Published Feb 2019

This brief case study presents the challenges of performing a U-value measurement on a roof and the precautions and steps to overcome them. The challenges of measuring a very low U-value and the corresponding measurement quality assessment methods are also discussed. A potential solution, in the form of a U-value calculation algorithm, is then proposed to faster achieve ISO 9869 conformity.

U-Value Measurements at the Roof of an Indoor Swimming Pool

An indoor swimming pool facility in Oberwil, Switzerland was due to be renovated. Prior to the renovation, BERPLAN, a building consultant company, was commissioned to determine the pre-retrofit building thermal envelope performance. Using greenTEG's gO-Measurement System, a quantitative in-situ assessment of the building's roof was performed.

Figure 1 Indoor swimming pool at a glance (left) and skylights on the building roof (right)

Measurement Setup

As seen in Figure 1, the roof of the building is covered with skylights. Using infra-red thermal imaging, it was easily established that these skylights were a great source of thermal leakage due to poor conductive insulation. Additionally, a quick inspection of the skylight's simple fasteners indicated that air leakage were also a highly likely source of thermal leakage. However, the U-values of the skylights were not assessed as they only represented a small surface area of the whole roof. Instead the U-value measurements were taken on the standard roof structure, but not over the swimming area. This was because the ceiling over the swimming area was too inaccessible and impractical to reach. The locations and serial number pairings of each node are shown in Figure 2.

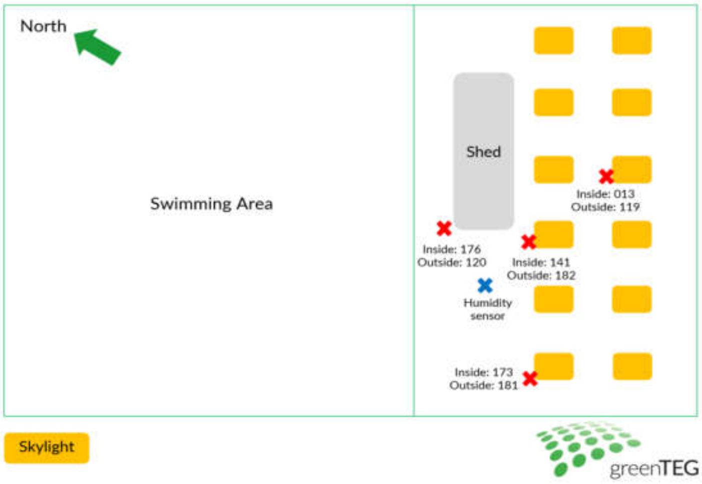

Figure 2 Rough schematic of building roof plan (not to scale), location of sensors and sensor serial number pairing. Humidity sensor was placed indoors.

Pair Number	Inside-Outside S/Ns
1	176-120
2	141-182
3	173-181
4	013-119

Table 1 Measurement node serial numbers and pairings

Another significant challenge of taking U-value measurements on the roof was the exposure to solar radiation. Taking advantage of the sun's low solar angle during winter time, the sensors were placed in the north-side of each skylight to minimise solar radiation effects on the outside temperature sensors as can be seen in Figure 3.

Figure 3 Nodes placed on the north-facing side of the skylight to avoid radiation exposure

Since the measurements were performed on a flat surface and weather forecasts predicted heavy snowfall for two consecutive days after the measurement start, there was some concern about water ingress into the gOMS electronics. (The gOMS is IP44 weatherproof and splash proof, but is not designed to withstand submersion or prolonged water exposure.) A simple but effective solution was devised: each measurement node was placed into a Ziploc-like plastic bag, but not fully sealed, to allow the node cables and sensors out of the plastic bag. This is seen in Figure 4.

Figure 4 Protecting nodes from water ingress using Ziploc-like plastic bags and removing gravel until a flat and clean surface was reached

Another measurement setup challenge was the presence of loose gravel on the roof which prevented outdoor surface temperature sensors from being mounted directly. The gravel was removed until a flat surface was reached, which was then cleaned before the sensors were mounted onto it. It should be noted that these steps to mount the outdoor surface temperature sensor are unnecessary if R-value measurements are not required. (U-value measurements only require heat flux and ambient temperature measurement inputs, not surface temperature)

Additionally, a humidity sensor was placed in the middle of the reception/office area as a test/demonstration measurement. There were no known humidity or mold issues within the building.

Results and Analysis

Figure 5 Screenshot of cloud-based U-value calculator that shows results in real time

The measurement results are summarised in Table 2. Using greenTEG's cloud-based U-value data calculator, the U-value measurement results of each sample point could be quickly and easily accessed and viewed in real time. A screenshot of the U-value results can be viewed in Figure 5. The material composition of the roof and ceiling was not known, hence no theoretical comparison is available. However, all the sample points show relatively good agreement of a very low U-value (~ 0.1 W/(m^2 K)), indicating that the conductive thermal insulation quality of the roof is unexpectedly quite good. Such a low U-value represents the challenging limits of measuring low thermal flux values, and is a successful demonstration of the high sensitivity and performance of greenTEG's heat flux sensors integrated into the gO-Measurement System. (Most U-value measurements range from 0.5 -2.0 W/(m^2 K), an order of magnitude difference to the measurements here).

Pair Number	U-value Measured (W/(m^2 K))	Absolute Error to Mean (W/(m^2 K))
1	0.054	-0.021
2	0.036	-0.039
3	0.125	0.050
4	0.083	0.008
Mean	0.075	0.030

Table 2 Measurement results

Due to limited measurement time, the measurement did not proceed until the percentage - based statistical ISO 9869 conditions were met (e.g. U-value data points of last consecutive data points differ by <5%). It is anticipated that achieving these conditions would require at least some additional days of measurement time.

However, the trend of the U-value measurements was quite clear, and thus indicative of qualitative confidence in the results. Additionally, a basic statistical analysis of the measurement results indicate that the maximum absolute error of all data points to the mean U-value of 0.075 W/(m^2 K) was only 0.051 W/(m^2 K).

Conclusions

U-value measurements to be performed on a roof represents slightly challenging measurement conditions due to solar, rain and snow exposure. However, certain precautions and steps to shield the heat flux sensors and nodes from these elements can be taken to ensure the validity and quality of U-value measurements. Additionally, mounting the surface temperature sensor onto a building envelope component without a solid surface to measure R-values is very difficult, and the loose material needs to be removed and the underlying surface cleaned before the measurement can be conducted.

For very low measured U-values (~0.1 W/(m^{2}K)), reaching the ISO-9869 conformity conditions using the running average calculation method within a week is extremely challenging, thus a qualitative assessment and a basic error-based analysis represent practical yet effective methods for assessing the U-value measurement quality.

Looking forward, greenTEG is currently testing an ISO 9869-approved U-value calculation algorithm, called the Dynamic Method, that could potentially shorten measurement time and improve measurement result confidence. It is assumed that the implementation of such a method would result in faster ISO-conformity for the range of U-values presented in this report.