U-Value and Mold Measurement – Potential and Technical Feasibility of Renovation of Listed Heritage Buildings

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This case study reports U-value and a_w-value measurements carried out on a listed historic building in Switzerland. The aim was to determine the minimum insulation required for renovation and examine the risk of mold growth in the basement. All necessary measurements were conducted with the gO-Measurement System from greenTEG and a thermal imaging camera.

Keywords: U-value measurement, listed heritage building, renovation, mold formation, humidity measurement

1. Introduction

When renovating listed heritage buildings, compliance with a minimum level of insulation (which is regulated at the cantonal level in Switzerland) is necessary in order to qualify for subsidy grants. When designing the insulation, regulatory issues complicate the implementation because the façade must not be altered in many cases. As a result, it is necessary to resort to internal insulation. A U-value measurement is often the only way to avoid overdimensioning and its resultant excessive reduction of valuable living space. Furthermore, the problem of excessive humidity and the associated risk of mold growth should be well analyzed, especially in older buildings. The reasons for this are various, but can be related to the lack of insulation (e.g. due to heat bridges) and water/moisture penetration through building elements.

The present case concerns a 16th century mansion in Schwyz, Switzerland (https://www.immenfeld.com/). The owner intended to restore the home to rent out the premises for events and the following questions arose:

- Would it be possible to reduce the proposed insulation thickness of 16 cm of sheep's wool (as per expert's original recommendation) in the inner wall insulation?
- Could the cellar be used as a storage area for furniture without the risk of mildew?

For an exact quantitative assessment of the situation, several measurements were made on the building using greenTEG's gO-Measurement System. The U-value of a wall was measured before and after renovation. In order to analyse the cellar area for mold growth, the air humidity and the dew point development on the wall (a_w value) were also measured , but recorded over a longer period of time.

2. Description

Figure 1-1: Aerial view of the 16th century estate with the manor located at its centre.

The measurement site is a manor house (shown in Figure 1-1) built in 1580 and is a typical timber-framed building. The first additions and alterations took place in 1671, which included the construction of an oriel, a gable and a courtyard wall. In 1687 a chapel was built on the estate and in 1710 a ballroom was constructed within the manor. After several changes of ownership, the Weber family finally came into its possession in 1947. After a good 300 years since the last modifications, Thomas Weber renovated the entire property in 2017. The renovation included a variety of works such as the renovation of the façade, roof and the courtyard wall, but also the repair of floors in the chapel. This short case study focuses on the façade renovation, for which the wall thermal insulation had to be dimensioned and the basement humidity had to be assessed (i.e. potential for mold growth).

3. Measurement Device and Setup

The gO-Measurement System is a wireless measurement system, developed by the Swiss company greenTEG. It consists of a base station which receives the measurement data from up to 16 measuring nodes via LoRa (868MHz signal, designed specifically for buildings). The measurement data is sent via mobile network (2G/3G) to the cloud (Microsoft Azure Hosting). From there, all data can be conveniently monitored and evaluated. In particular, the multi-channel option offers the advantage that several measurements can be carried out in parallel with only one system. This simplifies the installation of the measurement devices and the evaluation of all measurement data. Three different measurement node types are offered for the system. Depending on the type, ambient temperature, wall temperature, humidity and/or heat flow can be measured. The exact specifications of the various measuring nodes are shown in Table 3-1. Depending on the combination of the measuring nodes, the U-value (in accordance with ISO 9869) and the a_w-value can be calculated from the measured data. More information on the gO measurement system is available at: https://www.greenteg.com/gO-Measurement-System/

Type 1 Measurement Node	Type 2 Measurement Node	Type 3 Measurement Node
Measures: - Heat flux - Surface temperature - Ambient temperature	Measures: - Surface temperature - Ambient temperature	Measures: - Ambient temperature -Relative humidity

Table 3-1: Overview of various measurement nodes of the gO-Measurement System

As described above, the building U-values were measured on an insulated and an uninsulated wall. Additional humidity and dew point measurements were taken in the basement. For the U-value measurements, one Type 1 Measurement Node was attached to the interior side of each wall to measure heat flow and interior temperature. A Type 2 Measurement Node was installed on the exterior side of the wall, which measured the outside surface and ambient air temperature over the measurement period. All three measurement nodes are shown in Figure 3-1.
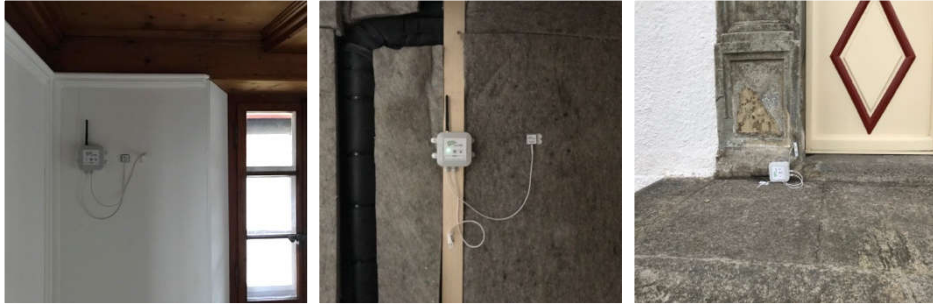
Figure 3-1: Type 1 measurement nodes on the uninsulated wall (left), Type 1 measurement nodes on the insulated wall (centre) and Type 2 measurement nodes outside (right)

The relative humidity and a_w were measured in two different basement rooms. A Type 3 Measurement Node was installed to measure relative humidity in the middle of the room, while a Type 2 Measurement Node was installed to measure surface temperature at a critical point of the wall. The four measurement nodes are shown in Figure 3-2.
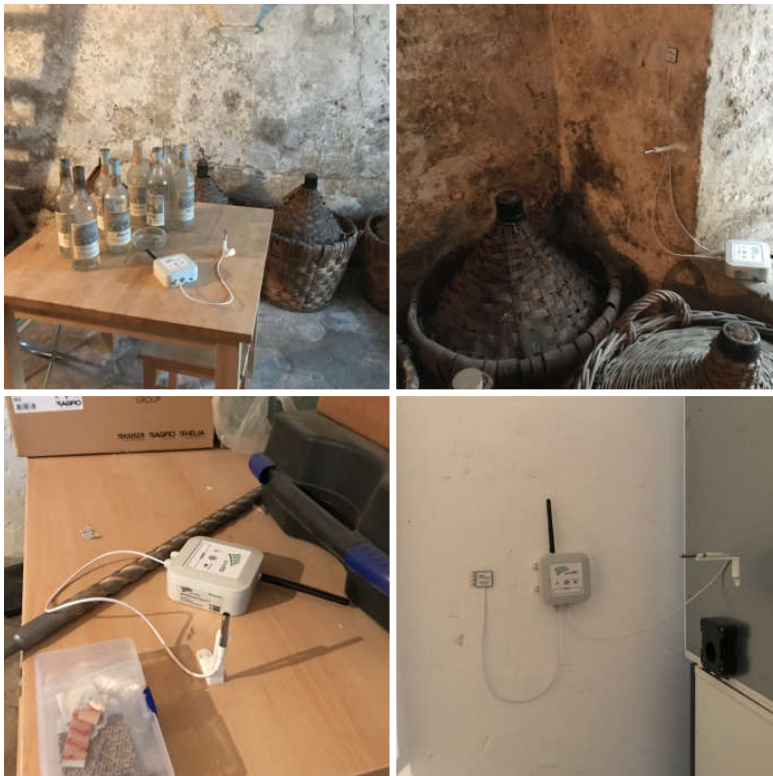

Figure 3-2: Type 3 Measurement Nodes for measuring relative humidity (top & bottom left) and Type 2 Measurement Nodes for measuring wall temperature (top & bottom right)

4   Measurement Results
4.1   U-Value Measurements

In preparation for the U-value measurements, the walls to be measured were analysed with a thermal imaging camera to ensure the measurements were taken on a wall section that is as homogeneous and representative as possible.

The U-value measurement on the un-insulated wall took place between 10 February 2018 and 13 February 2018. The measurement results are shown in Figure 4-1. The meteorological conditions were very constant during the measuring period and with a constant temperature difference of approximately 20°C, which is ideal for a U-value measurement. The measured U-value is $0.77 \frac{W}{m^2 \cdot K}$, which was better than expected.

Figure 4.1-1: U-value measurement data of the uninsulated wall

To meet cantonal requirements to qualify for subsidies, refurbished walls may have a maximum U-value (U_{max}) of $0.3 \frac{W}{m^2 \cdot K}$. Sheep wool was chosen as the insulation material, which has a λ-value of $0.04 \frac{W}{m \cdot K}$ ($\lambda_{sheep\ wool}$). From this the required insulation thickness ($d_{sheep\ wool}$) can be calculated as follows:

$$U_{max} = \cfrac{1}{\cfrac{1}{U_{wall}} + \cfrac{d_{sheep\ wool}}{\lambda_{sheep\ wool}}}$$

$$d_{sheep\,wool} = \left(\frac{1}{U_{max}} - \frac{1}{U_{wall}}\right) \cdot \lambda_{sheepwool} = \left(\frac{1}{0.3\frac{W}{m^2 \cdot K}} - \frac{1}{0.77\frac{W}{m^2 \cdot K}}\right) \cdot 0.04\frac{W}{m \cdot K} = 0.08m$$

The required insulation thickness for this wall is therefore 8 cm, which is well below the 16 cm recommended by the expert.

The measurements on the already renovated and insulated wall (with 16 cm sheep's wool), took place at the same time as the measurements on the un-insulated wall. So the same ideal measuring conditions prevailed. The measurement results are shown in Figure 4-2. The measured U-value was $0.078\frac{W}{m^2 \cdot K}$. It is thus significantly less than the calculated U-value of $0.19\frac{W}{m^2 \cdot K}$ (based on the formula above). The most likely reason for this is that the refurbished wall does not have the same construction/thickness as the un-insulated wall, thus making it better insulated.
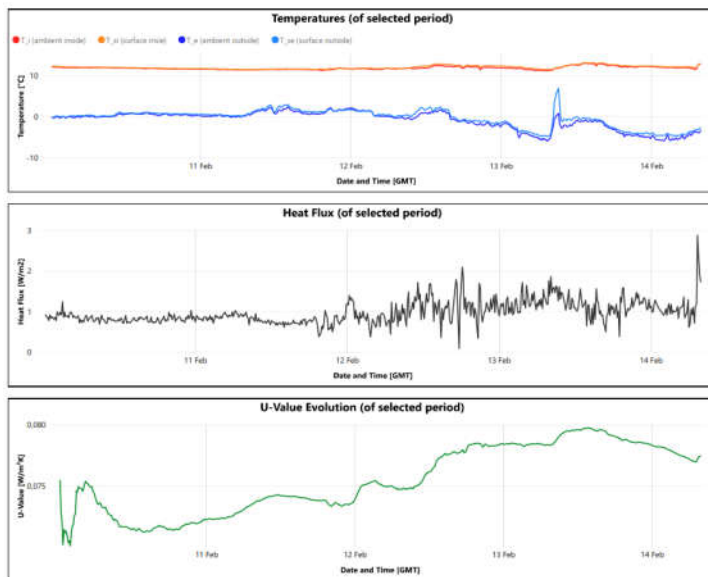

Figure 4-2: U-value measurement data of the insulated wall

4.2   Humidity and a_w-value measurements

To check the risk of mold formation in the cellar area, moisture and a_w-value measurements were carried out in two different cellar rooms. Both measurements took place between 08.02.2018 and 14.02.2018.
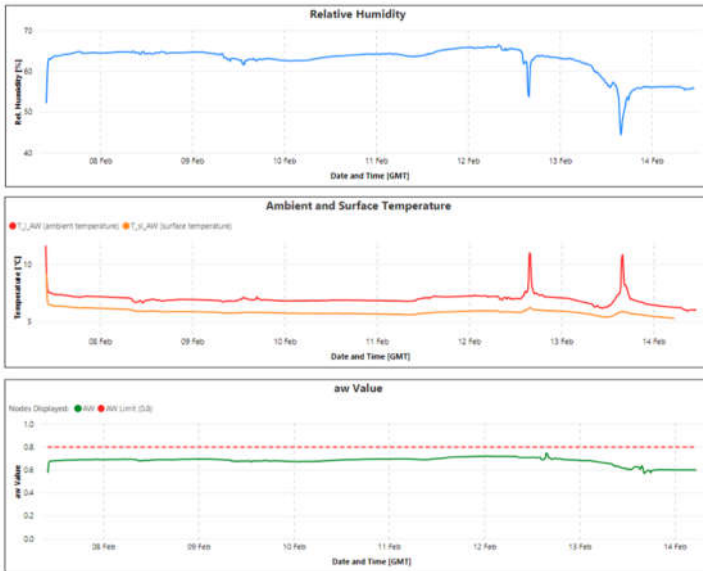
Figure 4-3: Measurement data from Cellar Room 1

The measurement data of Cellar Room 1 (see Figure 3-2 above) can be taken from Figure 4-3. The relative air humidity was constant with approx. 65% over the measured period. The room temperature was approximately 7.5 °C and the wall temperature was approximately 6.5°C. The relative humidity was constant over the measured period. The a_w-value calculated was on average around 0.7 and thus just under the critical limit of 0.8.
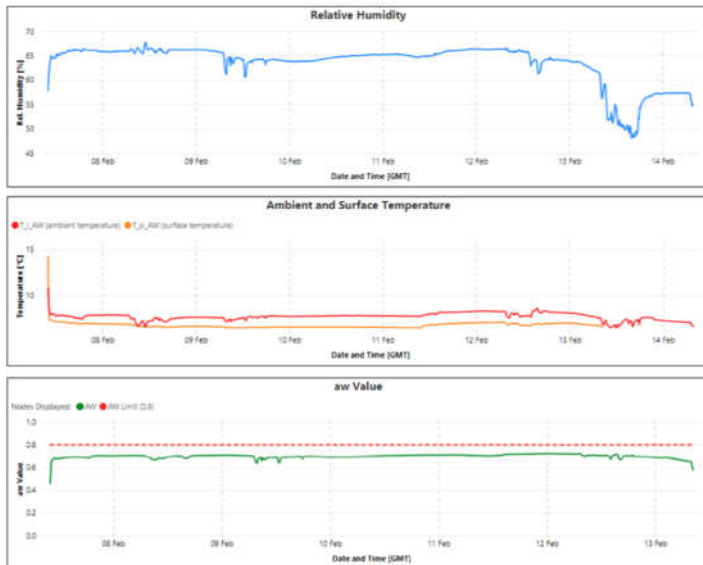

Figure 4-4: Measurement data from Cellar Room 2

The measurements in Cellar Room 2 (see Figure 4-4 below) are visible in Figure 4-4. The measurement results are similar to those in Cellar Room 1. The air humidity was approximately 65%, room temperature approximately 7 °C and the wall temperature approximately 6.5°C. The calculated a_w-value similarly fluctuated around 0.7.

Since the a_w-values are just slightly less than the critical limit in both rooms, in principle, one can say that there is a risk of mold formation. Since the risk of mold formation for old buildings tends to be higher in the summer, the measurements should be repeated then. In addition, it is also useful to regularly check the humidity in the rooms and, if necessary, use a dehumidifier.

4. Conclusion

In this case study, U-value and a_w-value (humidity) measurements were carried out on a building over 400 years old. The aim was to optimally dimension the required insulation thickness and examine the basement area for the risk of mold growth. The use of the gO-Measurement System enabled a precise quantitative assessment of the building site.

This case study showed how difficult it is to accurately estimate the insulation quality of masonry in old buildings. In the present case, this led to an over-dimensioning of the insulation. This is especially the case for listed buildings, where interior insulation is usually used, and leads to high costs and an unnecessarily high reduction of living space, which could have been otherwise avoided with more precise dimensioning. In addition, the measurements also showed that wall structures are not always homogeneous. Therefore, the different walls should be ideally first compared with each other using thermographic images. Then, it can be determined which walls should have their U-values measured for renovation planning.

The a_w-value measurements carried out in the cellar were useful for assessing the risk of mold formation and to assess different basement room's suitability as a storage/archive room. Although the air humidity was not excessively high, there was still a certain risk of mold formation due to the rather low temperatures, which makes it advisable to check the air humidity.