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Modeling of the heating and cooling needs of a hempcrete building

STUDY REPORT

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Summary 'study:

As part of this study, the theoretical heating and cooling needs of a fictitious R + 1 building of 100 m^2 , the walls of which are insulated by 30 cm of hempcrete, are evaluated using the WUFI® software More. It has been established that the coupled heat and humidity transfers within hempcrete walls can reduce the building's heating requirement by up to 70%. Further work will be necessary to refine this first result.

In addition, the impact of the interior wall cladding on the building's heating and cooling needs is evaluated by comparing 3 cases: 15 mm Fermacell sheet (BA15), 20 mm lime-sand plaster and lime-hemp of 30 mm. No significant difference was noted.

CONTENTS

1. INTRODUCTION

For several years, feedback has shown that new hempcrete constructions consume up to 40% less energy than indicated in the note for RT 2012 regulatory calculation. This is explained by the fact that the coupled transfers of heat and humidity, highlighted by numerous research works, which occur within hemcrete walls are not taken into account. in the regulatory calculation engine.

As part of this exploratory study, the theoretical heating and cooling needs of a fictitious R + 1 building of 100 m^2 , the walls of which are insulated by 30 cm of hempcrete, are evaluated using the WUFIsoftware® Plus. The main objective is to quantify, on a building scale, the energy savings generated by the coupled transfers of heat and humidity within hempcrete walls. In addition, the impact of the interior wall cladding on the building's heating and cooling needs is evaluated by comparing 3 cases: 15 mm Fermacell sheet (BA15), 20 mm lime-sand plaster and hemp-lime plaster of 30 mm.

2. DESCRIPTION OF THE BUILDING STUDY

The building studied is a R + 1 building with a square base (7.07 m side) with a living area close to 100 m^2. It is not surrounded by any vegetation or building likely to create cast shadows and its walls are exposed according to the four cardinal points.

2.1. Slab

The 15 cm thick concrete slab is insulated with 10 cm of polyurethane. Its thermal resistance is 4.125 m^2.K / W.

1. Walls

The walls consist of an exterior facing (20 mm lime-sand rendering), 30 cm of hempcrete and an interior facing (15 mm Fermacell plate, 20 mm lime-sand rendering or lime rendering -30 mm hemp).

Since the material files for hempcrete and lime-hemp plaster do not appear in the WUFI database, they were implemented for the purposes of the study from the results of research work carried out on these materials. Their main characteristics are given in the following table:

	Hempcrete		**Lime-plaster**	
Dry density [kg / m^3]	400		850	
Porosity [%]	80		65	
Specific heat capacity [J / kg.K]	1300		1890	
Dry thermal conductivity [W / mK]	0.1		0.256	
Resistance to water vapor diffusion [-]	6.5		13.7	
Sorption isotherm	RH [-]	Water content [kg / m^3]	RH [-]	Water content [kg / m^3]
	0	0	0	0
	0.5	10	0.5	21
	0.8	33	0.8	70
	0.96	60	0.96	127
	0.98	100	0.98	212
	0.99	117	0.99	248
	1	546	1	1160

3. Windows

The glazed area is 17%. The double-glazed windows considered have a U_W of 1.1 W / m^2.K.

1. Roof

The roof has an inclination of 40 ° and is insulated with 30 cm of hemp wool. Its thermal resistance is 8,168 m^2.K / W.

3. MODELING ASSUMPTIONS

Within the framework of this study, various assumptions were made to be able to model the heating and cooling needs of the hempcrete building.

3.1. Climatic zone

It is assumed that the building is located in Nancy (climatic zone H1b).

3.2. Occupation

The building is occupied by a family made up of 2 adults and 2 children between 3 and 6 years old. It is assumed that the building is unoccupied between 8 a.m. and 6 p.m. on weekdays and that the occupants have a more intense activity in this time slot on weekends.

3.3. Heating and cooling instructions

A minimum temperature of 18 ° C is imposed between 8 a.m. and 5 p.m. during the week and 20 ° C the rest of the time.

The maximum temperature required is 28 ° C between 8 a.m. and 5 p.m. on weekdays and 26 ° C the rest of the time.

1. Mechanical ventilation

Mechanical ventilation is provided by a humidity sensitive low consumption CMV.

2. Initial conditions

At the start of each simulation, the temperature of all materials is assumed to be 20 ° C while their relative humidity is 80%. Inside the building, the temperature is also 20 ° C and the relative humidity is 50%.

1. Absence of moisture transfers

To highlight the energy savings generated by the coupled transfers of heat and moisture within hempcrete walls and, to a lesser extent, lime-hemp plasters, fictitious materials having the physical and thermal properties of hempcrete and lime-hemp plaster and the water properties of rock wool were considered. Their main characteristics are given in the following table:

	Hempcrete "without hygro"		**Lime-hemp plaster "without hygro"**	
Dry density [kg / m^3]	400		850	
Porosity [%]	80		65	
Specific heat capacity [J / kg. K]	1300		1890	
Dry thermal conductivity [W / mK]	0.1		0.256	
Resistance to water vapor diffusion [-]	6.5		13.7	
Sorption isotherm	RH [-]	Water content [kg / m^3]	RH [-]	Water content [kg / m^3]
	0	0	0	0
	0.5	0	0.5	0
	1	0	1	0

4. DETERMINED HEATING AND COOLING REQUIREMENTS

In this paragraph, the results of the simulations carried out are presented and discussed.

4.1. Heating requirements In

order to assess the sensitivity to the initial conditions of the materials, the simulations were carried out over periods of 1 year, 5 years, 10 years and 30 years. The heating requirements obtained are presented in the following table, expressed in kWh:

Interior wall facing Wall	filling material	1 year	5 years	10 years	30 years
Lime-hemp plaster	hempcrete	1581.9	5303.6	9690.3	26952
Lime-hemp plaster "without hygro"	Hempcrete "without hygro"	4598.7	15896.2	30337.8	87895.1
Lime-sand	Hempcrete	plaster15 70.3	5279.1	9664.9	26937.5
Lime-sand plaster	Hempcrete "without hygro"	4626	16598.7	31243.5	89593.7
Fermacell BA15	Hempcrete	1579.5	5278.5	9654	26874
Fermacell BA15	Hempcrete"without hygro"	4608.9	16521.5	31086.1	89115.8

On firstly observe that for each simulated configuration, the annual heating requirement decreases over time: in the first example, it goes from 15.8 kWh / m^2 the first year to 9 kWh / m^2/ year on average over 30 years. This is probably due to the choice of the initial conditions of the materials: their water content decreases over time and then stabilizes. Consequently, the thermal resistances of the walls are lower in the first years and the need for heating is then greater.

Then, we note that the nature of the interior facing of the walls has very little influence on the heating consumption.

Finally, the simulations carried out indicate that the coupled transfers of heat and humidity within the hemp concrete walls make it possible to reduce the building's heating requirement by up to 70%. This result must, however, be considered with caution since such an economy has never been observed *in situ*. In addition, by replacing in the last simulation (case of the Fermacell interior cladding) the hemp concrete with rock wool of the same thickness (thermal resistance of 7.5 m^2.K / W), we obtain a consumption of the building over 30 years of 49,733.9 kWh is almost twice as much as in the case of hempcrete, which goes against the many empirical data available at present.
Different hypotheses can explain this result. In the first place, hempcrete is known to be an excellent water regulator: the ventilation flow rates at the humidity sensitive ventilation system will therefore be significantly less and the heat losses by air renewal (which represent 20 to 25% of losses in a building) will therefore also be less. Moreover, for a given interior facing, the calculation time increases by approximately 40 to 50% in the case of hempcrete: this is quite logical given that the transfer equations heat and humidity are coupled. However, the increase in the number of iterations at each step of calculation time increases the risk of propagation of errors and therefore of drift of the model: to be free from it, it would be necessary to work on a perfectly characterized building and to ensure at any time that the temperature and relative humidity profile in the hempcrete corresponds to that actually measured *in situ*.

1.2. Cooling requirements

During the various simulations carried out, the cooling requirement was systematically zero. Indeed, the choice of the location of the building in Nancy (climatic zone H1b) means that the scorching periods are limited both in time and in intensity. However, it is quite surprising that the interior temperature never exceeds 26 ° C: additional simulations will therefore be carried out on this building in other climatic zones to verify the functioning of the model.

4.2. Additional simulations

The climate database of thesoftware WUFI® Pluscontains two sites located in France: Nancy and Grenoble. We therefore wanted to repeat the previous simulations over a period of 10 years, this time considering the climatic zone of Grenoble (H1c). The heating and cooling requirements obtained are presented in the following table, expressed in kWh:

Interior wall facing Wall	Filler material	Heating	Cooling
Lime-hemp plaster	Hempcrete	8245.4	1003.8
Lime-hemp plaster "without hygro"	Hempcrete "without hygro"	27138.3	258.1
Lime-sand	Hempcrete	plaster8185.4	975.5
Lime-sand plaster	Hempcrete "without hygro"	30418.9	197.8
Fermacell BA15	Hempcrete	8289.7	995.3
Fermacell BA15	Hempcrete “without hygro” 30	298.6	189.9

Once again, a 70% reduction in the building's heating requirement is observed thanks to the coupled transfers of heat and humidity in the walls of the building with hempcrete. These needs are also quite close to those obtained during the first series of simulation.

The main difference observed lies in the cooling requirements which, this time, are not zero. These needs are 4 to 5 times lower in the absence of hygrothermal transfers in the wall. This result is very surprising insofar as the changes in the state of the water (vaporization) which occur within the hempcrete when the outside temperature increases are endothermic phenomena and should therefore help to cool the building, which should imply a lower cooling requirement.

5. CONCLUSION

The simulations carried out using the WUFIsoftware® Pluson a fictitious R + 1 building of 100 m^2 whose walls are insulated by 30 cm of Hempcrete have made it possible to demonstrate that the coupled transfers of heat and humidity in hempcrete walls can reduce the building's heating requirement by up to 70%. However, we must remain cautious with regard to these simulation results, which go well beyond the heating savings actually observed over the past ten years on this type of building. By way of comparison, the fictitious hempcrete building studied would consume almost half as much heat as a similar building containing an equivalent thickness of rock wool.

The important point to remember from this study is that the hygrothermal transfers within the hempcrete significantly modify the heating and cooling needs of the building in which this material is used. However, although the physics of the phenomena involved at the scale of hempcrete is now well known and mastered, it appears that their translation in terms of the energy savings generated constitutes a scientific obstacle that is rather difficult to remove. . Additional work using WUFIsoftware® Plusor another software should therefore be carried out in the coming months.

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