Tradical® Hemcrete®
The Thermal Performance

Introduction

1.1 The thermal performance of buildings is very complicated and this guide is not intended to be an authoritative work on building physics. In order to explain the thermal performance of Tradical® Hemcrete® it is useful to start with the explanation of a few basic facts. Heat moves by three mechanisms, conduction, convection and radiation. However building regulations have generally focused on the heat lost by conduction and largely ignores the other two mechanisms. Consequently most building professionals have become obsessed by the common measurement of conduction for materials, the U-value of building elements. The U-value gives a figure for the heat energy conducted through a square metre of material or building element for each degree difference in temperature on each side (in watts per square metre per degree centigrade).

1.2 Unfortunately it is 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?

1.3 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 and therefore the actual performance of the material in real buildings, where a degree of moisture is always going to be 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 it is widely understood that most fail to perform as well as anticipated by the designer. This may have serious consequences for the end user.

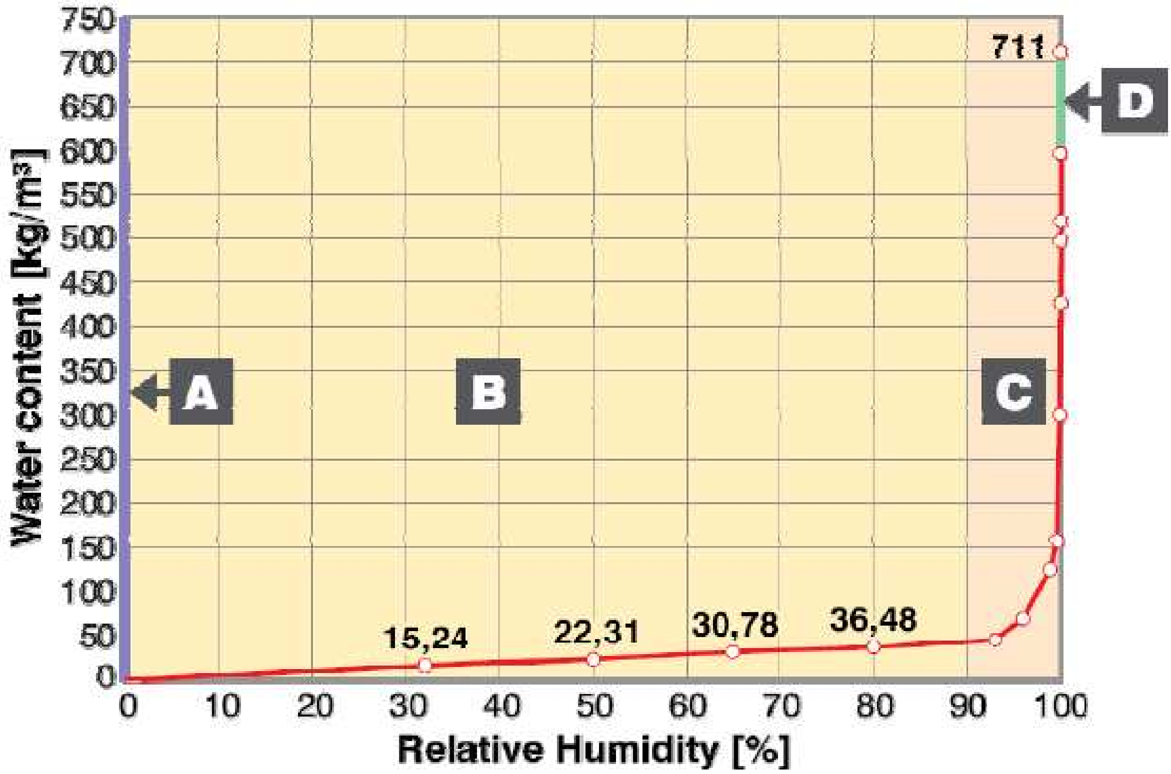

Figure 1: Hygrothermal response to relative humidity - (Evrard, UCL, BE)

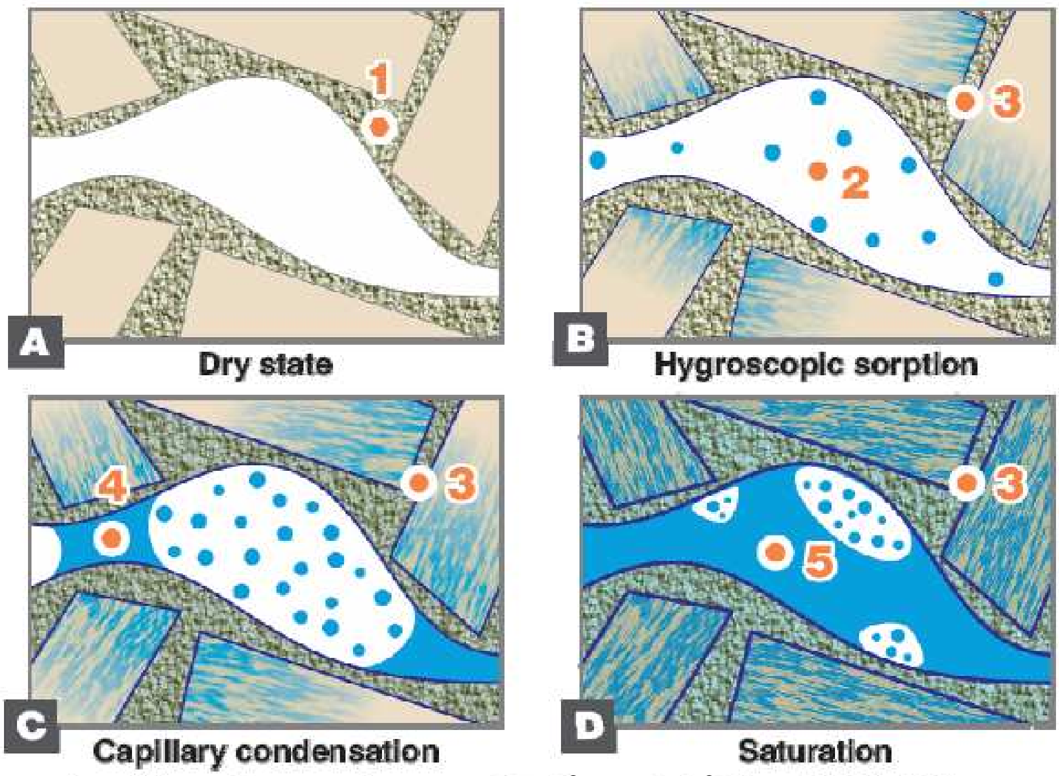

Figure 2: The way in which moisture can be present in Tradical® Hemcrete®- (Evrard, UCL, BE)

Thermal Performance

2.1 Figures 1 and 2 show the ways in which water can be present in Tradical® Hemcrete®. 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% Relative Humidity (RH). C shows water beginning to fill the pores of the Tradical® Hemcrete® at very high levels of RH and D shows the state of saturation at 100% RH.

2.2 Since buildings are known to be normally in the range of 40 to 70% RH, Tradical® Hemcrete® is predominantly in state B. This small amount of moisture in the Tradical® Hemcrete® plays an important role in its thermal performance by adding a phase change property. This is where the change of water state from liquid to vapour, or back, stores or releases energy. The characteristic of water being able to be in liquid or vapour states at a wide range of temperatures is the cause of humidity in the air. Water is in vapour state at the full range of normal building temperatures and it therefore has a direct bearing on the thermal performance of all building materials.

2.3 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 most climates but particularly in a temperate climate.

2.4 Heat capacity is normally expressed in J/kg, 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 heat capacity of different materials, including Tradical® Hemcrete® wall mix.

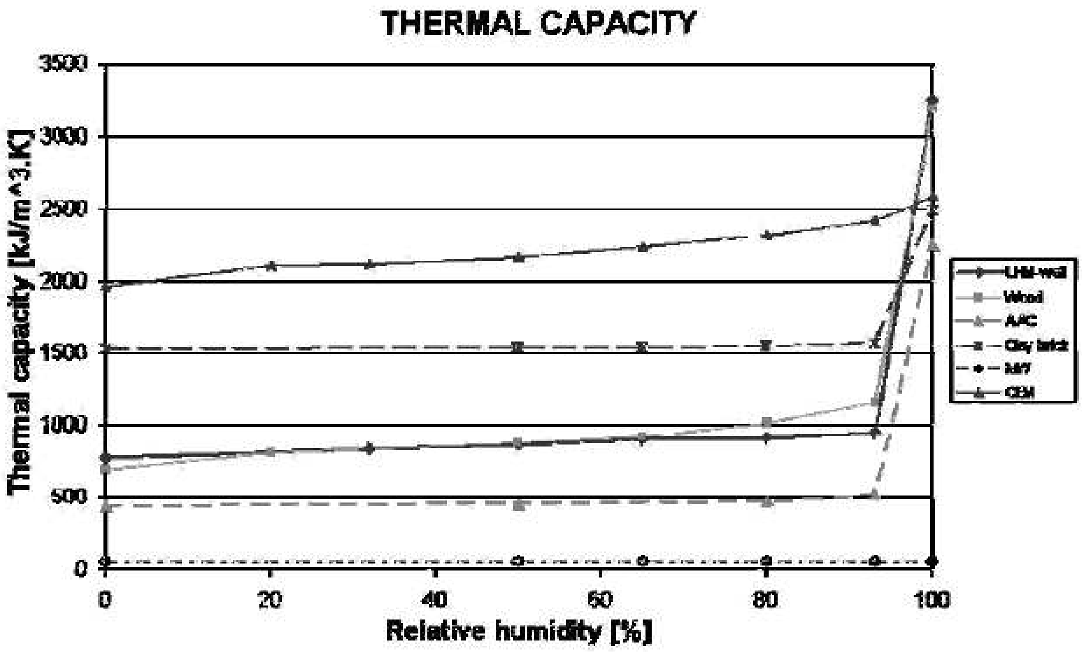

Figure 3: Thermal capacity of materials - (Evrard, UCL, BE)

2.5 Our weather gives temperatures that vary all the time but with an underlying 24 hour cycle (diurnal changes). It stands to reason that 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.

2.6 Research by Prof. de Herd and Dr Arnaud Everard, using lab test figures input into WUFI software has shown that 250mm thick Tradical® Hemcrete® walls subjected to (simulated) sudden cooling of 20°C take 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 is less in the Tradical® Hemcrete® than mineral wool (despite the mineral wool having better laboratory tested thermal conductivity performance) and less than half that of cellular concrete (This is represented by the red area on the graph).

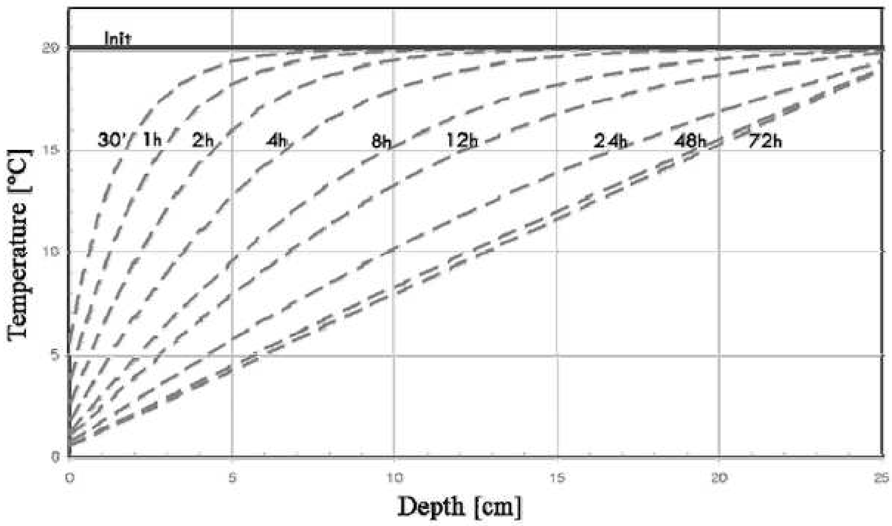

Figure 4: Heat transfer following sudden cooling - (Evrard, UCL, BE)

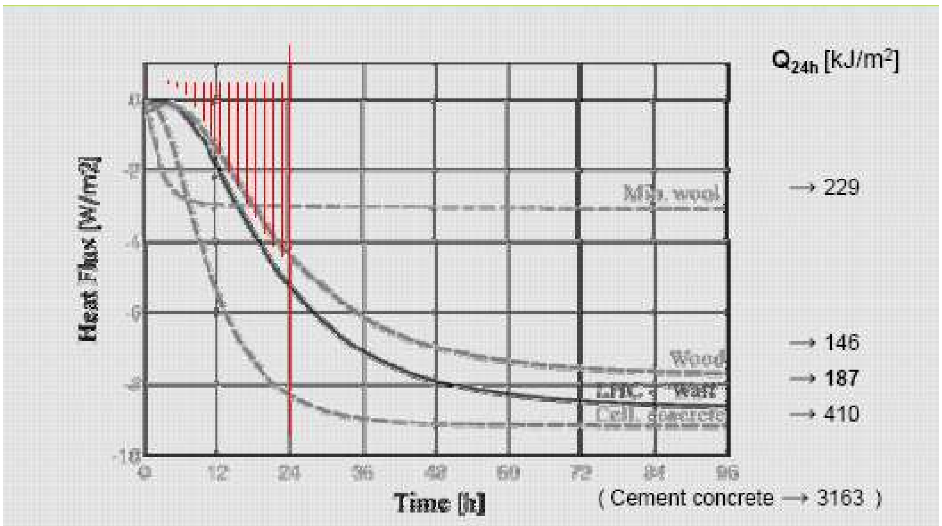

Figure 5: Energy loss response - (Evrard, UCL, BE)

2.7 The energy lost from the Tradical® Hemcrete® in the first 24 hours Q24 was 187 KJ/m^2, this equates to an average heat loss of 0.11W/m^2.K despite the fact that the measured U-value for this thickness of Tradical® Hemcrete® is 0.29W/m^2.K. This is one striking example of how dynamic thermal performance can be very different from predictions based on steady state figures.

2.8 The thermal diffusivity is very low for Tradical® Hemcrete® compared to many other materials, which means it will take longer to change temperature (see figure 6).

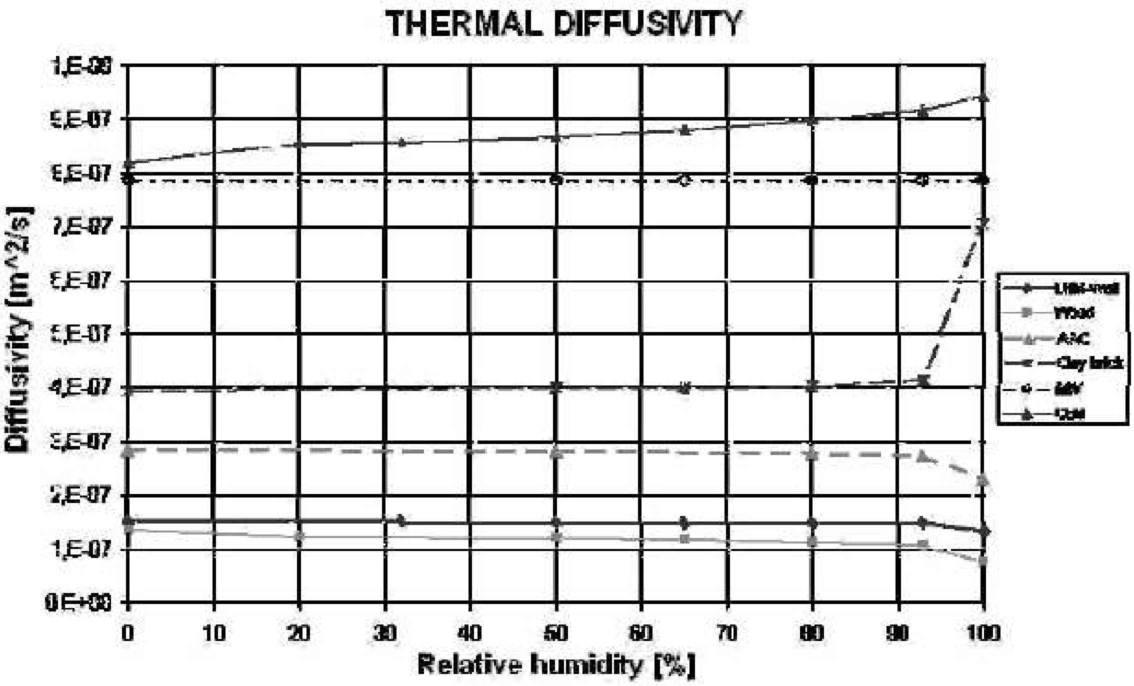

Figure 6: Thermal diffusivity - (Evrard, UCL, BE)

2.9 This research also showed 250mm of Tradical® 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).

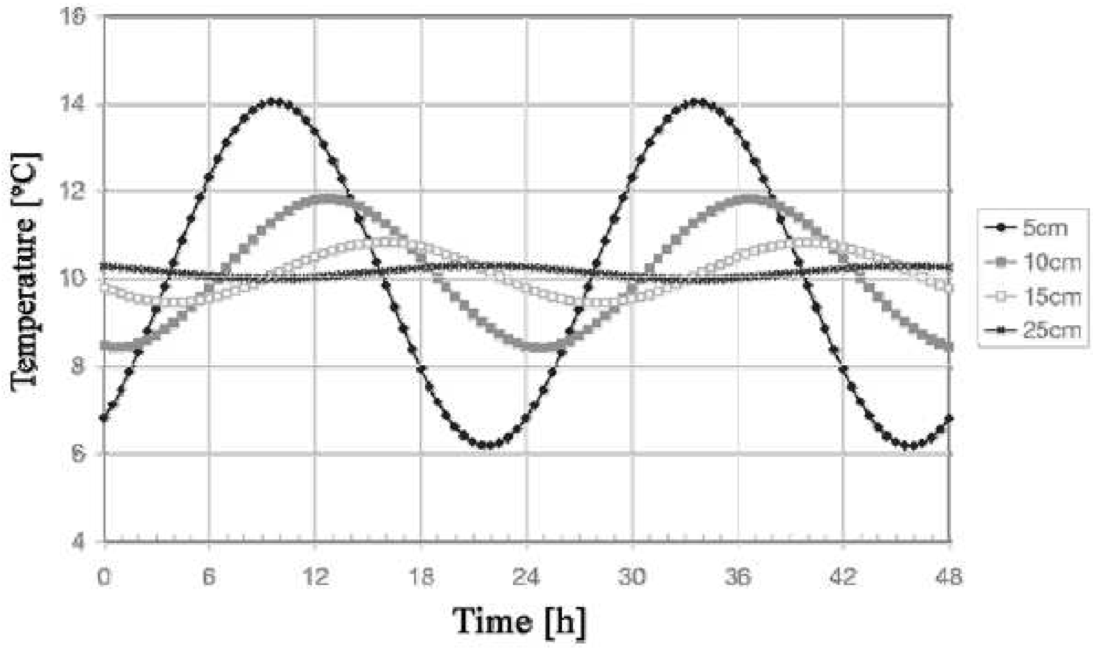

Figure 7: Dampening of sinusoidal temperature change - (Evrard, UCL, BE)

2.10 Figure 8 shows the comparisons of the dampening factor of the Tradical® Hemcrete® and other materials in the same simulation. Mineral wool, which is generally considered as a very good insulation material doesn't perform as well as the Tradical® 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 because this defers the time when the peak heat condition will occur within the building and if it is deferred beyond the 12 hours then as the diurnal temperature change has occurred then the lower temperature means that there is no heating continuing to increase the temperature and in fact there is cooling going on.

Material	Dampening factor at 25 cm $\upsilon_{25cm} = 1-(\theta_{25cm}/\theta_{init})$ [-]	Time shift at 25 cm $\eta_{25cm} = t_{max,25cm} - t_{max,init}$ [h]
LHC – "Wall" mixture	98,5	15
Wood	98,8	16
Cellular concrete	95	10,5
Mineral wool	77,5	6
CEM concrete	89,5	7

Figure 8: Dampening factor of materials - (Evrard, UCL, BE)

2.11 Figure 9 shows the laboratory apparatus used by Prof. Arnaud at ENTPE to do the same tests in the laboratory. These physical tests have given similar results as the WUFI simulations.

Figure 6: Laboratory testing suite (Arnaud, ENTPE)

2.12 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 (generally replaced by cold air from outside), which dramatically reduces the overall thermal performance of the building. Tradical® Hemcrete® is a monolithic material that is inherently airtight and it is easy to build with to create buildings with high air tightness performance. The construction concept of the solid Tradical® Hemcrete® walls is that there is no need for lots of complicated layers, just a simple solid cast or sprayed wall. This high level of air-tightness minimises the heat lost through air leakage and drafts.

2.13 Current building regulations require air leakage rates of below $10m^3/h.m^{-2}$ at 50 pascals (Pa). Tests carried out on commercial Tradical® Hemcrete® buildings have achieved air leakage figures of around $2m^3/h.m^{-2}$ at 50 Pa. Extrapolation and predictions for new domestic Tradical® Hemcrete® buildings predict figures of around $1m^3/h.m^{-2}$ at 50 Pa.

2.14 It is beginning to be more widely understood how important it is to design and construct buildings that perform in reality rather than just on paper. In order to do this we need to understand all the properties of materials and building elements 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.

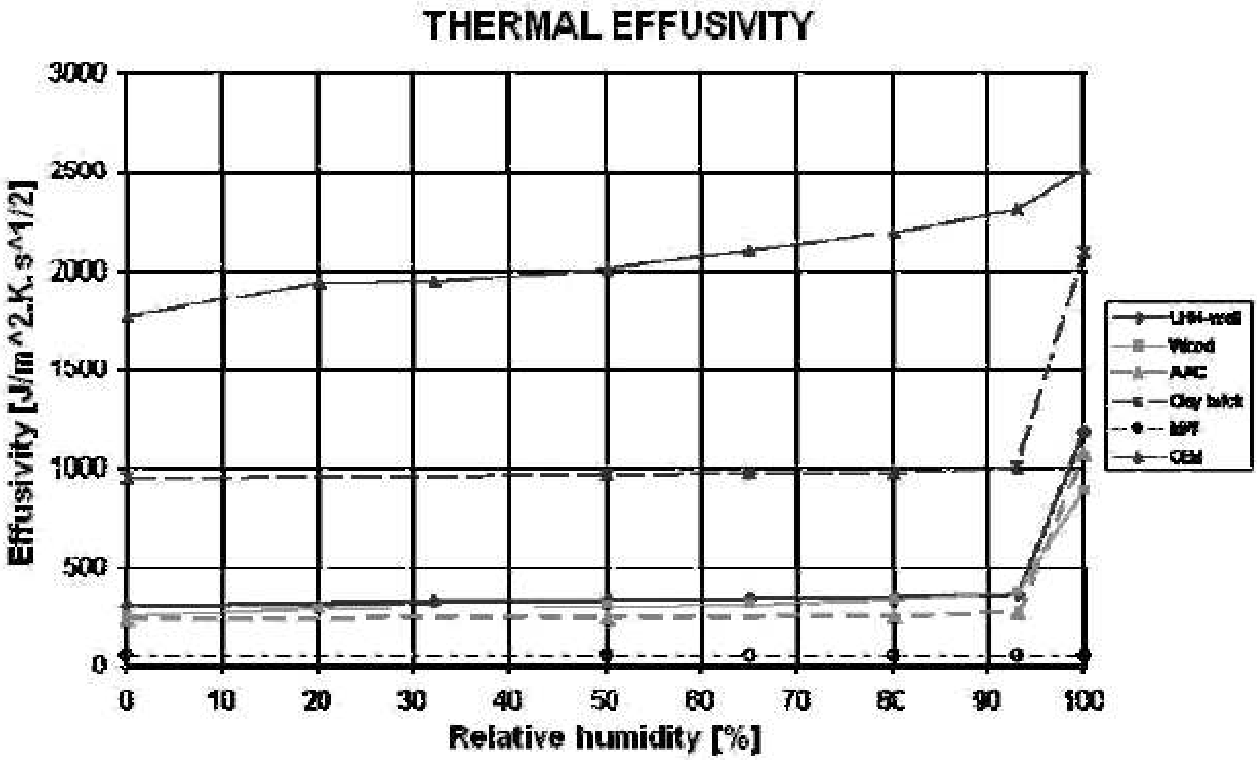

Figure 10: Thermal effusively of materials - *(Evrard, UCL, BE)*

2.15 The thermal effusivity of Tradical® Hemcrete® is low (see figure 10) which is why it feels warm to the touch. This warm feeling greatly improves the thermal comfort of a building. Experience of Tradical® Hemcrete® buildings in France and the UK shows that 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 money on heating costs.

2.16 The graphs of thermal capacity, diffusivity and effusivity (figures 3, 6 &10) show that the properties of Tradical® Hemcrete® are quite similar to wood. Tradical® Hemcrete® is normally used in combination with a timber frame and this similarity of thermal properties is useful when considering thermal bridging. It is important to recognize here that wood and timber frame construction using mineral wool or hydrocarbon based insulation materials has given wood a poor reputation in terms of its thermal performance.

It is worth noting that solid timber walling for example as log cabins are thermally very effective. It is only where wood is being used as the frame for its excellent lightweight and adaptable structural performance that it suffers this poor thermal reputation. Timber in a framed building 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 Tradical® Hemcrete® does not behave as a thermal bridge because of the similarity of good thermal performance in full thickness application. This gives Tradical® Hemcrete® a significant advantage over other construction methods because it is free of thermal bridges.

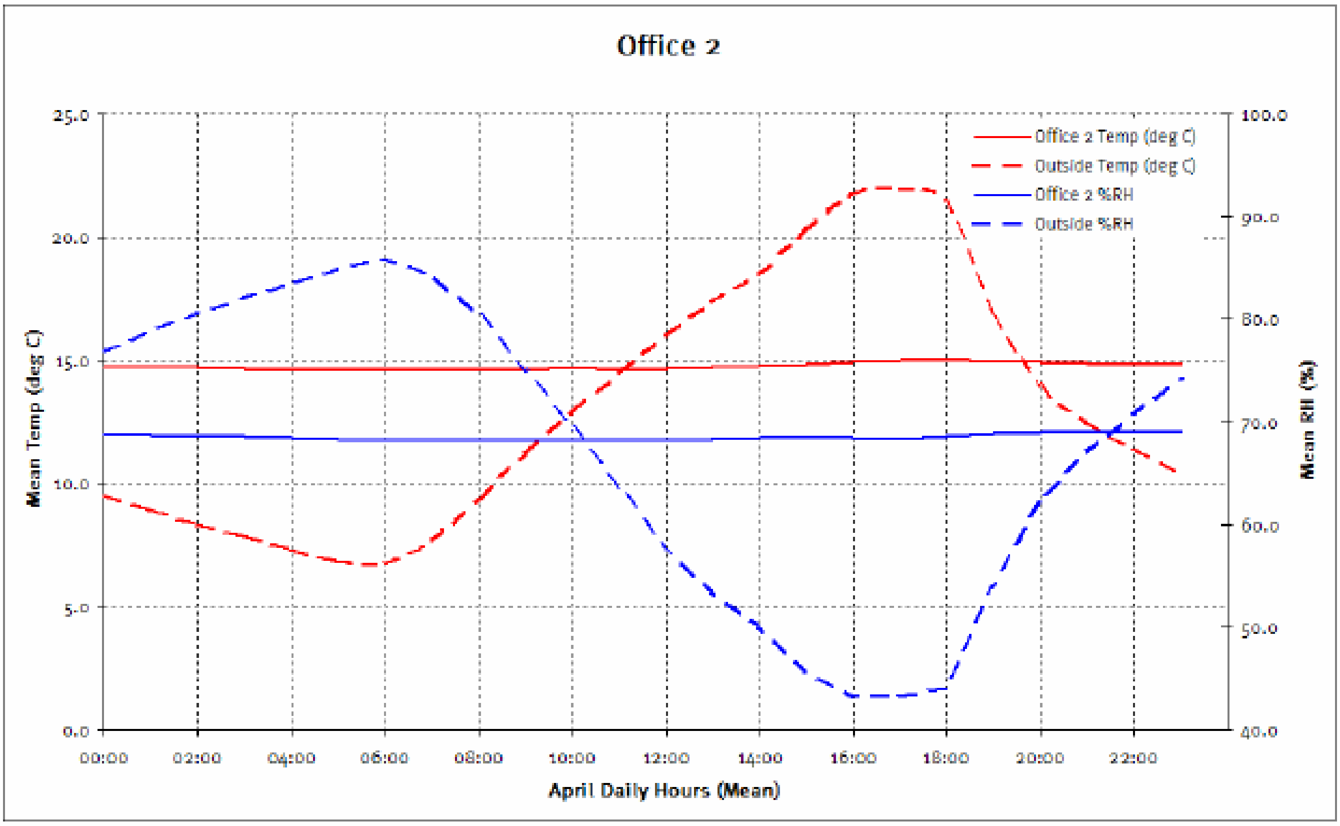

Figure 11: Climatic variations and internal conditions in the Lime Technology office

2.17 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 Tradical® Hemcrete® walls and is currently being monitored to check thermal performance. Figure 11 shows the mean external temperature (dotted red line) and mean RH (dotted blue line) during the month of April 2007, compared to the mean internal temperatures (solid red line) and RH (solid blue line) over the same period. The graph clearly illustrates that the Tradical® Hemcrete® walls are creating a very stable internal environment, which is usually a characteristic of heavyweight structures.

Figure 12: The Adnams Brewery project

Figure 13: The warehouse

2.18 The Adnams Brewery Distribution Centre (figures 12 and 13) 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. The energy savings are considerable and ongoing thanks to the passive performance of the Tradical® Hemcrete® and other natural building products used in the building in combination with good design and construction.

2.19 Hemp-lime plasters, Tradical® Hemcoat®, 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 have a beneficial effect on the buffering of humidity and temperature changes as well as improving the air-tightness through their method of application as a sealing coating and improve the feelings of comfort. In a recent French study 65mm of Tradical® Hemcoat® plaster used as part of a range of energy saving measures reduced the heating bills of a traditional stone building by 75% (see figure 14).

Figure 14: Hemp-lime plaster for refurbishment

Credits: With thanks to Prof. A. de Herde, and A. Evrard (Architecture et climat), and Laurent Arnaud (Departement Genie Civil et Batiment (DGCB))

2.20 **Tradical® Hemcrete® wall mix spray applied:**
Density 330kg/m^3
Thermal conductivity 0.07W/mK
Heat capacity (est) 1400 J/kgK.

Tradical® Hemcrete® wall mix shuttered and tamped:
Density 330 to 480kg/m^3
Thermal conductivity 0.07 to 0.11W/mK
Heat capacity 1400 to 1550 J/kgK.

Tradical® Hemcoat®:
Density 700 to 950kg/m^3
Thermal conductivity 0.12 to 0.13W/mK