Summary Report on all Wall Prototype 2 Tests Conducted for the SB&WRC Project

ARchitectural Visualisation and Environmental Analysis
ARVEA Consultants

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Introduction

The following report summarises the methodologies and results of all wall protoype 2 tests conducted for the SB&WRC project. The wall prototype 2 employed reused duvets as the main insulative element. Lab tests were conducted at the Universities of Bath and Caen; in-situ tests were conducted at the Brighton WasteHouse by ARVEA Consultants for the University of Brighton.

Testing Methodologies

Caen[1234]

Physical set-up

The used duvets were cleaned and the polyester fibre layers were removed from their coverings. The layers were then laid within a OSB box of external dimensions 2m by 2m by 0.1m; the 2m by 2m (standard double duvet size) dimension is assumed to conform to the size of the supplied duvets. The OSB board as 12mm in thickness giving an internal volume of $0.23m^3$. Approximately 8kg of fibres were placed within the specimen box resulting in an installed density of approximately $34kg/m^3$.

Monitoring set-up

The OSB box specimen was placed within the wall of a climate chamber held at 10°C. A heated monitoring chamber has placed over the specimen and maintained at 30°C. Heat flux through the wall appears to have been measured via the power required to maintain a steady state temperature within the monitoring chamber in accordance with ISO8890 and ASTM C1363-11. This power value combined with the temperatures within the climate chamber and monitoring chamber were used to derive the thermal conductivity of the specimen.

Results

The thermal conductivity of the entire sample is given as 0.0505W/m·K and the thermal resistance of this layer is reported as being $1.98m^2K/W$, a figure which excludes surface resistances. This results in a U-Value of $0.51W/m^2K$ without surface resistances. Taking nominal values for surface resistances of 0.06 and 0.12W/m.K a total indicative U-Value of $0.46W/m^2K$ is arrived at. Taking an accepted thermal conductivity of OSB of 0.13W/m·K, the thermal resistance of the duvet alone is $1.79m^2K/W$, which with the same nominal internal and external surface resistances would lead to $0.51W/m^2K$ U-Value. The thermal conductivity of the duvet material itself 0.042W/m·K, a figure very close to the common figure of 0.04 for building insulation materials.

The University of Brighton asked for U-Values for 100 and 150mm of duvet insulation based purely on the calculated thermal conductivity of the duvet layers i.e. ignoring surface resistances. Based on these tests these figures are 0.42 and 0.28 W/m^2K respectively.

Conclusions

This testing phase concluded that the although the recycled polyester fibres delivered good thermal insulation values, and would be cost effective, the even suspension of the polyester fibres within a building construction panel would require some kind of support mechanism.

[1] Facility Presentation Sheet: Guarded Hot Box Appartus - University of Caen
[2] Installation Report: Guarded Hot Box Apparatus - University of Caen
[3] Technical Fact Sheet: Prototype 2 made from polyester - University of Caen
[4] R&D Protocol: Prototype 2 - University of Caen

Bath[5]

Physical set-up

A $1.1m^2$ prototype 2 wall was installed along with two other wall prototypes in the Large Environmental Chamber (LEC) at the University of Bath. The wall prototype was made up of 9mm OSB, 140mm duvet filled stud work, and 9mm OSB. The weight of the installed duvet was 1.3kg installed in the central stud space giving an installed density of $26kg/m^3$. No membranes were installed as part of the construction.

Monitoring set-up

Different temperature and humidity conditions were maintained across the wall prototypes in three distinct phases.

Heat flux was measured with a heat flux meter placed on the surface of the prototype construction. Temperatures and humidities were monitored on both sides of the prototype. Surface temperatures and temperatures & humidities within the prototype construction were also monitored.

Results

U-Values results are presented for the three testing phases. Phase 1 & 3 present very similar values of 0.282 and $0.277W/m^2K$ respectively.

Phase 2 presented a lower U-Value of $0.237W/m^2K$. In this test the temperature differential across the walls was reversed, temperatures on the cooler side were allowed to vary and humidities on either side of the wall were the highest. It is not expected that the latter two would significantly effect steady state heat flux though the wall but the reversing of temperature differential may have had an effect on the surface convection heat transfer coefficients.

For further result processing phase 3 was chosen as the temperature difference across the sample was stable and at 7°C the most representative of a southern UK, northern France annual temperature difference as seen by a building fabric.

Taking the calculated U-Value figure and assuming that this figure does include internal and external surface resistances, and assuming again a standard value for the thermal conductivity of the OSB, then the thermal conductivity of the duvet fabric 0.043W/m·K. This is a very close figure to the Caen results and to the common building insulation of 0.04W/m·K.

Conclusions

No conclusion specific to the protoype 2 duvet wall was presented.

Brighton[6]

Physical set-up

A $0.525m^2$ section of wall in the Brighton WasteHouse was selected to replace the existing insulation with folded duvets in both the inner 364mm deep cavity and outer 100mm cavity. The density of duvet installation was 21.4 and $11.3kg/m^3$ for the inner and outer cavities respectively giving an overall density of 19.2 kg/m^3. The duvet layers were pinned to the interstitial plywood layers at the top and allowed to hang in the cavities. The complete make-up of the test wall construction is shown in figure 1a of the monitoring report (footnote 6). External conditions were ambient and internal conditions varied depending on occupancy and heating regime in the office room as shown in figure 4 of the monitoring report (footnote 6).

Monitoring set-up

In addition to a heat flux mat placed on the inner surface of the wall a probe was constructed and inserted into the centre point of the wall section to monitor temperatures and humidities in the internal and external environments and at the mid-point of each duvet layer. Results were generated in accordance with ISO 9869-1:2014.

[5]Installation report (D6.4): University of Bath's Building Research Park and University of Brighton's Waste House - University of Bath
[6]Monitoring Report on the SB&WRC Wall Prototype 2 at the Brighton WasteHouse - ARVEA Consultants

Results

In terms of thermal performance, a good U-Value of 0.138 W/m^2K is achieved with the duvet installation but the overall thickness of the insulation layers (464mm) means that the thermal conductivity was not as good as conventional insulation products. An overall thermal conductivity for both duvet layers was derived and came to 0.069 W/m·K.

In terms of condensation risk, none was detected during the curse of the tests. Water vapour exchange, as evidenced by the dew-point temperature results, would have also acted to help eliminate condensation risk.

Conclusions

The monitoring report concludes that although a good U-Value of 0.138 W/m^2K was attained, a large thickness of duvet material installation was required to achieve it, and the thermal conductivity of the duvet layers was significantly higher than conventional insulation materials. Dew-point data suggested water vapour exchange between the duvet layers and the internal/external environments indicating that significant air exchange may also be occurring. The low relatively low density of installation and the possibility or large air cavities within the duvet installations are also mentioned as potential reasons for the relatively high thermal conductivity.

Summary

Below is a summary table of results for comparison.

Institution	Thickness (mm)	Density (kg/m^3)	Thermal conductivity (W/m·K)	Raw U-Value 100mm (W/m^2K)	Raw U-Value 150mm (W/m^2K)
Caen	76	34	0.042	0.42	0.28
Bath	140	26	0.043	0.43	0.28
Brighton	464	19	0.069	0.69	0.46

Table 1: Duvet thermo-physical properties for all tests

Conclusions

There is quite a large disparity between the lab based results produced by the Universities of Caen and Bath, and the in situ monitoring results produced by ARVEA Consultants at the University of Brighton's Waste House. The thermal conductivity of the duvet installation, as calculated from the overall heat flux measurements, is what one would expect a good insulative material to be in both of the lab tests. In the WasteHouse test it is 64% higher.

Moving from a controlled lab experiment to a 'real world' test often results in some degradation in monitored performance due to the increase in variables and the attendant increase in possible factors that can decrease performance. There are however some specific factors that it is believed have contributed to this variation in performance:

- The very different densities of duvet installation is likely to have had an effect. The higher density of installations in the lab would have resulted in less air being present within the duvet installation. Although air can be a good thermal insulator, this is only the case when large convection currents within the air are not generated. In conventional insulation products this is usually achieved by having small, rather than large, pockets of air present within the insulation medium. The larger amount of air within the WasteHouse installation would have given more opportunity for these convection currents to be generated. It does however appear than going above $26kg/m^3$ of installed duvet density used in the Bath tests does not provide any thermal insulation benefits as they produced similar results to Caen $34kg/m^3$.

- Placing a test sample in the external wall of a building will expose the sample to wind-induced pressure differentials. With a well sealed construction unit this would not in itself cause a degradation in thermal performance but the dew-point data generated by the WasteHouse testing would indicate that water vapour, and quite likely air, could move into and out of the layers of the test construction. This air movement, exacerbated by the wind pressure differentials, would have caused the heat resident in the construction to leave by air exchange and not just through conventional heat transfer mechanisms. This increase in heat loss would then be picked up by the heat flux mat placed on the interior surface of the wall.

In summary, the duvet material has clearly shown in terms of pure insulative capability to be as effective as many commercial insulative materials, but installation and implementation is a key parameter than can significantly degrade performance. This is obliquely noted in Caen's conclusions which mentions a support mechanism for the duvet fibres to present pooling of the insulation material.

Given that attention to relevant details during the construction process may be lacking, further work could focus on the pre-processing of the duvet fibres before installation e.g. placed within their own containing and supporting unit that guarantees minimal air exchange whilst maintaining material homogeneity and avoidance of large air pockets being formed.