SB&WRC Project

Technical Fact Sheet :

Prototype 2 made from polyester

June 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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Summary

The present report synthesises the experimental results obtained for Prototype 2 which is a thermal insulation material made from recycled polyester within the SB&WRC project. The production process of this prototype is straightforward as it implies, mostly, to sanitise the waste bedding material, cut them open to remove the casing and reuse directly the polyester.

The choice of waste polyester was made on two main grounds It will allow construction professionals to recycle waste duvets which are currently not reused at all while taking advantage of the inherent thermal properties of the polyester component of this waste.

Experimental tests on this material have been undertaken by fours partners: ESITC Caen, University of Brighton, University of Bath and UniLaSalle (specifically for the fire reaction). In terms of its main performance, thermal conductivity and thermal transmittance (U-value) have shown that it has potential and may be considered as a good thermal insulant with a lambda value of comprised between 0,042 and 0,069 $W.m^{-1}.K^{-1}$ which is close to that of industry standards such as glass or rockwool, whose thermal conductivity is around 0.04 $W.m^{-1}.K^{-1}$.

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1. From resource to prototype

1.1 Recycled polyester

Figure 1: Left: picture of the resource (used bedding), Right : picture of a prototype made from waste polyester

The University of Brighton and ESITC Caen elected used bedding (other possibilities included waste from demolition sites such as concrete and terracotta) as the primary resource for the construction of Prototype 2, and specifically duvets. After a phase of tests (binding techniques notably) of duck feathers and polyester, the two main constituents of the bedding's stuffing, the partners decided to continue working solely with polyester.

1.2 Prototype 2 construction (ESITC Caen)

Upon receipt of the waste duvets (acquired thanks to partner Veolia), the duvets were first cleaned and sanitised, then the polyester was taken out of 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 2.

Figure 2: illustration of the different steps of prototype 2 construction

2. Properties of the resource (ESITC Caen)

2.1 Densities (apparent, true, porosity)

2.1.1 Experimental procedure

Bulk density

Bulk density was determined by using helium pycnometer (AccuPyc 1330_ micromeritics). This method enables the precise measurement of the sample's volume. It consists in introducing helium into a reference chamber with a known pressure and then allowing it to expand into the chamber containing the sample. The drop in pressure in the reference chamber is then measured. The sample volume may then be determined according to Mariotte's law:

$$V_s = V_c - \frac{P_2 - P_a}{P_1 - P_a} V_2$$

whereby:

- P_1: gas pressure in the reference chamber (Pa);
- P_2: gas pressure in the expansion chamber (which contains the sample) (Pa);
- P_a: atmospheric pressure (Pa);
- V_2: expansion volume (cm^3);
- V_c: chamber volume (cm^3);
- V_s: sample volume (cm^3).

Bulk density is then given by the following equation: $\rho_b = \frac{m_s}{V_s}$, with ρ_b being the density and m_s the sample's mass.

True density

True density is measured by means of a pycnometer with a countenance of 500 mL according to the procedure described below:

- Weigh the pycnometer filled with propanol to the mark: M_1
- Weigh the pycnometer filled with saturated sample and propanol to the mark: M_2
- Weigh the test sample in the dry state: M_d

True density is then given by the following equation:

$$\rho_s = \frac{M_d}{M_d - (M_2 - M_1)} \rho_p$$

with ρ_p being the propanol's density.

Propanol was selected as an immersion liquid because it is characterised by a density which is lower than that of water thus enabling the feasibility and the execution of the test.

2.1.2 Experimental results

Bulk density

The results of bulk density are given in the following table. Two samples of two different types of polyester were tested. The values for each sample transcribed in Table 1 represent an average of 3 measurements.

Table 1: Bulk density of the waste polyester [kg.m^{-3}]

	Polyester filling 1 (fabric)		Polyester filling 2 (balls)	
	Sample 1	Sample 2	Sample 1	Sample 2
ρ_b	1455.4	1466.9	1475.5	1472.5
$\rho_{b\ mean}$	1461.15		1474	

True density

The results of true density measurements are summarised in the following table.

Table 2: True density of the waste polyester [kg.m^{-3}]

	Polyester filling 1 (fabric)		Polyester filling 2 (balls)	
	Sample 1	Sample 2	Sample 1	Sample 2
ρ_b	1283.13	1186.59	987.37	1108.88
$\rho_{b\ mean}$	1234.86		1048.12	

2.2 Moisture and hydric properties

2.2.1 Experimental procedure

Water content

The test consists in drying the sample in a proofer at a temperature of 40 °C until the mass stabilises. Water content corresponds to the registered loss of mass. It is calculated according to the following equation:

$$W(\%) = \frac{M_w - M_d}{M_d} \,.100$$

with :

- M_w : mass at the wet state ;
- M_d : mass at the dried state.

Water absorption

This test is derived from an experimental protocol developed by the RILEM TC 236-BBM group. The procedure used to measure the water absorption of the different materials is as follows:

1. Dry the sample at 40°C until a mass variation lower than 0.1% is obtained over a 24 hours period;
2. Immerse completely a plastic micro-perforated bag in water;
3. Place and attach the bag in a centrifuge and let it turn for 30 seconds at 500 RPM, then note the bag's mass;
4. Weigh the mass (M_0) of the material and place it in the bag;
5. Immerse completely the bag filled with the material in water for 5 minutes;
6. Take the bag out of the water, place it in the centrifuge and let it turn for 30 seconds at 500 RPM;
7. Weigh the spin-dried bag and note the mass M_1 (5 min);
8. Repeat steps 5, 6 and 7 for other samples for different immersion durations;
9. Calculate the water absorption according to the following equation:

$$M(t) = \frac{M_t - M_0}{M_0} \,.100$$

2.2.2 Experimental results

Water content

The test was repeated three times for each sample. The results of water content are given in the following table.

Table 3: Water content of the polyester waste [%]

Sample	Polyester filling 1 (fabric)			Polyester filling 2 (balls)		
	1	2	3	1	2	3
W	1.0	0.8	0.7	1.2	0.9	2.1
W_{mean}	0.8			1.4		

Water absorption

The results of water absorption are given in the following Figure.

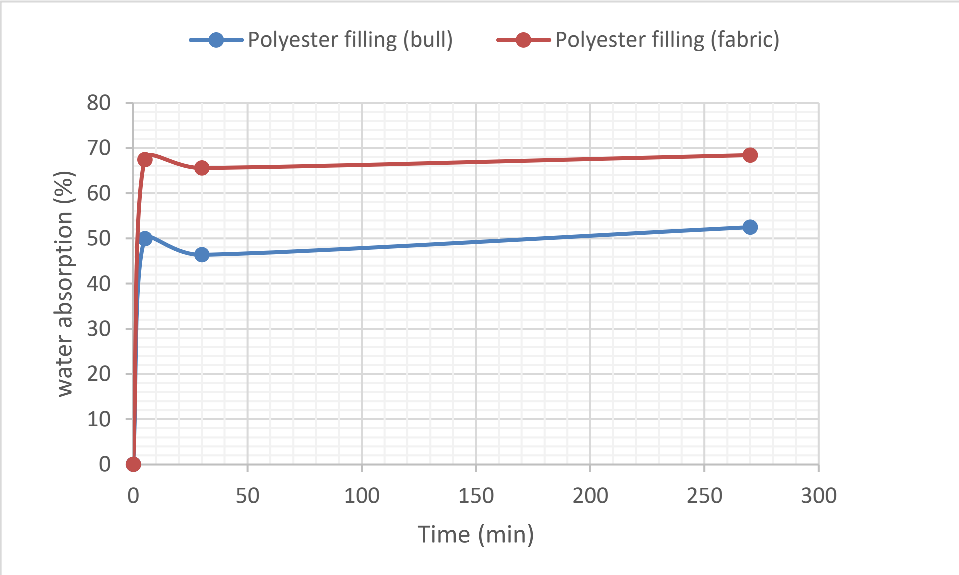


Figure 3: Water absorption of the used polyester

3. Thermal properties of the prototype (ESITC Caen)

3.1 Thermal conductivity and Thermal Resistance

3.1.1 Experimental procedure

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

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

λ: prototype's effective thermal conductivity, W/(m.K).
L: prototype's 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 4: Overview of the experimental device used for thermal characterisation of prototype 2.

3.1.2 Experimental results

After calibration of the developed Hot Box apparatus, the thermal properties of prototype 2 were investigated. The values recorded in Table 4 below represents an average of five measurements in the same environmental conditions

Table 4: Thermal conductivity and resistance measurements

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

From the performances reported in the above table, we can notice that the thermal conductivity of 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 $\lambda \approx 0.04$ $W.m^{-1}.K^{-1}$. Thus, from a thermal standpoint, recycled polyester may be considered as a good thermal insulation material.

4. Discussion (ESITC Caen)

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. In addition, prior to any commercialisation attempt more investigations should be performed, especially ones considering its hygrometric behaviour and durability.

5. Thermal properties of the prototype (University of Brighton)

5.1 Introduction

The following report summarises the methodologies and results of all wall prototype 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.

5.2 Summary of ESITC Caen's testing methodologies

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

5.2.1 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 is12mm thick thus 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}.

5.2.2 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.

5.2.3 Results

The thermal conductivity of the entire sample is given as 0.0505W.m^{-1}K^{-1} and the thermal resistance of this layer is reported as being 1.98 m^2.K^{-1}.W^{-1}, a figure which excludes surface resistances. This results in a U-Value of 0.51W.m^{-2}.K^{-1} without surface resistances. Taking nominal values for surface resistances of 0.06 and 0.12W.m^{-1}.K^{-1} a total indicative U-Value of 0.46W.m^{-2}.K^{-1} is arrived at. Taking an accepted thermal conductivity of OSB of 0.13W.m^{-1}.K^{-1}, the thermal resistance of the duvet alone is 1.79m^2.K.W^{-1}, which with the same nominal internal and external surface resistances would lead to 0.51W.m^{-2}.K^{-1} U-Value. The thermal conductivity of the duvet material itself 0.042W.m^{-1}K^{-1}, 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^{-2}.K^{-1} respectively.

5.2.4 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.

5.3 University of Bath Testing Methodologies

Bath Installation report (D6.4): University of Bath's Building Research Park and University of Brighton's Waste House - University of Bath

5.3.1 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.

5.3.2 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 internal temperatures and humidities within the prototype construction were also monitored.

5.3.3 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^{-2}.K^{-1} respectively.

Phase 2 presented a lower U-Value of 0.237W.m^{-2}.K^{-1}. 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^{-1}.K^{-1}. This is a very close figure to the Caen results and to the common building insulation of 0.04W.m^{-1}K^{-1}.

5.3.4 Conclusions

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

5.4 University of Brighton Testing Methodologies

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).

5.4.1 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.

5.4.2 Results

In terms of thermal performance, a good U-Value of 0.138 W.m^{-2}.K^{-1} 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^{-1}K^{-1}.

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

5.4.3 Conclusions

The monitoring report concludes that although a good U-Value of 0.138 W.m^{-2}.K^{-1} 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 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.

5.5 Summary table

Below is a summary table of results for comparison purposes.

Table 5: Prototype 2 (waste polyester) thermo-physical properties in all three deployment sites

Institution	Thickness (mm)	Density	Thermal conductivity (W.m^{-1}.K^{-1})	Raw U-Value 100mm (W.m^{-2}.K^{-1})	Raw U-Value 100mm (W.m^{-2}.K^{-1})
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

6. Conclusion on the thermal properties

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 Waste House, however, the tests showed a thermal conductivity which was 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 are believed to 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 Waste House 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 Waste House 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.

7. Fire tests on prototype 2 (UniLaSalle)

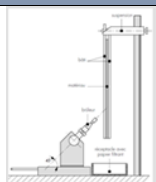
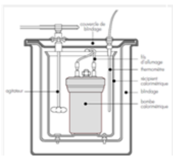
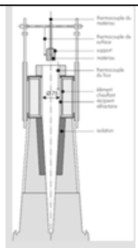
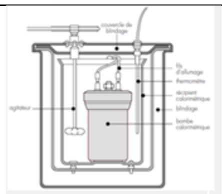
7.1 Context

A fire is an uncontrolled fire which, by spreading rapidly and uncontrollably, causes significant damage. Most fires are created by the combination of three elements: a fuel, an oxidizer and a source of energy also known as the «fire triangle».

To limit the damage caused by fires, the regulations on the fire safety of buildings have a number of requirements, particularly in terms of choice of materials. The behaviours of building materials when exposed to fire are assessed through the following measures: *(i)* **the fire reaction of the material**, *i.e.* its behaviour of materials during the first phases of the fire, the ease of ignition & *(ii)* **fire resistance**.

Since 2002[1], construction products for which a classification is mandatory, have to undergo a series of tests that simulate the first three phases of the development of a fire to obtain their reaction to fire classification. Existing tests corresponding to the three development phases are illustrated and are summarised in Table 6:

Table 6: Simulation of fire phases and associated tests

	Tests undertaken		Principle	Classification category
Starting of test	Method for testing of ignitability		Punctual attack at the small flame on a sample of material being arranged vertically	B, C, D, E and F
Starting of Fire	Test single Burning Item (SBI)		Attack with inflamed object with measurement of temperature and oxygen and carbon dioxide concentration	A2, B, C and D
Complete inflammation	ISO oven test		Flammability test on a sample exposed vertically in oven at 750°C during 60 minutes	A1 or A2
	Calorimetric test		Measurement of the higher calorific value	A1 or A2

[1] EN 13501-1 : Classement au feu des produits et éléments de construction - Partie 1 : Classement à partir des données d'essais de réaction au feu. AFNOR (2018).

When all these tests are carried out, a classification letter is attributed to the material according to the following European classification (Table 7):

Table 7: Simulation of fire phases and associated tests

A1	No contribution to fire
A2	Very low contribution to fire
B	Low fire contribution
C	Significant contribution to fire
D	High contribution to fire
E	Significant contribution to fire
F	Very important contribution to fire
NPD	No behavior in response to determined fire

7.2 Experimental protocol

According to the NF EN ISO 11925-2[2] standard, the small flame ignitability method corresponding to the first phase for development of fire (described in standard EN 13501-1). It consists in placing a sample of the prototype in a chamber test (Figure 1), and apply a 2cm propane flame for 15 seconds on the lower surface of a sample of material. This test give us some information about the capacity of a material to ignite more or less quickly in contact with a flame. After removal of the burner, a visual observation can determine if there is inflammation and the time during which the persistent flame has exceeded the height set by the standard to 15 cm. The presence of any inflamed droplets should be noted.

Figure 5: Left: Fire test chamber, Right: Sample before test.

According to the NF EN ISO 11925-2 standard, materials having a degradation zone inferior than 15cm and not producing inflamed droplets, have good resistance to ignitability.

7.3 Experimental results

The small flame ignitability method for prototype 2 and for a commercial polystyrene reference was carried out at UniLaSalle. The results of this test are summarized in the following table (3).

[2] NF EN ISO 11925-2 : Réaction au feu – Allumabilité des produits de bâtiment soumis à l'incidence directe de la flamme – Partie 2 : Essai à l'aide d'une source à flamme unique. AFNOR (2013).

Table 6: Results of the fire tests

Material	Prototype 2	Commercial polystyrene (reference material)
Sample before testing		
Sample after 15 seconds in contact with small flame		
Height of damage area	Superior to 15 cm	Superior to 15 cm
Total destruction time of the sample	2 minutes	15 seconds
Droplet production	Yes	Yes

The observations made during these first tests show that after removal of the burner, the damaged area is greater than the 15 cm recommended by the standard for both materials. The prototype 2, based on synthetic products, tests show an immediate inflammation of the sample with droplet production. The sample is totally destroyed in 2 minutes. We observe during the tests that the tyvek® envelope protecting the polyester accentuates the inflammation of sample.

The tests for the commercial reference of polystyrene demonstrate an immediate inflammation of the sample with droplet production. The sample is totally destroyed in 15 seconds.

At the end of this first test, the **prototype 2 as well as the polystyrene commercial reference are classified E. According to NF EN ISO 11925-2 standard, they contribute significantly to fire**.

8. Biodegradability of prototype 2 (UniLaSalle)

The end of life of biobased materials is still poorly known, due to the recent nature of the deployment of this type of material in buildings. However, a study carried out by ADEME[3] estimates the arrival of the first bio-based insulation materials in the end-of-life sectors as early as 2020. In the context of material recovery processes, manufacturers are looking for simple, pragmatic and economically viable solutions.

The composting method is a process on an industrial scale that represents a solution for the sustainable management of agricultural byproducts. It is one of the fastest ways of transforming biowaste into a kind of humus, a stable material that can return to the soil as an organic amendment, thus completing the cycle of organic matter and to bring a beneficial effect taken into account in the context of a LCA, related to the ecosystem service (biodegradation) rendered by microorganisms degrading materials.

The compostability of a material is defined by a standard ISO 14855[4] and undertaken in laboratory (Figure 6), which measures the amount of CO_2 produced (mineralization phase) by microorganisms during the compost biodegradation process.

Figure 6: experimental biodegradability system

There is no compostability standard for building materials. However, this type of standard exists for packaging, short-lived products (compared to the life of a building): it is the 13 432 standard for the biodegradation of packaging materials by composting. This standard is based on a laboratory test, which follows ISO / CEN 14 855 standard, which measures the amount of CO_2 produced (or O_2 consumed) by microorganisms during the process of biodegradability in compost. This standard indicates that a material is compostable if more than 90% of the material's carbon has been converted (mineralized) to CO_2 after 6 months.

[3] Rapport ADEME 2014, Identification des gisements et valorisation des matériaux biosourcés en fin de vie en France.

[4] ISO 14855, Évaluation de la biodégradabilité aérobie ultime des matériaux plastiques dans des conditions contrôlées de compostage -- Méthode par analyse du dioxyde de carbone libéré.

The prototype 2 being a petrobased material is not compostable and its biodegradability will take several hundred years.

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