ISOBIO: dynamic hygrothermal simulation and full-scale validation of a structural insulated panel made from bio-based materials

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Abstract

The article presents the results of ISOBIO, a European project that ran from 2015 to 2019, financed under the Horizon2020 program. The project developed new insulating materials and plasters from plant fibres, agricultural residues, and bio-based binders, with the aim of reducing both the embodied energy in the materials as well as operational energy consumption. The materials were incorporated into a prefabricated structural insulated panel, and installed and monitored in 2 demonstrators in the UK and Spain. The panel's hygrothermal performance was monitored and validated dynamically with a WUFI Pro model (to EN 15026 [1]), showing very reliable hygrothermal performance and a close correlation between modelled and measured values.

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Keywords: ISOBIO; H2020; hygrothermal modelling; bio-based materials; embodied energy; energy efficiency; thermal insulation; WUFI; EN 15026; ISO 6946; heat and moisture transfer; hemp; straw; clay; lime;

1. ISOBIO structural insulated panel for new buildings

The prototype panel measured 1.95m x 1.95m, with a total thickness of 33.2cm in 8 layers with 9 different materials (Figure 1). The panel was rendered external with 25mm of lime and hemp plaster, applied on a rigid 50mm hemp insulation board, mechanically fixed to the 145mm red pine wood structure filled with hemp, cotton, and flax insulation, followed by a 12mm OSB 3 board. An airtight and dynamic vapour control membrane was fixed to the inner face of the OSB, followed by a 45mm service void with hemp, cotton, and flax insulation, between timber battens, swing 90° in relation to the main structural joists to reduce the thermal bridging through the timber. The inner service void was lined with a 40mm thermo-compressed straw board, plastered on the inside with 15mm of composite clay-hemp plaster, applied in 3 layers.

Figure 1: ISOBIO panel section drawings and materials

Figure 2: Location and type of sensors installed in the panel

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2. Test set-up

A monitoring system was installed with a meteorological station recording the external conditions, with a temperature sensor on the outside face of the panel, a heat flow and temperature sensor on the inner face, in accordance with ISO 9869 [1]. In addition, temperature and relative humidity sensors were installed at 3 positions within the panel (Figure 2), to measure the transient hygrothermal behaviour inside the panel and compare the results with the WUFI model, according to EN 15026 [2]. The data was measured at an interval of 5 minutes. The interior temperature was maintained at an average temperature of 25.5 °C throughout the period, with an electric air heater.

3. Monitoring Results and Validation

Figure 3 shows measured and modelled temperature and RH at position 2 (between the CAVAC rigid insulation and Biofib Trio insulation). Figure 4 shows the measured and modelled temperature at position 3 (between the Biofib Trio insulation and OSB board). Figure 5 shows the measured and modelled temperature and RH at position 4 (between the Intello membrane and the Biofib Trio insulation).

Figure 3: Measured vs. modelled (WUFI) interstitial temperature and relative humidity, position 2, ISOBIO new-build panel, HIVE

Figure 4: Measured vs. modelled (WUFI) interstitial temperature and relative humidity, position 3, ISOBIO new-build panel, HIVE

Figure 5: Measured vs. modelled (WUFI) interstitial temperature and relative humidity, position 4, ISOBIO new-build panel, HIVE

4. Conclusions

The results of the temperature and RH measured and modelled with WUFI in positions 2, 3 and 4 show that the dynamic temperature variations are very well reflected in the model. The short-term variations in relative humidity are not modelled with the same precision in the model, possibly due to the assumption that the equilibrium water content in the materials is instantaneous, when in reality, there is hysteresis [2]. However, the results show a very good correlation between the measured and the calculated values, demonstrating that the materials of biological origin in a composite panel of this type, can contribute to the reduction of energy consumption of a building in its operation phase with a minimum amount of energy embedded in the materials in the manufacturing phase. The results also indicate that moisture transfer within a panel of this kind can be adequately and accurately modelled, providing a means to “stress-test” building elements at design phase and assess their durability under varying moisture conditions.

References

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