SB&WRC Project

Installation report:

Guarded Hot Box apparatus

May 2019

Abstract of the project

The SB&WRC *(Sustainable Bio&Waste Resources for Construction)* project, an undertaking of more than two years, aims to conceive, produce and test three innovative, low-carbon, thermal insulation materials from agricultural co-products and recycled waste. The project is supported by the development program Interreg VA France (Channel) England and its budget, estimated to be 1.8M€, is co-financed by the ERDF (European Regional Development Fund) for 69% (1.26M€ contribution).

This project, led by Nomadéis, is carried out by a cross-channel partnership which gathers academic research laboratories, private research and consulting companies, manufacturers and professional non-profit organisation of the building sector:

- Nomadéis;
- Veolia Propreté Nord Normandie;
- University of Bath;
- Ecole Supérieure d'Ingénieurs des Travaux de la Construction de Caen (ESITC Caen);
- Construction21;
- UniLaSalle;
- University of Brighton;
- Alliance for Sustainable Building Products.

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1. Presentation of the facility

Figure 1: Picture of the guarded Hot Box apparatus with the prototype 2 placed between two ambiences. Left side: hot ambience. Right side: cold ambience.

To determine the thermal properties of a building material on a real scale, a Hot Box apparatus is often used. With this apparatus, a wall to be tested is positioned between two ambiences, one hot and the other cold. Once the steady state is reached, measurement of the heat dissipated to keep a constant temperature gradient through the specimen wall is performed. Thanks to these data, dissipated power and temperature difference between the two atmospheres, thermal performance of the wall can be calculated. So, the prototype thermal resistance can be determined by using the following relationship:

$$R = \frac{A.(T_h - T_c)}{Q}$$

Where:
R: prototype overall thermal resistance, $m^2.K/W$
A: metering box opening area, m^2
T_h: Environmental temperature at the hot side (metering chamber), °C
T_c: Environmental temperature at the cold side (climatic chamber), °C
Q: rate of heat flow throw the prototype to be tested, W.

Once the prototype thermal resistance is known, an effective thermal conductivity can be calculated using the following relationship:

$$\lambda = \frac{L}{R}$$

λ: prototype effective thermal conductivity, W/(m.K)
L: prototype thickness, m

In this project, the thermal performance of Prototype 2 (OSB + polyester + OSB) was studied. To this end, a measurement system was developed following the ASTM C1363-11 and NF EN ISO 8990 norms.

Our measurement system consists of two climatic chambers separated by a polyurethane wall. The separating wall contain a 2 m x 2 m opening where the sample to characterise should be placed. A metering chamber having an opening of 1.27 m x 1.46 m was built (Figure 1). A heating system was placed inside this metering chamber and powered by a DC power supply (Aim-TTi - CPX400DP). Temperatures on both sides of the wall are measured by T-type thermocouples which are linked to a data acquisition system (3706A KEITHLEY). A LabVIEW program was created in a computer in order to perform temperature regulation, data acquisition and signal processing simultaneously as shown in the following figure.

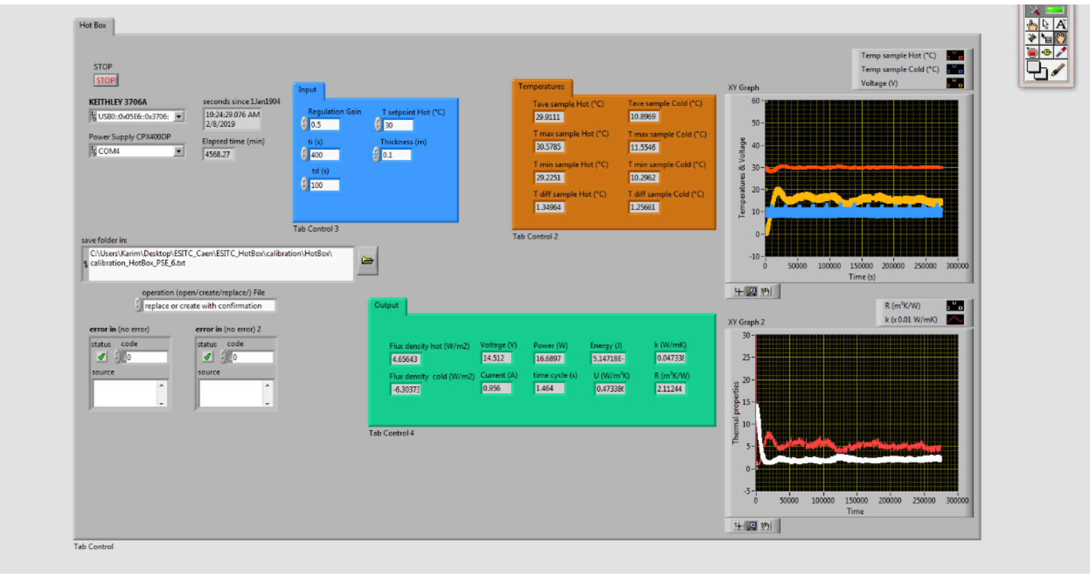

Figure 2: The LabVIEW program developed during the SB&WRC project.

In the following figure, an overview of the Hot Box apparatus is shown.

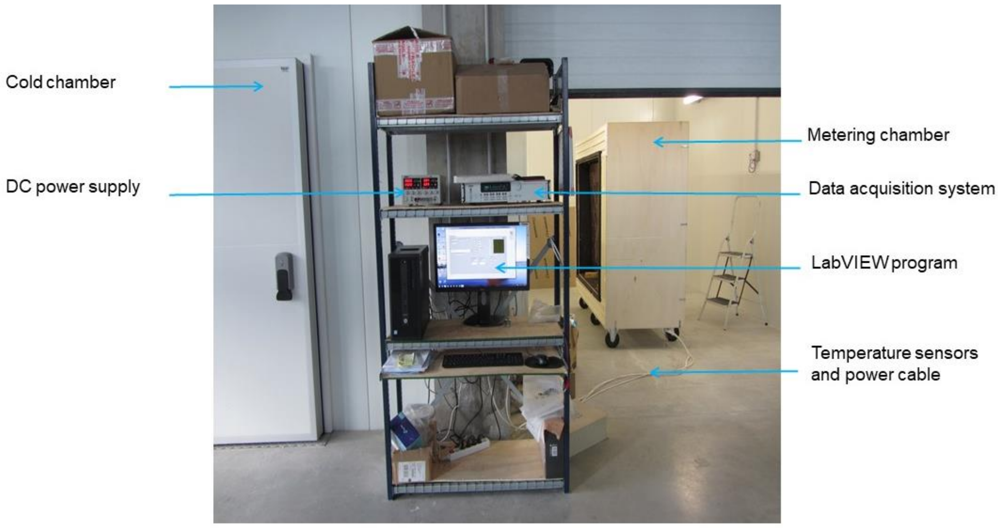

Figure 3: Overview of the experimental device used for thermal characterisation of the prototype 2.

During the development of the Guarded Hot Box apparatus, air flow velocity, temperature distribution in the metering chamber and in the cold chamber should be taken into account. To maintain air movement in the direction of natural convection and a homogeneous temperature distribution on the hot side of samples to be studied, two fans were installed in the metering chamber. To ensure that the temperature distribution on the cold side of the samples is homogeneous, a thermal infrared camera (FLIR E75) was used. Figure 4 shows the temperature distribution on the cold side of Prototype 2. This image shows that the temperature distribution is homogeneous in the area of interest.

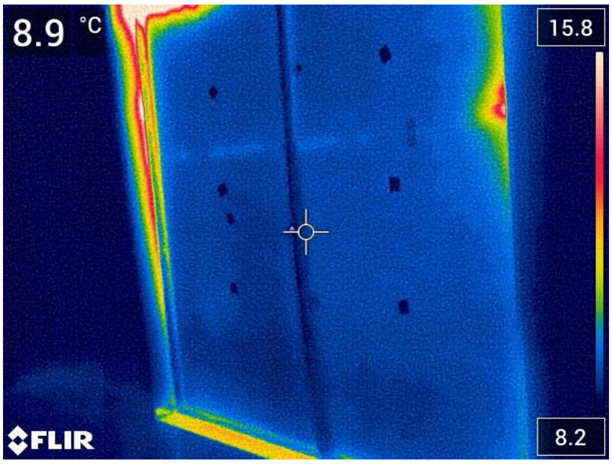

Figure 4: Temperature distribution the temperature distribution on the cold side of the prototype 2.

2. Issues encountered

When the thermal studies of the prototype 2 were started, we encountered a few problems with the temperature distribution on the hot side of this prototype. To overcome this issue, we first added two fans in the metering chamber and we performed the calibration of the temperature sensors, then, we recalibrated all the guarded Hot Box apparatus.

3. Measurement of performance

3.1 Experimental conditions

Upon receipt, the recycled duvets were first cleaned and sanitised, then the polyester was taken out from the duvets and placed layer by layer inside the constructed OSB box, which had the following dimensions: 2 m height, 2 m large and 0.1 m for thickness. The weight of the polyester introduced in the box was approximately 8 kg. The different steps of the prototype 2 construction are illustrated in Figure 5.

Figure 6: Illustration of the different steps of the prototype 2 construction.

Figure 5: Prototype 2 placed between the metering chamber and the cold chamber.

Once built, prototype 2 was placed in the Guarded Hot Box system for the thermal properties investigation as shown in Figure 6.

The prototype was then subjected to a temperature difference of 20°C. The hot side temperature was set to 30°C and the cold side temperature was set to 10°C; enabling us to obtain the prototype thermal properties at 20°C.

3.2 Experimental results

The evolution of temperature, on both sides, as a function of time is showed in Figure 7. On figure 7, it is evolution as function of time of the prototype 2 thermal conductivity and resistance which is illustrated. The system makes between one and two days to reach the steady state.

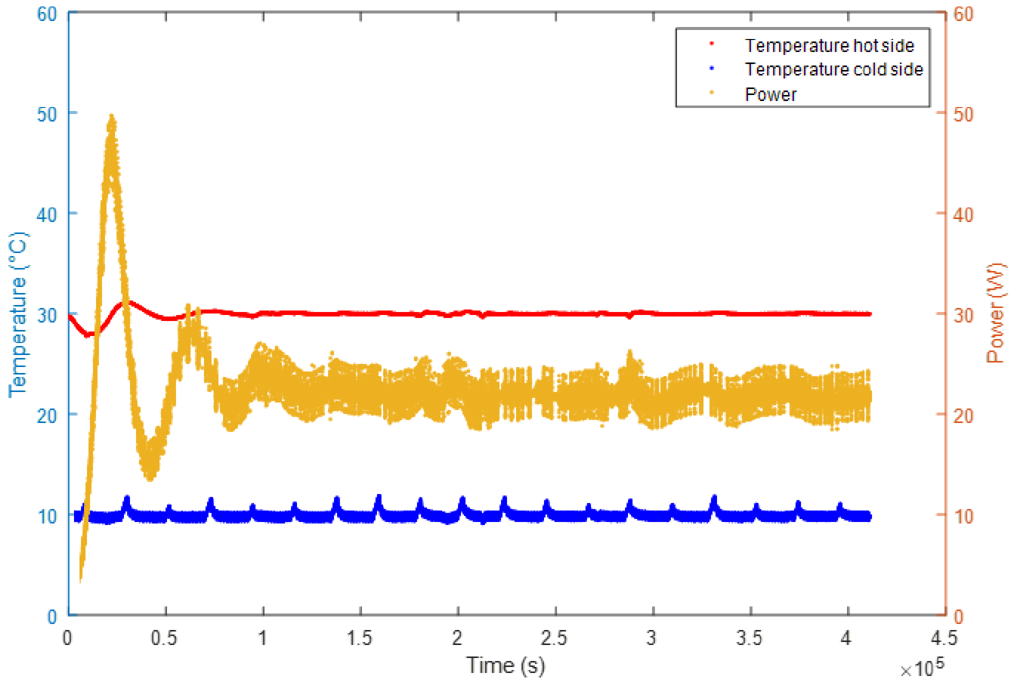

Figure 8: temperatures and heating power evolution as function of time

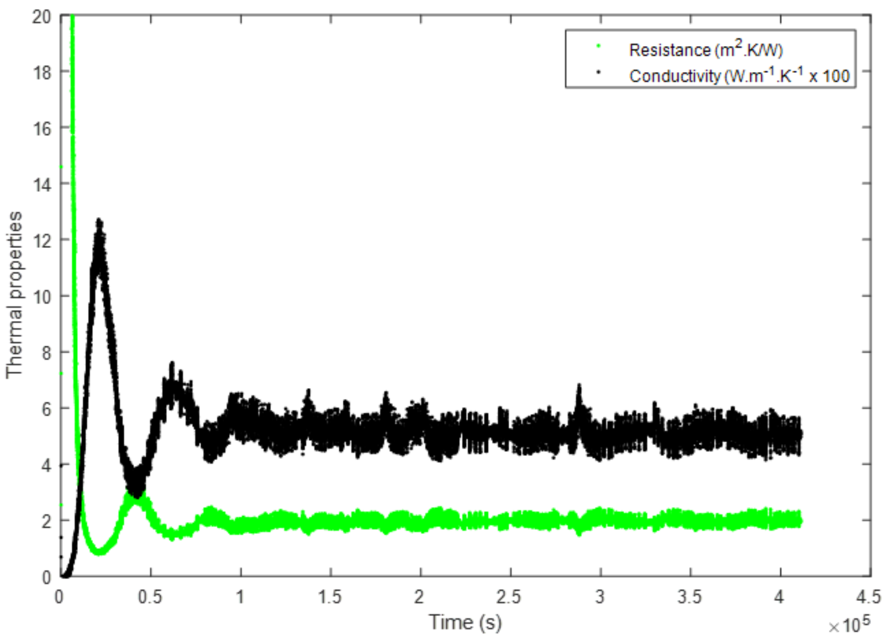

Figure 7: prototype 2 thermal conductivity and resistance evolution as function of time.

Once the steady state is reached, the thermal properties of prototype 2 were calculated. The results are given in the following table:

Prototype	Dimensions (cm)	Thermal conductivity ($W.m^{-1}.K^{-1}$)	Thermal resistance ($m^2.K/W$)
Prototype 2	**200 x 200 x 10**	**0.0505**	**1.98**

*The thermal properties represents an average of five measurements in the same environmental conditions.

From the performances reported in the above table, we can notice that the thermal conductivity of the prototype 2 is close to the one of the common thermal insulating materials already available on the market. For instance, rockwool, glass wool or polystyrene all have an $\lambda \approx 0.04$ $W.m^{-1}.K^{-1}$.

So, these results allow us to say that from a thermal standpoint, the recycled polyester can be considered as a good thermal insulation material.

As the raw material (recycled polyester) constituting Prototype2 is a waste product, it should have a very competitive price compared to materials marketed today. However, the deployment of this prototype may face one main limitation: its implementation within buildings may be hampered by the fact that polyester cannot support its own weight in a vertical position. In this sense, some reflection will be required to find a way to facilitate its implementation as a thermal insulant.

The SB&WRC project is part of the Cross Border European Territorial Cooperation (ETC) Program Interreg VA France (Channel) England and benefits from financial support from the ERDF (European Regional Development Fund).