In situ U-value measurement: Heat flux method versus temperature based method

Background information

The energy performance of a building envelope and corresponding U-values can be accurately estimated in an analytical way if the material values of its constituent layers and the influence of the environmental conditions are well known [1]. However, in many cases accurate material and environmental data is not available or altered due to ageing effects. Therefore, experts have a growing demand for reliable U-value data based on empirical in situ measurements.

Comparison of methods

Two different methods are currently available to perform a U-value measurement: the temperature based method (TBM) and the heat flux method (HFM). Although both types of measurements provide the user with an in-situ U-value, there is a significant difference between the two kinds of measurements especially in terms of quality and accuracy.

The difference between the two methods can be explained by reviewing the following formula for calculating the U-value ($W/m^2 K$).

$$U = \frac{Q}{T_{in} - T_{out}}$$

Formula 1: U-value calculation

in which T_{in} and T_{out} are, respectively, the inside temperature and outside temperature in Kelvin and Q the corresponding heat flux through the wall (W/m^2). Both measuring methods make use of temperature sensors to determine the inside temperature (T_{in}) and the outside temperature (T_{out}). The difference is related to the way the heat flux (Q) is determined.

With the **HFM** (figure 1), the heat flux data (Q) is obtained from a heat flux sensor attached to the inside of the wall. The inside temperature (T_{in}) and outside temperature (T_{out}) are measured with two temperature sensors. All three parameters required to calculate the U-value are thus determined directly.

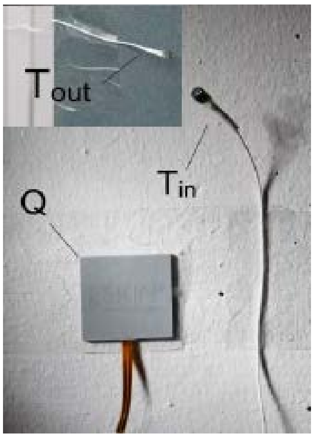

Figure. 1: Set-up for HFM

Technoparkstrasse 1
8005 Zürich, Switzerland
T: +41 44 632 04 20
F: +41 44 633 13 68
info@greenTEG.com
greenTEG.com

With the **TBM** the heat flux (Q) is **approximated** by measuring the inside temperature and the wall temperature assuming a constant thermal boundary resistance between the inside wall surface and the inside air:

$$Q = \frac{T_{in} - T_{wall}}{R_{si}}$$

Formula 2: Heat flux calculation for TBM

In which T_{in} is the inside temperature, T_{wall} the inside temperature of the wall and R_{si} the thermal boundary resistance between the inside wall surface and the inside air (m^2K/W). A temperature sensor is required to measure T_{wall}. The thermal boundary resistance (R_{si}) is not measured but derived from standard values for building elements. A commonly used value is 0.13 m^2K/W. Since this value is just an estimation, it can significantly deviate from the actual in-situ value. The heat flux (Q) can be derived in this way which allows the calculation of the U-value according to formula 1 (using a 3rd temperature sensor for the outside temperature).

Conclusion

To summarize, the HFM provides the user with a U-value based on three parameters which are measured in-situ. In this way it reflects all peculiar environmental conditions of the measurement site. On the other hand, the TBM relies partly on estimated values. Therefore, the HFM offers the user better insight into actual in-situ U-values and the influence of the environmental conditions.

Both methods require a minimal temperature gradient between inside and outside temperature in order to work. However, there is an important difference between the two methods regarding this minimal gradient. While the TBM requires a temperature difference of at least 15 °C, the HFM can be applied starting from a temperature difference of as little as 5 °C [2].

The HFM is standardized in the ISO norm 9869, which takes into account important factors such as weather conditions and the thermal mass of the wall. For instance, the standard defines a minimal measurement time to account for the thermal lag of a building during the day cycle. For the TBM no ISO standard has been established. Hence only a heat flux measurement according to the ISO norm 9869 guarantees reliable and precise in-situ U-values.

References

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

[2] EN ISO 9869-1:2014 Thermal insulation -- Building elements -- In-situ measurement of thermal resistance and thermal transmittance -- Part 1: Heat flow meter method

greenTEG AG
Technoparkstrasse 1
8005 Zürich, Switzerland
T: +41 44 632 04 20
F: +41 44 633 13 68
info@greenTEG.com
greenTEG.com