauten, Bundesamt für Energie, 2002