Interreg France (Channel Manche) England

European Regional Development Fund

SB&WRC

Sustainable Bio & Waste Resources for Construction

SB&WRC Project

Specification of raw materials

November 2017

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. Maize and rapeseed straw for Prototype 1

1.1 Short description

A coproduct of the grain or fodder maize (corn) or rapeseed consisting of a stalk, the leaves and the spathes of the plant. The stalk is made of a spongy and lacunar pith in its core surrounded by the bark/peristem?

1.2 Measurements

1.2.1 Chemical composition

Both material's lignocellulosic composition were determined using the Van Soest Procedure[1].

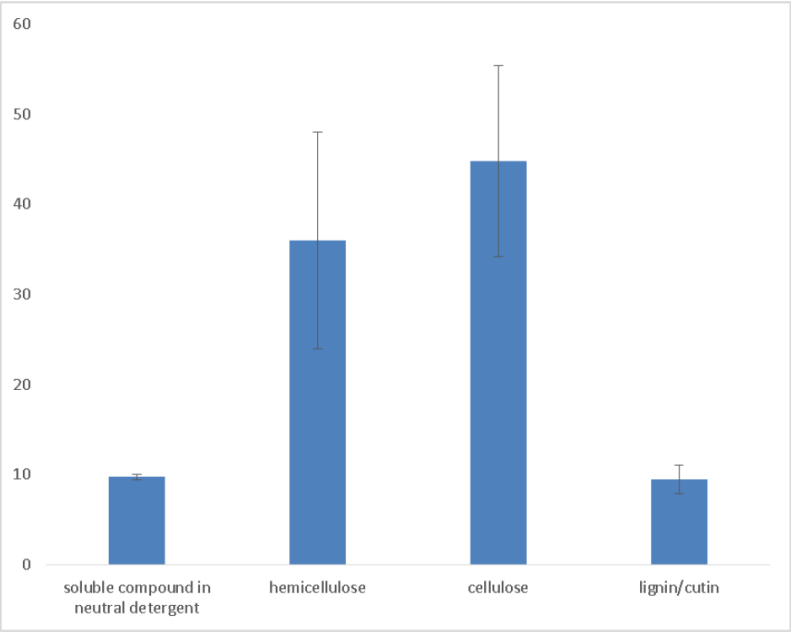

Figure 1: Lignocellulosic composition of maize straw using the Van Soest procedure (percentage of total composition)

[1] Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J Dairy Sci*.

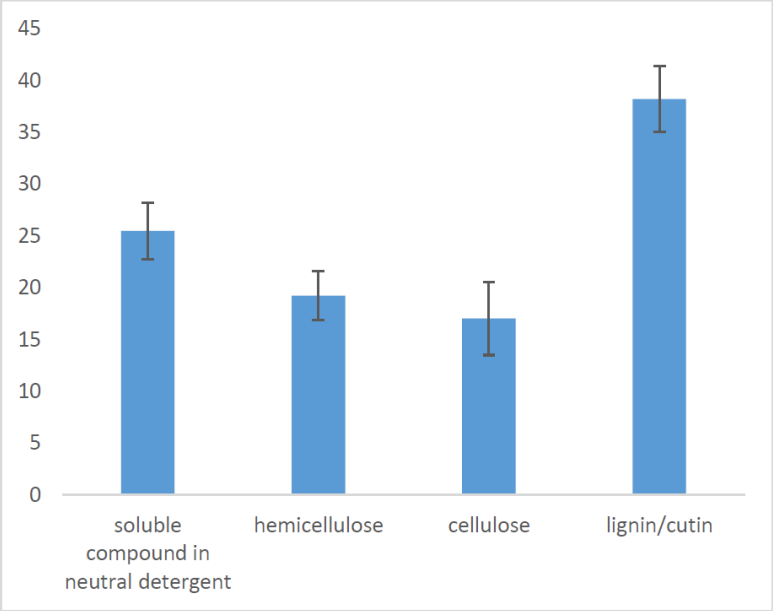

Figure 2: Lignocellulosic composition of rapeseed straw determined using the Van Soest procedure (percentage of total composition)

1.2.2 Physical properties

Table 1: Comparative table of the physical tests results (made in accordance with RILEM Technical Committee 236 guidelines)

	Maize straw	Rapeseed straw
Bulk density of the whole stem (kg.m^{-3})	43.8	56.4
Bulk density of the pith (kg.m^{-3})	14	/
Water absorption coefficient (%)	586	450

1.2.3 Thermal properties

Table 2: Comparative table of the thermal tests results

	Maize straw	Rapeseed straw
Degradation temperature via thermogravimetric analysis (°C)	≥210	≥210
Thermal conductivity via heat flow meter	0.056	0.054

2. Waste bedding materials for Prototpe 2

2.1 Short description

Three types of waste bedding products are being considered as raw materials for the insulation prototype 2, they are:

- Polyester filling that may be either in the form of fabric or balls;
- Duck feathers.

Figure 3: photographs of the samples that underwent characterisation. From left to right : (a) polyester filling (fabric), (b) polyester filling (balls) and (c) duck feathers

2.2 Experimental methods

2.2.1 Bulk density

Bulk density was determined using a helium pycnometer (AccuPyc 1330_micromeritics) which ensures a precise measure of the sample's volume. It consists in introducing helium into a reference chamber with a known pressure and then it is allowed to expand into the chamber containing the sample. Thus, the drop in pressure is measured. The sample's volume is determined using Mariotte's law :

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

with :

- 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 : $\rho_b = \frac{m_s}{V_s}$ whereby ρ_b is the bulk density and m_s is the sample's mass.

Two samples were tested per type of waste products and the following bulk densities were found (summarised in Table 3).

Table 3: Bulk density of the three bedding waste materials (kg.m^{-3})

	Polyester fabric		Polyester balls		Duck feather	
Samples	1	2	1	2	1	2
ρ_b	1455.4	1466.9	1475.5	1472.5	1279.1	1274.9
ρ_{mean}	1461.15		1474		1277	

2.2.2 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: $\rho_s = \frac{M_d}{M_d-(M_2-M_1)}\rho_d$, with ρ_d being the density of propanol.

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. The resultd of the true density measurements are summarised in the Table 4 below.

Table 4: True density of the three bedding waste materials (kg.m^{-3})

	Polyester fabric		Polyester balls		Duck feather	
Samples	1	2	1	2	1	2
ρ_s	1283.13	1186.59	987.37	1108.88	830.10	977.88
ρ_{mean}	1234.86		1048.12		903.98	

2.2.3 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:

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

With M_w : mass in the wet state and M_d : mass in the dried state.

The test was repeated three times for each material. The results of water content are given in the Table below.

Table 5: Water content of the three bedding waste materials (%)

	Polyester fabric			Polyester balls			Duck feather		
Samples	1	2	3	1	2	3	1	2	3
W	1.0	0.8	0.7	1.2	0.9	2.1	5.4	5.7	5.7
W_{mean}	0.8			1.4			5.6		

2.2.4 Water absorption

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

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

$$M_t = \frac{M_t - M_0}{M_0} \times 100$$

The results of water absorption are given in figure 4 below.

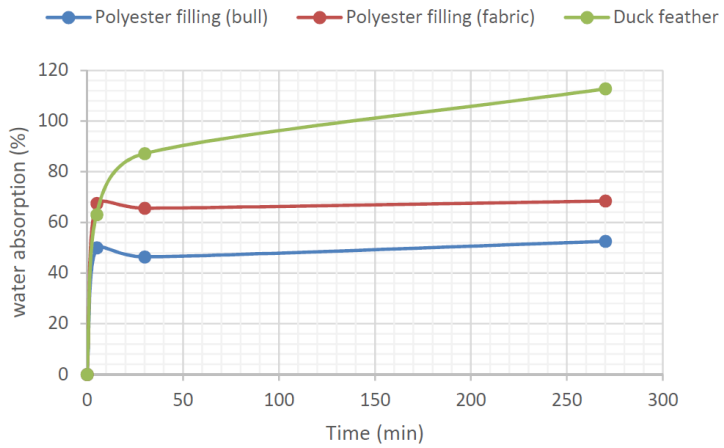

Figure 4: Water absorption of the three waste bedding materials.

3. Wheat straw for Prototype 3

3.1 Short description

Wheat straw is co-product of cereal grains made of the stalk of the plant. Straw may either be used locally as an organic soil amendment or exported out of the plot for other uses.

3.2 Experimental Method

The lignocellulosic biomass of wheat straw characterisation was made by using the standard AFNOR XPU44-162 (Van Soest procedure) test which is based on the determination of its composition (cellulose, hemicellulose and lignin). Van Soest procedure was used to determine the cellulose-like, hemicellulose-like and lignin-like content of raw straw and digested straw by chemical fractionation with detergents (neutral detergent, NDF; acid detergent fiber, ADF and acid detergent lignin, ADL).

Notes on the procedure

- Wheat straw is ground and sieved to obtain powdered straw (≤ 1mm);
- Experiments were performed with 3 samples of 1g each.

Results are summarised in the figure 5 below :

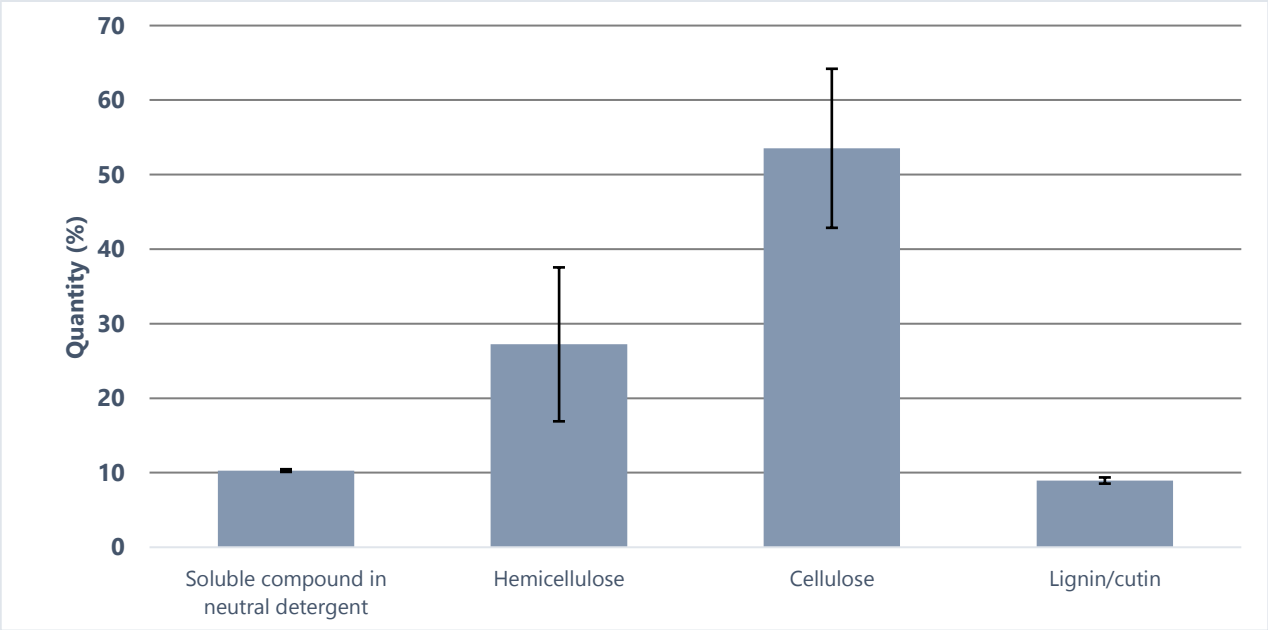

Figure 5: Composition of wheat straw according to AFNOR XPU44-162 test (%)

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