

## The Thermal Performance of Tradical<sup>®</sup> Hemcrete<sup>®</sup>.

The thermal performance of buildings is very complicated. Heat moves by three mechanisms, conduction, convection and radiation. However building regulations have generally focused on the heat lost by conduction. Consequently most building professionals have become obsessed by the U-value of building elements. The U-value gives a figure for the heat energy conducted through a square metre of wall, floor or roof for each degree difference in temperature on each side (in watts per square metre per degree centigrade).

Unfortunately it not normal practice in the UK to carry out post completion monitoring of thermal performance. This raises several important questions:–

- If there is no checking, how do we know what works and what doesn't?
- How can we hope to improve if we don't know how good we are now?
- Can we ever hope to achieve zero-carbon buildings, when we are flying blind?

To obtain the thermal conductivity of a material it is measured in a laboratory test using a hot plate/hot box. The sample is monitored until a steady state heat flow is achieved. The nature of this test dries the material sample. Their actual performance of the material in buildings where a degree of moisture is present may be very different from the dry laboratory test. Consequently very few buildings perform thermally as predicted at the design stage. Some buildings perform better, but most fail to perform as well as anticipated by the designer.

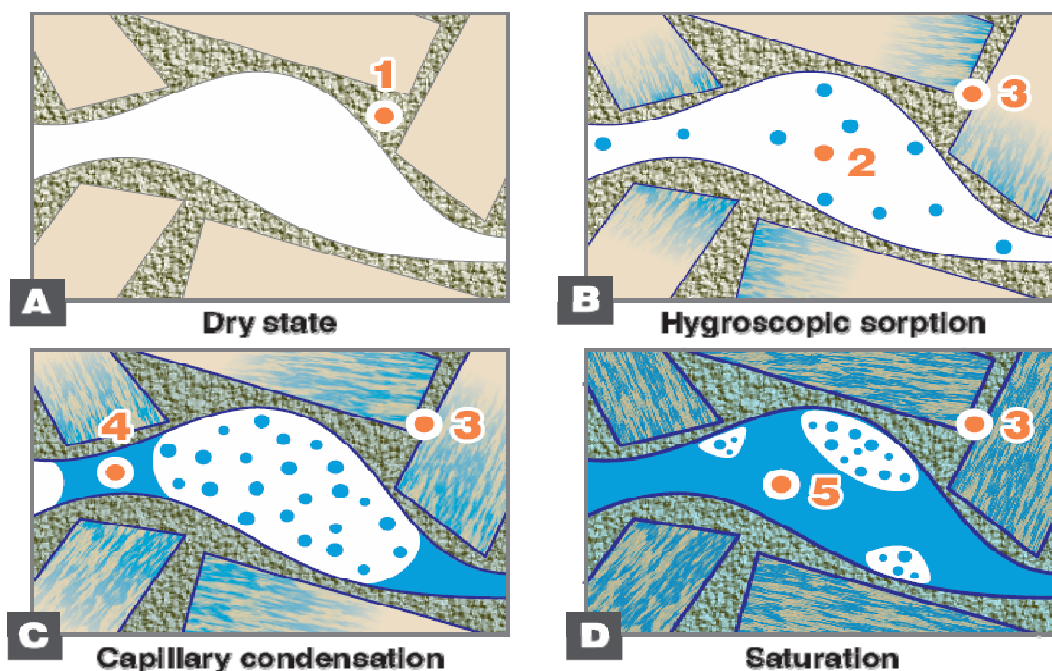
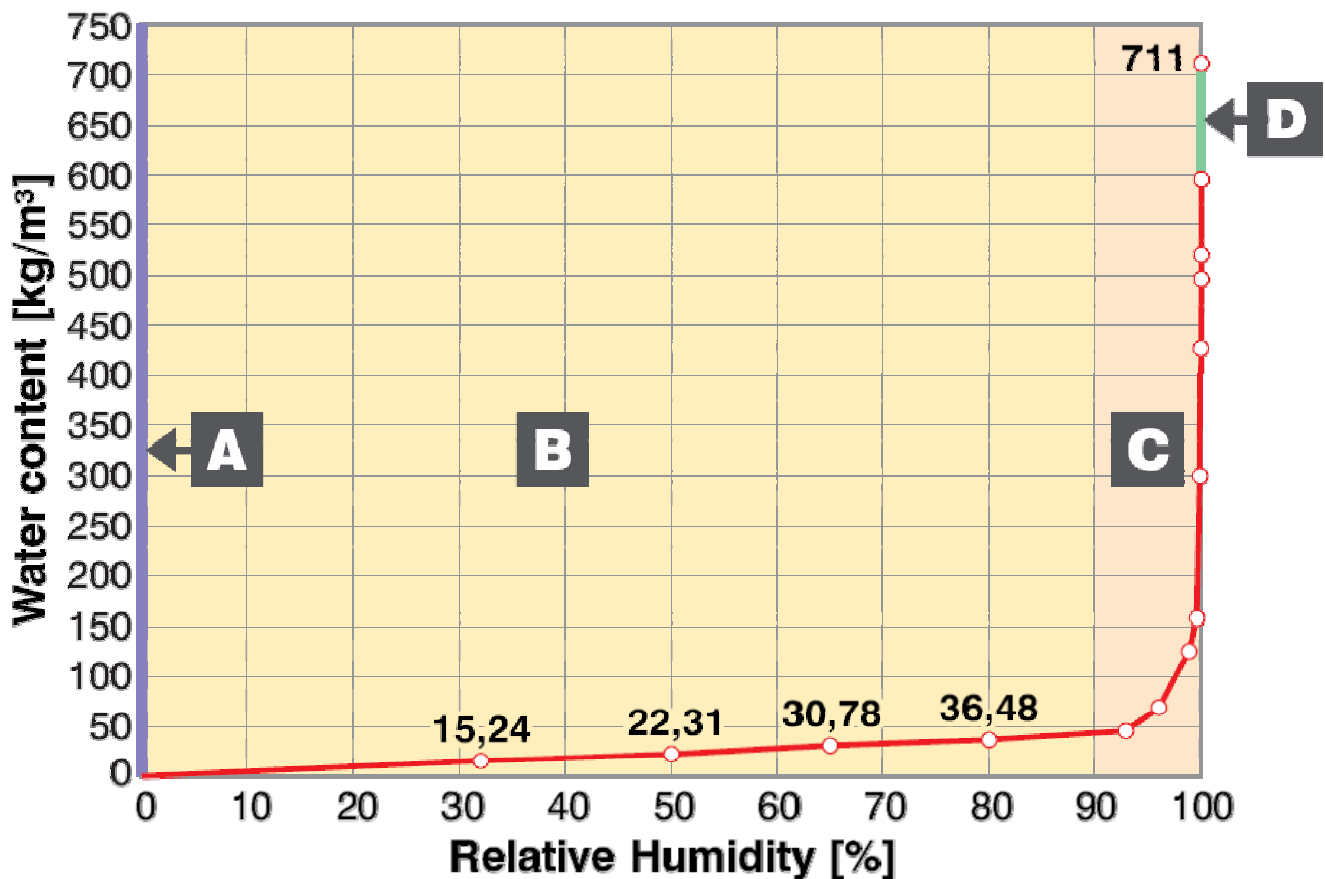


Figure 1 Different moisture states of Hemcrete<sup>®</sup> (Evrard, UCL, 2006)

Figures 1 and 2 come from Belgian research of prof. A. De Herde and A. Evrard (UCL-Architecture et climat), presented in "*Sorption behaviour of Lime-Hemp Concrete and its relation to indoor comfort and energy demand*", published in the proceedings of the 23<sup>rd</sup> Conference on Passive and Low Energy Architecture, A. Evrard, pp.I-553-557, Geneva, Switzerland, 2006. Figure 1 shows the ways in which water can be present in Hemcrete<sup>®</sup>. A shows the totally dry state, which only occurs when there is no humidity present. B shows some water present in the pores of the material. This is the normal state that occurs up to about 90% RH. C shows water beginning to fill the pores of the Hemcrete at very high levels of RH and D shows the state of saturation at 100% RH.



**Figure 2 Graph of water content vs. relative humidity (Evrard, UCL, 2006)**

Since buildings are normally in the range of 40 to 70% RH, Hemcrete<sup>®</sup> is normally in state B. This small amount of moisture in the Hemcrete<sup>®</sup> plays an important role in its thermal performance by adding a phase change property. This is where the change from liquid to vapour, or back, stores or releases energy.

There is no doubt that walls with the same U-values transmit heat at the same rate when they are in a steady state. However, walls in buildings are very rarely, if ever, in a steady state. In fact only a portion of the heat energy on one side of a wall is conducted through to the other side. The rest is simply stored and then released later. The higher the heat capacity of a material the greater its ability to store heat. This dynamic performance is very important to buildings in a temperate climate.

Heat (or thermal) capacity is normally expressed in J/kg.K, however since materials can vary significantly in density it is more useful to consider the thermal capacity of a cubic metre in order to appreciate how different materials can perform. Figure 3 shows the thermal capacity of different materials, including Hemcrete®, as presented in A. Evrard PhD (*“Transient hygrothermal behaviour of Lime-Hemp Materials”*, PhD in Applied Science, Université catholique de Louvain, 2008).

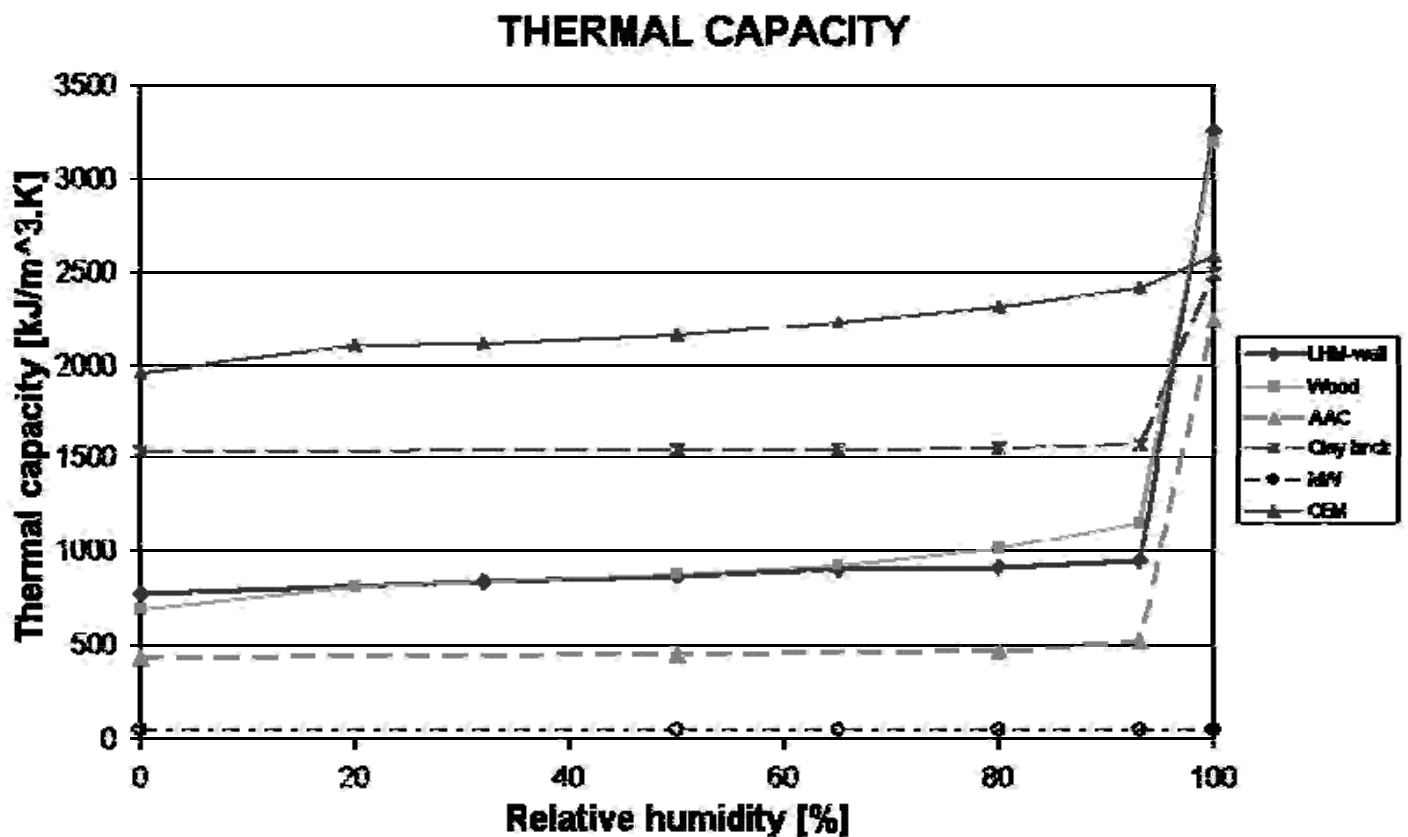
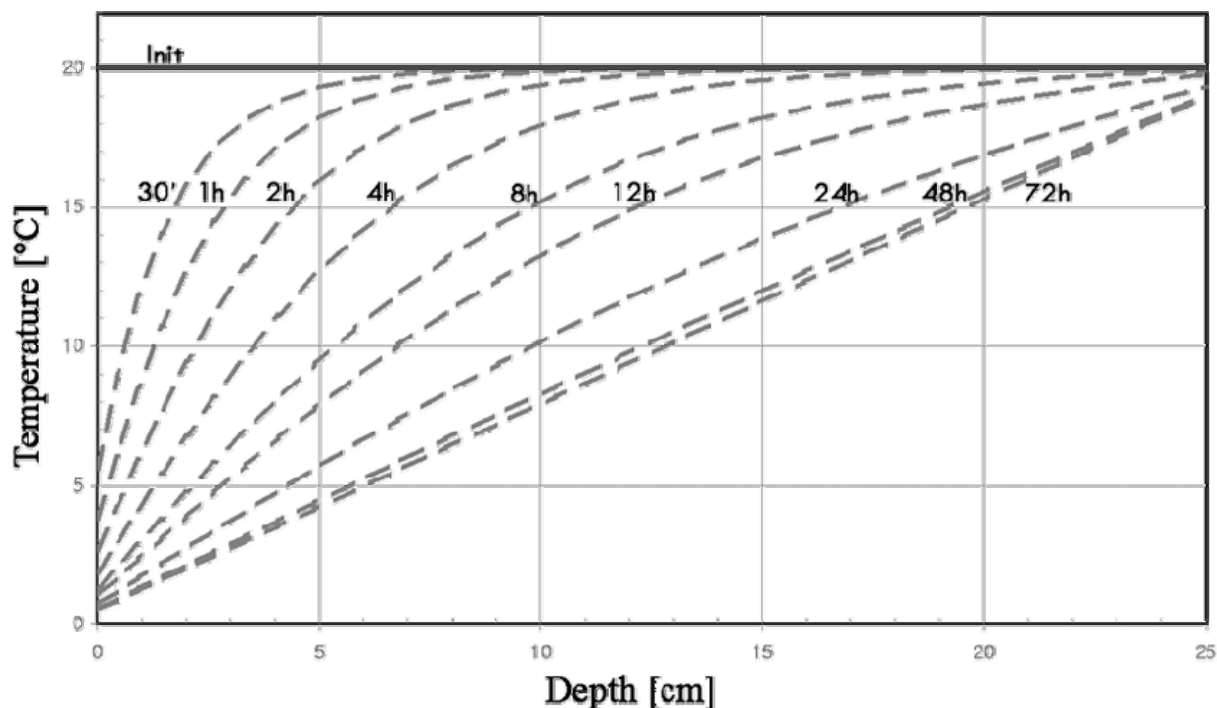


Figure 3 Thermal capacity of various materials (Evrard, UCL, 2008)

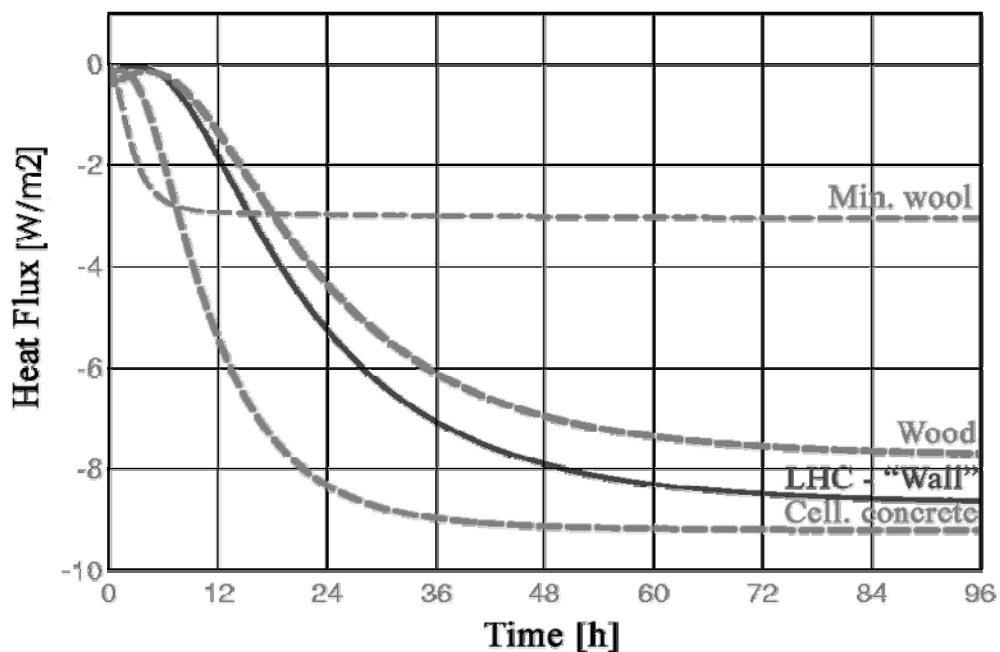
Our weather gives temperatures that vary on a 24 hour cycle (diurnal changes). Materials and designs that can create a stable internal temperature, despite the external variations lead to buildings that require the minimum of heating or cooling.

Research by Prof. A. De Herde and A. Evrard, presented in *"Bioclimatic envelopes made of lime and hemp concrete"*, published in the proceedings from conference CISBAT 2005, A. Evrard, A. De Herde, pp.25-30, Lausanne, Switzerland, 2005 uses lab test figures input into WUFI software. Results show that Hemcrete<sup>®</sup> subjected to (simulated) sudden cooling of 20°C takes 72 hours to reach a steady state of heat transfer (see figure 4) compared to 30 hours in cellular concrete and 12 hours in mineral wool of the same thickness (see figure 5). The amount of energy lost from the internal environment in the first 24 hours, represented by the red area on figure 5, is less in Hemcrete<sup>®</sup> than mineral wool (despite the mineral wool having better thermal conductivity) and less than half that of cellular concrete.



**Figure 4 Temperature profile through Hemcrete<sup>®</sup> (Evrard, UCL, 2005)**

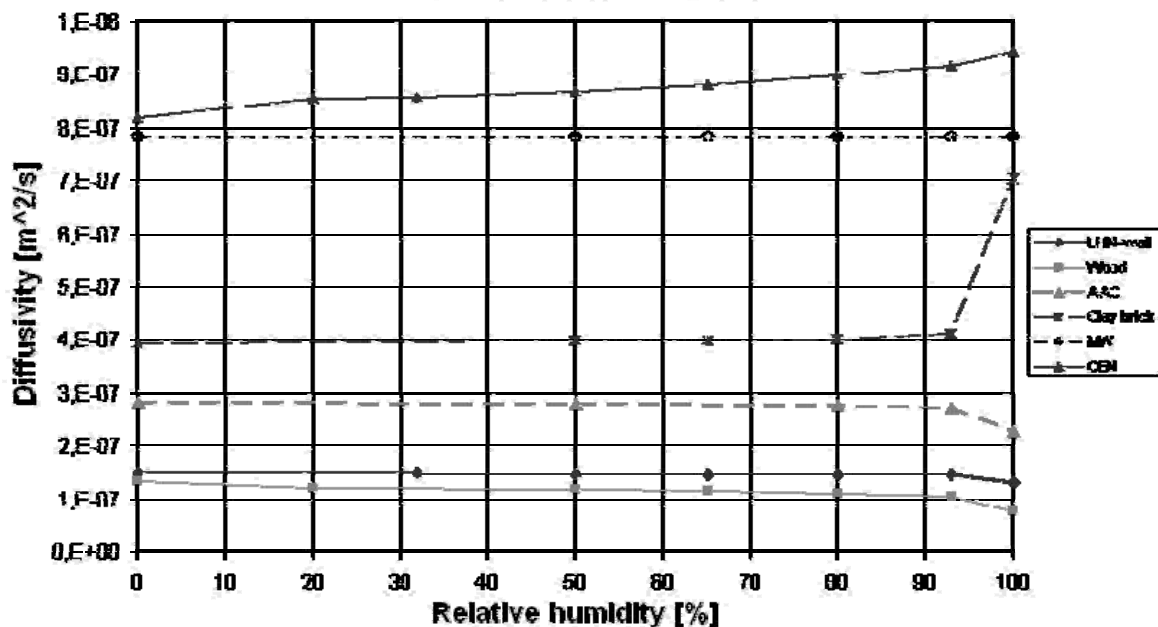
The energy lost from the Hemcrete<sup>®</sup> in the first 24 hours  $Q_{24}$  was 187 KJ/m<sup>2</sup>, this equates to an average heat loss of 0.11W/m<sup>2</sup>.K despite the fact that the theoretical U-value for this thickness of Hemcrete<sup>®</sup> is 0.29W/m<sup>2</sup>.K. This is one striking example of how dynamic thermal performance can be very different from predictions based on steady state figures.



**Figure 5** heat flow through various materials (Evrard, UCL, 2005)

As presented in A. Evrard PhD (*"Transient hygrothermal behaviour of Lime-Hemp Materials"*, PhD in Applied Science, Université catholique de Louvain, 2008), thermal diffusivity is very low for Hemcrete<sup>®</sup> compared to many other materials, which means it will take longer to change temperature (see figure 6).

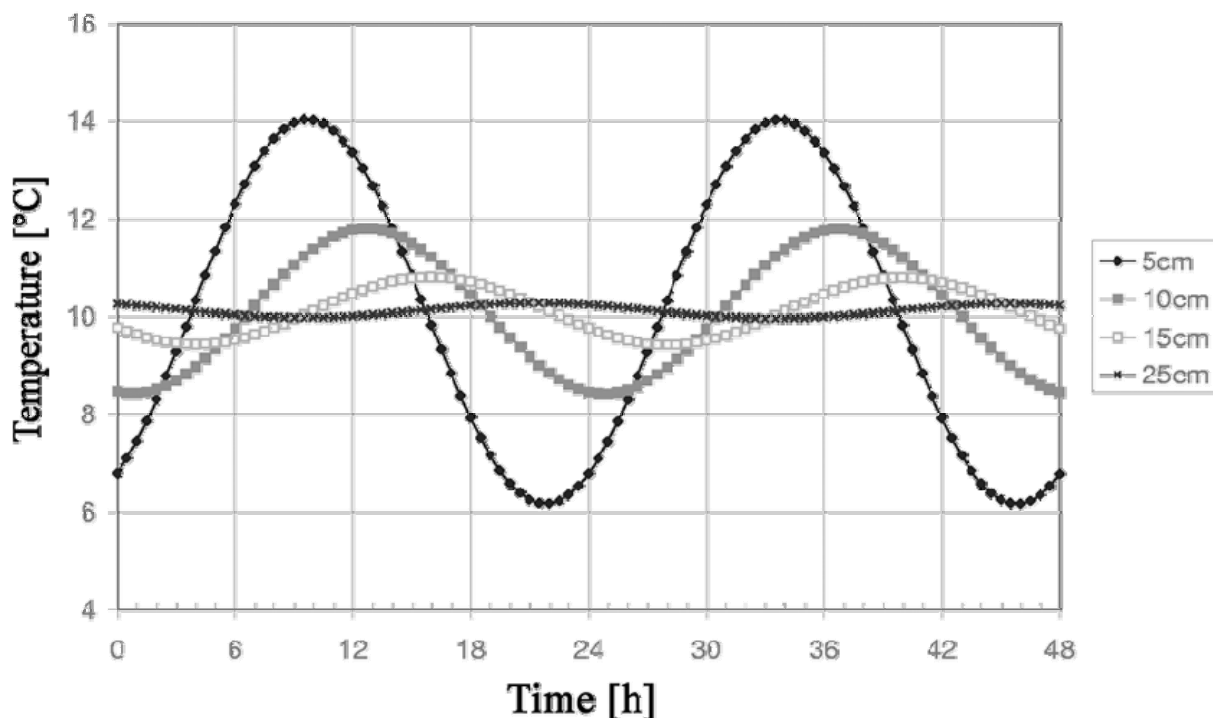
#### THERMAL DIFFUSIVITY



**Figure 6** Thermal diffusivity of various materials (Evrard, UCL, 2008)



The paper "*Bioclimatic envelopes made of lime and hemp concrete*", published in the proceedings from conference CISBAT 2005, A. Evrard, A. De Herde, pp.25-30, Lausanne, Switzerland, 2005, also showed 250mm of Hemcrete® could almost completely (98.5%) dampen a sinusoidal change in external temperature of 20°C to 0°C over a 24hr cycle (see figure 7).



**Figure 7 Dampening of diurnal temperature variation in Hemcrete® (Evrard, UCL, 2005)**

The table below shows the comparisons of the dampening factor of Hemcrete® and other materials in the same simulation. Mineral wool, which is generally considered as a very good insulation material performs worse than the Hemcrete® in this dynamic simulation despite the fact that 250mm is much thicker than would normally be used. The table also shows the time shift. This is the time delay of the peak temperature getting through the wall. The longer the time shift, the better.

| MATERIAL          | % DAMPENING AT 25cm | TIME SHIFT AT 25cm |
|-------------------|---------------------|--------------------|
| Hemcrete®         | 98.5%               | 15                 |
| Wood              | 98.8%               | 16                 |
| Cellular concrete | 95%                 | 10.5               |
| Mineral wool      | 77.5%               | 6                  |
| CEM concrete      | 89.5%               | 7                  |

Dynamic measurements done by Prof. Arnaud at ENTPE in France have given similar results to the WUFI simulations.

Significant amounts of heat are lost from buildings through air leakage. This simply means the hot air leaks through gaps and takes the heat with it. Hemcrete® is a monolithic material that is inherently airtight and it is easy to use. There is no need for lots of complicated layers. Just a simple solid cast or spayed wall. This high level of air-tightness minimises the heat lost through air leakage and drafts. Current building regulations require air leakage rates of below  $10\text{m}^3/\text{m}^2$  at 50 pascals. Tests carried out on commercial Hemcrete® buildings have achieved air leakage figures of around  $2\text{m}^3/\text{m}^2$  at 50 pascals. Extrapolation and predictions for new domestic Hemcrete® buildings predict figures of around  $1\text{m}^3/\text{m}^2$  at 50 pascals.

It is important to design and construct buildings that perform in reality rather than just on paper. In order to do this we need understand all the properties of a material and how these properties relate to the real performance. There is no doubt that walls should prevent as much heat being lost as possible, and they should contribute to the feeling of comfort within the building.

As presented in A. Evrard PhD (*"Transient hygrothermal behaviour of Lime-Hemp Materials"*, PhD in Applied Science, Université catholique de Louvain, 2008), the thermal effusivity of Hemcrete is low (see figure 8) which is why it feels warm to the touch. This warm feeling greatly improves the thermal comfort of a building. The research quantify what is experienced in Hemcrete® buildings. Sub-conscious feelings of thermal comfort (average between air temperature and wall temperature) are achieved at an air temperature of 1 to 2 degrees lower than in conventional masonry structures. This means that you feel warm even though the heating is turned down, saving hundreds of pounds per year in heating costs.

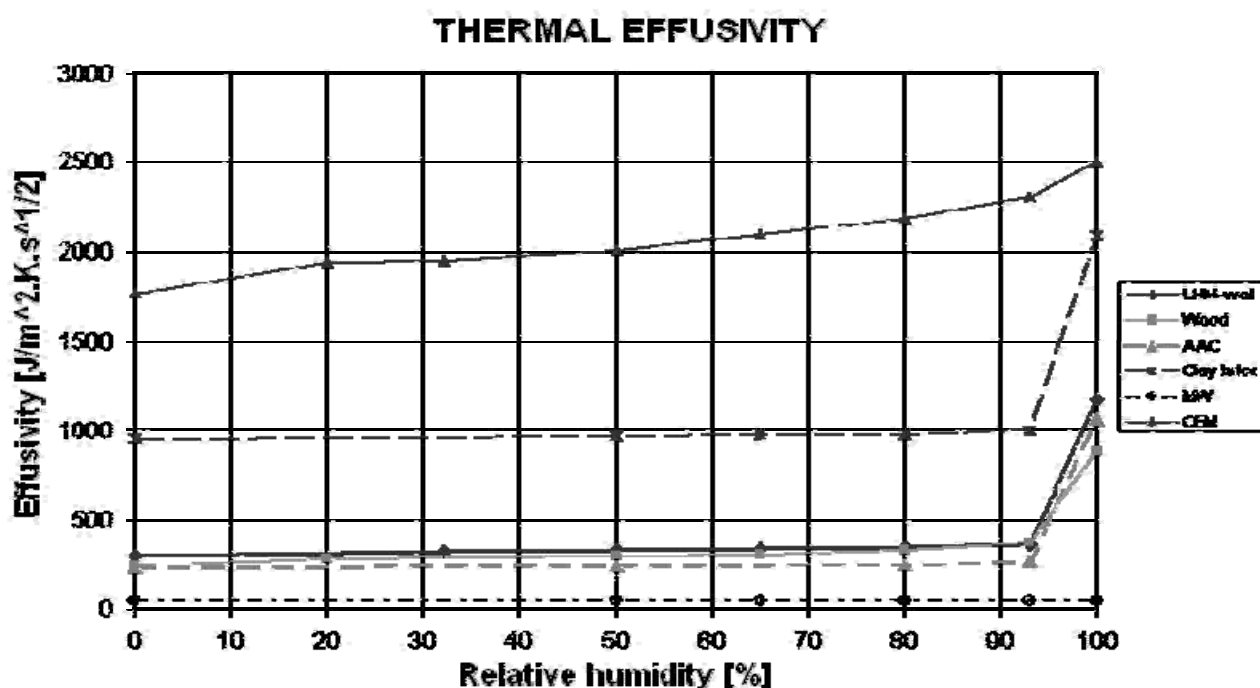
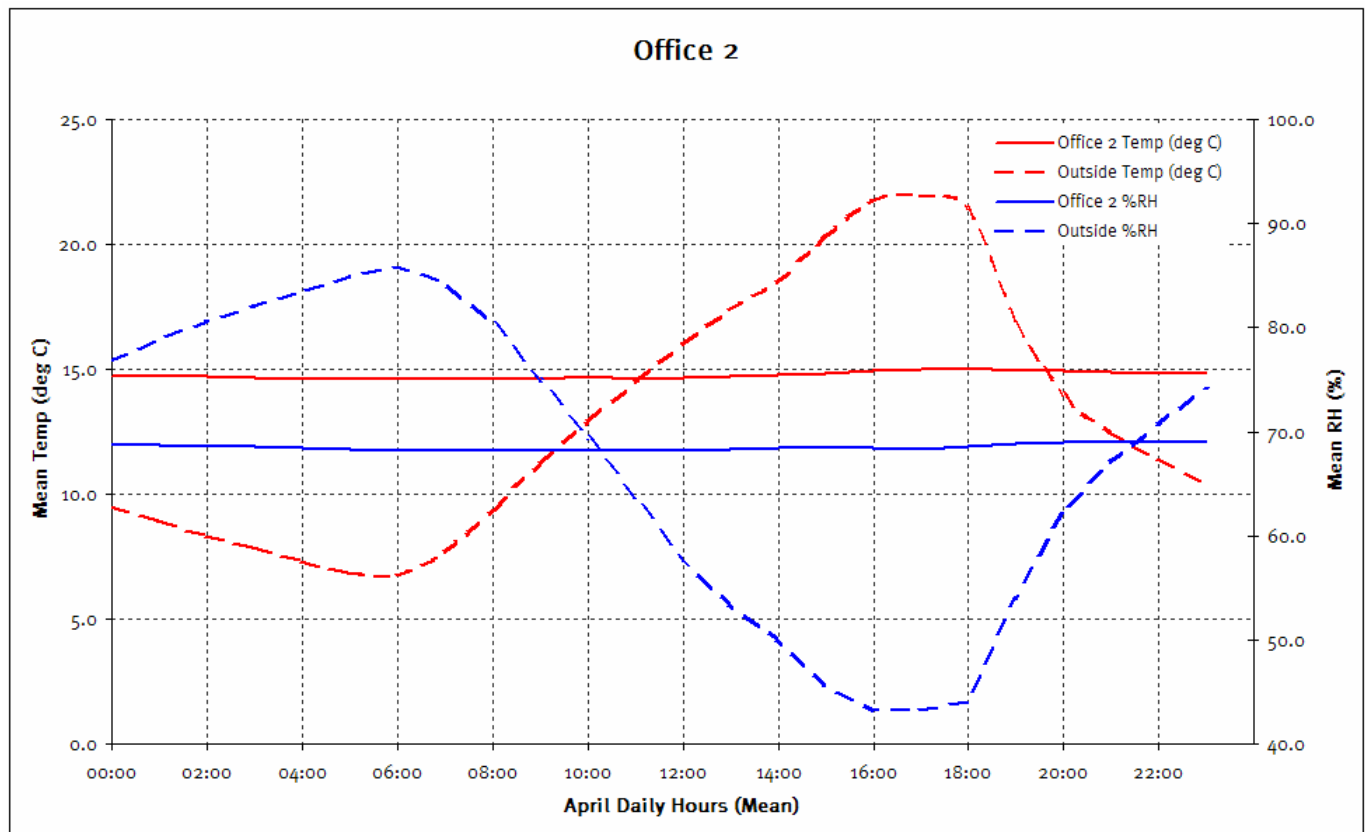


Figure 8 Thermal effusivity of various materials (Evrard, UCL, 2008)

The graphs of thermal capacity, diffusivity and effusivity (figures 3, 6 & 8) show that the properties of Hemcrete® are quite similar to wood. Hemcrete® is normally used in combination with a timber frame and this similarity of thermal properties is useful when considering thermal bridging. Timber is normally considered to be a thermal bridge where it interrupts insulation and current building regulations require that repeating and non-repeating thermal bridges are calculated and considered. They also set a limit on the non-repeating thermal bridges. However timber framing used in combination with Hemcrete® does not behave as a thermal bridge. This gives Hemcrete® a significant advantage over other construction methods because it is free of thermal bridges.

Even sophisticated computer simulations and laboratory tests can only go so far in the prediction of thermal performance. The real test comes when real buildings are constructed and monitored. The new Lime Technology office has 500mm thick Hemcrete® walls and has been monitored to check thermal performance. Figure 9 shows the external temperature (dotted red line) and RH (dotted blue line) compared to internal temperatures (solid red line) and RH (solid blue line). The graph confirms that the Hemcrete® walls are creating a very stable internal environment.



**Figure 9 Monitoring of Lime Technology office**



The Adnams Brewery Distribution Centre (figures 10 and 11) passively regulates the internal temperature of the warehouse using the combination of the good design and materials. It does not use any mechanical heating or cooling to maintain this stable temperature.



**Figure 10 Adnams Brewery Distribution Centre**



**Figure 11 Adnams Brewery warehouse**

Hemp-lime plasters can also be used in the refurbishment of solid wall masonry structures to improve their thermal performance. Although they will not greatly improve the U-value of the wall, they will improve the air-tightness and feelings of comfort. In a recent French study 65mm of hemp plaster used as part of a range of energy saving measures reduced the heating bills of a traditional stone building by 75% (see figures 12 & 13).





**Figure 12 Applying hemp-lime plaster**



**Figure 13 Stone building renovated with hemp-lime plaster**

**Hemcrete wall mix spray applied.**

|                      |                      |
|----------------------|----------------------|
| Density              | 330kg/m <sup>3</sup> |
| Thermal conductivity | 0.07W/mK             |
| Heat capacity (est)  | 1400 J/kgK.          |

**Hemcrete wall mix shuttered and tamped.**

|                      |                             |
|----------------------|-----------------------------|
| Density              | 330 to 480kg/m <sup>3</sup> |
| Thermal conductivity | 0.07 to 0.11W/mK            |

**Measurements of A. Evrard, presented in his PhD, give for LHM-wall:**

|                          |                       |
|--------------------------|-----------------------|
| Dry density              | 440 kg/m <sup>3</sup> |
| Dry thermal conductivity | 0,115 W/mK            |
| Dry thermal capacity     | 1560 J/kg.K           |

**Hemp plaster**

|                      |                             |
|----------------------|-----------------------------|
| Density              | 700 to 950kg/m <sup>3</sup> |
| Thermal conductivity | 0.12 to 0.13W/mK            |