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Sorption properties of biobased and raw earth materials: investigation of temperature and dry mass measurements

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Abstract

Relative humidity influence strongly the indoor air quality and human comfort. Therefore, the hygrothermal behaviour of building materials is an important parameter and there has been a growing interest in studying passive solutions to regulate the indoor relative humidity. Since earth materials have the ability to absorb and release water vapour, they can be used to moderate the amplitude of indoor relative humidity and therefore to improve the indoor air quality and consequently save energy.

Many researchers have been focussed on studying the hygrothermal properties of earth building materials, but it is still a scientific challenge to characterize precisely the hygrothermal coupling of those materials.

This dissertation focuses on two main objectives, developed and studied in three different porous materials: compacted earth, earth plaster and hemp concrete. The first one is to analyse the effectiveness and the influence of three different drying-methods (oven-drying at 60°C, oven-drying at 105°C and vacuum-drying), and recommend one standard method, for each material studied, since there is no clear guidance to determine the correct dry mass of biobased and earth materials. Complementary to the first objective, it is evaluated the impact of drying/wetting cycles using the same three drying-methods. The second objective is to study the evolution of sorption curves with temperature, for biobased and raw-earth materials.

The analysis of the results showed that the first drying process affects the moisture uptake of all the studied materials, from there forward. Oven-drying at 60°C and vacuum-drying are the methods that produce less impact in the porous network. More specifically, vacuum-drying is the method that allows less impact in the first drying of compacted earth and hemp concrete, and both, vacuum-drying and oven-drying at 60°C, are suitable for a non-impact drying of earth plaster. However, they are not completely efficient in drying earth materials since hysteresis is observed in drying/wetting cycles. Using oven-drying at 105°C it is not observed hysteresis and therefore, this is the most effective method, but it is the method that most presents impact in the porous network after the first drying.

Analysing the influence of temperature on the absorption curves, the results show that temperature cycles have no relevant impact on the hygrothermal behaviour of earth materials. Comparing the sorption curves of the three materials plotted at the same temperature, the influence of temperature is more relevant than the materials itself for compacted earth and earth plaster. The same cannot be stated for the hemp concrete.

Keywords: Compacted earth; Earth plaster; Hemp concrete; Drying-method; Temperature; Hygrothermal behaviour

Resumo

A humidade relativa influencia fortemente a qualidade do ar interior e o conforto humano. Assim sendo, o comportamento higrotérmico é um parâmetro importante e o interesse em estudar soluções passivas para regular a humidade relativa interna tem crescido. Uma vez que os materiais de terra têm a capacidade de absorver e libertar vapor de água, estes podem ser usados para moderar a amplitude da humidade relativa interna e, portanto, melhorar a qualidade do ar interno e consequentemente economizar energia.

A comunidade científica tem se concentrado no estudo das propriedades higrotérmicas dos materiais de construção de terra, mas ainda é um desafio caracterizar o comportamento higrotérmico desses materiais.

Esta dissertação foca-se em dois objetivos diferentes, desenvolvidos e estudados em três materiais porosos diferentes: terra compactada, argamassa de terra e betão de cânhamo. Sendo que não existe nenhuma orientação clara para determinar a correta massa seca de materiais de terra. O primeiro objetivo é analisar a eficácia, a confiabilidade e a influência de três métodos diferentes de secagem (secagem em estufa a 60°C, secagem em estufa a 105°C e secagem usando vácuo) e recomendar um método padrão que possa ser usado como método standard para cada material estudado. Complementariamente ao primeiro objetivo é avaliado o impacto de ciclos de secagem/molhagem usando os mesmos três métodos de secagem. O segundo objetivo é estudar a evolução das curvas de adsorção com a temperatura.

A análise dos resultados mostrou que a primeira secagem, em todos os materiais de terra estudados, afeta o seu comportamento higrotérmico daí para frente, e que o método de secagem em estufa a 60°C e a secagem usando vácuo são os métodos que menor impacto produzem na rede porosa. Mais especificamente, a secagem usando vácuo é o método que permite menor impacto na primeira secagem de terra compactada e betão de cânhamo. Ambos os métodos, secagem a vácuo e secagem no forno a 60°C, são adequados para secagem de argamassa de terra. No entanto, eles não são completamente eficientes na secagem de materiais de terra, pois é observada histerese nos ciclos de secagem/molhagem. Utilizando a secagem em estufa a 105°C não é observada histerese e, portanto, é o método mais eficaz, mas é observado que é o método que mais afeta a porosidade do material.

Analisando a influência da temperatura nas curvas de absorção, os resultados mostram que os ciclos de temperatura não têm impacto relevante no comportamento higrotérmico dos materiais de terra. Comparando as curvas de absorção dos três materiais determinadas à mesma temperatura, a influência da temperatura é mais relevante do que os próprios materiais para terra compactada e argamassa de terra. Relativamente ao betão de cânhamo, não se pode afirmar o mesmo.

Palavras-chave: Terra compactada; Argamassa de terra; Betão de cânhamo; Método de secagem; Temperatura; Comportamento higrotérmico

Notations and symbols

Roman-letter notations:

A	Exposed surface area (m^2)
d	Thickness (m)
e	Voids Index (-)
EMC	Equilibrium moisture content (%)
g	Gravity acceleration (m/s^2)
g_v	Water vapour diffusion flux density ($kg/(m^2s)$)
MBV	Moisture buffering value ($g/(m^2 \cdot \%RH)$)
m	Mass of wet material (g)
m_0	Mass of dry material (g)
M_w	Molar mass of water (kg/mol)
ρ_c	Capillary pressure (Pa)
P_v	Water vapour partial pressure (Pa)
$P_{v,sat}$	Saturation water vapour pressure (Pa)
Δp	Capillary pressure gradient (Pa)
Δp_v	Water vapour pressure gradient (Pa)
R	Perfect gas constant (J/kg mol)
R_v	Gas constant for water vapour (J/kg mol)
RH	Relative humidity (%)
r	Pore radius (m)
S	Sorptivity (m/\sqrt{s})
S_r	Saturation degree (-)
T	Temperature (K)
t	Time (s)
t_s	Dew point temperature ($^{\circ}C$)
u	Water content (kg/kg) (is also used w (%))
W_w	Weight of the water (kg)
W_s	Weight of the solid particles (kg)
w	Water content (%) (is also used u (kg/kg))
x	Distance of the humid front (m)
x_{air}	Absolute humidity (kg/kg)

Greek-letter notation:

δ_a	Water vapour permeability of air (kg/ (m.s.Pa))
δ_p	Water vapour permeability within the material (kg/ (m.s.Pa))
θ	Wetting contact angle (°)
λ	Thermal conductivity (W/ (m °C))
μ	Water vapour resistance factor of a dry material (-)
μ_w	Water viscosity (Pa.s)
v	Water vapour concentration (kg/m ³)
v_s	Saturation limit (kg/ m ³)
ξ	Specific hygroscopic capacity (kg/kg/RH)
σ	Surface tension of water (N/m)
ρ	Liquid density (kg/m ³)
ρ_w	Water density (kg/m ³)
Φ	Porosity (-)
Φ_L	Porosity filled by liquid (-)
Φ_G	Porosity filled by gas (-)
Ω	Total volume of the material (m ³)
Ω_L	Volume of the liquid (m ³)
Ω_v	Volume of voids (m ³)
Ω_G	Volume of the gas (m ³)
Ω_s	Volume of the solid (m ³)

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1. Introduction

1.1 Context

A variety of building materials, based on organic and natural materials have been studied in the last decades. Organic materials may consist of plant, such as hemp, cob, straw or corn pith, or animal wastes, such as hair or fur. Natural materials come directly from nature, such as clay, silt, sand or wood.

New materials, mainly synthetic materials, and new building methods were created in the industrial revolution. These changes, in the way that buildings were constructed, leads to a loss of concern about the transfer of heat between the exterior and interior, thermal properties of the materials and the architecture of the buildings. The passive methods, to control climatic conditions and improve indoor comfort, were discarded in much of modern architecture, and mechanized methods were adopted (Mahdavi & Kumar, 1996), although it leads to an increase of the energy consumption of the buildings. Besides the passive methods, the mechanic ones, such as the air conditioning, depend on human intervention and are not a sustainable option (Woloszyn et al., 2009).

The appearance of new building materials, such as cement and cement composites like concrete, has created a sociological impact on construction industry. With these new materials and techniques, old techniques such as the application coatings with fake works, decorative coatings based in lime and gypsum, were lost during the last century and mainly in the last decades. Therefore, construction masters of these old techniques stopped practicing it and passing it on to the younger generations. (Fabbri, 2017)

Materials with less impact on the environment and more efficient, from a thermal point of view, have been studied in order to reduce the environmental impact of buildings. In addition to these environmental concerns, indoor air quality and occupant comfort are also becoming essential parameters. The nature of the materials is therefore very important since they might control the temperature and the humidity through their properties. Nowadays, earth building materials are known for regulating humidity and therefore are widely prescribed (McGregor et al., 2016). Big advantages, such as the existence in large quantities of these materials, the low energy to extract, transform and produce them and the fact that these materials can be totally recyclable (when they are not stabilised), make them very interesting materials to be studied. These materials have other advantages, such as the high thermal inertia and the strong hygroscopic properties (Karlsson et al., 2013).

Indoor air quality is affected by the transfers of moisture between air and earthen walls in three different ways. Firstly, the relative humidity inside the building can be regulated by the earthen walls. Secondly, the transfers of moisture create damping of humidity and this variation in buildings helps to increase indoor comfort. Third, according to the people living in earthen buildings, evaporation of the water contained within the earthen walls has a cooling effect in hot weather, so earth walls become natural air conditioners (Cagnon et al., 2014).

The affinity to water in clay materials is usually known as detrimental, but this hygrothermal coupling phenomenon are still under investigation. The moisture buffering capacity is being studied in a variety of building materials since they represent a great potential to regulate indoor humidity.

Earth materials are very sensitive to water in both liquid and vapour phases, therefore the moisture content influences its thermal properties, such as thermal conductivity and apparent heat capacity. These properties tend to increase with the amount of water within the material and this can affect energy performance of the building, which can have either positive or negative consequences (Allinson & Hall, 2010).

In the indoor environment, the levels of RH fluctuate due to internal moisture loads. Earth materials adsorb the excess of moisture and release it during low moisture periods. Therefore, these materials are known as passive buffering materials (McGregor et al., 2016). Some researchers have shown that of all common building materials the earth is the one with the highest moisture buffering capacity. Its advantages can be improved by adding fibres. The addition of fibres increases the compressive strength, reduces shrinkage cracks and improves thermal insulation properties (Galán-Marín et al., 2010). Besides those advantages, the fibres influence the equilibrium moisture content and the dynamic moisture buffering properties. However, the influence of fibre types and the relevance of this influence have not yet been fully studied. Some studies are being conducted to determine how the composite properties of earth materials can be affected by the addition of vegetable materials, the nature of soil composition and the manufacturing process (Palumbo et al., 2016).

The RH inside the buildings is linked with the indoor air quality and therefore, moisture buffering could be beneficial for the health and the comfort of the occupants. Moisture buffering capacity of a material is the ability to moderate variations in the relative humidity of its surrounding environment. High indoor air relative humidity causes discomfort and leads to propagation of biotic hazards, such as moulds and dust mites, which indicate low indoor air quality. Low air relative humidity causes dryness of the mucous in the respiratory tracts and discomfort (Ridley et al., 2006). The control of moisture has positive effects on indoor air quality and can reduce the ventilation rate and thus, the heat loss due to air renovation (Osanyintola & Simonson, 2006).

Some errors are committed when the mass flow inside the material is simplified. A new module (Humimur) was created and validated. This module has the ability to make a precise representation of the sorption isotherm and vapour permeability dependence on relative humidity. It has been proved by many researchers (Mukhopadhyaya, 2002; Salonvaara et al., 2001) that vapour permeability and sorption isotherm are the two most important hygric properties of materials, since they have significant influence on the hygrothermal behaviour of building materials (Kwiatkowski et al., 2009).

The Moisture Buffering Value (MBV) indicates the amount of water vapour that is transported in or out of a material, during a certain period of time, after a controlled variation of relative humidity on one face of a sample. Other properties that play a role in moist are the water vapour permeability, the thermal conductivity and the diffusivity. These properties have influence on the risk of interstitial condensations, which results in health problems and causes damages on the building structure (Ridley et al., 2006).

In conclusion, buildings with earth components are a good solution compared to modern building materials in sociological, economic and ecological terms. However, is difficult to understand and to predict their long-term performance, which represents an obstacle to increase its use. Important variations of indoor and outdoor relative humidity occur inside the buildings. The earthen walls have to face these variations, which induce gradients in their water content. The water inside the wall is a rather important feature, since it confers a cohesion of the material (Champiré et al., 2016), it gave the ability to buffer temperature variations through liquid/vapour phase change phenomena and leads to variations of the apparent thermal inertia of the wall (Morel et al., 2001).

1.2 Objective and methodology

This dissertation focuses on two different objectives. In the first objective, the influence of three different drying methods in porous hygroscopic materials are analysed.

The impact of drying/wetting cycles using the same three drying-methods is also evaluated and the aim is to recommend a standard dry method for each tested material. More specifically, the biobased materials used in this study were earth plaster and hemp concrete, and the earth material was compacted earth. The drying methods used in this study are oven-drying at 60°C, oven-drying at 105°C and vacuum-drying (at 23°C).

Sorption isotherms and Moisture Buffer Value test were determined, before and after the first drying process, to assess the impact of the different drying methods. To analyse the impact of the cycles, the same three drying methods were used to achieve the dry mass and to evaluate the evolutions of the dry and wet mass at each cycle.

The second objective is to study the influence of the temperature on the sorption isotherms in the same porous materials, taking them to different steps of temperatures. In this objective, the drying methods are not a subject of study, but since the materials were only dried after the temperature cycles, the dry mass for each material were estimated, using the dry mass reached through vacuum-drying. These estimations were made in order to analyse the results, given by different materials, without dependence on the drying method used.

1.3 Dissertation structure

A literature review on hygroscopic characteristics and hygrothermal behaviour of clay-based and biobased materials is presented in Chapter 2. Porous materials are known for their capacity to adsorb and release moisture, and therefore, to understand the moisture buffering behaviour, the porous materials properties are described in this chapter.

Biobased and raw-earth materials were studied in this dissertation. The biobased materials are earth plaster and hemp concrete and the raw-earth is compacted earth. Chapter 3 describes the composition of each material and samples dimensions. The experimental procedures to determine the dry mass, the sorption isotherms, the drying/wetting cycles and the moisture buffering value are also presented in this chapter.

The effect of drying methods (and cycles) is then studied and analysed for compacted earth, earth plaster and hemp concrete in Chapter 4, through the results given by the sorption isotherms and the MBV. The influence of the temperature on the sorption isotherms is investigated in Chapter 5. The temperature impact related on the type of material is also studied in this chapter. Finally, the conclusions of this dissertation and the future work suggestions are presented in Chapter 6.

2. Hygrothermal behaviour of clay-based and biobased materials

2.1 Porous materials

2.1.1 Phases characteristics

The existence of voids in the materials make them porous materials. It is possible to obtain three different states. If there is no presence of water in the voids it is called the dry state, otherwise, if all the voids are filled with water it is named the saturated state. The last state, and the most common, it is known by unsaturated state, which means that water and air are present in the voids. This structure is represented in Figure 2.1.

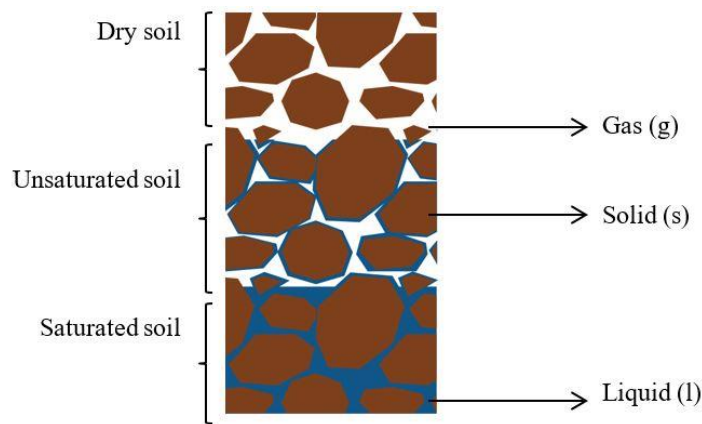


Figure 2.1- Porous material as a three-phase system – based on Fredlund & Rahardjo (1993).

Following this description, earth can be viewed as a three-phase system, since it has solid particles (solid phase), water (liquid phase) and voids with air (air phase). It is possible to quantify the relative proportion of these phases in terms of volume and mass ratios.

2.1.1.1 Volumetric features

The total volume (Ω) is composed by the volume of the solid (Ω_S), the volume of the liquid (Ω_L) and the volume of the gas (Ω_G). The sum of the volume of the liquid with the volume of the gas, present in the voids, is known by pore volume (Ω_v), since the both states fill the pores. Thus, pores are voids in the material which can be filled by liquid or gas. In saturated soils, since there is only solid and water, the pore volume is equal to the volume of water. Similar relation can be established to dry soils, since there is only gas in the pores.

Volumetric quantities, such voids index (e), porosity of the material (ϕ), and saturation degree (S_r) can be related to each other. These three characteristics are given by eq.1 to 3.

$$e = \frac{\Omega_v}{\Omega_S} \quad (1)$$

$$\phi = \frac{\Omega_v}{\Omega} = \frac{e}{1 + e} \quad (2)$$

$$S_r = \frac{\Omega_L}{\Omega_v} \quad (3)$$

From the equations above, equations relating to the volume of the solid, liquid and gas are represented in eq. 4 to 7.

$$\Omega = \Omega_S + \Omega_v = \Omega_S + e\Omega_S = \Omega_S * (1 + e) \quad (4)$$

$$\Omega_S = \Omega(1 - \phi) \quad (5)$$

$$\Omega_L = \Omega S_r \phi = \Omega \phi_L \quad (6)$$

$$\Omega_G = \Omega(1 - S_r)\phi = \Omega \phi_G \quad (7)$$

Where ϕ_L is the porosity filled by the liquid and ϕ_G is the porosity filled by gas.

2.1.1.2 Gavimetric features

The main gravimetric feature is the water content, represented by u (kg/kg) or w (%). This characteristic is presented as the relation between the weight of the water (W_w) and the weight of the solid particles (W_s). As explained before, for the weight determination of the solid particles the solid must be dry, so there is no water in it. This characteristic is also known by dry mass (m_0), whereas the wet sample is known as m . Therefore, the weight of the water can be written as seen in eq. 8.

$$u = \frac{W_w}{W_s} = \frac{m - m_0}{m_0} \quad (8)$$

2.1.2 Type of pores

Porous networks can be classified according to their availability to let fluids penetrate the pores. There are two categories of pores. The ones that are totally closed, which are known as closed pores (a), and for that reason, water or gas cannot invade the pore. On the other hand, there are open pores, which have channels of communication with the exterior. They can have channels only in one side, which are known as blind pores (b), or have connection between two sides (through pores) (c) or can link two or more pores, known as interconnected pores (d).

The closed pores influence the mechanical strength, density and thermal conductivity, but not the mass transfer properties, while the open pores are responsible for the mass transfers (Rouquerol et al., 1994). A schematic cross-section of a porous network is represented in Figure 2.2.

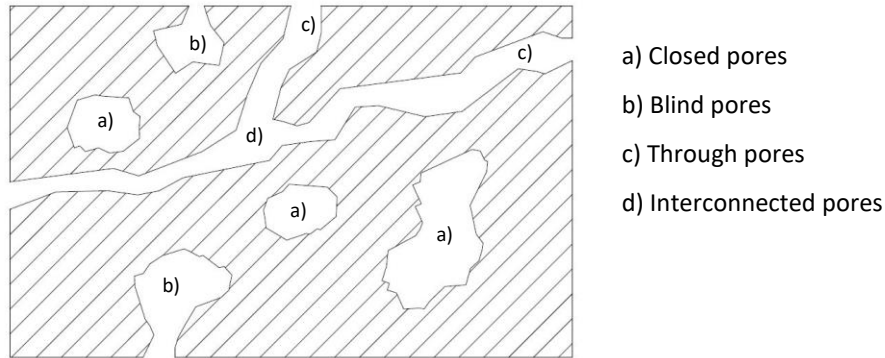


Figure 2.2- Schematic cross-section of a porous network - adapted from Rouquerol et al. (1994).

2.1.3 Clay based porous material

Clay mineral species have crystals in their composition. The crystal shape and size depend on the physico-chemical conditions prevailing during their growth (Meunier, 2005). Surface forces play an important role in the behaviour of clay materials. The crystalline structure of clays forms flattened particles, which have negative electrical charges on their surface. These charges attract the cations within the water.

Clay particles are composed by dozens of clay minerals that can be grouped in two big subgroups: Non-swelling clays (like Kaolinite and Illite) and swelling clays (like Montmorillonite). Non-swelling clays are known for detach from the pore wall and migrate due to ionic changing conditions and, as result, the pore suffers a blockage. Swelling clays suffers a swelling of clays lining due to ionic changing conditions, which leads to the reduction of the cross-sectional area for flow (Mohan et al., 1993; Gomes et al., 2016). Figure 2.3 shows the mechanism of permeability reduction caused by clays porous media.

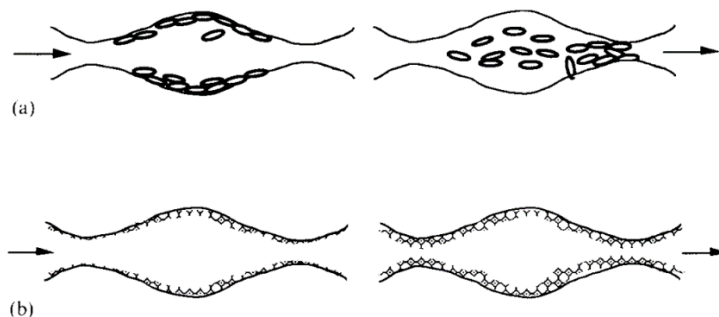


Figure 2.3- mechanism of permeability reduction caused by clays porous media. (a) Migration (non-swelling effect): changing ionic conditions cause the detachment of clays from pore walls and result in pore blockage. (b) Swelling: changing ionic conditions cause swelling of clays, lining the pore walls and reduce the cross-sectional area for flow (Mohan et al., 1993)

Both swelling and non-swelling clays reduce the effective area for flow and cause reduction in permeability. Non-montmorillonite, when placed in contact with water, increases its volume by about 20 times comparing with swelling clay (Norrish, 1954). In general, permeability decreases with increasing clay content. The effect of swelling clays on permeability reduction depends on the matrix grain size. In high porosity samples, the reduction in porosity due to clay swelling is insufficient to cause a meaningful reduction of permeability (Aksu et al., 2015).

Montmorillonite looks like flakes whose rims are wound around themselves (a), kaolinite crystals exhibit very often the shape of hexagonal prisms, which are flattened (b) and illite exhibit hairy crystals, which are very elongated (c) – see Figure 2.4.

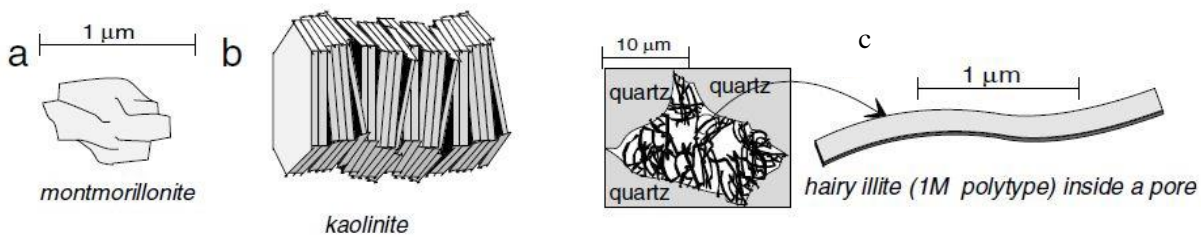


Figure 2.4- Examples of morphology of crystals of clay species: a) montmorillonite, b) kaolinite and c) illite (Meunier, 2005).

These minerals have two basic crystalline units and they differ in the way that they are combined. One of the basic crystalline units is the silicon-oxygen tetrahedron (T) and the other is the aluminum octahedron (O). The tetrahedron layers are combined with silicon sheets and the octahedron with gibbsite sheets. Kaolinite is composed of two layers: silicon and gibbsite. This combination is known as T-O structure or 1:1 structure, and the link between the layers is relatively strong in several layers. Montmorillonite is composed of three layers: silicon-gibbsite-silicon. This combination is known as T-O-T structure or 2:1 structure, and the link between the layers is weak and the water can enter between the layers, causing expansion (McGregor et al., 2014; Meunier, 2005). The clay minerals structure is represented in Figure 2.5.

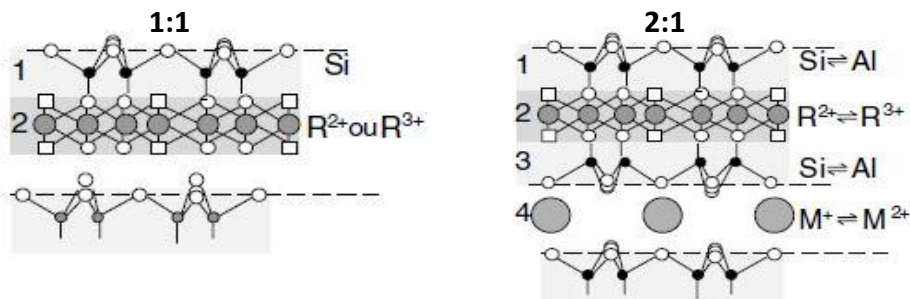


Figure 2.5- Clay minerals structures: kaolinite layers (1:1 structure) and Montmorillonite layers (2:1 structure), (Meunier, 2005).

Since the surface of the clay particles is negatively charged, they can attract the cations that exist in the water. The immediately adjacent water molecules are oriented and equally attracted to the surface of the clay particle. Thus, the cations form a positively charged zone, adjacent to the clay particle, which cause the existence of another negatively charged zone, but more diffuse. These two layers constitute the double ionic layer, see Figure 2.6. These characteristics condition the behaviour of clayey materials and their properties, that are influenced by ionic changes (Douillard & Salles, 2004).

In the 2:1 structure, the interlayer cation compensates the negative surface charges and when hydrated, its volume increases during the adsorption, or it can decrease during the desorption. This phenomenon is known as swelling affect, as explained above in this chapter. In the 1:1 structure, Kaolinite minerals have a very low surface charge and no interlayer cations, so the main adsorption sites are on the edges, where the Oxygen and Hydrogen molecules are present. The size of clay minerals ranges between 10 nm and 10 µm, with different shapes depending on the crystallization conditions (Meunier, 2005). Figure 2.7 shows a microtomography of clay particle.

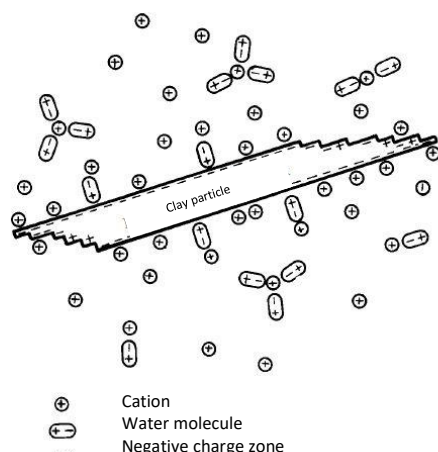


Figure 2.6- Ionic layer: arrangement between the clay particle and water molecules – adapted from Antão (2010).

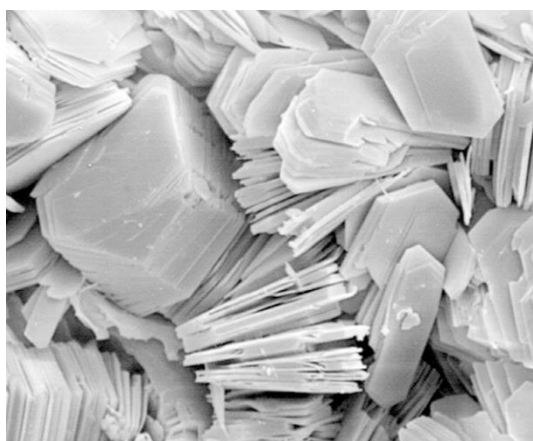


Figure 2.7- Microtomography of clay particle (open source).

2.1.4 Biobased porous material

2.1.4.1 Hemp shives characteristics

The term hemp is used for the strain of the plant *Cannabis sativa*. This plant was one of the first crops cultivated in the world and is one of the first plants to be spun into usable fiber. Hemp is also one of the fastest growing plants (4 m in 3.5 months), with low fertilization and irrigation, making it very efficient in use and material resources. Hemp crops are well adapted to most regions of the world (in a wide range of climatic zones). China, Europe and Canada are the three most important hemp planting regions in the world, producing in 2011 globally 61.318 ha. Hemp used to be cultivated to manufacture paper, rope and tissue. Nowadays, the different parts of the plant are used for several uses, such as agriculture, animal feeding, fabrication of alimentary oil, wool, textiles, paper, cosmetics, pharmaceutical industry, produce energy from biomass, combustible oils and building materials. Hemp does not contain proteins, so it is

unlikely attacked by insects and moths. As this does not contain either harmful substances nor it is dangerous for health both in production and laying phases (Salentijn et al., 2015; Benfratello et al., 2013).

The stems are cut and transformed to obtain fibers and shiv. The fibres are used to produce high quality paper and insulation wool, since the fibres are the most valuable part of the plant, while shiv particles, which are highly porous, are used in panels for interspaces in wooden structures, internal walls coating, ventilated coverings, ceilings and floors, or as aggregates in hemp concrete. These panels have very low specific weight and a high tensile, compressive and flexural strength. Hemp can also be used as plaster for outside walls (Glé et al., 2011; Benfratello et al., 2013).

Hemp has to be processed before its utilization. In summer, the plants are cut and dried in the sun for two weeks; then they are swingled for separating the fibres, located in the stalk, from the shives, that is the wooden inner part (Benfratello et al., 2013). The size of the particles is different depending on the growth climate, which means that their microstructure will be different due to their origin. In this study, since the particles have the same origin, only the effect of their size distribution was observed (Glé et al., 2011). Figure 2.8 shows hemp shives (a) and the micro porosity of hemp shives (b).

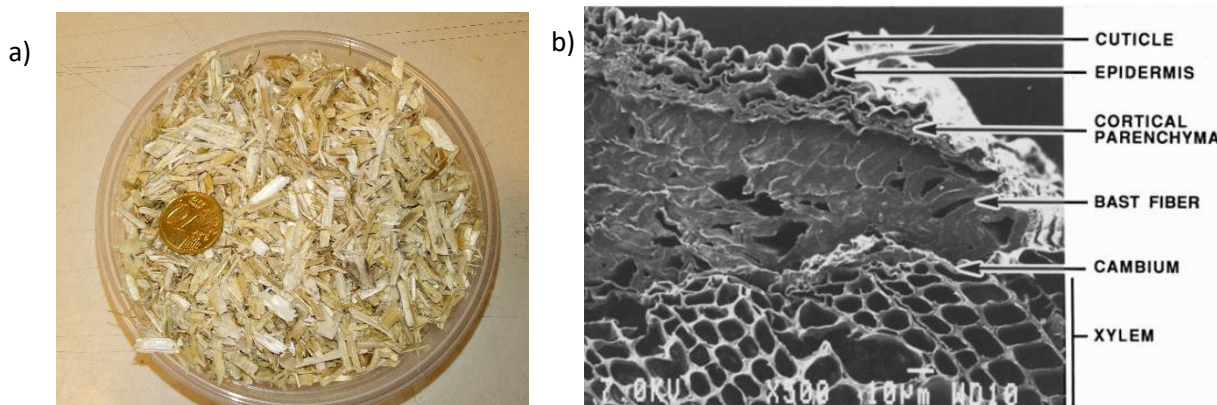


Figure 2.8- hemp shives (a) and microtomography of hemp shives (b). Figure (b) from open source.

Since hemp shives are a highly porous material it leads to an impact in the strength/density ratio, in the strength of link with the binder and in the mechanical properties. The porosity also influences the thermal conductivity. The open porosity in the surface, as is possible to see in the Figure 2.7, gives the material a good sound absorption and the possibility to water vapour diffusion. Its highly porosity gives it the potential to be a good hygroscopic material.

2.1.4.2 Hemp concrete

Hemp shives have been used to produce building materials, such as lime-hemp concrete, known as hemp concrete. This material is generally used for filling wood frames, bricks, blocks or mortar for coating masonry wall. Hemp concrete consists of shives mixed with lime-based binder. The proportions of the shives-binder determines the mechanical acoustic and hygrothermal properties (Dubois et al., 2014; Salentijn et al., 2015).

Hemp concrete is a very porous material, which has a huge influence on its acoustical properties. Other kinds of porous concrete have already been studied, such as autoclaved concrete, concrete with grains of irregular shape and dimension or concrete using recycled waste concrete aggregate. These porous concretes are also acoustically efficient. However, the particularity of hemp concrete is its multi-scale porosity, since it has different sizes (ranging between 1 μm and 1 cm), into the binder and into and between the particles. In hemp concrete, three or four different physical scales of porosity can be distinguished.

The microscopic pores of the shives and the binder, and the macropores between the particles make hemp concrete a high porosity material (Glé et al., 2011). Figure 2.9 shows the microporosity of hemp concrete. This characteristic makes hemp concrete a serious candidate in the search of sustainable and energy-efficient building material. The porous structure determines the sorption and capillary behaviour, since the moisture storage and moisture exchange capacity is directly related to their porous structure.

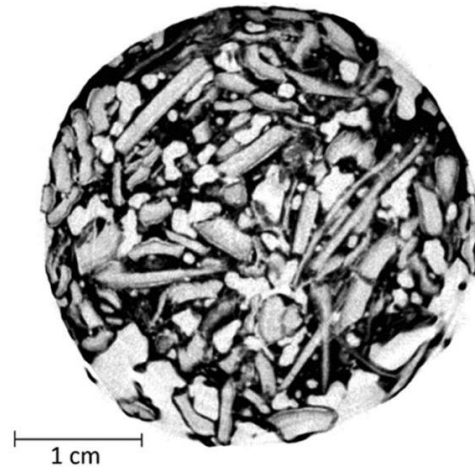


Figure 2.9- Microtomography of hemp concrete (Dubois et al., 2014)

2.2 Moisture transport

The dry state is reached by drying the material to constant weight, according to standard DIN 52620. The notion of humidity has several concepts, known as absolute humidity (x_{air}), water vapour concentration (v), relative humidity (RH) and dew point temperature (t_s). The absolute humidity (x_{air}) is the amount of water vapour in the air, translated in kg of water vapour per kg of dry air. The same definition can be applied to the water vapour concentration (v) with the difference that the units are expressed in kg of water vapour per volume of air (m^3). Of all the concepts that translate air humidity, the relative humidity (RH) is probably the most well-known. The relative humidity translates a ratio between the current amount of water vapour in the air and the maximum amount of water vapour that the air could contain, at the same temperature (eq. 9). Therefore, RH is a function of a relation between two variables. One of which is a characteristic of the environment (partial pressure that exists, P_v) and the other always translates the same value for a given temperature (Saturation pressure, $P_{v,sat}$). The dew point (t_s) translates the temperature for which the air reaches saturation, considering the temperature and the RH of the air (Henriques, 2007).

$$RH = \frac{v}{v_s} * 100 = \frac{P_v}{P_{v,sat}} * 100 (\%) \quad (9)$$

Humidity transfer phenomena are considered as mass transfer mechanisms. In case of buildings, and according to several studies (Henriques, 2007) the phenomena of moisture transfer correspond to the transfer of water in the liquid state or in the vapour state, which are known as liquid water transport and water vapour diffusion, respectively. These moisture transfers are conditioned by the existence of porous with open porosity and depend on the pore size.

2.2.1 Water vapour diffusion

As the earth materials are porous materials, it means that they have open and connected voids through which the water vapour diffuses. The water vapour permeability can be obtained according to the standard EN ISO 12572:2001, for building materials.

Water vapour permeability (δ_p) is the amount of water vapour that flows through the material per unit time through a unitary thickness, and judging that the vapour pressure between the two faces is unitary. To characterize the permeability of a material, it is most often used the concept of water vapour resistance factor (μ), which relates the ratio between δ_a and δ_p . This relation is presented in eq. 10:

$$\mu = \frac{\delta_a}{\delta_p} \quad (10)$$

where δ_a is the water vapour permeability of the air, and its average value (at 23°C) can be assumed as $1,9 \times 10^{-10}$ kg/(m.s.Pa), while δ_p is the water vapour permeability within the material [kg/(m.s.Pa)]. The water vapour permeability is defined as the mass of water vapour that trough the specimen thickness by time, divided by the water vapour pressure between the two faces of the specimen (Henriques, 2007; McGregor et al., 2014). The higher the value of μ the smaller the value of vapour permeability of the material will be.

In general, the potential difference in heat transfers is related with temperature, while in mass transfers the potential results of the differences of concentration. If the difference of temperature or concentration are zero, there is no flow (Henriques, 2007). Diffusion is a mechanism of vapour transport and it is expressed by Fick's law, which can be written in the form of eq. 11:

$$\mathbf{g}_v = -\delta_p * \mathbf{grad}(p_v) \quad (11)$$

Where \mathbf{g}_v is the water vapour flux density vector due to diffusion [kg/(m².s)], δ_p is the water vapour permeability, which depends on the vapour pressure, and $\mathbf{grad}(p_v)$ is the water vapour pressure gradient.

The vapour pressure (p_v) is depicted by Kelvin's equation, which is expressed in eq. 12:

$$p_v = p_{vsat} * \exp\left(\frac{p_c}{\rho_w * R_v * T}\right) \quad (12)$$

where p_{vsat} is the saturated water vapour pressure, ρ_w is the density of water, R_v is the gas constant for water vapour, T is the temperature and p_c is the capillary pressure, which is defined as the difference between the liquid and the gaseous phase inside the pore.

When the vapour diffusion within the porous network is considered, the Fick's law can be represented as it shows in eq. 13:

$$\mathbf{g}_v = -\delta_p * \mathbf{grad}(p_v) = -\frac{\delta_a}{\mu} * \mathbf{grad}(p_v) \quad (13)$$

where \mathbf{g}_v is the vapour flow vector due to diffusion within the porous network.

2.2.2 Liquid water transport

The movement of water in porous materials can happen due to different ways: by the action of gravity, contrary to the action of gravity, which is known as capillarity, horizontal migration or due to differences in pressure.

Capillarity

The capillarity phenomenon happens due to suction forces that enable the water to move in the opposite direction of gravity. When a building material in contact with liquid water absorbs it by capillary suction, it is called capillary-active, if does not it is called hydrophobic. Capillary-active materials absorbs liquid water until it reaches a certain state of saturation called free water saturation or capillary saturation. To overcome the capillary saturation state, it is necessary to use additional methods, such as pressure or water vapour diffusion in a temperature gradient (Künzel, 1995).

This phenomenon depends on the characteristics of the liquid, such as its surface tension (σ) and its contact angle (θ). The water molecules attract each other, and one molecule integrally encased in others has its attraction forces annulled. At the surface, the water molecules are not equilibrated, therefore, there is a surface tension (σ), which can be determined as a function of temperature. Where the water touches the pore walls there is another force known as contact angle (θ), which is determined by the inclination of the tangent between a drop of water and the surface. In construction materials, without superficial treatment, the contact angle is normally close to zero.

The Young-Laplace equation shows that the difference of capillary pressure (Δp) between the liquid and the air depends on the surface tension and the mean curvature (C), as explained in eq. 14.

$$\Delta p = 2\sigma C \quad (14)$$

where, the mean curvature is the inverse of the meniscus radius in two orthogonal directions.

If a circular tube with the same radius in both orthogonal directions and $R=r/\cos\theta$ is considered, the equation can be written as eq. 15:

$$\Delta p = \frac{2\sigma\cos\theta}{r} \quad (15)$$

where, r is the tube radius.

The capillary pressure is compensated by the height that the water reaches (h). The hydrostatic equilibrium is expressed in eq. 16:

$$h = \frac{2\sigma\cos\theta}{r\rho g} \quad (16)$$

where ρ is the density of the liquid (kg/m^3) and g is the gravity acceleration.

The capillary ascending process begins when the pore contacts with water, mobilizing forces of gravity, capillary suction, air friction in the upper pore area and water friction. The sum of these forces must be in equilibrium, which means that height reached by water is related with the capillary pressure (Henriques, 2007).

The geometric relations are classified in the scheme shown in Figure 2.10. As mentioned before, the contact angle and the pore size influence the height that the water can reach by capillarity.

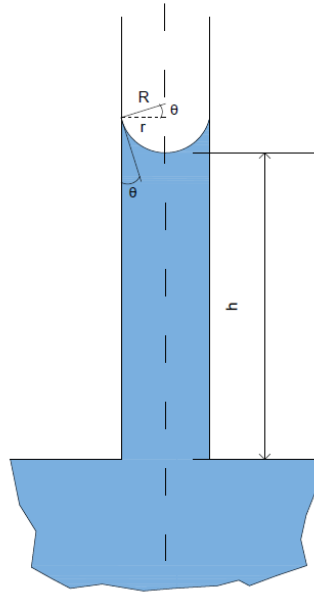


Figure 2.10- Capillary suction within a pore – based on Henriques (2007)

The capillary ascending process begins when the pore contacts with water, mobilizing forces of gravity, capillary suction, air friction in the upper pore area and water friction. The sum of these forces must be in equilibrium, which means that height reached by water is related with the capillary pressure (Henriques, 2007).

Horizontal migration

In the case of horizontal water migration, the pore is considered to be exclusively horizontal, so the pore slope is given as $\alpha=90^\circ$. If the air friction is neglected, the distance to the humid front (x) can be calculated by eq. 17. It is possible to verify that the distance depends on the radius of the pore and the time. It can be verified by the expression that the narrower the pore the smaller the speed of absorption. This finding is important for facade cladding materials as they are subject to rainfall (Henriques, 2007).

$$x = \sqrt{\frac{r\sigma\cos\theta}{2 * \mu_w}} * \sqrt{t} = S * \sqrt{t} \quad (17)$$

where S is the sorptivity (m/\sqrt{s}), which means the velocity of water transport within the porous material and μ_w is the viscosity of water (Pa.s).

Differences in pressure

The movements of water in porous materials are due to pressure differences, which create suction forces. These movements occur in laminar regime, since the Reynolds's number is much lower than the limit value of the turbulent regime.

2.3 Moisture storage

Porous materials always retain some water, in the liquid or vapour form from the air, whatever the temperature and the water vapour. Therefore, porous materials are known to have the ability to retain moisture. The phenomenon of adhesion of water molecules to the surface of the pores is called adsorption.

In buildings, the level of moisture inside increase with occupancy. When the level of moisture is high it means that the water vapour pressure in the air is high, which leads to the transport of water vapour through the building materials. Porous materials used for construction present a progressively higher adsorption when the relative humidity increase. If the material has hygroscopic salts inside it, such as chlorides or nitrates, this effect is more drastic because the salts have the ability to adsorb large amounts of water vapour, thus altering the typical behaviour of the material. Since it is often difficult to determine separately the different physical state of water inside of the materials, the sum of the different states is examined together and presented in water content.

Earth building materials normally present a “S” shaped isotherm. Depending on the relative amount of liquid and gas within the porous network, several states of adsorption can be defined. The graph shown in Figure 2.11 shows three adsorption domains consonant with the water content within the material and three pore saturation states consonant with the relative humidity.

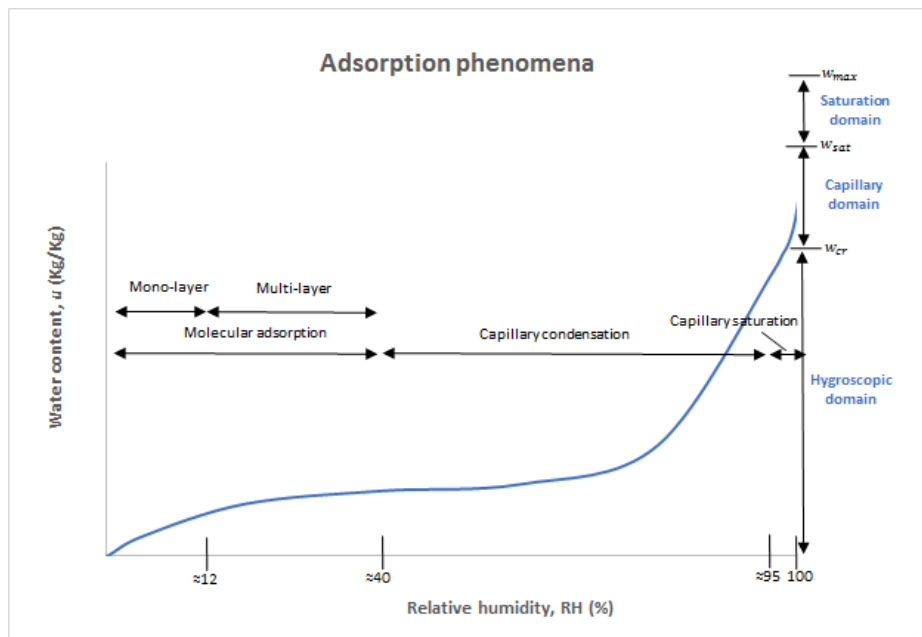


Figure 2.11- Adsorption domains and molecular saturation states - adapted from Hall & Allison (2009) and Henriques (2007)

The adsorption process contains three domains: hygroscopic, capillary and saturation. The **hygroscopic domain** is known to be a transition between the dried state and the unsaturated state, where the liquid phase is present within the porous network. Since the liquid is attracted to the surface of the clay particles, the migration through the porous network is very limited. In building physics, the hygroscopic domain is described by sorption isotherms. These curves are classified in six different types – see Figure 2.12. Clayey building materials have a sorption isotherm like II B figure.

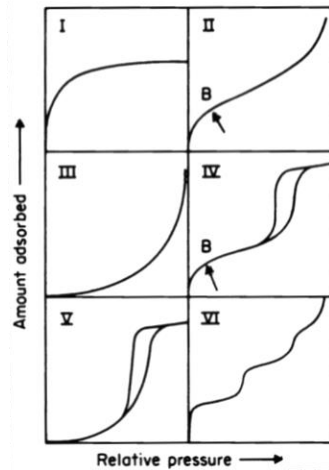


Figure 2.12- Types of sorption isotherms (Sing et al., 1985)

The **capillary domain**, also known as unsaturated domain, contains both liquid and gas phases. Despite the air pressure and in-pore liquid pressure being higher than the entry air suction, most of the molecules of the liquid do not move freely within the porous network since they are sufficiently distant from the pore walls. The **saturated domain** is also known as quasi-saturated, since the gaseous phase is discontinuous taking into account that there is only trapped air in porous network. It takes the forms of air bubbles or pockets that are embedded within the liquid phase (Fabbri, 2017; Künzel, 1995).

The molecular saturation states contain two phases: **molecular adsorption**, which is the deposition of a single layer of water molecules on the surface of the pores, which usually corresponds to 0% to 20% of relative humidity, and the second phase is the multi-layer adsorption, approximately between 20% and 40% of relative humidity. The **capillary condensation** phase begins when the various layers of adsorbed water touch each other, which first happens in the smaller pores. Due to the effect of the forces of attraction, the water molecules are arranged in a more stable form. The surface tensions cause the formation of meniscus on the extremities. According to the Young-Laplace equation, the shape of the meniscus determines the pressure (eq. 14 shown above). Kelvin's law, shown in eq. 18, relates the pressure with the saturation pressure on the porous radius with the value of the relative humidity for saturation.

$$\varphi = \frac{P_v}{P_{v,sat}} = e^{\left[-\frac{2\sigma M_w \cos\theta}{r\rho_w RT}\right]} \quad (18)$$

Where M_w is the molar mass of water (kg/mol), R is the gas constant (J/kg.mol) and T is the temperature (K).

In the **capillary saturation**, about 98% relative humidity, the capillary condensation does not occur in the entire pore space due to the existence of air pockets in the pores, which prevent the normal progression of the humid front. To reach the state of total saturation it is necessary to subject the materials to the vacuum, before the adsorption process, in order to remove the air in the pores. However, if the water remains for a long period of time in contact with the air pockets can dissolve them and reach the saturation level, without necessity to use the vacuum mechanism.

From the adsorption curves, it is possible to determine the specific hygroscopic capacity (ξ), which translates the amount of moisture that the material adsorbs or releases per unit mass and relative humidity. This material property is obtained by the rate of change of the moisture content in mass u_H (kg/kg) as a function of the relative humidity (eq. 19).

$$\xi = \frac{\partial u_H}{\partial \phi} \quad (19)$$

The relationships between water vapour concentration, relative humidity and air temperature can be expressed through the psychrometric diagram. A simplified version of the diagram is shown in Figure 2.13. The diagram presents in abscissas the values of the air temperature (°C), in ordinates the values of partial vapour pressure (kPa) and relative humidity (%).

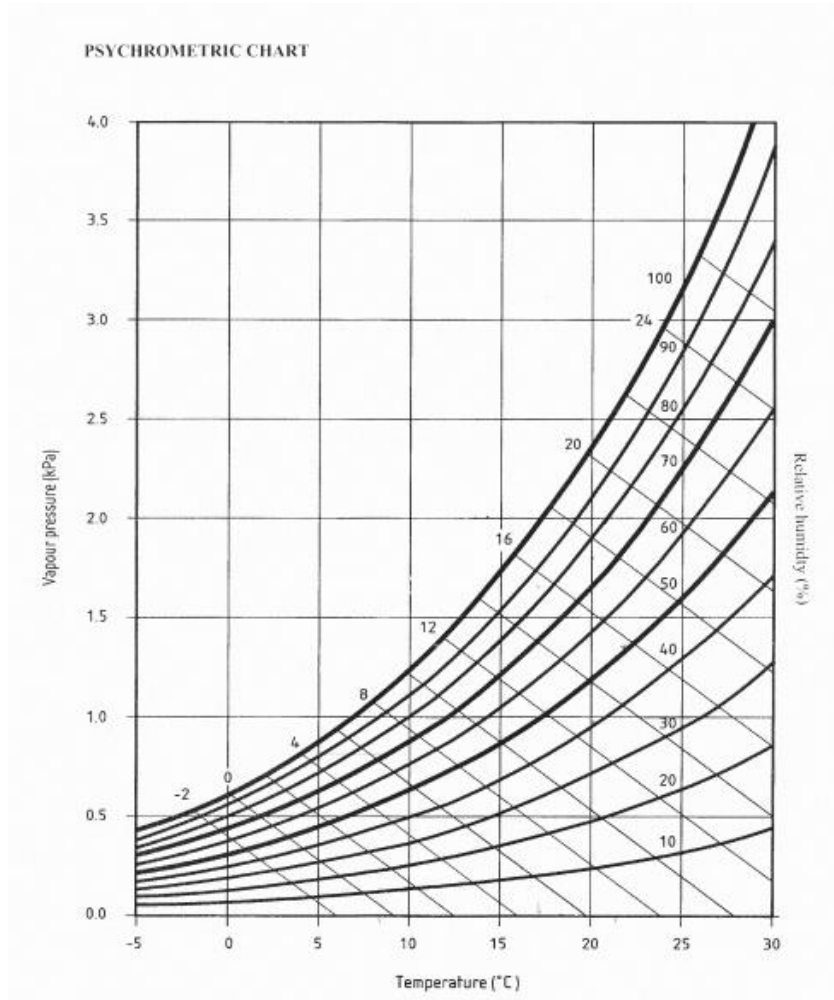


Figure 2.13- Psychrometric diagram (open source).

Conversely to the adsorption process, the material can lose water, which is called desorption. In ideal conditions, the desorption must correspond to the adsorption, however, this is not the case for many current building materials, in which desorption is slower than adsorption. This difference in the behaviour between the two phenomena is known as **hysteresis**. The shape of curves is similar but the desorption isotherm has higher values of water content than the adsorption isotherm for the same value of relative humidity. Moisture hysteresis refers to the phenomenon that, at the same relative humidity, the material experiences a different level of moisture content depending on its loading history. In general, materials with mineral binders have a marked hysteresis, such as concrete and mortars (a). Other materials have a near zero hysteresis and therefore the hysteresis phenomenon is negligible, such as wood and rocks (b) (Derluyn et al., 2012; Henriques, 2007; Kwiatkowski et al., 2009). Figure 2.14 shows two different examples of hysteresis of two different materials.

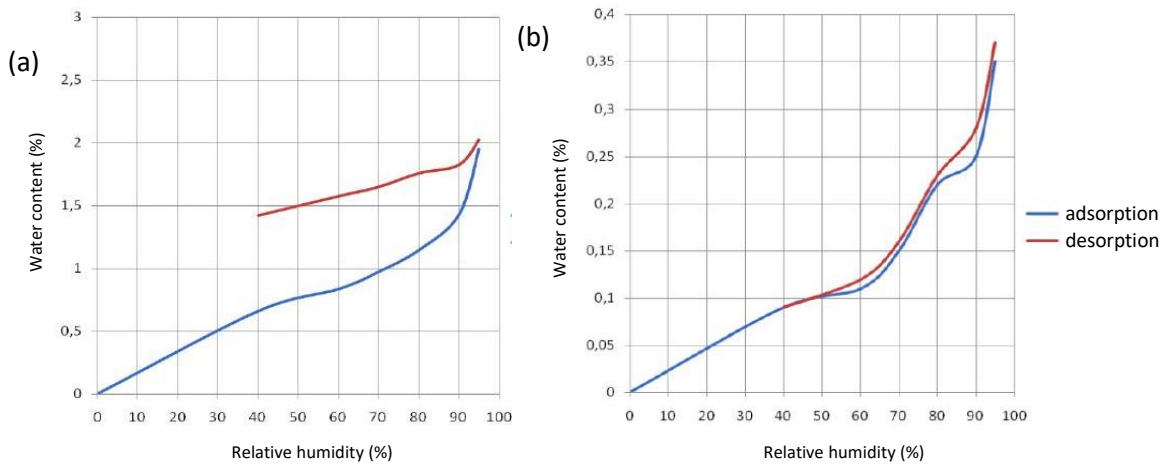


Figure 2.14- Examples of hysteresis of two different materials: Materials with mineral binders (a) and materials like rocks (b) – adapted from Henriques (2007).

Hysteresis influences the dynamic behaviour of materials. The water vapour permeability describes the moisture transport property of the material. Permeability is not a constant value, but it is a function of the saturation ratio. For each relative humidity level, there will be equilibrium in water content in the material. The differences in the sorption curves for different materials are due to micro-structural properties, such as specific surface area, pore-size distribution and total porosity. Therefore, when results of the RH are needed, the hysteresis effect should be taken in account (Kwiatkowski et al., 2009). Hysteresis is common in soil-water phenomena. The water retention in earth materials is not a simple relationship between the effective degree of saturation (S_r) and the matric suction s (or soil-water potential ψ). The soil-water characteristic curve (SWCC) is defined as the relationship between these two properties. This curve is also called the soil moisture characteristics curve or the soil-water retention curve. The SWCC is widely used to predict, soil-water storage, permeability and stress–strain relationships of unsaturated soils (Zhou, 2013).

During the adsorption/desorption process, the contact angle in drying process (θ_R) and the contact angle in wetting process (θ_A) are not constant, as shown in Figure 2.15.

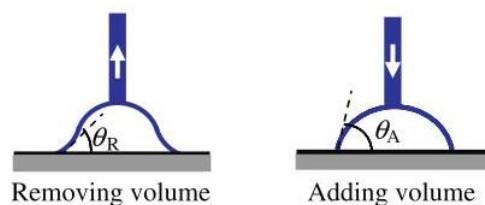


Figure 2.15- Contact angles in adding/removing volume method (Zhou, 2013).

A predicted SWCC, when k is set to constant value, is represented in Figure 2.16.

In Figure 2.16, S_e represents the effective degree of saturation, k represents the ratio of suction increment (eq. 20) and its value is equal to zero in the main branches, since the contact angle stays constant in the main drying and wetting branches. k varies from 0 to 1 during the process, from reversing the drying-wetting processes. n is a parameter related to the pore size distribution and a_d is a parameter related to the air entry value. As k is constant, the SWCC is almost linear, as shown in Figure 2.15 (Zhou, 2013).

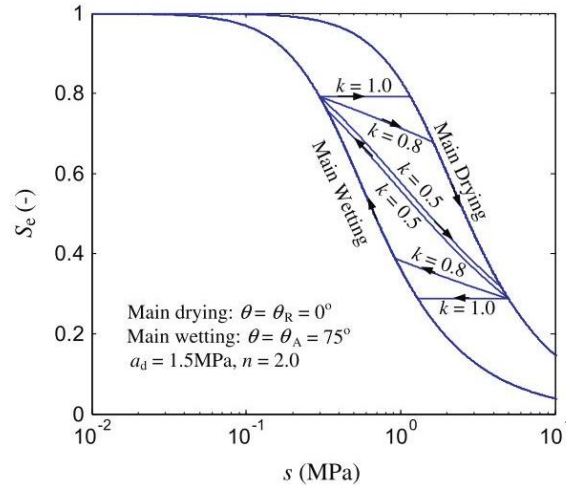


Figure 2.16- Predicted scanning curves when k is set to a constant (Zhou, 2013).

$$\frac{d\theta}{ds} = -\frac{k}{s \tan \theta}, 0 \leq k \leq 1 \quad (20)$$

Where s is the arbitrary suction and θ is the liquid–solid contact angle.

In unsaturated soil mechanics, the hysteresis behaviour is given by a linear scanning curve. However, the linear scanning curve does not usually provide satisfactory predictions of hydraulic hysteresis behaviour. Modelling of the hysteresis effect is not so simple because the nature of this process is not very well known. The sorption process depends not only on material properties but also on varying indoor conditions. Indoor air humidity is also strongly influenced by sorption processes in materials in contact with the indoor air (Kwiatkowski et al., 2009; Zhou, 2013).

This graphic is very limited in the study of hygrothermal properties, since the water content reached is very low (below 10%). The water content values are in this range since this variable is studied using water vapour rather than liquid water. Therefore, under these conditions, only the lower right corner of the Figure 2.16 is studied, since the suction force is very low. In this study, the vapour pressure is used instead of suction forces and the water content is used instead of the effective degree of saturation, since the materials are very far from being saturated.

2.4 Moisture buffering

The moisture buffer performance of a material is its ability to moderate the relative humidity variations of indoor atmosphere. These variations can be daily or seasonal. The daily variations have more relevance and therefore receive more attention. Figure 2.17 shows a scheme that describes moisture buffer phenomena in a room, divided in three levels. The room level is related to the exposure areas of surface materials, such as building and furnishing materials, moisture loads, indoor climate, ventilation rate and other factors that could influence the moisture buffering in the room. The system level includes material combinations, where the simple material is a homogeneous material with the convective boundary air layer. On the material level, it is admitted that the surrounding climate is negligible in the determination of material properties, such as the density, porosity, water vapour permeability, sorption properties, etc. (Rode et al., 2005).

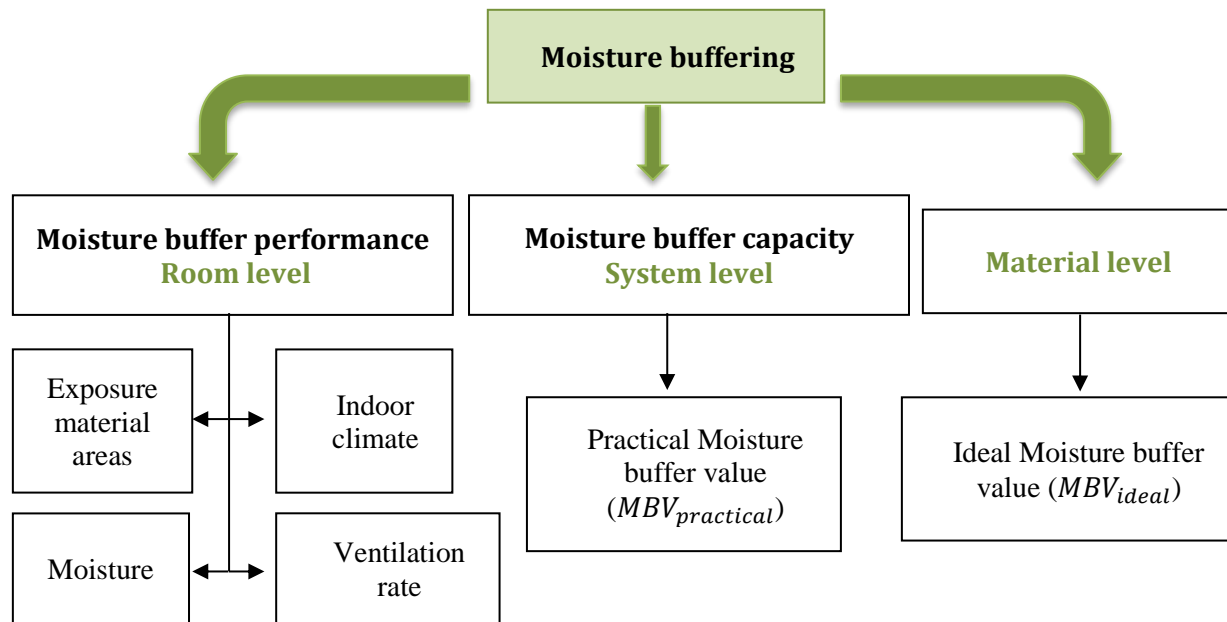


Figure 2.17- Moisture buffer phenomena in the indoor environment, divided into three descriptive levels: room level, system level and material level – adapted from Rode et al. (2005)

The moisture buffering capacity influences beneficially the indoor environment, which benefits the material durability, the building energy performance and the occupant comfort and health. The use of building materials as an active agent to regulate indoor relative humidity consequently produce a healthier environment (McGregor et al., 2014). The ideal moisture buffer capacity is based on the assumption that the materials studied have a thickness that exceeds the penetration depth. The determination of a practical Moisture Buffer Value (MBV) involves a run time which corresponds to a typically daily variation. The $MBV_{practical}$ indicates the amount of water that is transported in the material through the open surface area, during a certain period of time, when it is subject to variations in relative humidity (Rode et al., 2005).

The processes of mass transfer in the material influence the conditions within the material and inside the connected air spaces. The equilibrium moisture content (EMC) is determined by the hysteresis phenomenon, during successive adsorption/desorption cycles. Equilibrium moisture content is also influenced by the temperature. It is known that the warmer the temperature, the lower will be the equilibrium moisture content at the same relative humidity. The comparison of the pore size distributions shows the presence of pores with larger diameters at higher temperatures than in lower temperatures (Oumeziane et al., 2016).

The study of the hygrothermal behaviour in biobased and raw earth materials have been a scientific and technical challenge. Several studies have been made. McGregor et al. (2017) studied the film resistance on the hygric properties of composite clay/fibre plasters, Rode et al. (2005) standardized the characterization of the Moisture Buffering Values for Building Materials, Hall & Allison (2009; 2010) analysed the hygrothermal behaviour of stabilised rammed earth in laboratory samples and in a full scale building, Cerolini et al. (2009) investigates the possibility to use highly absorbing materials to regulate indoor humidity variations, McGregor et al. (2014) study the moisture buffering capacity of unfired clay masonry, Cagnon et al. (2014) study the hygrothermal properties of earth brick, and finally, McGregor et al. (2016) presents a review on the buffering capacity of earth building materials.

Peuhkuri et al. (2005) study the effect of method, step size and drying temperature on sorption isotherms. More specially, the investigation of the effect, using different drying temperature on the equilibrium moisture content and the impact that drying at elevated temperatures creates in the hygroscopic behaviour of the material. Previous FCT UNL MSc students (Simões et al., 2016; Simões, 2015; Ferreira, 2016)

studied the contribution of earth plaster and hemp concrete in the passive regulation of humidity inside buildings and, the influence of the temperature on the hygrothermal behaviour in compacted earth and earth plaster, respectively. Although, there is still a lack of information about the exact determination and standardization of test procedure of the correct dry mass for biobased and raw materials. The influence of drying/wetting cycles and the influencing of reproducing sorption isotherms at different temperatures also need a deeper investigation. Therefore, based on the hygric properties of porous materials and the hygrothermal coupling of those materials, as described in this chapter, this dissertation is intended to continue the previous research done by FCT UNL students at the ENTPE laboratory.

3. Materials and methods

3.1 Initial remarks

This chapter describes the tested materials and the methods used to determine the hygrothermal properties of biobased and raw earth materials. As there is no clear guidance to determinate a correct dry mass for biobased and raw earth materials, the aim of the experimental campaign is to investigate the influence of the drying method and recommend a standard one.

Two different experiments were made (sorption isotherms and MBV). Same materials were used for the both experiments, although, the samples size and mass were different. The samples were bigger in the MBV tests, since only one surface area is studied.

This work is developed under the IBIS project¹ and the BIOTERRA project², where ENTPE is a partner. The IBIS project promotes the study of hemp concrete while the BIOTERRA project has the purpose of studying earth mortar plasters.

3.2 Materials

The materials used in this study are biobased and raw earth materials. For biobased materials, two different samples were tested: earth plasters and hemp concrete. For raw earth materials, compacted earth samples were tested. Figures 3.1 and 3.2 shows examples of samples used in sorption isotherm and MBV tests, respectively. Table 3.1 present the samples dimensions used for both tests.



Figure 3.1- Example of samples used in sorption isotherm test - Earth plaster on the left, hemp concrete in the middle and compacted earth on the right.

¹ **IBIS** (Started in 2013, co-funded by ADEME). Leader: Parex Group, Partners: LGCB-ENTPE, ESITPA, C&B. Subject: Innovative bio-based insulation systems for the renovation of buildings made with local materials

² **BioTerra** (started in 2014, co-funded by ANR: French National Research Agency) Leader: LMDC, Partners: Agencement Structure, AGN Agronutrition, Carrières du Boulonnais, CTMNC, CEREMA, LGC, LGCB-ENTPE, UPS-LRSV. Subject: Control of the microbial proliferation on earth bio-based products for healthy and sustainable buildings



Figure 3.2- Example of samples used in MBV test - Earth plaster on the left (with two thicknesses: 2cm and 4cm), hemp concrete on the superior right corner and compacted earth on the inferior right corner.

Table 3.1- Samples dimensions used in the sorptions isotherms and MBV tests.

Sorption isotherms				
	Shape	Number of samples	Thickness (cm)	Diameter/length (cm)
CE	Cylindrical	15	1	3.5
EP	Parallelepiped	15	≈ 2.0	≈ 4.3
HC	Parallelepiped	15	≈ 4.5	≈ 3.8
MBV				
	Shape	Number of samples	Thickness (cm)	Diameter (cm)
CE	Cylindrical	6	3.5	3.5
EP	Cylindrical	3	2	12.5
		3	4	12.5
HC	Cylindrical	1	6	15.5
		2	5	15.5

3.2.1 Compacted earth

The material used to produce the compacted earth samples was extracted from existing centenarian rammed earth constructions located in the Rhône-Alpes region in South-East of France, from Cras-sur-Reyssouze (CRA). The samples formulation was done by ENTPE, according to Chabriac et al. (2014) and Champiré et al. (2016).

The properties of the compacted earth samples are presented in the following Table 3.2.

Table 3.2- Properties of compacted earth samples

	CRA
Main clay minerals	Illite+Kaolinite
Clay content <2μm (%)	16
Bulk density (g/cm³)	1.97
Porosity (%)	26

The first step of the compacted samples fabrication protocol consists in crushing the earth blocks, which were taken from the construction site, into small particles that have been sifted in a 2mm sieve to obtain a homogeneous material. The material underwent a double compacting process with a loading charge of 4MPa to realize cylindrical samples with 3.5cm in diameter and 7cm in height. The water content of fabrication was fix on 11% in order to reach the higher dry density. This fabrication ensures a homogeneity of the samples and a good repeatability of their main characteristics, such as the density, vapour resistance factor and sorption-desorption curves. The samples were dried in a controlled environment in a conditioning room at $20\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH.

The samples were cut with 1cm and 3.5cm of thickness, from the initial cylindrical samples given by the fabrication process, to be used in sorption isotherms and MBV tests, respectively.

3.2.2 Earth plaster

The earth plaster samples are denominated by the main type of clay or commercial name. The samples that were tested are mainly composted by Kaolinite (F0). Kaolinite is a clay with a low specific surface compared to other clays, yet with a high sorption capacity compared to most minerals. The formulation of the earth plasters samples is presented in the following Table 3.3.

Table 3.3- Formulation of earth plaster (F0)

	Kaolinite (F0)	Sand (0/2)	Straw (3-5cm)	Water
Volume (l)	7.77	15.54	15.54	9.71
Mass (kg)	8.00	23.59	0.81	9.71

The Kaolinite minerals have a particles size distribution of $95\% < 80\mu\text{m}$ and $43\% < 2\mu\text{m}$, the sand particles size is lower than 2mm and the straw particles size is between 10mm and 30mm. The formulation of the samples was done by ENTPE and they were prepared according to the procedure described by Simões (2015). The samples were mixed with water (30%wt), after then they were placed in two different formworks (50 x 50 x 2 cm and cylindrical moulds with 12.5cm in diameter and with 2 and 4cm in height.), They were dried in a controlled environment in a conditioning room at $20\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH.

The samples were cut with approximately 4.3cm in length and 2cm in thickness to be used in in sorption isotherms tests. For the MBV tests were used samples with the initial cylindrical dimensions, given by the fabrication process.

3.2.3 Hemp concrete

The hemp concrete samples are composed of shives, binder and water. The binder is known as Tradical 70 and it is formulated based on lime binder (75%), with hydraulic binders (15%) and pozzolanas (10%). The formulation of the samples was done by ENTPE. The composition of hemp concrete samples is represented in the Table 3.4.

Table 3.4- Mixtures proportions of hemp concrete, wet density and curing conditions

Material	PF 70
Binder	Lime based binder (Tradical 70)
Hemp/binder mass ratio (-)	0.33
Water/binder mass ratio (-)	0.81
Wet density after the realization (-)	0.78
Manufacturing	Moulding
Curing Conditions	50 % of RH in the mould

Hemp concrete is the result of the mixing of hemp particles, binder and water. Various mixes of hemp concrete can be produced depending on the binder content, the degree of compaction, the size of the particles and the binder type. Thus, the porous network of the hemp concrete is defined by four different sizes of pores, which are the size of the intra-binder pores (about 1 μm), the two sizes of the intra-particle pores (about 70 μm and 400 μm) and the size of the inter-particle pores (about 1 mm) (Glé et al., 2011). Firstly, the dry lime was mixed with about 90% of the water during 5mins. Then, the hemp and the remaining amount of water are progressively added in the lime paste in approximately 10mins. Just after mixing, the mix are rammed into cylindrical moulds with 16cm x 32cm moulds.

The samples were cut with approximately 4.5cm in length and with 3.8cm in height, from the initial cylindrical samples given by the fabrication process, to be used in sorption isotherms tests and with 15.5cm in diameter and with 5 and 6cm in height, to be used in the MBV tests.

3.3 Experimental methods

Since there are two objectives in this study, the effect of drying methods (and cycles) and the effect of the temperature on the sorption isotherms, the experimental methods used for each subject are different. Sorption isotherms and Moisture Buffering Value were used to study the effect of drying methods. Sorption isotherms were also used to estimate the impact of the temperature in the sorption curves. The electronic equipment used were calibrated before the experimental tests.

3.3.1 Methods used to study the drying methods

3.3.1.1 Drying methods

The drying techniques can affect the microstructural network of porous materials. Desorption phenomena associated to drying may generate damages like microcracking, fine pores collapse or mineralogical transformations.

Two drying methods were used in this study: oven- and vacuum-drying. Two temperatures were considering using oven-drying: 60°C and 105°C. The vacuum-drying method was carried out at ambient temperature (23°C) and three interconnected desiccators were used (Vacuum 1, 2 and 3) to form a vacuum system. In the oven at 105°C the RH is quite low and so it is considered that it is close to 0%. Besides that, any datalogger equipment can be used at 105°C because all the equipment available use battery. The temperature and RH were evaluated, using EasyLog equipment, inside the oven at 60°C and inside the vacuum system. Silica-gel was used to adsorb any moisture present. The RH in the oven at 60°C was verified as 7±2% and in the vacuum system was under 5%. Figures 3.3 and 3.4 shows the temperature and the RH inside the oven at 60°C and inside the vacuum system, respectively.

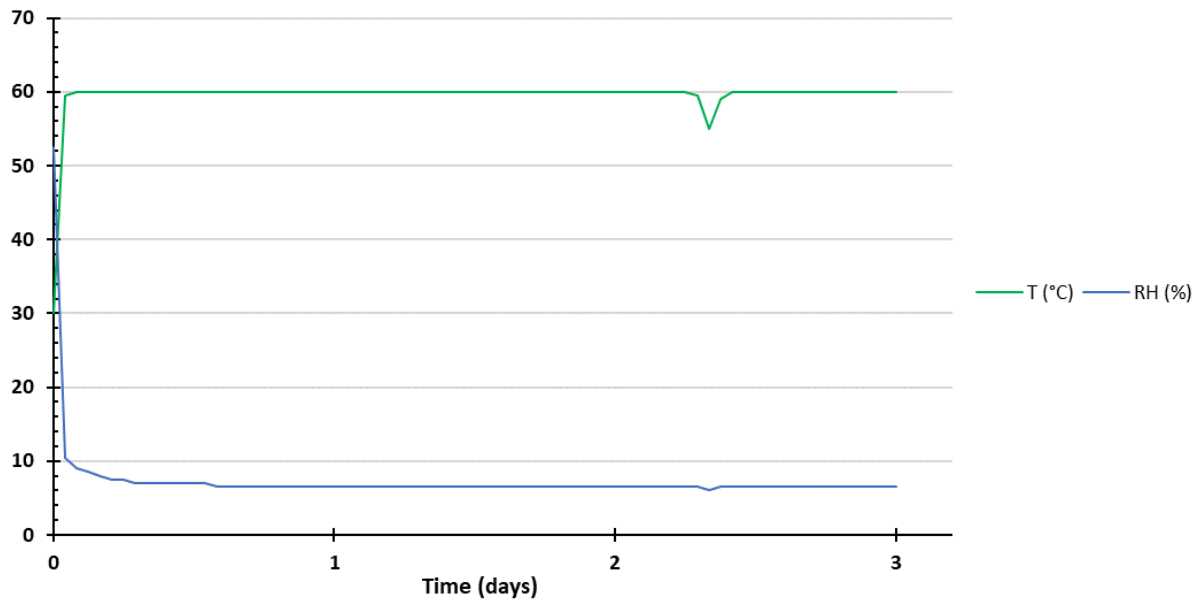


Figure 3.3- Temperature and RH inside the oven (60°C), with silica-gel.

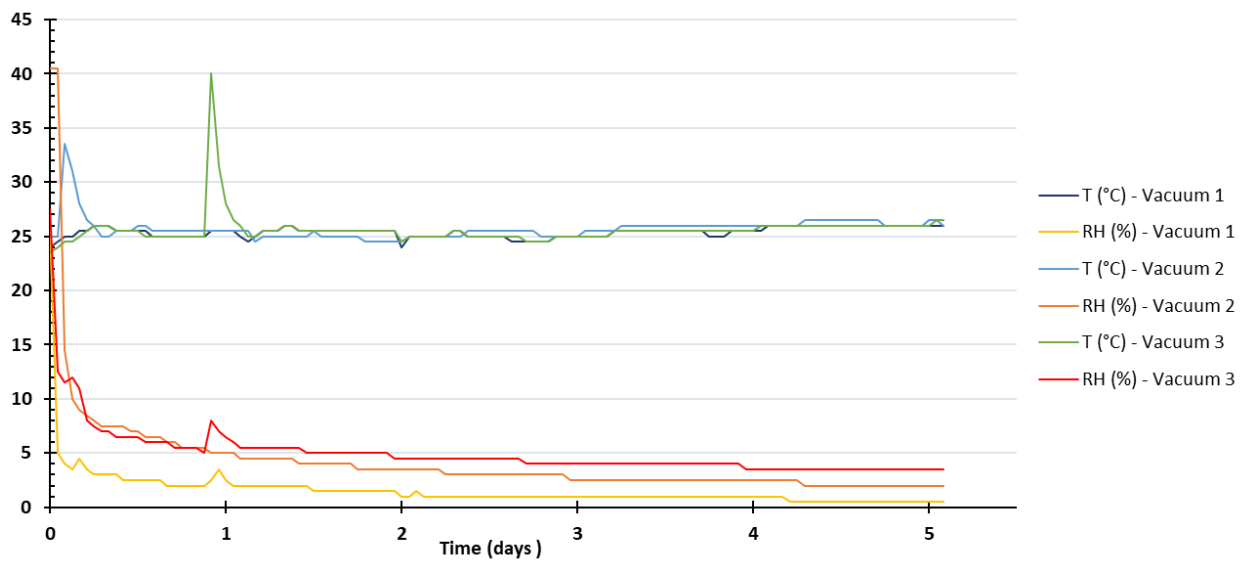


Figure 3.4- Temperature and RH inside the vacuum system, with silica-gel.

The vacuum system is composed of three desiccators with silica gel, an air pressure system, a pump vacuum, a manometer and plastic tubes that connect the desiccators to the other elements and to the air system. The system is represented in Figure 3.5.



Figure 3.5- Elements of the vacuum system.

3.3.1.2 Sorption isotherms

The characteristic storage of biobased and raw earth materials, in the hygroscopic regime, can be evaluated through the sorption isotherm. To determine the sorption curves, three methods can be used. The first one is using the "Desiccator method", where the relative humidity is maintained by the saturated salt solutions. The second one is using a "Climatic chamber method", where the temperature and RH of the air in the chamber are controlled, and the third one is using the Dynamic Vapour Sorption (DVS) equipment. The great advantages of salt solutions are that this method does not consume energy and several samples, at different RH, can be studied at the same time. Although, a sorption-desorption curve, for earth materials and hemp concrete, can be made in approximately 3-4 months, while using the DVS equipment it can be made in 1-2 weeks. The DVS equipment is more precise since it works at microscale and all the process is made inside of the DVS equipment in a controlled environment. However, only one sample can be tested at the time and its maximum weight is 1g. DVS method do not have representativeness when fibre and sand materials are tested, like hemp concrete. The experimental error using the DVS is lower than the salt solutions method, since the scale has an accuracy of ± 0.1 mg, the temperature can be maintained to ± 0.1 °C and the RH is maintained to $\pm 1\%$ RH. The sorption-desorption curves should be intrinsic to the material tested whatever method is used. However, some significant differences are observed when direct comparisons are made between the curves obtained by the DVS and by the desiccator method.

In this case, only the "Desiccator method" was used. The DVS method was not developed during this study due to machine problems, which led to the lack of time to perform the DVS tests. However, results taken from previous experiments made in LTDS, ENTPE by a previous internship student (cf. master thesis of João Ferreira) were used in order to confirm the results given by the desiccator method. Therefore, the DVS method is also presented as an experimental method.

Salt Solutions

To determinate sorption isotherms and sorption cycles, the salt solutions method was applied according to EN ISO 12571 (CEN 2000). Fifteen samples of each material (earth plasters, hemp concrete and compacted earth) were tested. Being that, three representative samples of each material, with more than 10g, were placed in each box, with different RH. Therefore, each box had nine samples, three of each material. The samples used in this test are presented in Figure 3.1, chapter 3. The samples were placed in glass containers to avoid the loss of material, during the sorption isotherm tests - see Figure 3.6. Since the value of RH can be modified by a larger number of factors like impurities in salts or water, non-saturation of the saline solution or changes in temperature, a portable sensor (Rotronic HygroLog HL-NT) was used for constant control of the RH and the temperature inside the boxes. The equilibrium moisture content for

each RH level was reached when the difference of mass between two consecutive measurements was less than 1% of the last measurement.

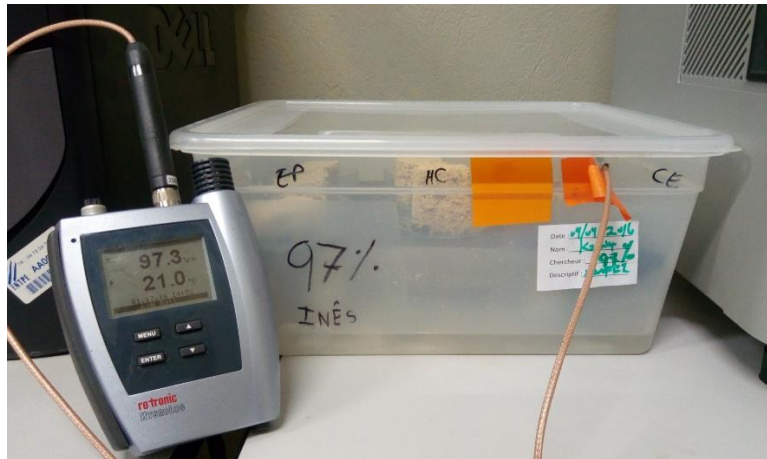


Figure 3.6- Samples placed in a salt solution box for the sorption isotherms test.

In this study, the RH chosen were 23, 53, 75 and 97%. Two boxes of 75% of RH were used for the repeatability test. To achieve the relative humidity intended, the salt solutions were prepared according to Annex B in the EN ISO 12571 (CEN 2000). The correspondent RH for each salt is presented in Table 3.5.

Table 3.5- Salt solutions substances for each RH at 23°C.

RH (%)	Substance
23	Potassium acetate ($\text{KC}_2\text{H}_3\text{O}_2$)
53	Sodium bromide (NaBr)
75	Sodium chloride (NaCl)
97	Potassium Sulphate (K_2SO_4)

To study the effect of drying methods (and cycles) the samples were dried using the drying methods explained above in this chapter. Firstly, the samples were placed in desiccators with salt solutions (at 23°C) and after that, they were dried. After the first drying, the samples were placed again in desiccators (at 23°C) and four cycles of drying/wetting were made. The samples were weighed periodically (≈ 3 in 3 days) until constant mass, using a scale with an accuracy of 0,1 mg. Figure 3.7 shows a scheme about the experimental steps used to study the effect of drying methods and their effect on cycles of drying.

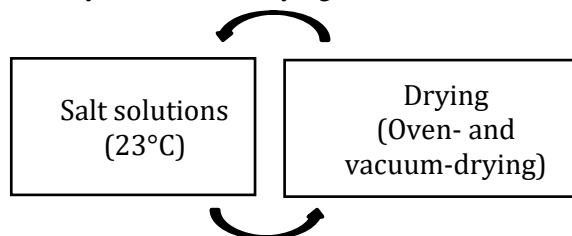


Figure 3.7- Experimental steps used to study the effect of drying methods (and cycles)

Dynamic Vapour Sorption

DVS equipment are used to determine precise isotherms. This equipment measures the gain and loss of moisture by inserting a gas at a specified relative humidity (or partial pressure) over a small sample (with less than 1g) suspended from the microbalance with ultrasensitive recording.

Variations in the gas's relative humidity are automatically calculated by the device when the target condition in mass stability is reached. The DVS equipment in a controlled environment (at 23°C) is shown in Figure 3.8.



Figure 3.8- DVS equipment (Intrinsic 2, SMS®)

3.3.1.3 Moisture buffer value

The hygroscopic potential of a porous material can be quantified using the dynamic sorption-desorption tests, also called **MBV**_{33–75%} test. The practical Moisture Buffer Value (MBV) is defined as the amount of water uptake or release of a material per open surface area, during a certain period of time, when it is subjected to variations in RH of the surrounding air (Peuhkuri et al., 2005).

The protocol of this test was originally defined by the NordTest project (Rode et al., 2005). The test is composed by daily cycles of relative humidity between 33 and 75% at 23°C. A climatic chamber was used to set cycles of either 8h at 75% RH and 16h at 33% RH. The samples tested are isolated on all sides except the face that faces up. The MBV (kg/(m².%RH)) is given by the mass variation per unit of surface area of the open surface (eq.22).

$$MBV_{33-75\%} = \frac{\Delta m}{A(75 - 33)} \quad (22)$$

where Δm is the maximum mass variation of the sample during a cycle and A is the exposed surface area. The **MBV**_{33–75%} can be classified into five categories between negligible and excellent hygroscopic potential, as explained in Rode et al. (2005) – see Figure 3.9

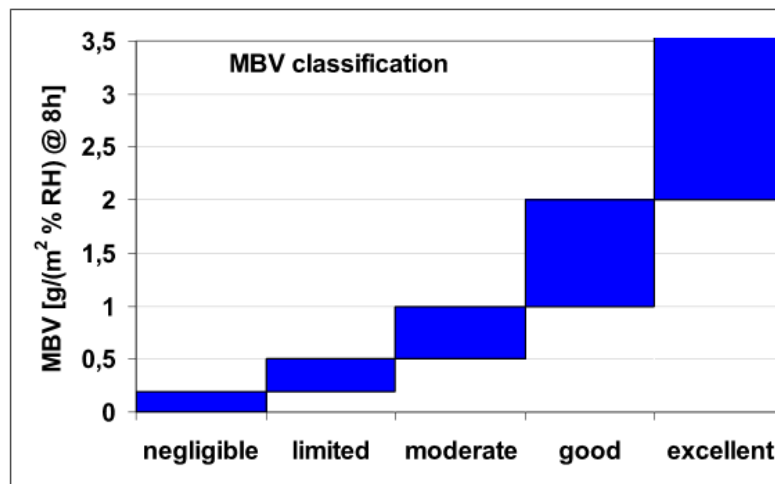


Figure 3.9- Practical Moisture Buffer Value categories (Rode et al., 2005)

Figures 3.10 and 3.11 shows the humidity and temperature inside the climatic chamber during the MBV cycles, measured experimentally, respectively.

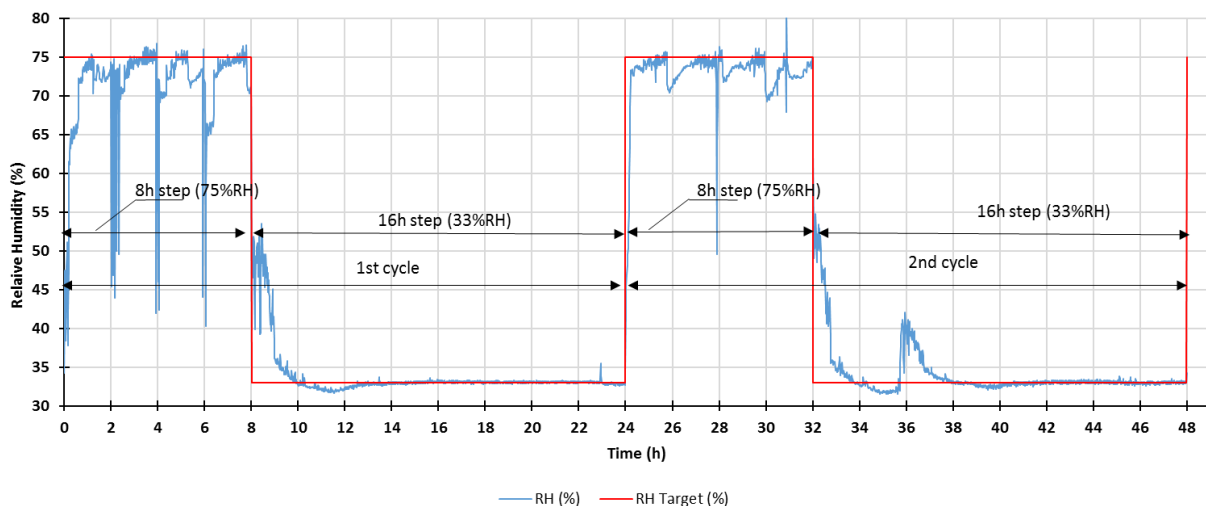


Figure 3.10- RH measured experimentally in MBV cycle.

In the first cycle, the chamber was open every 2h, during the 75% RH step, to weigh the samples. Both humidity and temperature had big peaks during the chamber opening and both had difficulty to reach back to the target value. For each cycle, the climatic chamber was capable of reach a 75-33% RH transition in approximately 6h and 33-75% RH in 30 minutes. The absorption/desorption dynamics can be analysed through the weight variation of the sample in each cycle. It is important to note that the cycles are only interpreted when the difference in moisture uptake per square meter is less than 1% between the values at 9h30 of each daily cycle. The samples used in this test are presented in Figure 3.2, chapter 3.

To study the effect of drying methods (and cycles) a MBV test was done for all the samples. After that, 3 cycles of 75%RH/drying were made. The drying process were made using the same three drying methods explain in this chapter. A last MBV test were made after the cycles to evaluate the impact of drying cycles in the MBV – see Figure 3.12.

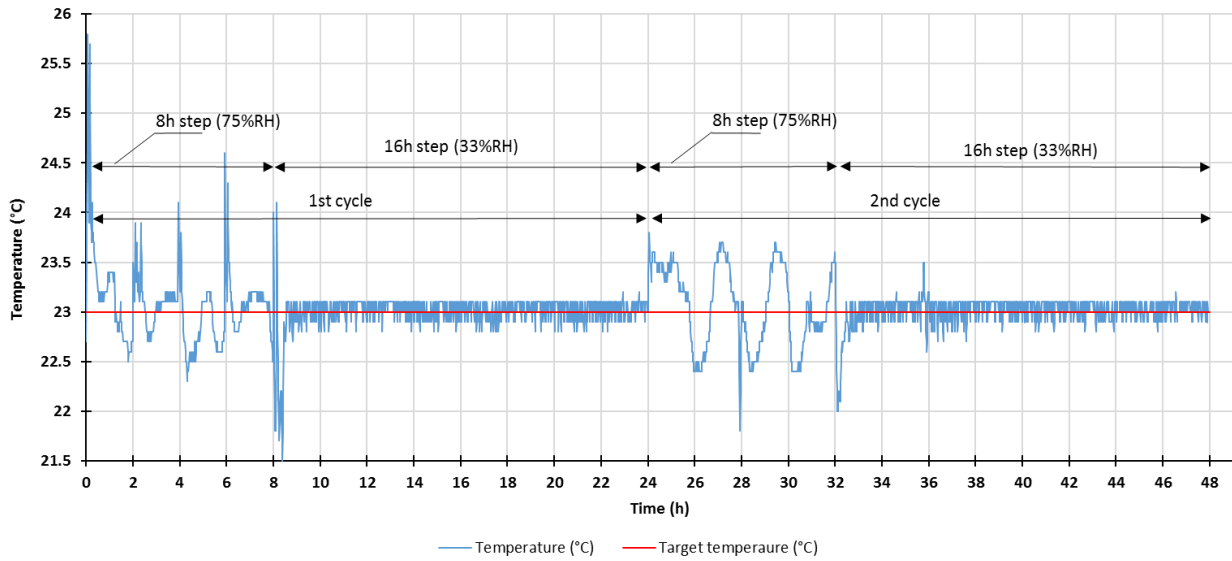


Figure 3.11- Temperature measured experimentally in MBV cycle.

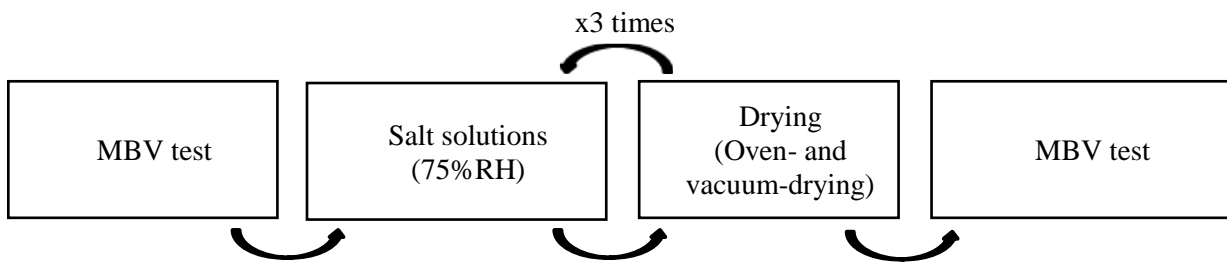


Figure 3.12- Experimental steps used to study the effect of drying methods (and cycles) using the MBV.

3.3.2 Methods used to estimate the impact of temperature

To study the effect of the temperature on the sorption isotherms, three temperatures were tested: $10^{\circ}\text{C}\pm 2^{\circ}\text{C}$, $40^{\circ}\text{C}\pm 2^{\circ}\text{C}$, and the reference temperature of $23^{\circ}\text{C}\pm 2^{\circ}\text{C}$. A climatic chamber (Froilabo) was used to achieve the temperatures of $10^{\circ}\text{C}\pm 2^{\circ}\text{C}$ and $40^{\circ}\text{C}\pm 2^{\circ}\text{C}$, and a conditioning room was used for reaching $23^{\circ}\text{C}\pm 2^{\circ}\text{C}$. Nine samples of each material (CE, EP and HC), three placed at each RH (23, 53 and 75%), were taken stepwise from $10^{\circ}\text{C}\pm 2^{\circ}\text{C}$ to $23^{\circ}\text{C}\pm 2^{\circ}\text{C}$, and then to $40^{\circ}\text{C}\pm 2^{\circ}\text{C}$ and to $23^{\circ}\text{C}\pm 2^{\circ}\text{C}$ again. The samples at 97%RH were taken stepwise like the others, but since to achieve its equilibrium takes longer, they were only brought up to 40°C . The samples were weighed periodically (≈ 3 in 3 days) until constant mass, using a scale with an accuracy of 0,1 mg. Figure 3.13 shows a scheme about the experimental steps used to study the effect of the temperature on the sorption isotherms.

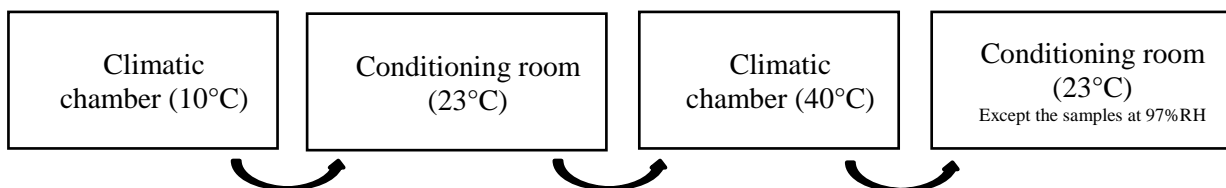


Figure 3.13- Experimental steps used to study the effect of the temperature on the sorption isotherms.

Salt solutions were used to achieve the relative humidity intended. The salt solutions method was the same as the one presented above, in section 3.2.1.2. The equilibrium moisture content for each RH level was reached if the difference of mass between two consecutive measurements was less than 1% of the last measurement.

The samples were dried after the temperature cycles, using the drying methods presented in section 3.2.1.1

4. Effect of drying method (and cycles)

4.1 Initial remarks

As explain in chapter 3, the sorption isotherms were determined using the salt solution method and three different dry methods (vacuum-drying, oven-drying at 60°C and oven-drying at 105°C) were used to dry the samples. The dry mass was obtained by placing five samples of each material in each dry method. It is considered that the dry mass corresponds to a 0% of water content and the RH level is near 0%

The results obtained for each of the materials are presented together, with the evidences of the similarities and the differences between the materials. in the oven at 105°C, 7% in the oven at 60°C and less than 5% in the vacuum system, as shown in chapter 3. After the first drying, the samples were placed in the desiccators at 23°C and four cycles of drying/wetting were made for all the materials – see Figure 3.7 in chapter 3.

4.2 Sorption isotherms before and after drying

The sorption curves, before and after drying, of all the materials, present a linear increase of water content from 0%RH to 55%RH following by a sharp increase until 97% of RH. The water content correspondent to 97%RH before drying, is not presented in the sorption isotherms, since they did not reach the equilibrium at 23°C. Therefore, this two stages (before and after drying) can not be compared but the water content after drying is presented in sorption isotherms to show the shape of the sorption curve. Two values of water content at 75%RH are presented in the sorption isotherms to validate the repeatability of the sorption curves. The difference of water content between sorption curves obtained before and after drying is presented in Table 4.1.

Table 4.1- Percentage of water content between sorption curves before and after drying.

Drying method Material	Oven-drying (60°C)	Oven-drying (105°C)	Vacuum- drying
Compacted earth	0.14-0.25 %	0.22-0.40 %	0.06-0.14 %
Earth plaster	0.05-0.13%	0.14-0.15%	0.04-0.07%
Hemp concrete	0.17-0.38%	1.26-1.70%	0.01-0.14%

It can be seen that the difference of water content, before and after the first drying process of compacted earth, using the oven-drying method at 105°C and at 60°C is higher than using vacuum-drying method. For earth plaster and hemp concrete, the difference of water content using the oven-drying method at 105°C is higher than using the other two methods.

Knowing that these results were taken only when the wet mass were completely stabilised, it can be stated that the vacuum-drying method provides the smallest impact in the first drying of compacted earth and hemp concrete. For earth plaster, using both, oven-drying at 60°C and vacuum-drying methods, provides the smallest impact in the first drying of the material. The oven-drying at 105°C might generate some impact, since the differences in water content values between the sorption curves before and after drying are higher in all the materials using this method. The sorption curves of compacted earth, earth plaster and hemp concrete samples obtained at 23°C, before and after drying the samples using oven-drying at 60°C (a), at 105°C (b) and using vacuum-drying method (c) are presented in Figures 4.1, 4.2 and 4.3, respectively.

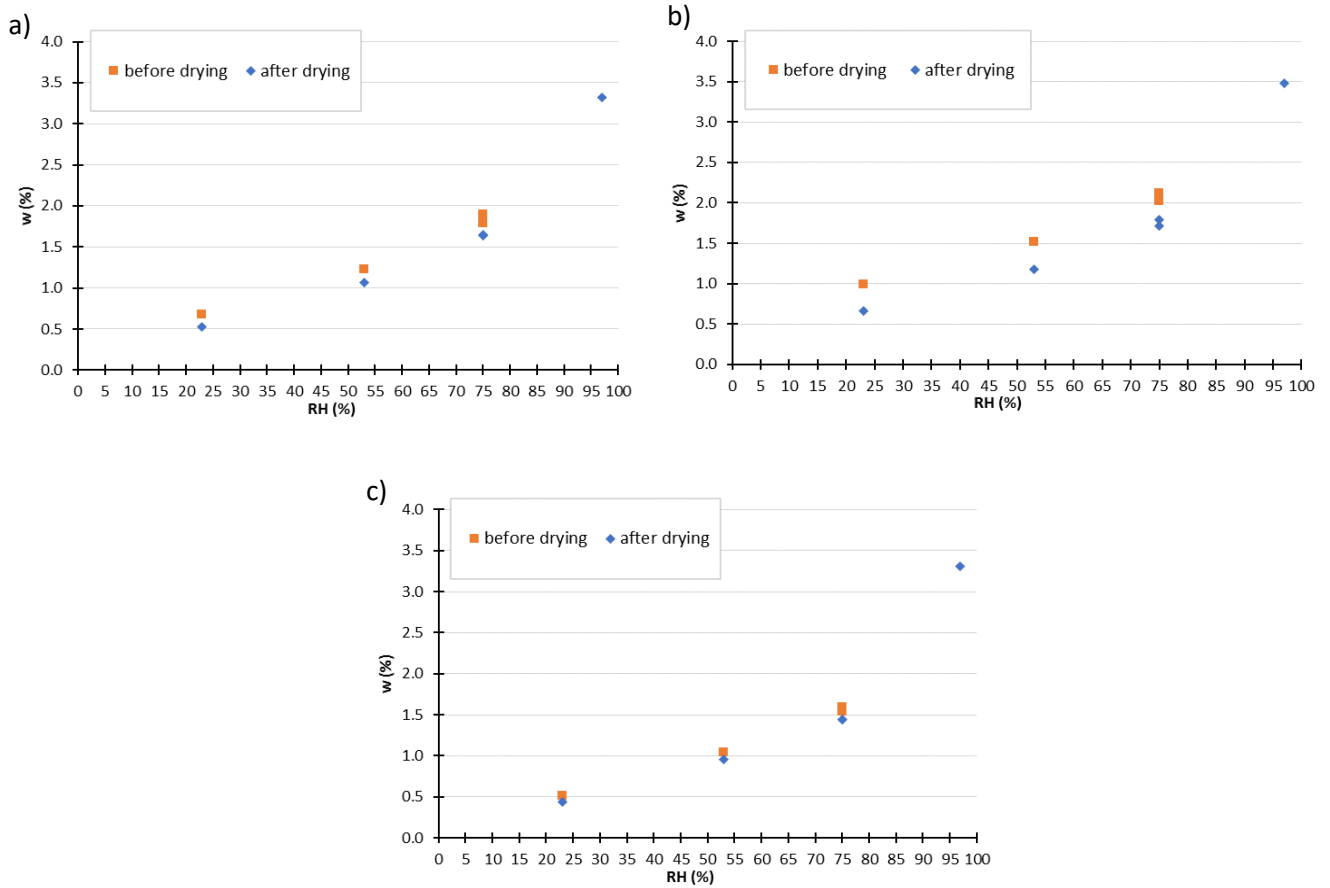


Figure 4.1- Sorption isotherms at 23°C before and after drying for compacted earth, using oven-drying method at 60°C (a), oven-drying method at 105°C (b) and vacuum-drying method (c).

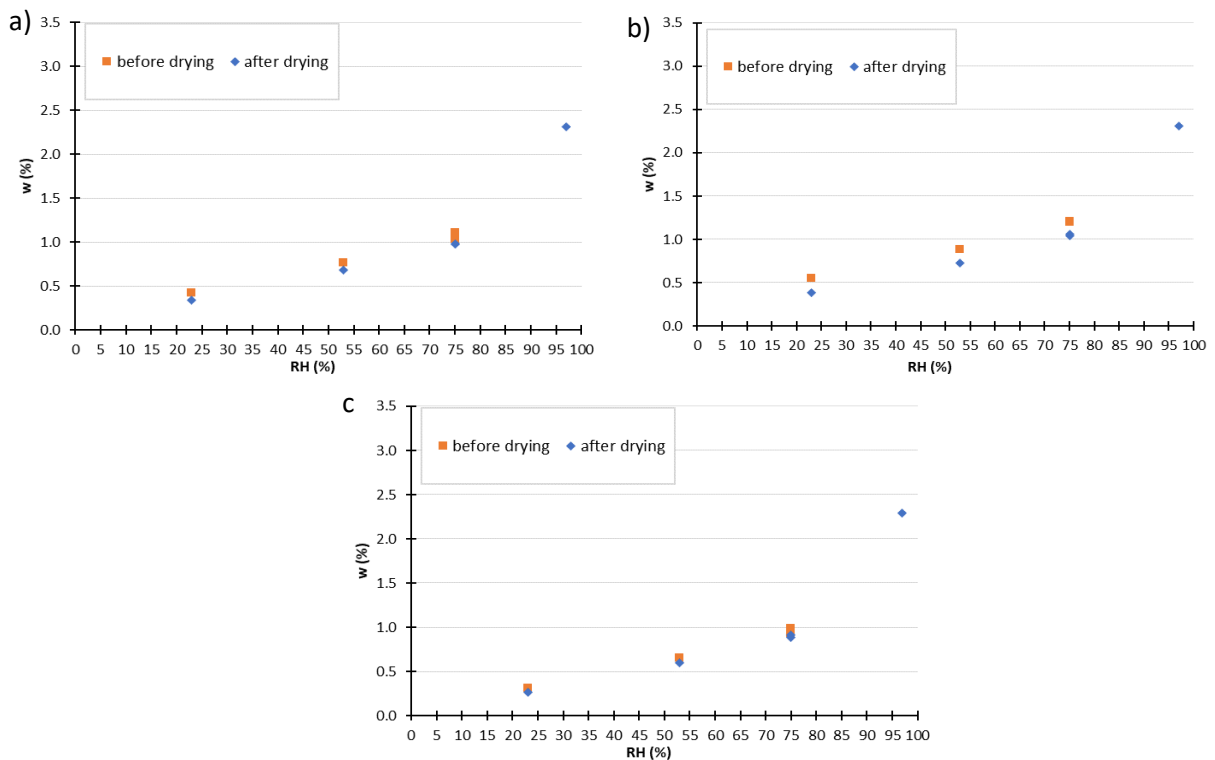


Figure 4.2- Sorption isotherms at 23°C before and after drying for earth plaster, using oven-drying method at 60°C (a), oven-drying method at 105°C (b) and vacuum-drying method (c).

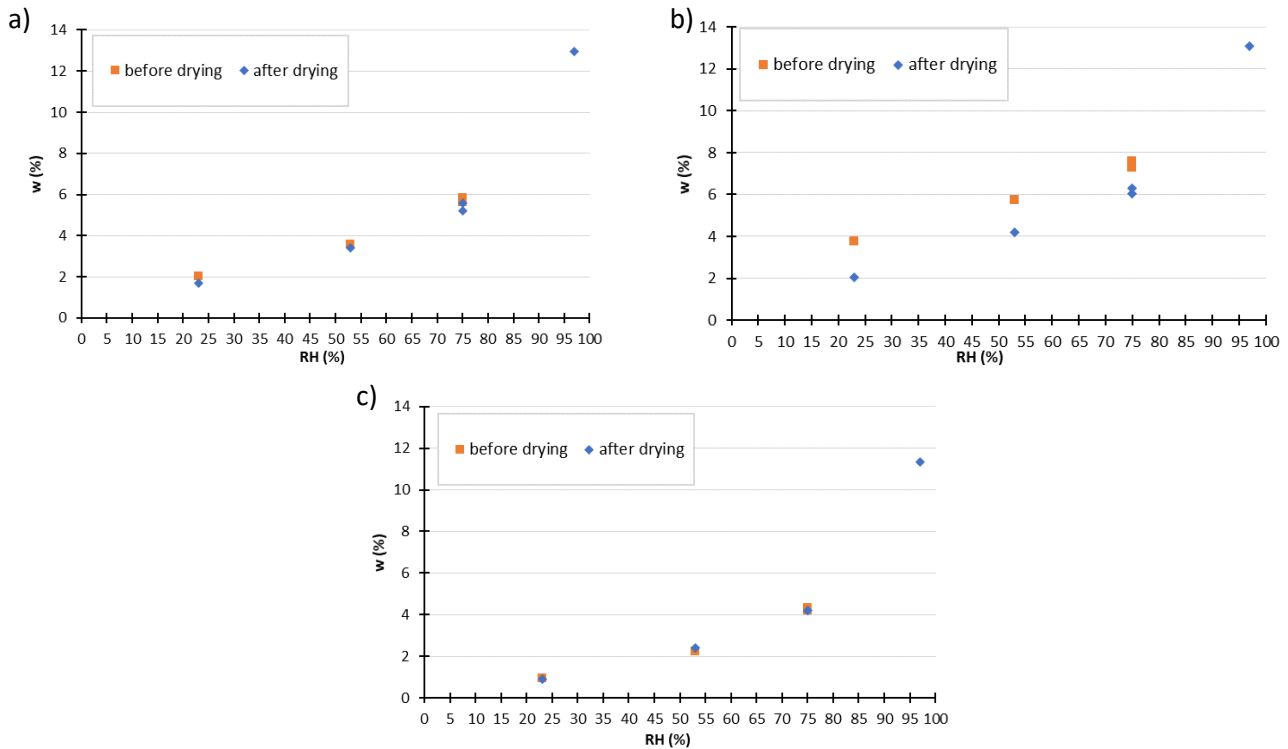


Figure 4.3- Sorption isotherms at 23°C before and after drying for hemp concrete, using oven-drying method at 60°C (a), oven-drying method at 105°C (b) and vacuum-drying method (c).

4.3 Cycles of drying and wetting

Specifically analysing the samples placed at 75%RH, Figures 4.4, 4.5 and 4.6 shows the water content present in the dry mass and in the wet mass, in each cycle, for compacted earth, earth plaster and hemp concrete, respectively. Each figure present cycles using oven-drying method at 60°C, at 105°C and using the vacuum-drying method to dry the samples.

It can be seen, for all the materials, that using oven-drying at 60°C and vacuum-drying is not enough to dry completely the material, since a percentage of water is retained in the pores comparing with the first drying (0.2% in compacted earth and hemp concrete and 0.1% in earth plaster, in the 3rd cycle). Using oven-drying at 105°C the water content in the dry mass at each cycle is practically the same as in the first dry mass, which means that this dry method is effective and does not create hysteresis. The percentage of water in the wet mass presents some small variations, remaining more or less constant at all cycles and no repetitive behavior is noted.

The water content present in the dry mass in each cycle, compared to the first dry mass, and the water content of the wet mass compared to the wet mass before the first drying, are presented in Figures 4.7, 4.8 and 4.9 for compacted earth, earth plaster and hemp concrete, respectively, using the oven-drying method at 60°C (1), at 105°C (2) and using the vacuum-drying method (3), respectively. The values of dry and wet mass presented are the second points of each cycle, as shown in Figures 4.4, 4.5 and 4.6. The zero cycle corresponds to a water content before the first drying of the samples and each cycle corresponds to a timeline of 7 days. This period was chosen in order to the dry and wet mass, of the three different materials, could stabilise in a period of 7 days, having each cycle had the same drying and sorption time. In an overall perspective, the variations of the dry mass are lower than 1% for compacted earth and earth plaster and lower than 2.5% for hemp concrete, which is very small. The variation of the wet mass is much more important, especially at 23%RH for compacted earth, at 23% and 97%RH for earth plaster and for hemp concrete. In addition, the variations of the wet mass after the first cycle are more important than the variations of the dry mass.

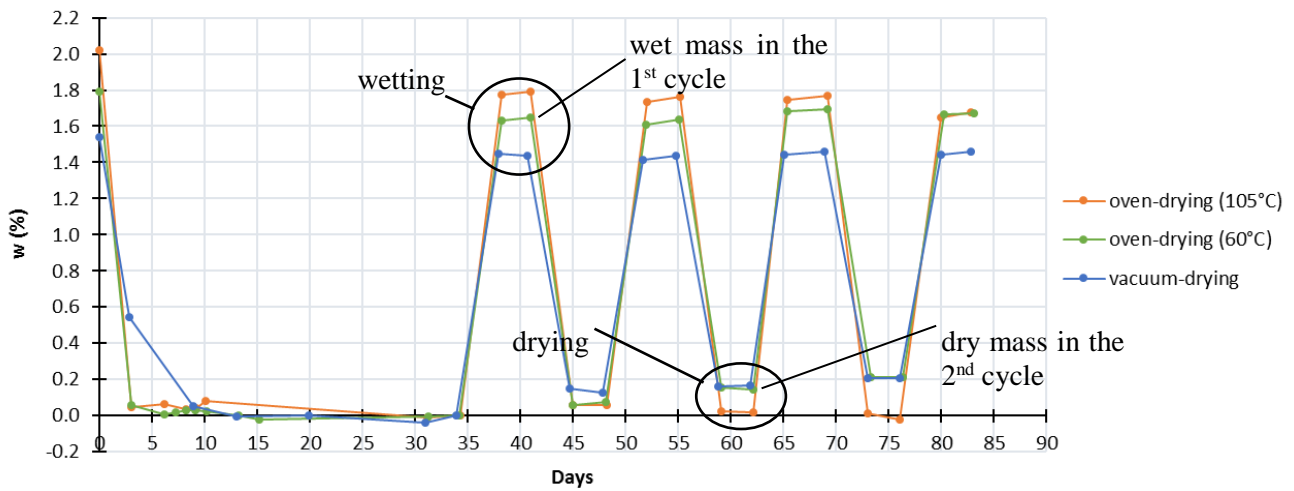


Figure 4.4- Water content in dry mass and wet mass during the drying/wetting cycles, using oven-drying method at 60°C, oven-drying method at 105°C and the vacuum-drying method in compacted earth samples placed at 75%RH.

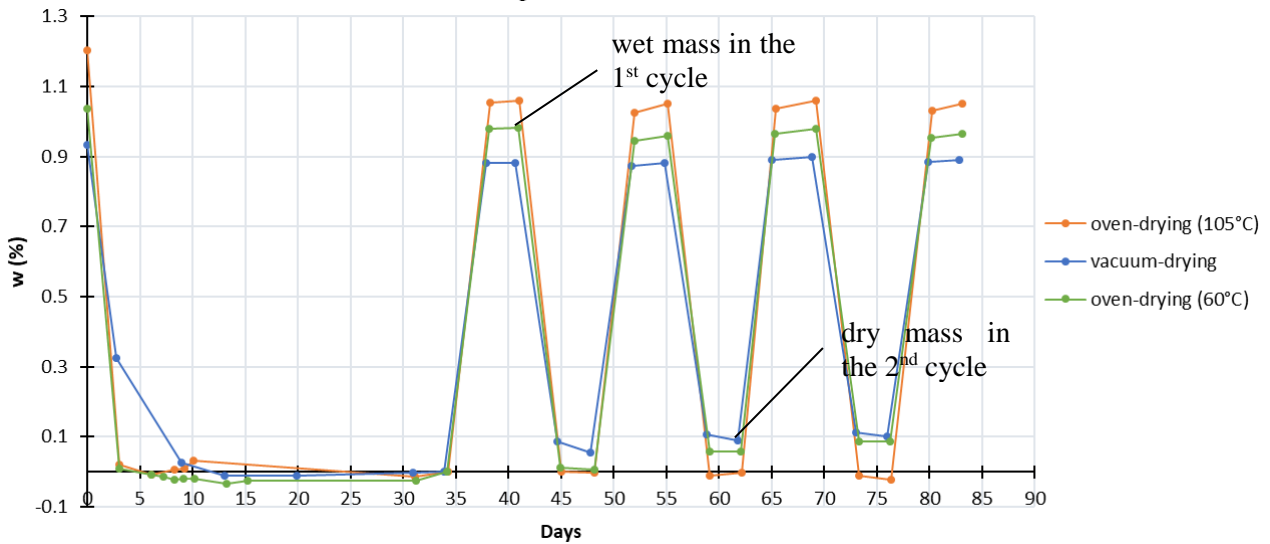


Figure 4.5- Water content in dry mass and wet mass during the drying/wetting cycles, using oven-drying method at 60°C, oven-drying method at 105°C and the vacuum-drying method in earth plaster samples placed at 75%RH.

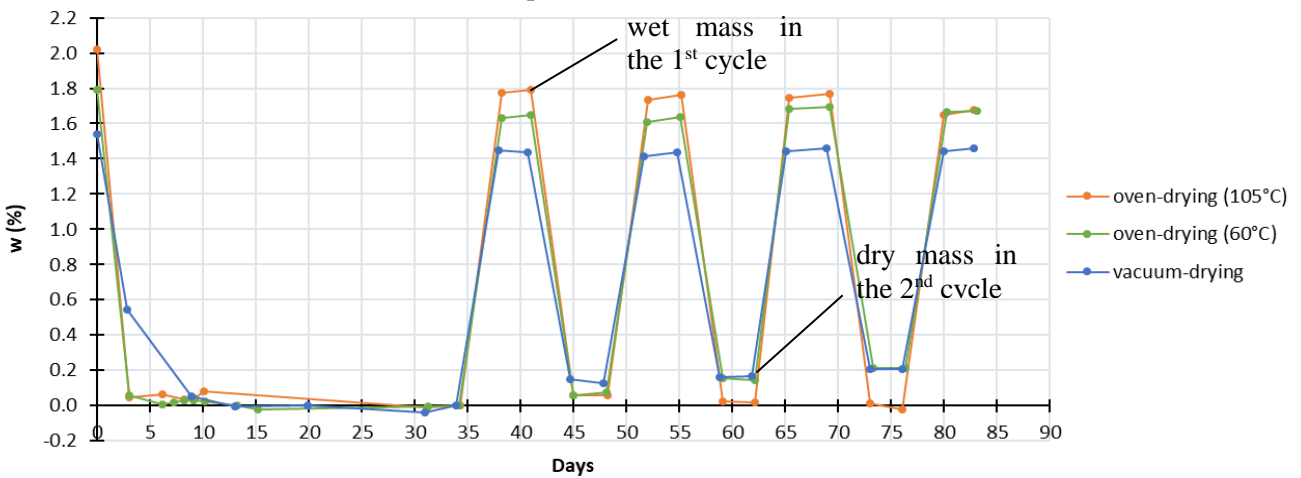


Figure 4.6- Water content in dry mass and wet mass during the drying/wetting cycles, using oven-drying method at 60°C, oven-drying method at 105°C and the vacuum-drying method in hemp concrete samples placed at 75%RH.

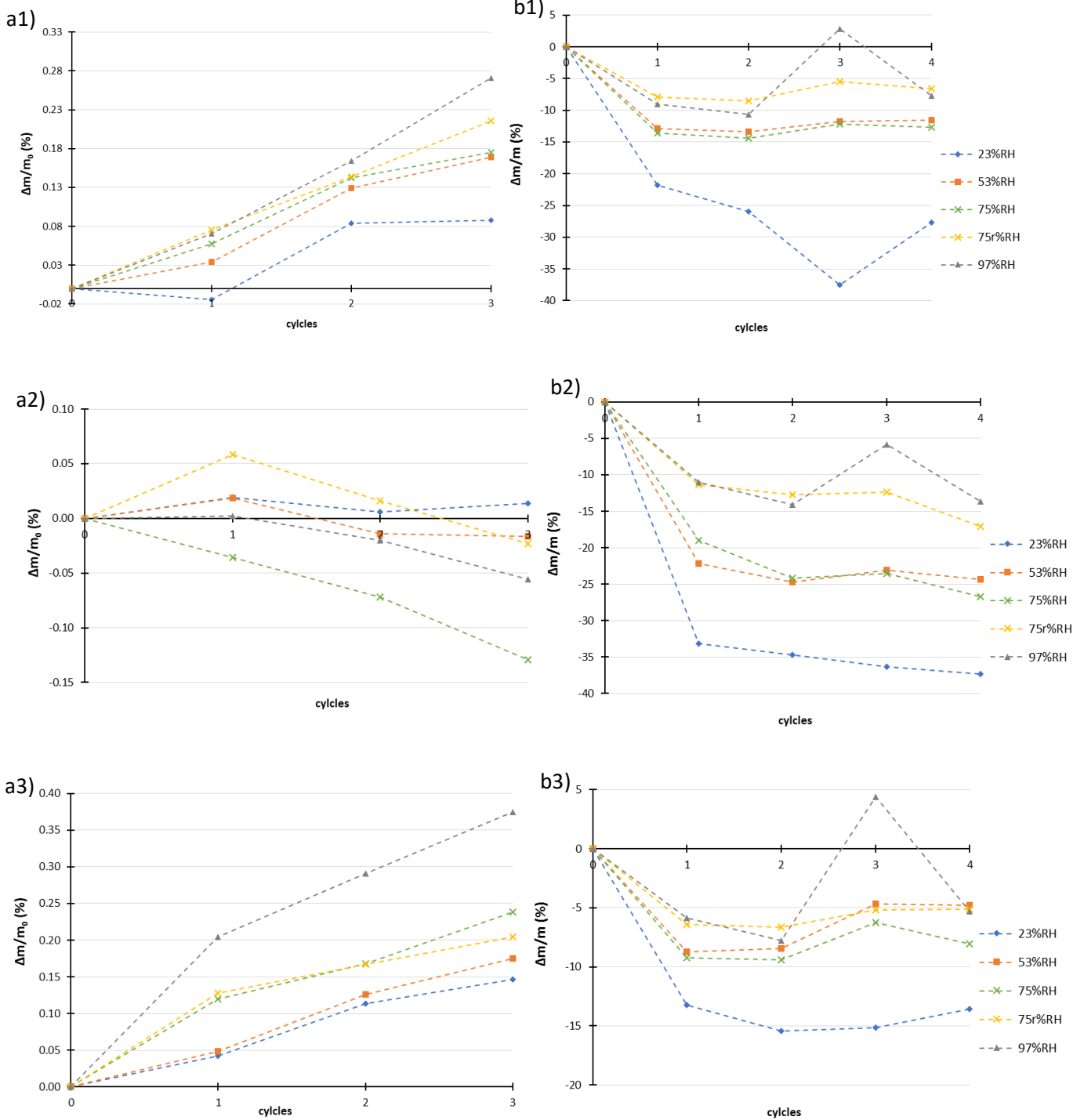


Figure 4.7- dry mass (a) and wet mass (b) in each cycle for compacted earth samples, using oven-drying method at 60°C (1), oven-drying method at 105°C (2) and the vacuum-drying (3).

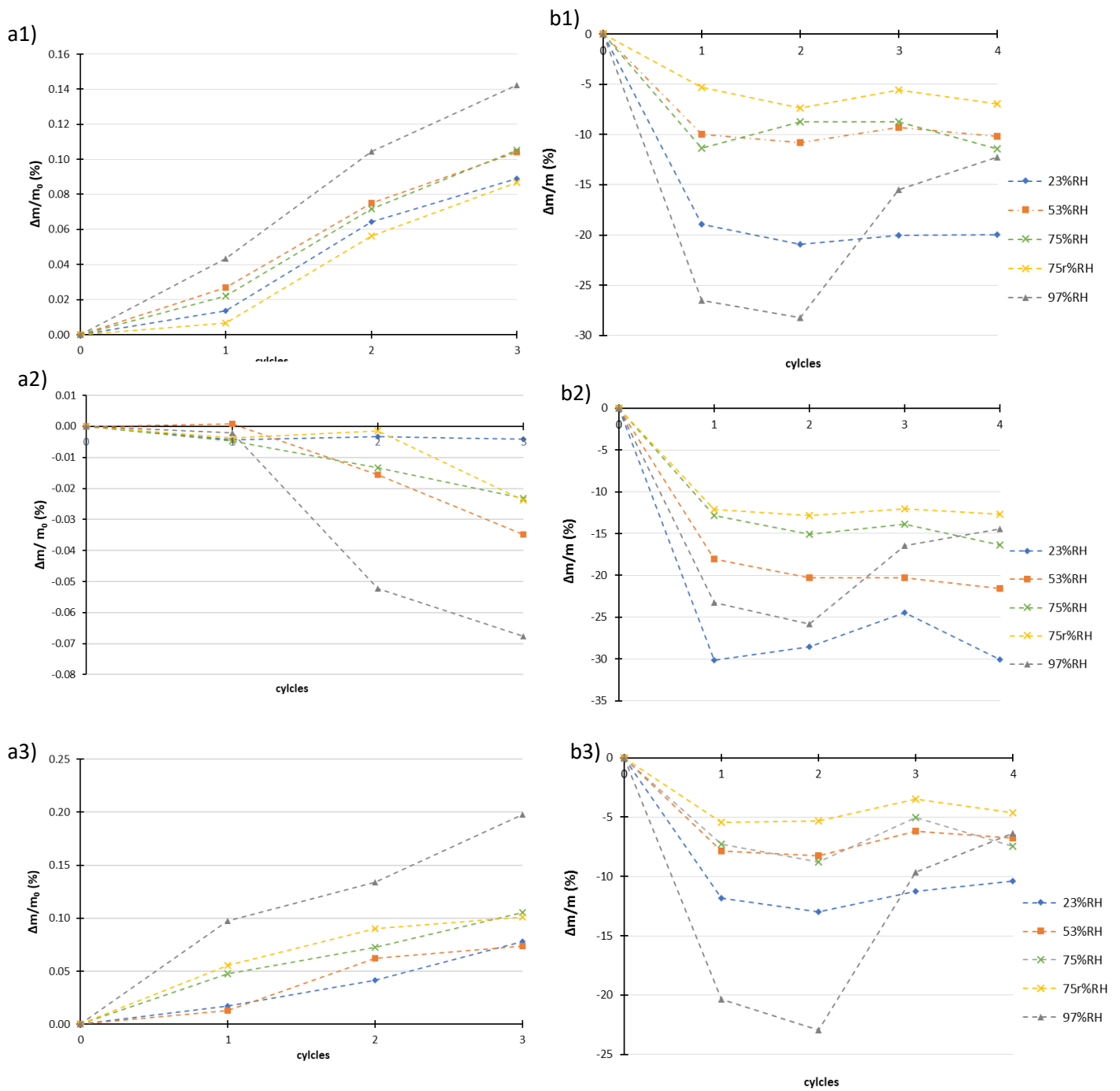


Figure 4.8- dry mass (a) and wet mass (b) in each cycle for earth plaster samples, using oven-drying method at 60°C (1), oven-drying method at 105°C (2) and the vacuum-drying (3).

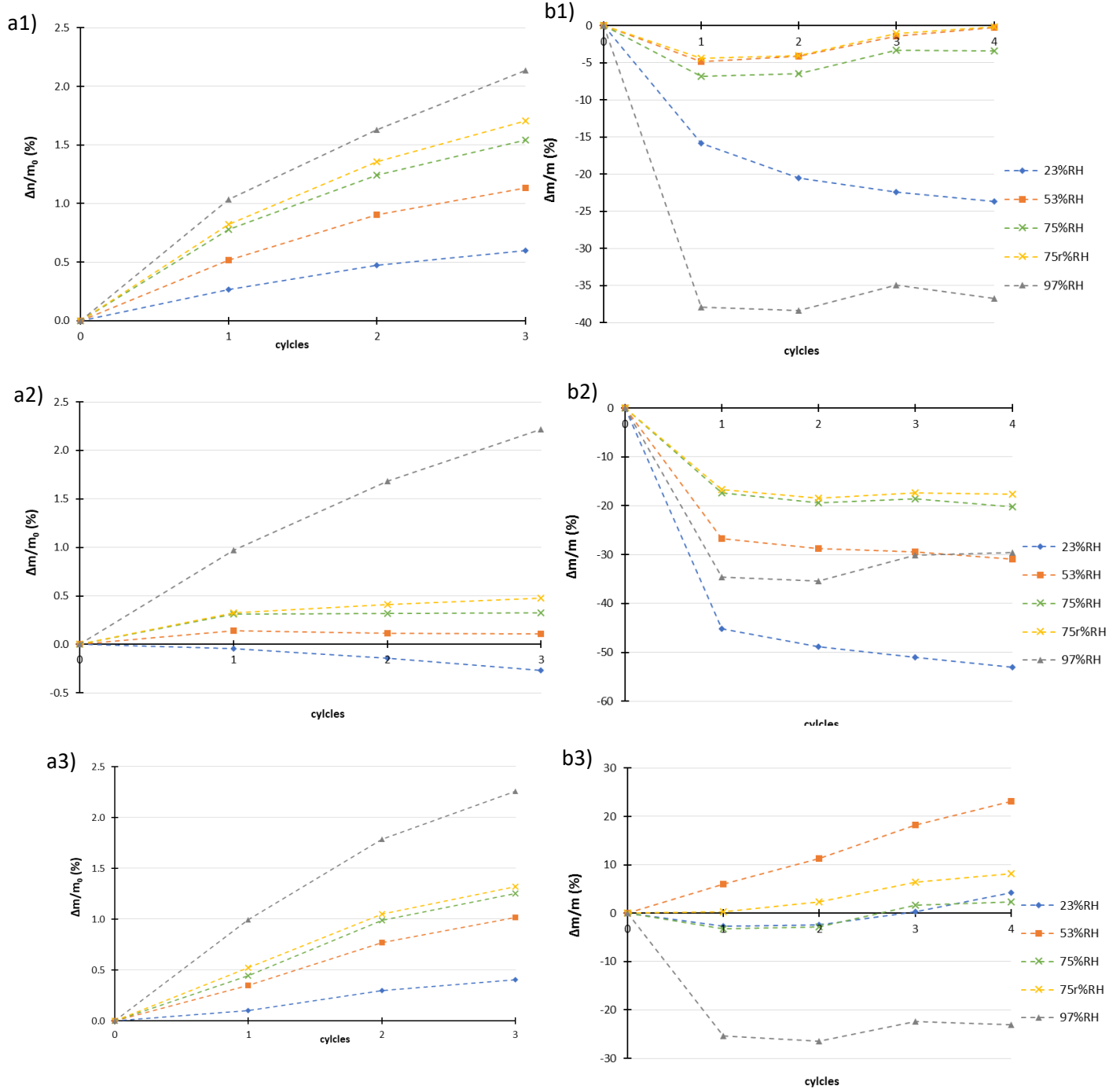


Figure 4.9- dry mass (a) and wet mass (b) in each cycle for hemp concrete samples, using oven-drying method at 60°C (1), oven-drying method at 105°C (2) and the vacuum-drying (3).

4.4 Moisture buffer value

A MBV test was done for all the samples, as explained in chapter 3. After that, three cycles of 75%RH and drying were made. The drying process were made using the same three drying methods explained in

chapter 3. A last MBV test was made after the cycles to evaluate the impact of drying cycles in the MBV – see Figure 3.12.

Figures 4.10, 4.11 and 4.12 present the MBV test for compacted earth, earth plaster and hemp concrete, respectively. The moisture uptake range is between 56.44 and 63.15 g/m² for compacted earth, between 44.0 and 51.3 g/m² for earth plaster and between 61 and 68.9 g/m² for hemp concrete.

For compacted earth is possible to see that the variation of mass is similar for all the samples. These similar variations were expected since all the samples have the same composition and the same dimensions. Earth plaster samples have two different thickness values: 2cm and 4cm, as shown in Table 3.1, chapter 3. The samples with 2cm of thickness are represented as EP 2.1, 2.2 and 2.3, while the samples with 4cm thickness are represented as EP 1.1, 1.2 and 1.3.

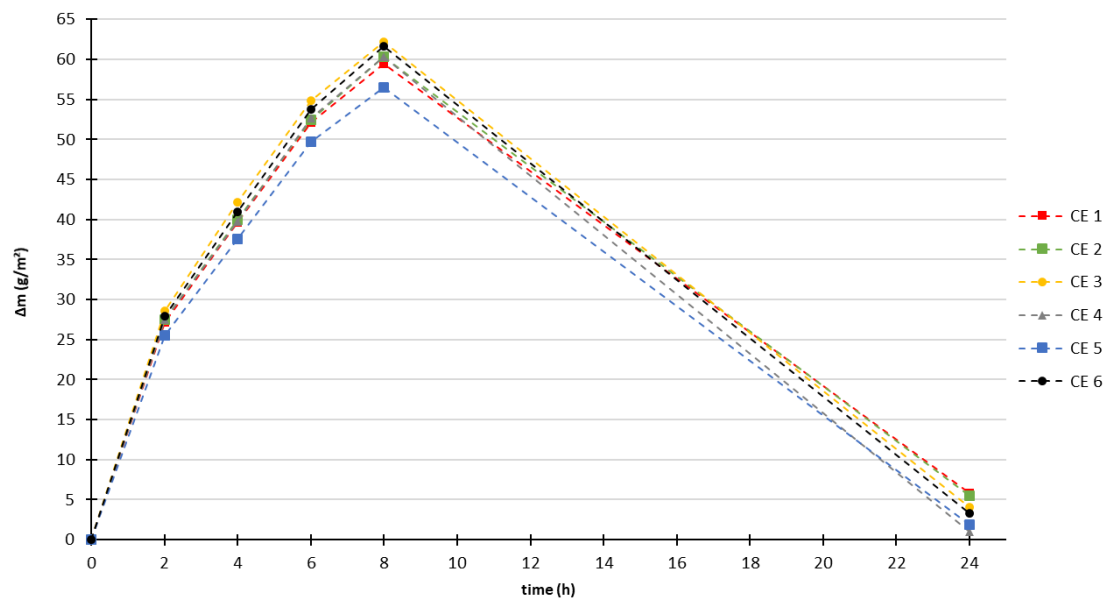


Figure 4.10- MBV test for compacted earth samples.

decreases, since the amount of water absorbed per square meter, after de cycles, decreases about 17% in compacted earth, between 6 and 8% in the 2cm earth plaster samples, between 4 and 13% in the 4cm earth plaster samples and between 4 and 15% in hemp concrete.

To analyse the impact of the drying methods, for all the materials, used in the drying/wetting cycles, the differences of moisture uptake per square meter, obtained using the MBV test, before and after the drying cycles are presented in Table 4.2, 4.3, 4.4 and 4.5 for compacted earth, earth plaster with 2cm of thickness, earth plaster with 4cm of thickness and hemp concrete, respectively. It can be seen that the vacuum-drying is the method that leads to the smallest impact for compacted earth and hemp concrete. For earth plaster, the oven-drying at 60°C and the vacuum drying are the methods that less impacts the moisture absorption. The results of earth plaster with 2cm of thickness are dubious as it shows that using oven-drying at 105°C creates less impact when all the other tests indicate the counter. It should be noted that the results given by the climatic chamber, that leads to an assessment where the absorption capacity decrease after drying cycles, may be related to errors, such as loss of mass during samples handling or due to fluctuations in temperature and humidity occurring within the climatic chamber, as shown in Figures 3.10 and 3.11, in chapter 3

The six CE samples presented in Figure 4.13 are composed of the exact same materials, the same fabrication method and the same dimensions, as shown in Table 3.1 and 3.2. CE 2 and 3 were dried using

the oven-drying method at 60°C, CE 1 and 6 using the oven-drying method at 105°C and CE 4 and 5 using the vacuum-drying method.

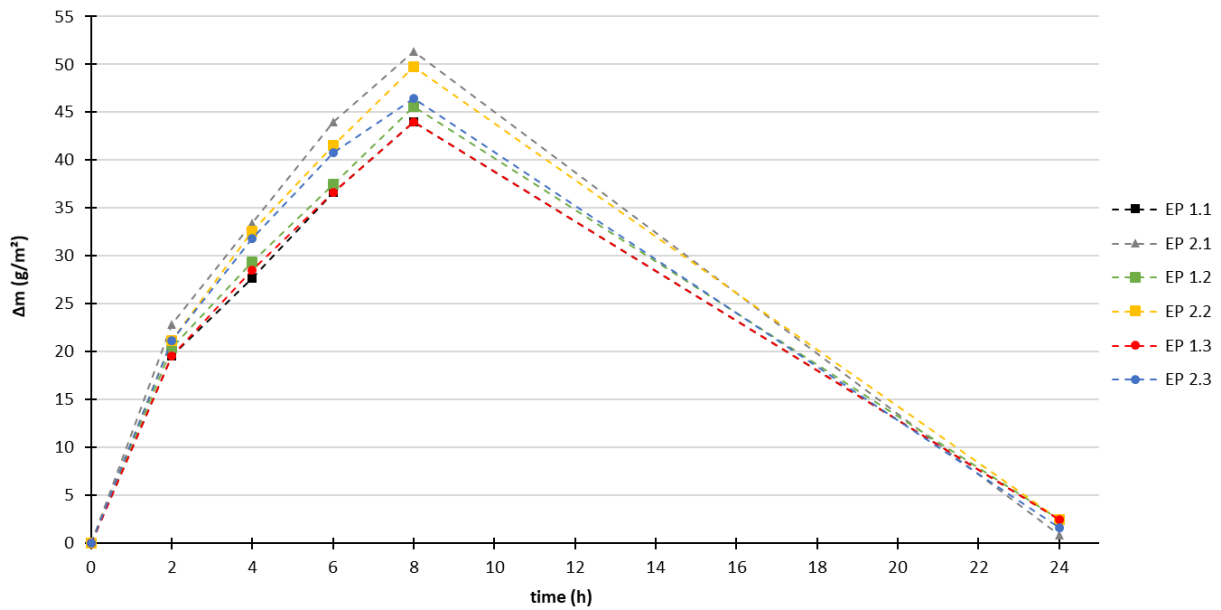


Figure 4.11- MBV test for earth plaster samples.

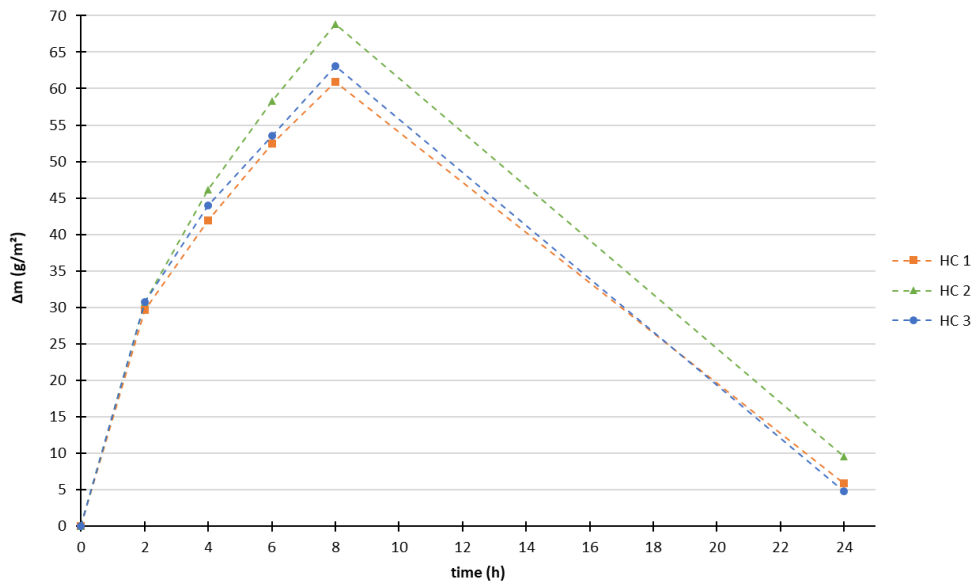


Figure 4.12- MBV test for hemp concrete samples.

Figures 4.13, 4.14, 4.15 and 4.16 show the first and the second MBV tests, which corresponds to the test before and the test after the drying cycles for compacted earth, earth plaster with 2cm thickness, earth plaster with 4cm thickness and hemp concrete, respectively. It can be seen that the moisture uptake

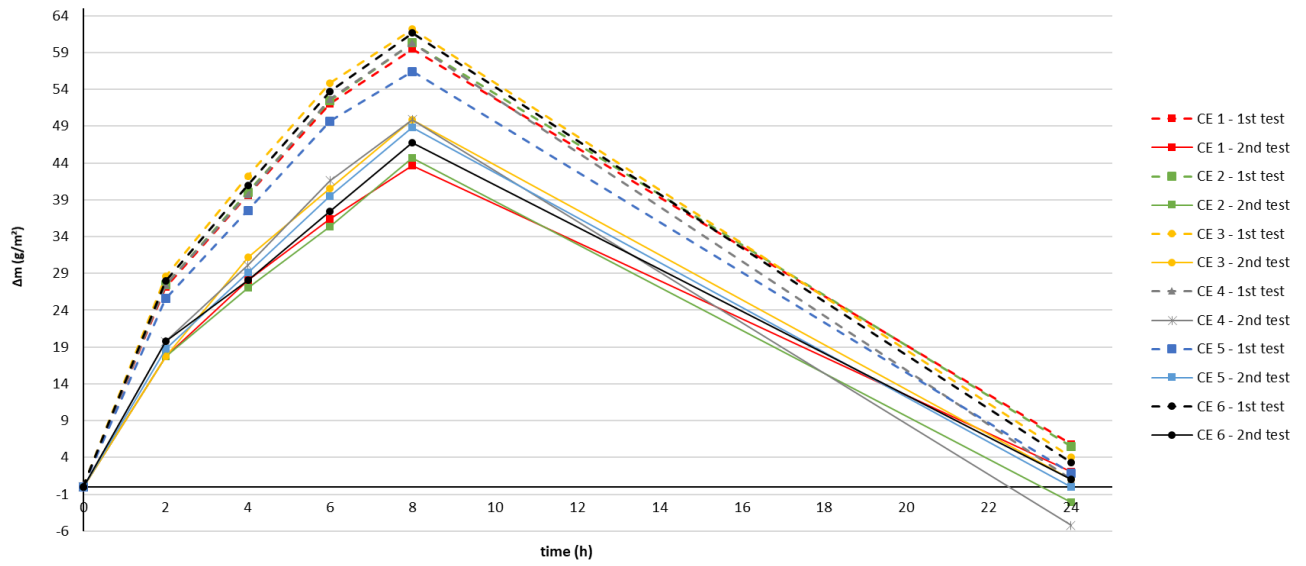


Figure 4.13- MBV test before (1st test) and after (2nd test) the drying cycles, for compacted earth samples.

Table 4.2- Difference in moisture uptake per square meter obtained through the MBV test, before and after the drying cycles, using each drying cycle, for compacted earth samples.

Samples	Drying method	Oven-drying (60°C) (g/m ²)	Oven-drying (105°C) (g/m ²)	Vacuum-drying (g/m ²)	Difference in moisture uptake (%)
CE 1 and 6			14.8-15.8		24-26
CE 2 and 3		12.5-15.5			20-26
CE 4 and 5				7.5-10.5	13-17

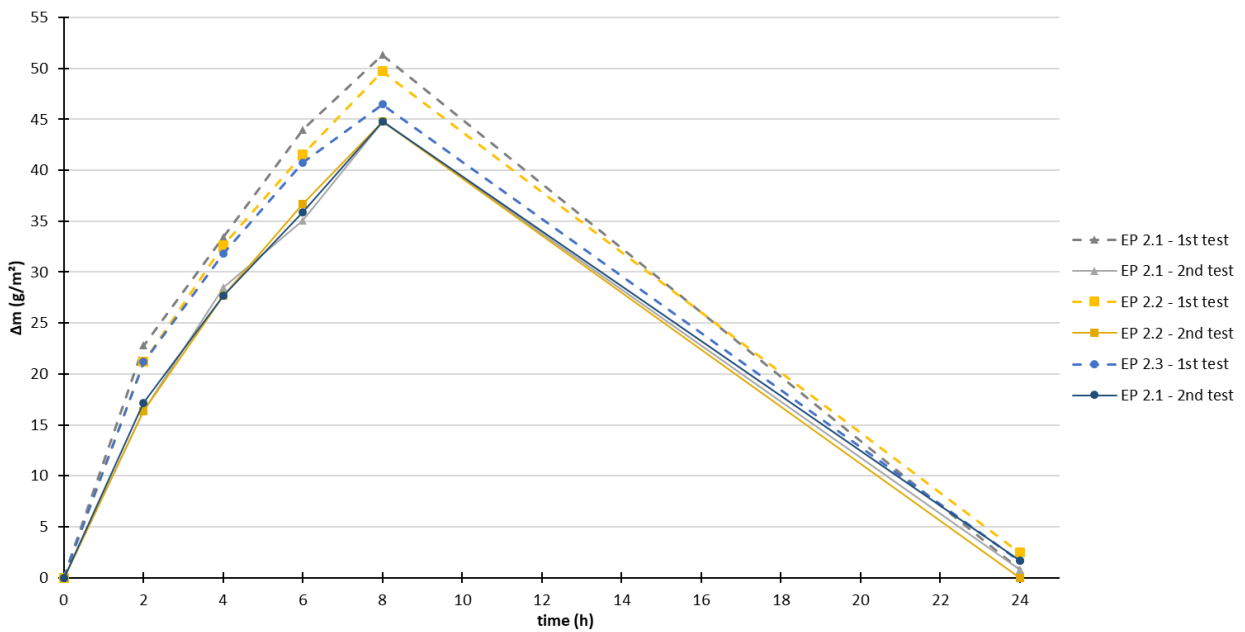
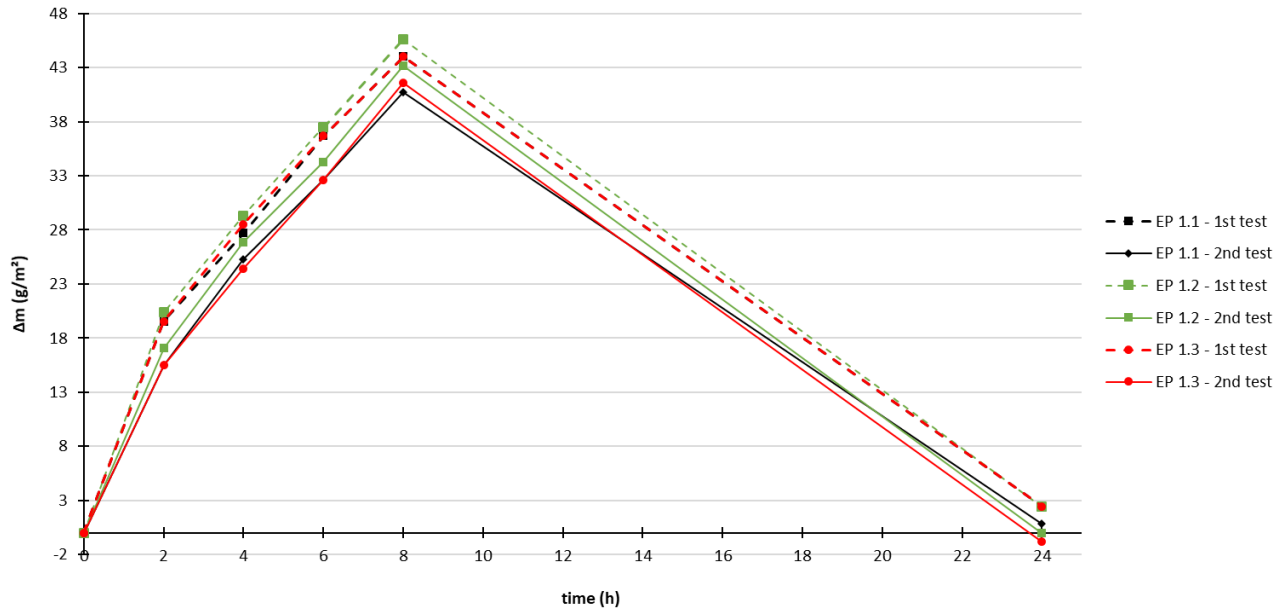


Figure 4.14- MBV test for earth plaster samples, with 2cm of thickness.

Table 4.3- Difference in moisture uptake per square meter obtained through the MBV test, before and after the drying cycles, using each drying cycle, for earth plaster samples, with 2cm thickness.

Drying method Samples	Oven-drying (60°C) (g/m ²)	Oven-drying (105°C) (g/m ²)	Vacuum- drying (g/m ²)	Difference in moisture uptake (%)
EP 2.1	6.5 g/m ²			13%
EP 2.2		4.9 g/m ²		10%
EP 2.3			1.6 g/m ²	4%

**Figure 4.15-** MBV test for earth plaster samples, with 4cm of thickness.**Table 4.4-** Difference in moisture uptake per square meter obtained through the MBV test, before and after the drying cycles, using each drying cycle, for earth plaster samples with 4cm of thickness.

Drying method Samples	Oven-drying (60°C) (g/m ²)	Oven-drying (105°C) (g/m ²)	Vacuum- drying (g/m ²)	Difference in moisture uptake (%)
EP 1.1		3.3		7
EP 1.2			2.4	5
EP 1.3	2.4			5

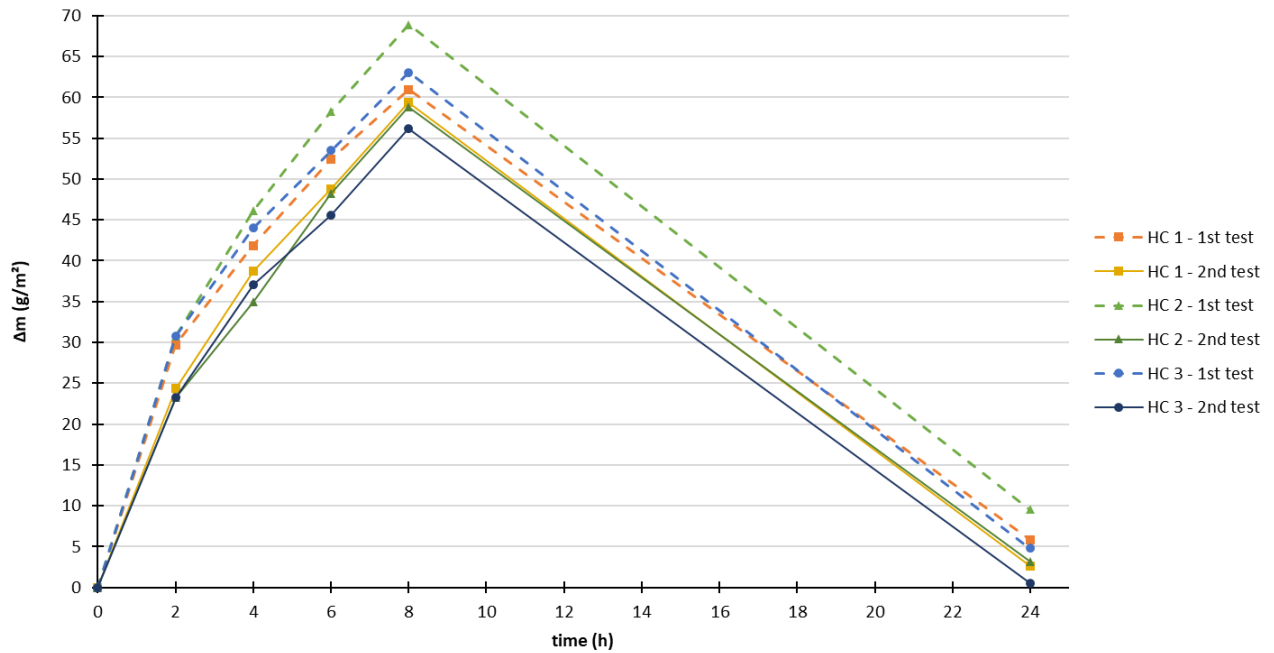


Figure 4.16- MBV test for hemp concrete samples.

Table 4.5- Difference in moisture uptake per square meter obtained through the MBV test, before and after the drying cycles, using each drying cycle, for hemp concrete samples.

Drying method Samples	Oven-drying (60°C) (g/m ²)	Oven-drying (105°C) (g/m ²)	Vacuum- drying (g/m ²)	Difference in moisture uptake (%)
HC 1			1.6	3
HC 2		10.0		15
HC 3	6.8			11

Comparing the Moisture Buffer Value of all the materials before and after the drying cycles it can be seen that the MBV decreases in a range of 0.3 g/(m².%RH) for compacted earth, 0.1 g/(m².%RH) for earth plaster and 0.2 g/(m².%RH) for hemp concrete. Despite the decrease observed in moisture buffer capacity, the classification remains in “good” for all the materials.

Table 4.6- Moisture Buffer Value classification for compacted earth, earth plaster with 2 and 4cm of thickness and hemp concrete.

	<i>MBV</i> _{33-75%} before drying cycles g/(m ² .%RH)	<i>MBV</i> _{33-75%} after drying cycles g/(m ² .%RH)	Classification
CE	≈1.3-1.5	≈1.0-1.2	Good
EP (2cm thickness)	≈1.1-1.2	≈1.1	Good
EP (4cm thickness)	≈1.0-1.1	≈1.0	Good
HC	≈1.5-1.6	≈1.3-1.4	Good

4.5 Discussion

The hemp concrete adsorbs more moisture than the compacted earth and the earth plaster in terms of gravimetric water content. This is due to the high porosity of hemp concrete, since it has four different sizes of pores, as explained in chapter 2. As expected, the compacted earth adsorbs more moisture than the earth plaster since it has higher clay content. The fibers of the earth plaster increase the porosity, but since it has less surface area of clay, less negative charges exist at the surface and therefore, less water molecules are absorbed.

By analysing the results with the ones presented by Gallé (2001) the vacuum-drying and the oven-drying at 60°C are similar methods, since the data of total water porosity obtained through these two drying methods are very close.

Drying methods

When earth building materials are submitted to drying process, it means that all the free water inside the pores will be removed. This process creates stress related with the surface tension of the receding water menisci and might generate a collapse of some of the fine pores and consequently an increase of the volume of larger pores. Since the fine pores largely confer the adsorption process, from the moment the first drying occurs, some of the fine pores can degrade and so the material tends to be less able to adsorb water. It is generally considered that, at 105°C, only free water is removed from porosity. This temperature is usually selected mainly because it is a quicker drying method. In fact, in relation to the hemp concrete, the hydration of the cement starts at lower temperatures, and therefore, pore structure is thus affected. As shown for all the three materials studied, oven-drying at 105°C might generate a collapse of some of the fine pores, which largely confer the adsorption process, and may cause chemical reaction, since the sorption curves after drying do not reach the sorption curves before drying. These results confirm the impact of oven-drying at 105°C in earth building materials. For all the RH levels, the oven-drying at 105°C is the method which allows a lower dry mass and therefore a greater amount of water content in each RH level. Physical phenomena and chemical reaction happen when the adsorption related to the drying process occurs and therefore, oven-drying at 105°C probably leads to more significant reactions, such as the release of water from the formulation and other components, than with the other two methods.

All the materials have higher moisture content values before drying the samples than after, which means that the first drying process, in biobased and raw earth materials, might influence the behaviour of moisture uptake. The first drying process affects the behaviour of the material from then onwards but vacuum-drying and oven drying at 60°C are the methods studied in this dissertation that further mitigate this effect. For compacted earth and hemp concrete, the vacuum-drying method is the method that allows less impact in the first drying of the material. For earth plaster, both vacuum-drying and oven-drying at 60°C are suitable for a non-impact drying.

Cycles of drying and wetting

In terms of drying/wetting cycles, using vacuum and oven-drying at 60°C, all the materials experience a small variation in dry mass after the first drying ($\approx 0.1\%$ for earth plaster and $\approx 0.2\%$ for compacted earth and hemp concrete), which means that these drying methods lead to a small moisture hysteresis. More cycles would have to be made to see in the long run whether the percentage of water in the dry mass stabilizes and when that happens. Using oven-drying at 105°C, hysteresis is not observed, since the water content in dry samples, of all the materials, remained close to 0%. Thus, this is an affective method in terms of drying. So, there is no important variations of the dry mass whatever the drying method, but it is noticed an important variation between the initial value and the value after the first cycle for the wet mass. This effect is more important using oven-drying at 105°C, and it is more limited using the vacuum-drying process, since no important variation in the wet mass after the first cycle is noticed.

The adsorption time in the cycles test was not sufficient, since it can be seen that the wet mass is not completely stabilized, but the associated error is the same for all methods, as the same time was used for the different methods.

Moisture Buffer Value

According to the test protocol, the MBV_{practical} has to be measured at 23°C. Variation of temperature in the climatic chamber may severely affect the MBV_{practical} measurements, since temperature variations change the test conditions due to varying temperature and partial vapour pressure gradients in and around the test sample. Therefore, looking at the experimental measurements made inside the climatic chamber it can be seen that the temperature and RH suffers some variations related to the opening of the camera and with the atmospheric variations outside the camera. Thus, the data presented must be evaluated with special care.

The MBV tests show an impact in biobased and raw earth materials when exposed to drying/wetting cycles, since the moisture uptake per square meter decreases after the drying cycles – see Table 4.7. This decrease is lower using vacuum-drying for compacted earth and hemp concrete samples. For earth plaster with 2cm of thickness, the results show that using oven-drying at 60°C and vacuum-drying the difference in moisture content is lower than using oven-drying at 105°C. For earth plaster with 4cm of thickness, oven-drying at 105°C and vacuum-drying are the methods that induce less difference in moisture uptake induce. Analysing the results given by the sorption isotherms and given by the cycles of drying/wetting using sorption isotherms, it can be stated that for earth plaster, the oven-drying at 60°C and the vacuum-drying are the methods that less impact the material. Therefore, knowing that the climatic chamber underwent some temperature variations, the results given for the earth plasters with 2cm of thickness and dried in the oven-drying at 60°C, using MBV, must be confirmed, since the results do not match with the previous ones, given by the sorption isotherms and the drying/wetting cycles.

Table 4.7- Difference in moisture uptake after the drying/wetting cycles, for all the materials, depending on the dry methods used.

Material \ Drying method	Difference in moisture uptake		
	Oven-drying (60°C)	Oven-drying (105°C)	Vacuum-drying
CE	20-26%	24-26%	13-17%
EP (2cm thickness)	13%	10%	4%
EP (4cm thickness)	5%	7%	5%
HC	11%	15%	3%

5. Effect of the temperature on the sorptions curves

5.1 Initial remarks

The sorption curves were obtained with the desiccator method with the salts reported in the Table 3.5., chapter 3. To study the influence of the temperature on the sorption curves, three temperatures were tested: $10\pm 2^\circ\text{C}$, $40\pm 2^\circ\text{C}$, and the reference temperature of $23\pm 2^\circ\text{C}$, as explained in section 3.2.2 – see Figure 3.13. The samples, of compacted earth, earth plaster and hemp concrete, at 97%RH were only brought up to 40°C and therefore, the last step of 23°C was skipped

The samples were only dried after the temperature cycles. So, the water content presented was only calculated after the drying process. Three samples of each material, at each RH, were used and each of the three samples was dried using different drying methods (oven-drying at 60°C , oven-drying at 105°C and vacuum-drying), as explained in section 3.2.1.1. The drying methods are not the focus of study of this chapter and, therefore, only the results given by the vacuum-drying are presented, because all the drying methods have shown the same trend. The remaining results, using the other two drying methods on the samples, are presented in the appendix.

5.2 Sorption isotherms at different temperatures

In order to understand the variation of sorption curves with temperature, a comparison between sorption curves at 10°C , 23°C (1st stage), 40°C and 23°C (2nd stage) were made. Figures 5.1, 5.2 and 5.3 shows the experimental results of sorption curves for the temperature steps for compacted earth, earth plaster and hemp concrete, respectively. It can be seen that the sorption curve at 23°C (1st stage) is similar to the 23°C (2nd stage). Therefore, the non-temperature hysteresis behaviour can be confirmed for all the materials. The point correspondent to 97%RH in the sorption curve at 23°C (2nd stage) was not plotted since the samples were not taken to the 2nd stage of 23°C , as explained before. The sorption isotherms are presented in partial pressure instead of relative humidity to see clearly the sorption curves at different temperatures.

By analyzing the experimental results of the sorption isotherms at 23°C with the results given by the DVS for earth plaster, it can be seen that the experimental results given by the salt solutions have a good approach to the DVS curve and therefore the experimental results are valid. The DVS results were taken from previous experiments made in LTDS, ENTPE.

Since the samples were only dried after the temperature cycles and since they were dried using different drying methods, the column charts are presented in “water content estimated”, using the dry mass reached through the vacuum-drying method. These estimations were made through the equation 8, chapter 2, where the reference dry mass was proportionally calculated from the percentage of water content that the samples have lost after being dried using vacuum drying, as shown in eq. 22.

$$m_{0\ ref} = m - \left(m * \frac{w_{ref}}{100}\right) \quad (22)$$

where m is the mass before drying and w_{ref} is the water content taken from the sample, using vacuum-drying.

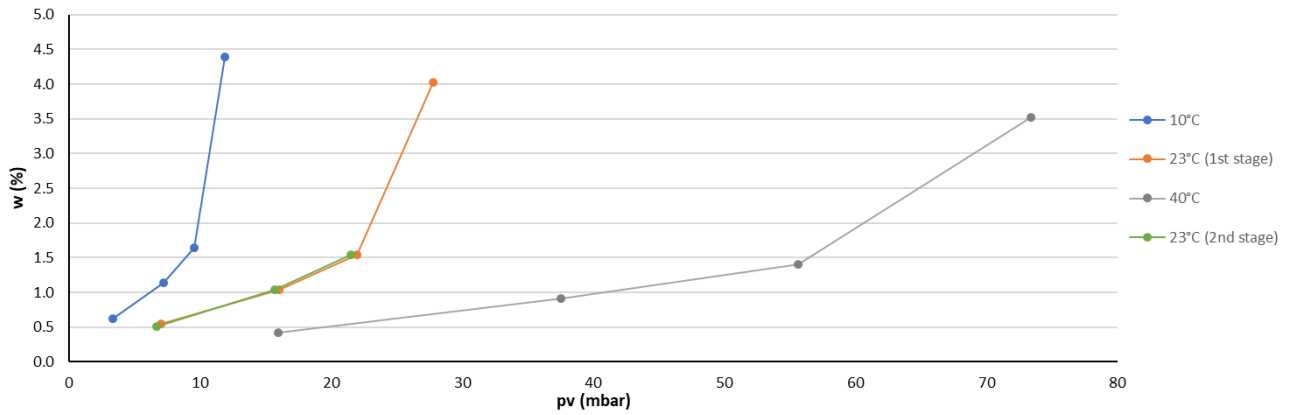


Figure 5.1- Sorption isotherms at each temperature step, for compacted earth,

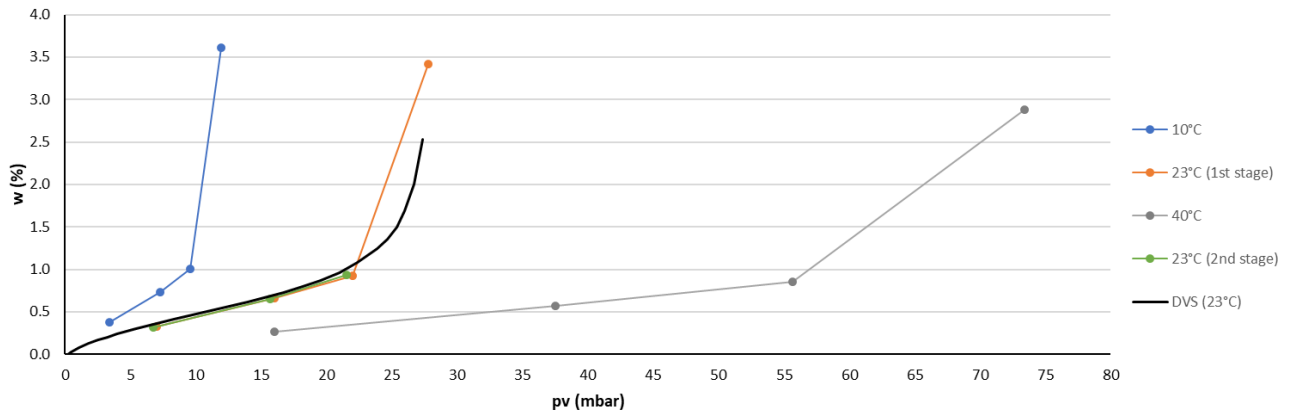


Figure 5.2- Sorption isotherms at each temperature step, for earth plaster.

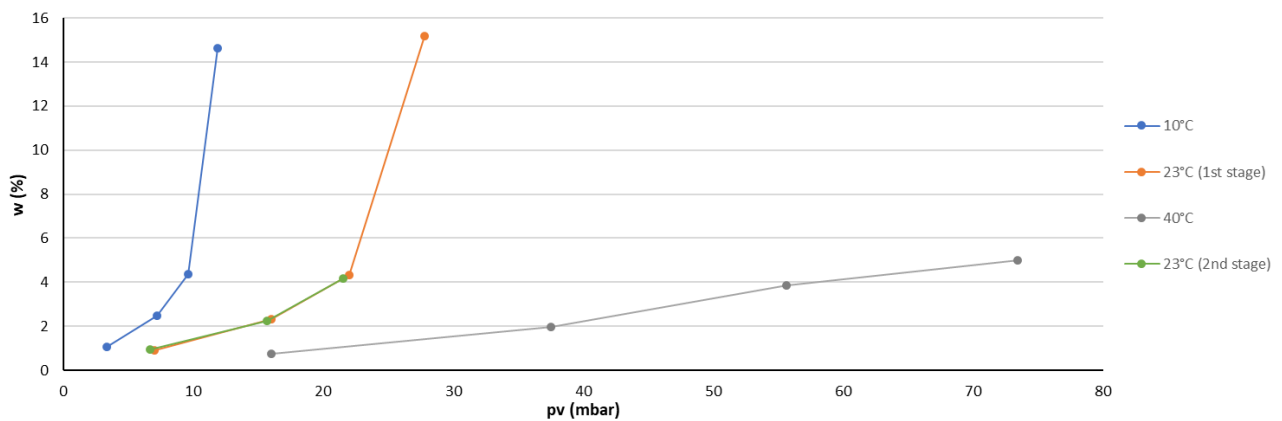


Figure 5.3- Sorption isotherms at each temperature step, for hemp concrete.

Thus, the behaviour of the three equal samples at each RH, in terms of moisture uptake, can be compared to each other. Figures 5.4, 5.5 and 5.6 presents the average of water content for 23, 53 and 75%RH at each level of temperature for compacted earth, earth plaster and hemp concrete, respectively. Each bar represents the average of three equal samples placed in the same RH and error bars were plotted to show the difference between the minimum and maximum values of water content given by the three equal samples placed in each RH. The bars that represent the water content at 10°C show an error bar without

deviations. This happens because the water content at 10°C corresponds to the reference water content obtained by the sample dried using vacuum-drying.

It can be seen that the water content value at 23°C, in the first and in the second stage, is almost the same for 23, 53 and 75% RH. At 97% RH this non-hysteresis behaviour cannot be evaluated since the samples were not placed in the 2nd stage of 23°C, because they did not reach the equilibrium at 40°C. Therefore, the samples placed in 97% RH were not plotted.

The three materials show higher water content with higher RH at constant temperature. There is repeatability in the temperature cycles at different RH. The water content reached in the 1st and in the 2nd stage of 23°C is almost the same for CE, EP and HC in a range between the two stages of 0.001-0.03% for the compacted earth, 0.06-0.02% for the earth plaster and 0.03-0.13% for the hemp concrete, which means that there is almost no temperature hysteresis.

Some mould was observed in compacted earth surface since they had been in a 97%RH environment for about 20 days, which may cause a different behaviour than the usual in the material in terms of moisture uptake and release. It was not noticed in the surface of earth plaster and hemp concrete, but since they were both on the same environment during the same time it can be admitted that they get mould too.

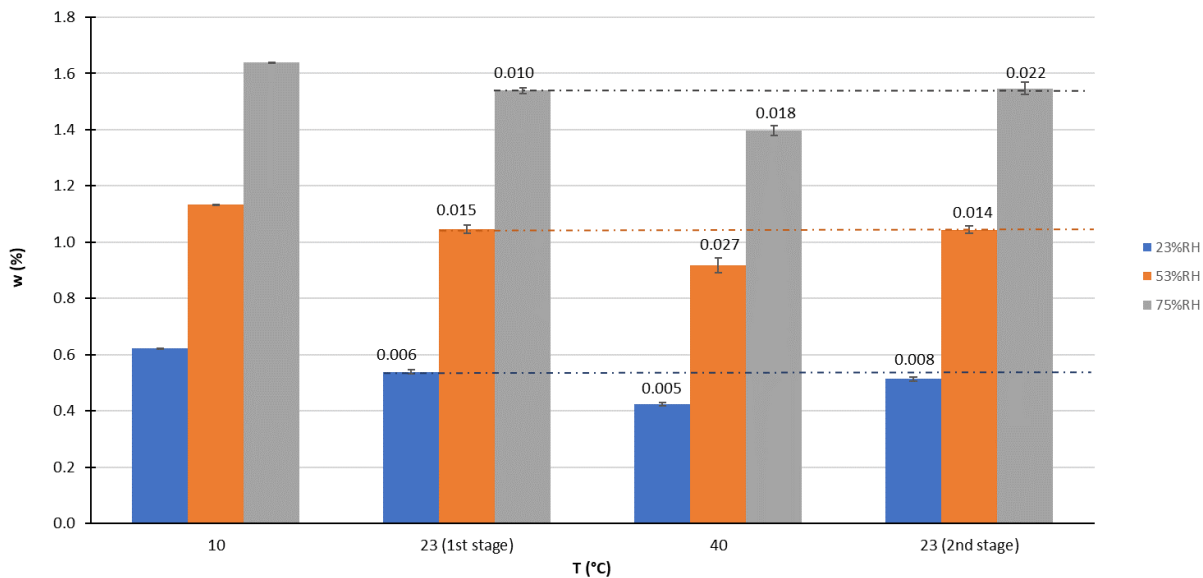


Figure 5.4- Average of water content in the temperatures steps, for compacted earth. Each bar represents the average of three equal samples placed in the same RH. The value corresponding to the error bar represents the difference between the maximum and the minimum water content value of the three samples.

To study if there is a related impact related on the type of material, all the sorption isotherms were plotted together. Figure 5.7 present the sorption isotherms given by compacted earth (green), earth plaster (blue) and hemp concrete (orange), resulting from different temperatures. Compacted earth and earth plaster have their sorption isotherms close to each other, while hemp concrete isotherms are significantly different. That shows that, for compacted earth and earth plaster, the influence of temperature is more relevant than the materials themselves. The same cannot be stated for the hemp concrete.

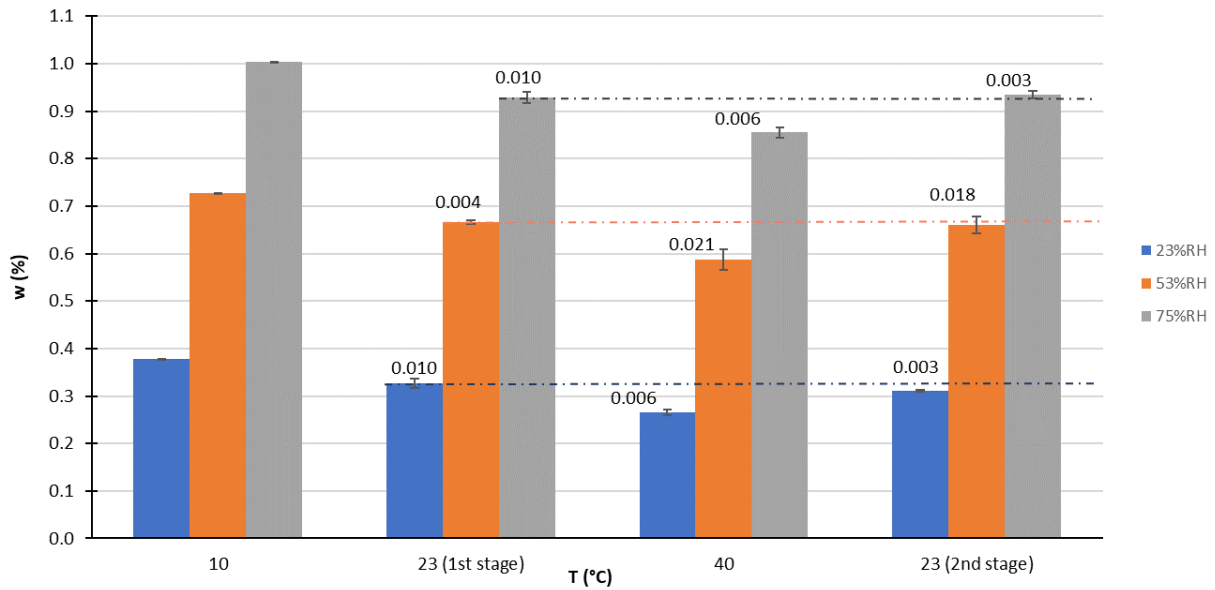


Figure 5.5- Average of water content in the temperatures steps, for earth plaster. Each bar represents the average of three equal samples placed in the same RH. The value corresponding to the error bar represents the difference between the maximum and the minimum water content value of the three samples.

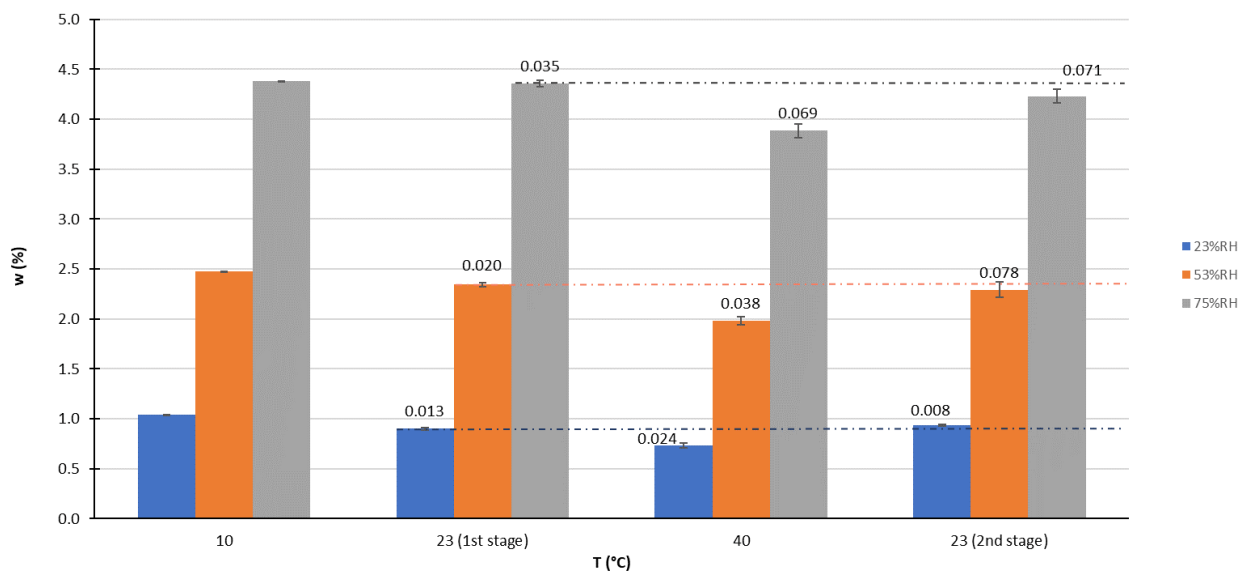


Figure 5.6- Average of water content for the temperatures steps, for hemp concrete. Each bar represents the average of three equal samples placed in the same RH. The value corresponding to the error bar represents the difference between the maximum and the minimum water content value of the three samples.

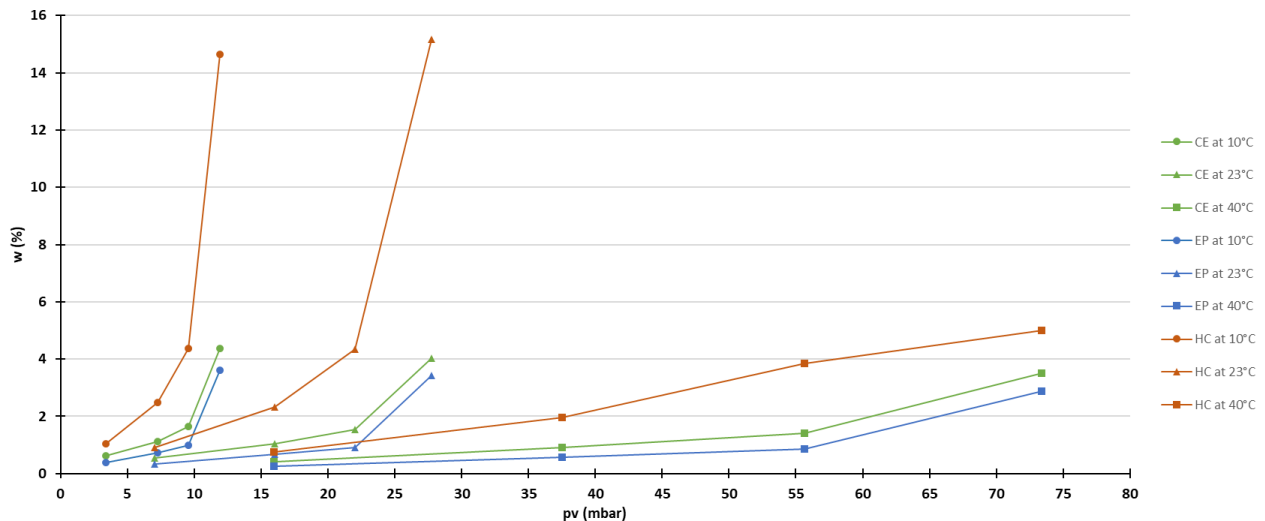


Figure 5.7- Sorption isotherms given by compacted earth (green), earth plaster (blue) and hemp concrete (orange), resulting from different temperatures.

5.3 Discussion

The sorption isotherms at 23°C in the first and second stage are overlapping, which means that the moisture uptake at 23°C, after temperature cycles at constant RH, is very similar. Therefore, temperature cycles do not influence the sorption behaviour for CE, EP and HC, but this consistence was not studied in a long term. For 97% RH the hysteresis phenomena cannot be discussed since the samples were not taken to the 2nd stage of 23°C. The temperature cycles do not influence the sorption behaviour for CE, EP and HC, but this consistence was not studied in a long term. Therefore, several cycles of different temperatures at constant RH should be made to confirm the consistence of the non-hysteresis behaviour for sorption curves at different temperatures. Of the three materials studied, the compacted earth present close humidity values at 23°C in the 1st and 2nd state, followed by earth plaster and hemp concrete, in this order.

Comparing the magnitude of this effect for compacted earth, earth plaster and hemp concrete, it can be stated that the influence of temperature is more relevant than the materials itself, since the sorption curves of the different materials, at the same temperature, are closer than the same sorption curves at different temperatures. The same cannot be stated for the hemp concrete, since the sorption curves of this material are diverted from the compacted earth about 2% of water content, looking at the value at 75% RH.

6. Conclusion

6.1 Summary

To evaluate the effect of drying methods in biobased materials, compacted earth, earth plaster and hemp concrete were dried using three different drying methods (oven-drying at 60°C, oven-drying at 105°C and vacuum-drying). Sorption isotherms and MBV tests were determined before and after the first drying of the studied materials. Cycles of drying/wetting, using the same drying methods, were made to analyse the impact of the cycles in the dry and wet mass after each cycle.

A different study was made, using the same biobased materials, where those materials were taken to temperature steps (10°C, 23°C, 40°C and returning to 23°C) to estimate the influence of the temperature on the sorption isotherms.

The study have shown that sorption isotherms before the first drying process, in biobased and raw earth materials, presents higher moisture uptake than after. This shows that vacuum-drying and oven-drying at 60°C are the methods that less affects the porous network of biobased material. This happens in a range between 0.06-0.14% for compacted earth and between 0.01-0.14% for hemp concrete, both using vacuum-drying. For earth plaster, both oven-drying at 60°C and vacuum-drying presents the lower difference in moisture uptake after the first drying, in a range of 0.05-0.13% and 0.04-0.07%, respectively.

The vacuum-drying and the oven-drying at 60°C are not effective in samples drying, and therefore, when cycles of drying/wetting cycles are applied, these methods lead to a moisture hysteresis behaviour. On the other hand, these drying methods do not impact the pore structure of the material, since they are the ones that less affect the behaviour of the material on the first drying process. So, oven-drying at 60°C and vacuum-drying used for the determination of the dry mass may have a very significant effect on the pore structure. For compacted earth and hemp concrete, the vacuum-drying method is the method that allows less impact in the first drying of the material. For earth plaster, both oven-drying at 60°C and vacuum-drying are suitable for a non-impact drying.

Using oven-drying at 105°C, hysteresis it is not observed, since the water content in dry samples, of all the materials, remained close to 0%. Therefore, is an effective method in terms of drying. Oven-drying at 105°C is widely used, because is a method that reaches the dry mass in a few days but it is an unsuitable procedure to preserve the microstructure of biobased materials. As shown for all the three materials studied, oven-drying at 105°C might generate a collapse of some of the fine pores, which largely confer the adsorption process. Therefore, it can be concluded that this method impacts earth building materials.

The MBV tests confirm the impact of drying in biobased and raw earth materials. The drying cycles show a bigger effect in compacted earth since the moisture uptake per square meter after the drying cycles, decreases about 17%. In hemp concrete and earth plaster the drying cycles effect is in a range between 6 and 8% in earth plaster samples with 2cm thickness, between 4 and 13% in the ones with 4cm thickness and between 4 and 15% in hemp concrete samples.

Thus, oven-drying at 60°C and vacuum-drying are the methods recommended to dry compacted earth and hemp concrete. For earth plaster, both oven-drying at 60°C and vacuum-drying are recommended to dry the material.

Compacted earth, earth plaster and hemp concrete have almost no temperature hysteresis for 23°C. The temperature seems to have a small effect on the water content at a given relative humidity. Of the three materials studied, the compacted earth presents similar humidity values at 23°C in the 1st and 2nd state, followed by earth plaster and hemp concrete, in this order. For compacted earth and earth plaster, the influence of temperature is more relevant than the difference due to the materials themselves.

6.2 Future work

Some future work should be done in order to develop the themes studied in this dissertation. Future tests will provide an accuracy of the obtained results, add complementary information and validate the results discussion about the study of the effect of drying methods.

Investigate repeatability:

More drying/wetting cycles would have to be made to see in a long run whether the percentage of water in the dry mass stabilizes and after how many cycles that happens. This increase in cycles would help to study the phenomenon of hysteresis and understand its scale in a long term. More MBV tests cycles should be made, after more cycles of drying, to evaluate the effect of them in biobased and raw earth materials.

Enlarge of the experimental data:

All the sorption isotherms and cycles of drying/wetting should be repeated to increase the accuracy of obtained data and enlarge the experimental data validation.

The porosity is an interesting parameter to evaluate the impact of the drying methods. Therefore, this characteristic should be obtained before and after the drying cycles.

DVS test should be made for compacted earth and hemp concrete to validate the sorption isotherms. Nevertheless, representative samples need to be used.

To study the effect of temperature on the sorption isotherms, more cycles with different temperatures, at constant RH, should be made to validate the non-hysteresis behaviour of compacted earth, earth plaster and hemp concrete.

Determine a procedure to obtain the dry mass:

A new procedure to determine the dry mass should be tested since all the drying methods studied in this dissertation have disadvantages in terms of the pore network impact. Therefore, a vacuum-drying system placed at higher temperature environment or oven-drying method at a temperature between 60 and 105°C should be used to test their effectiveness.

Dissemination of results:

Part of the results obtained in this dissertation will be disseminated in an article submitted to a scientific journal: Fabbri, A., McGregor, F., Costa, I., Faria, P. (submitted) Effect of temperature on the sorption curves of earthen materials. *Materials & Structures*.

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Appendix

I. Water content in sorption isotherms, before and after the first drying

Compacted earth

Table A.1- Water content in sorption isotherms, before and after the first drying, for compacted earth.

	Dry method					
	oven-drying 60°C		Vacuum-drying		oven-drying 105°C	
	RH (%)	w (%)	RH (%)	w (%)	RH (%)	w (%)
Before drying	23	0.42	23	0.31	23	0.55
	53	0.76	53	0.65	53	0.88
	75	1.11	75	0.98	75	1.19
	75	1.04	75	0.93	75	1.20
	97	3.15	97	2.88	97	3.01
After drying	23	0.34	23	0.27	23	0.38
	53	0.69	53	0.60	53	0.72
	75	0.98	75	0.91	75	1.04
	75	0.98	75	0.88	75	1.06
	97	2.31	97	2.29	97	2.31

Earth plaster

Table A. 2- Water content in sorption isotherms, before and after the first drying, for earth plaster.

	Dry method					
	oven-drying 60°C		Vacuum-drying		oven-drying 105°C	
	RH (%)	w (%)	RH (%)	w (%)	RH (%)	w (%)
Before drying	23	0.68	23	0.51	23	0.99
	53	1.23	53	1.04	53	1.51
	75	1.90	75	1.59	75	2.12
	75	1.79	75	1.54	75	2.02
	97	3.65	97	3.52	97	3.92
After drying	23	0.53	23	0.44	23	0.66
	53	1.07	53	0.95	53	1.18
	75	1.64	75	1.44	75	1.72
	75	1.65	75	1.44	75	1.79
	97	3.32	97	3.31	97	3.48

Hemp concrete

Table A. 3- Water content in sorption isotherms, before and after the first drying, for hemp concrete.

	Dry method					
	oven-drying 60°C		Vacuum-drying		oven-drying 105°C	
	RH (%)	w (%)	RH (%)	w (%)	RH (%)	w (%)
Before drying	23	2.01	23	0.93	23	3.76
	53	3.57	53	2.25	53	5.73
	75	5.61	75	4.34	75	7.30
	75	5.83	75	4.18	75	7.58
	97	20.87	97	15.18	97	27.48
After drying	23	1.69	23	0.91	23	2.06
	53	3.40	53	2.39	53	4.20
	75	5.22	75	4.20	75	6.03
	75	5.57	75	4.20	75	6.32
	97	12.96	97	11.34	97	13.10

II. Water content during the drying/wetting cycles

Compacted earth

Table A. 4- Water content during the drying/wetting cycles at 23%RH, using oven-drying at 60°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	24.0	12.1814	0.0000	12.0993	0.68
	3	60	7.0	12.1028	-0.0786		0.03
	6			12.0987	-0.0827		0.00
	7			12.1005	-0.0809		0.01
	8			12.0998	-0.0816		0.00
	9			12.0985	-0.0829		-0.01
	10			12.0983	-0.0831		-0.01
	13			12.0972	-0.0842		-0.02
	15			12.097	-0.0844		-0.02
	31			12.0952	-0.0862		-0.03
	34			12.0993	-0.0821		0.00
1st wetting	38			23	23.6	12.1621	0.0000
	41	12.1635	0.0014			0.53	
2nd drying	45	60	7.0	12.0987	0.0000	12.0976	0.00
	48			12.0976	-0.0011		-0.01
2nd wetting	52	23	23.4	12.1597	0.0000	-	0.50
	55			12.1601	0.0004		0.50
3rd drying	59	60	7.0	12.1080	0.0000	12.1095	0.07
	62			12.1095	0.0015		0.08
3rd wetting	65	23	23.7	12.1602	0.0000	-	0.50
	69			12.1506	-0.0096		0.42
4th drying	73	60	7.0	12.1164	0.0000	12.1099	0.14
	76			12.1099	-0.0065		0.09
4th wetting	80	23	24.8	12.1588	0.0000	-	0.49
	83			12.1587	-0.0001		0.49

Table A. 5- Water content during the drying/wetting cycles at 53%RH, using oven-drying at 60°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)				
1st drying	0	23	56.1	16.9694	0.0000	16.7638	1.23				
	3	60	7.0	16.7701	-0.0045		0.04				
	6			16.7656	-0.0036		0.01				
	7			16.7665	-0.0051		0.02				
	8			16.765	-0.0063		0.01				
	9			16.7638	-0.0049		0.00				
	10			16.7652	-0.0067		0.01				
	13			16.7634	-0.0056		0.00				
	15			16.7645	-0.0091		0.00				
	31			16.761	-0.0063		-0.02				
	34			16.7638	0.1722		0.00				
	1st wetting			38	23		54.1	16.9423	0.0000	-	1.06
				41				16.943	0.0007		1.07
2nd drying	45			60	7.0	16.7723	0.0000	16.7695	0.05		
	48	16.7695	-0.0028			0.03					
2nd wetting	52	23	54.3	16.9392	0.0000	-	1.05				
	55			16.9419	0.0027		1.06				
3rd drying	59	60	7.0	16.7847	0.0000	16.7855	0.12				
	62			16.7855	0.0008		0.13				
3rd wetting	65	23	54.7	16.9449	0.0000	-	1.08				
	69			16.9453	0.0004		1.08				
4th drying	73	60	7.0	16.7967	0.0000	16.7921	0.20				
	76			16.7921	-0.0046		0.17				
4th wetting	80	23	54.9	16.9432	0.0000	-	1.07				
	83			16.9457	0.0025		1.09				

Table A. 6- Water content during the drying/wetting cycles at 75%RH, using oven-drying at 60°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.4	17.3791	0.0000	17.0556	1.90
	3	60	7.0	17.0638	-0.3153		0.05
	6			17.0579	-0.3212		0.01
	7			17.0595	-0.3196		0.02
	8			17.0572	-0.3219		0.01
	9			17.0576	-0.3215		0.01
	10			17.0557	-0.3234		0.00
	13			17.0547	-0.3244		-0.01
	15			17.0554	-0.3237		0.00
	31			17.0517	-0.3274		-0.02
	34			17.0556	-0.3235		0.00
1st wetting	38			23	75.3	17.3325	0.0000
	41	17.335	0.0025			1.64	
2nd drying	45	60	7.0	17.0665	0.0000	17.0654	0.06
	48			17.0654	-0.0011		0.06
2nd wetting	52	23	75.1	17.3319	0.0000	-	1.62
	55			17.3324	0.0005		1.62
3rd drying	59	60	7.0	17.0805	0.0000	17.0799	0.15
	62			17.0799	-0.0006		0.14
3rd wetting	65	23	75.8	17.3313	0.0000	-	1.62
	69			17.3396	0.0083		1.67
4th drying	73	60	7.0	17.0824	0.0000	17.0855	0.16
	76			17.0855	0.0031		0.18
4th wetting	80	23	75.3	17.3327	0.0000	-	1.62
	83			17.338	0.0053		1.66

Table A. 7- Water content during the drying/wetting cycles at 75%RH (repeatability), using oven-drying at 60°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	76.9	17.082	0.0000	16.7816	1.79
	3	60	7.0	16.7913	-0.2907		0.06
	6			16.7825	-0.2995		0.01
	7			16.7843	-0.2977		0.02
	8			16.7864	-0.2956		0.03
	9			16.7867	-0.2953		0.03
	10			16.7861	-0.2959		0.03
	13			16.7817	-0.3003		0.00
	15			16.7775	-0.3045		-0.02
	31			16.7804	-0.3016		-0.01
	34			16.7816	-0.3004		0.00
1st wetting	38			23	75.4	17.0556	0.0000
	41	17.0582	0.0026			1.65	
2nd drying	45	60	7.0	16.7918	0.0000	16.7942	0.06
	48			16.7942	0.0024		0.08
2nd wetting	52	23	75.2	17.0513	0.0000	-	1.61
	55			17.0564	0.0051		1.64
3rd drying	59	60	7.0	16.8075	0.0000	16.8058	0.15
	62			16.8058	-0.0017		0.14
3rd wetting	65	23	77.3	17.0638	0.0000	-	1.68
	69			17.0656	0.0018		1.69
4th drying	73	60	7.0	16.8170	0.0000	16.8178	0.21
	76			16.8178	0.0008		0.22
4th wetting	80	23	75.7	17.0611	0.0000	-	1.67
	83			17.0621	0.0010		1.67

Table A. 8- Water content during the drying/wetting cycles at 97%RH, using oven-drying at 60°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)		
1st drying	0	40	99.2	17.3766	0.0000	16.7641	3.65		
	3	60	7.0	16.7656	-0.6110		0.01		
	6			16.7603	-0.6163		-0.02		
	7			16.7641	-0.6125		0.00		
	8			16.764	-0.6126		0.00		
	9			16.7625	-0.6141		-0.01		
	10			16.7653	-0.6113		0.01		
	13			16.762	-0.6146		-0.01		
	15			16.7639	-0.6127		0.00		
	31			16.7621	-0.6145		-0.01		
	34			16.7641	-0.6125		0.00		
	1st wetting			38	23		96.6	17.2979	0.0000
41				17.321		0.0231		3.32	
2nd drying	45	60	7.0	16.7767	0.0000	16.7760	0.08		
	48			16.776	-0.0007		0.07		
2nd wetting	52	23	96.6	17.2989	0.0000	-	3.19		
	55			17.3114	0.0125		3.26		
3rd drying	59	60	7.0	16.7907	0.0000	16.7916	0.16		
	62			16.7916	0.0009		0.16		
3rd wetting	65	23	97.4	17.3092	0.0000	-	3.25		
	69			17.3937	0.0845		3.76		
4th drying	73	60	7.0	17.3104	0.0000	16.8095	3.26		
	76			16.8095	-0.5009		0.27		
4th wetting	80	23	98.5	17.3356	0.0000	-	3.41		
	83			17.3296	-0.0060		3.37		

Table A. 9- Water content during the drying/wetting cycles at 23%RH, using oven-drying at 105°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	24.0	16.7800	0.0000	16.6158	0.99
	3	105	0.0	16.6287	-0.1513		0.08
	6			16.6171	-0.1629		0.01
	8			16.6259	-0.1541		0.06
	9			16.6274	-0.1526		0.07
	10			16.6328	-0.1472		0.10
	31			16.6190	-0.1610		0.02
	34			16.6158	-0.1642		0.00
1st wetting	38			23	23.6	16.7237	0.0950
	41	16.7256	0.0019			0.66	
2nd drying	45	105	0.0	16.6160	0.0000	16.619	0.00
	48			16.6190	0.0030		0.02
2nd wetting	52	23	23.4	16.7231	0.0000	-	0.65
	55			16.7231	0.0000		0.65
3rd drying	59	105	0.0	16.6157	0.0000	16.6168	0.00
	62			16.6168	0.0011		0.01
3rd wetting	65	23	23.7	16.7188	0.0000	-	0.62
	69			16.7203	0.0015		0.63
4th drying	73	105	0.0	16.6189	0.0000	16.6181	0.02
	76			16.6181	-0.0008		0.01
4th wetting	80	23	24.8	16.7187	0.0000	-	0.62
	83			16.7187	0.0000		0.62

Table A. 10- Water content during the drying/wetting cycles at 53%RH, using oven-drying at 105°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	105	0.0	16.9660	0.0000	16.7133	1.51
	3			16.7214	-0.2446		0.05
	6			16.7146	-0.2514		0.01
	8			16.7239	-0.2421		0.06
	9			16.7261	-0.2399		0.08
	10			16.7312	-0.2348		0.11
	31			16.7133	-0.2527		0.00
	34			16.7133	-0.2527		0.00
1st wetting	38	23	54.1	16.9063	0.0000	-	1.15
	41			16.9099	0.0036		1.18
2nd drying	45	105	0.0	16.7187	0.0000	16.7164	0.03
	48			16.7164	-0.0023		0.02
2nd wetting	52	23	54.3	16.9034	0.0000	-	1.14
	55			16.9035	0.0001		1.14
3rd drying	59	105	0.0	16.7108	0.0000	16.711	-0.01
	62			16.711	0.0002		-0.01
3rd wetting	65	23	54.7	16.915	0.0000	-	1.21
	69			16.9078	-0.0072		1.16
4th drying	73	105	0.0	16.7146	0.0000	16.7106	0.01
	76			16.7106	-0.0040		-0.02
4th wetting	80	23	54.9	16.9039	0.0000	-	1.14
	83			16.9044	0.0005		1.14

Table A. 11- Water content during the drying/wetting cycles at 75%RH, using oven-drying at 105°C, for compacted earth

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	105	0.0	17.1831	0.0000	16.8263	2.12
	3			16.8294	-0.3537		0.02
	6			16.8316	-0.3515		0.03
	8			16.834	-0.3491		0.05
	9			16.8388	-0.3443		0.07
	10			16.8417	-0.3414		0.09
	31			16.8259	-0.3572		0.00
	34			16.8263	-0.3568		0.00
1st wetting	38	23	75.3	17.1127	0.0000	-	1.70
	41			17.1153	0.0026		1.72
2nd drying	45	105	0.0	16.8224	0.0000	16.8203	-0.02
	48			16.8203	-0.0021		-0.04
2nd wetting	52	23	75.1	17.0891	0.0000	-	1.56
	55			17.0968	0.0077		1.61
3rd drying	59	105	0.0	16.8175	0.0000	16.8142	-0.05
	62			16.8142	-0.0033		-0.07
3rd wetting	65	23	75.8	17.0879	0.0000	-	1.55
	69			17.099	0.0111		1.62
4th drying	73	105	0.0	16.8133	0.0000	16.8046	-0.08
	76			16.8046	-0.0087		-0.13
4th wetting	80	23	75.3	17.0871	0.0000	-	1.55
	83			17.0879	0.0008		1.55

Table A. 12- Water content during the drying/wetting cycles at 75%RH (repeatability), using oven-drying at 105°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	76.9	17.8501	0.0000	17.4966	2.02
	3	105	0.0	17.5046	-0.3455		0.05
	6			17.508	-0.3421		0.07
	8			17.5027	-0.3474		0.03
	9			17.5037	-0.3464		0.04
	10			17.5111	-0.3390		0.08
	31			17.4950	-0.3551		-0.01
	34			17.4966	-0.3535		0.00
1st wetting	38			23	75.4	17.8066	0.0000
	41			17.8100	0.0034		1.79
2nd drying	45	105	0.0	17.5073	0.0000	17.5068	0.06
	48			17.5068	-0.0005		0.06
2nd wetting	52	23	75.2	17.7996	0.0000	-	1.73
	55			17.805	0.0054		1.76
3rd drying	59	105	0.0	17.5006	0.0000	17.4994	0.02
	62			17.4994	-0.0012		0.02
3rd wetting	65	23	77.3	17.8019	0.0000	-	1.74
	69			17.8065	0.0046		1.77
4th drying	73	105	0.0	17.499	0.0000	17.4926	0.01
	76			17.4926	-0.0064		-0.02
4th wetting	80	23	75.7	17.7854	0.0000	-	1.65
	83			17.7897	0.0043		1.68

Table A. 13- Water content during the drying/wetting cycles at 97%RH, using oven-drying at 105°C, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	40	99.2	15.1807	0.0000	14.6087	3.92
	3	105	0.0	14.6046	-0.5761		-0.03
	6			14.6214	-0.5593		0.09
	8			14.6139	-0.5668		0.04
	9			14.6181	-0.5626		0.06
	10			14.6223	-0.5584		0.09
	31			14.6052	-0.5755		-0.02
	34			14.6087	-0.5720		0.00
1st wetting	38			23	96.6	15.099	0.0000
	41			15.1176	0.0186		3.48
2nd drying	45	105	0.0	14.6110	0.0000	14.609	0.02
	48			14.6090	-0.0020		0.00
2nd wetting	52	23	96.6	15.085	0.0000	-	3.26
	55			15.1	0.0150		3.36
3rd drying	59	105	0.0	14.6034	0.0000	14.6058	-0.04
	62			14.6058	0.0024		-0.02
3rd wetting	65	23	97.4	15.0967	0.0000	-	3.34
	69			15.1473	0.0506		3.69
4th drying	73	105	0.0	14.609	0.0000	14.6006	0.00
	76			14.6006	-0.0084		-0.06
4th wetting	80	23	98.5	15.084	0.0000	-	3.25
	83			15.1025	0.0185		3.38

Table A. 14- Water content during the drying/wetting cycles at 23%RH, using vacuum-drying, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	24.0	17.0105	0.0000	16.9242	0.51
	3	23 (Vacuum 2)	2.0	16.9744	-0.0361		0.30
	9			16.9304	-0.0801		0.04
	13			16.9255	-0.0850		0.01
	20			16.9209	-0.0896		-0.02
	31			16.9184	-0.0921		-0.03
	34			16.9242	-0.0863		0.00
1st wetting	38			23	23.6	16.9969	0.0000
	41	16.9991	0.0022	0.44			
2nd drying	45	23	2.0	16.9358	0.0000	16.9314	0.07
	48	(Vacuum 2)	16.9314	-0.0044	0.04		
2nd wetting	52	23	23.4	16.9962	0.0000	-	0.43
	55	16.9972	0.0010	0.43			
3rd drying	59	23	2.0	16.9425	0.0000	16.9434	0.11
	62	(Vacuum 2)	16.9434	0.0009	0.11		
3rd wetting	65	23	23.7	16.9984	0.0000	-	0.44
	69	16.9974	-0.0010	0.43			
4th drying	73	23	2.0	16.9525	0.0000	16.9490	0.17
	76	(Vacuum 2)	16.949	-0.0035	0.15		
4th wetting	80	23	24.8	17.0016	0.0000	-	0.46
	83	16.9988	-0.0028	0.44			

Table A. 15- Water content during the drying/wetting cycles at 53%RH, using vacuum-drying, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	56.1	16.7188	0.0000	16.5465	1.04
	3	23 (Vacuum 2)	2.0	16.5986	-0.1202		0.31
	9			16.5533	-0.1655		0.04
	13			16.5462	-0.1726		0.00
	20			16.5439	-0.1749		-0.02
	31			16.5413	-0.1775		-0.03
	34			16.5465	-0.1723		0.00
1st wetting	38			23	54.1	16.7017	0.0000
	41	16.7038	0.0021	0.95			
2nd drying	45	23	2.0	16.5577	0.0000	16.5545	0.07
	48	(Vacuum 2)	16.5545	-0.0032	0.05		
2nd wetting	52	23	54.3	16.7051	0.0000	-	0.96
	55	16.7042	-0.0009	0.95			
3rd drying	59	23	2.0	16.5662	0.0000	16.5674	0.12
	62	(Vacuum 2)	16.5674	0.0012	0.13		
3rd wetting	65	23	54.7	16.7144	0.0000	-	1.01
	69	16.7107	-0.0037	0.99			
4th drying	73	23	2.0	16.5786	0.0000	16.5755	0.19
	76	(Vacuum 2)	16.5755	-0.0031	0.18		
4th wetting	80	23	54.9	16.7081	0.0000	-	0.98
	83	16.7106	0.0025	0.99			

Table A. 16- Water content during the drying/wetting cycles at 75%RH, using vacuum-drying, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.4	17.1806	0.0000	16.9117	1.59
	3	23 (Vacuum 3)	4.0	17.0007	-0.1799		0.53
	9			16.9197	-0.2609		0.05
	13			16.9102	-0.2704		-0.01
	20			16.9087	-0.2719		-0.02
	31			16.908	-0.2726		-0.02
	34			16.9117	-0.2689		0.00
1st wetting	38			23	75.3	17.1576	0.0000
	41			17.1557	-0.0019	-	1.44
2nd drying	45	23	4.0	16.9450	0.0000	16.9319	0.20
	48	(Vacuum 3)		16.9319	-0.0131		0.12
2nd wetting	52	23	75.1	17.1515	0.0000	-	1.42
	55			17.1553	0.0038	-	1.44
3rd drying	59	23	4.0	16.9387	0.0000	16.9401	0.16
	62	(Vacuum 3)		16.9401	0.0014		0.17
3rd wetting	65	23	75.8	17.1568	0.0000	-	1.45
	69			17.1638	0.0070	-	1.49
4th drying	73	23	4.0	16.9459	0.0000	16.9520	0.20
	76	(Vacuum 3)		16.952	0.0061		0.24
4th wetting	80	23	75.3	17.1612	0.0000	-	1.48
	83			17.1589	-0.0023	-	1.46

Table A. 17- Water content during the drying/wetting cycles at 75%RH (repeatability), using vacuum-drying, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	76.9	16.6235	0.0000	16.3717	1.54
	3	23 (Vacuum 3)	4.0	16.4606	-0.1629		0.54
	9			16.3806	-0.2429		0.05
	13			16.3712	-0.2523		0.00
	20			16.3717	-0.2518		0.00
	31			16.3657	-0.2578		-0.04
	34			16.3717	-0.2518		0.00
1st wetting	38			23	75.4	16.6089	0.0000
	41			16.6074	-0.0015	-	1.44
2nd drying	45	23	4.0	16.3966	0.0000	16.3926	0.15
	48	(Vacuum 3)		16.3926	-0.0040		0.13
2nd wetting	52	23	75.2	16.6034	0.0000	-	1.42
	55			16.6068	0.0034	-	1.44
3rd drying	59	23	4.0	16.3979	0.0000	16.3991	0.16
	62	(Vacuum 3)		16.3991	0.0012		0.17
3rd wetting	65	23	77.3	16.6077	0.0000	-	1.44
	69			16.6105	0.0028	-	1.46
4th drying	73	23	4.0	16.4052	0.0000	16.4052	0.20
	76	(Vacuum 3)		16.4052	0.0000		0.20
4th wetting	80	23	75.7	16.6075	0.0000	-	1.44
	83			16.6106	0.0031	-	1.46

Table A. 18- Water content during the drying/wetting cycles at 97%RH, using vacuum-drying, for compacted earth.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	40	99.2	15.1942	0.0000	14.6782	3.52
	3	23 (Vacuum 1)	1.0	14.7248	-0.4694		0.32
	9			14.6801	-0.5141		0.01
	13			14.6744	-0.5198		-0.03
	20			14.6779	-0.5163		0.00
	31			14.6785	-0.5157		0.00
	34			14.6782	-0.5160		0.00
1st wetting	38	23	96.6	15.1435	0.0000	-	3.17
	41			15.1641	0.0206		3.31
2nd drying	45	23 (Vacuum 1)	1.0	14.7117	0.0000	14.7082	0.23
	48			14.7082	-0.0035		0.20
2nd wetting	52	23	96.6	15.1438	0.0000	-	3.17
	55			15.154	0.0102		3.24
3rd drying	59	23 (Vacuum 1)	1.0	14.7187	0.0000	14.7209	0.28
	62			14.7209	0.0022		0.29
3rd wetting	65	23	97.4	15.1496	0.0000	-	3.21
	69			15.2168	0.0672		3.67
4th drying	73	23 (Vacuum 1)	1.0	14.7358	0.0000	14.7332	0.39
	76			14.7332	-0.0026		0.37
4th wetting	80	23	98.5	15.1647	0.0000	-	3.31
	83			15.167	0.0023		3.33

Earth plaster

Table A. 19- Water content during the drying/wetting cycles at 23%RH, using oven-drying at 60°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)				
1st drying	0	23	24.0	54.1481	-	53.9200	0.42				
	3	60	7.0	53.9407	0.0000		0.04				
	6			53.9211	-0.0196		0.00				
	7			53.9202	-0.0205		0.00				
	8			53.9148	-0.0259		-0.01				
	9			53.9152	-0.0255		-0.01				
	10			53.9148	-0.0259		-0.01				
	13			53.9129	-0.0278		-0.01				
	15			53.9147	-0.0260		-0.01				
	31			53.9138	-0.0269		-0.01				
	34			53.9200	-0.0207		0.00				
	1st wetting			38	23		23.6	54.0990	0.0000	-	0.33
				41				54.1049	0.0059		0.34
2nd drying	45	60	7.0	53.9280	0.0000	53.9274	0.01				
	48			53.9274	-0.0006		0.01				
2nd wetting	52	23	23.4	54.1002	0.0000	-	0.33				
	55			54.1003	0.0001		0.33				
3rd drying	59	60	7.0	53.9520	0.0000	53.9546	0.06				
	62			53.9546	0.0026		0.06				
3rd wetting	65	23	23.7	54.1005	0.0000	-	0.33				
	69			54.1024	0.0019		0.34				
4th drying	73	60	7.0	53.9678	0.0000	53.9679	0.09				
	76			53.9679	0.0001		0.09				
4th wetting	80	23	24.8	54.1013	0.0000	-	0.34				
	83			54.1026	0.0013		0.34				

Table A. 20- Water content during the drying/wetting cycles at 53%RH, using oven-drying at 60°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	56.1	65.9675	-	65.4684	0.76
	3	60	7.0	65.4885	0.0000		0.03
	6			65.4535	-0.0350		-0.02
	7			65.467	-0.0215		0.00
	8			65.4574	-0.0311		-0.02
	9			65.4608	-0.0277		-0.01
	10			65.4572	-0.0313		-0.02
	13			65.4536	-0.0349		-0.02
	15			65.4586	-0.0299		-0.01
	31			65.4561	-0.0324		-0.02
	34			65.4684	-0.0201		0.00
1st wetting	38			23	54.1	65.9130	0.0000
	41			65.9176	0.0046		0.69
2nd drying	45	60	7.0	65.4887	0.0000	65.4860	0.03
	48			65.486	-0.0027		0.03
2nd wetting	52	23	54.3	65.9087	0.0000	-	0.67
	55			65.9134	0.0047		0.68
3rd drying	59	60	7.0	65.5164	0.0000	65.5176	0.07
	62			65.5176	0.0012		0.08
3rd wetting	65	23	54.7	65.9188	0.0000	-	0.69
	69			65.921	0.0022		0.69
4th drying	73	60	7.0	65.5395	0.0000	65.5366	0.11
	76			65.5366	-0.0029		0.10
4th wetting	80	23	54.9	65.9115	0.0000	-	0.68
	83			65.9165	0.0000		0.68

Table A. 21- Water content during the drying/wetting cycles at 75%RH, using oven-drying at 60°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.4	71.8268	0.0000	71.0412	1.11
	3	60	7.0	71.0681	-0.7587		0.04
	6			71.0457	-0.7811		0.01
	7			71.0396	-0.7872		0.00
	8			71.0375	-0.7893		-0.01
	9			71.0378	-0.7890		0.00
	10			71.0361	-0.7907		-0.01
	13			71.0331	-0.7937		-0.01
	15			71.0407	-0.7861		0.00
	31			71.037	-0.7898		-0.01
	34			71.0412	-0.7856		0.00
1st wetting	38			23	75.3	71.7350	0.0000
	41	71.7376	0.0026			0.98	
2nd drying	45	60	7.0	71.0605	0.0000	71.0568	0.03
	48			71.0568	-0.0037		0.02
2nd wetting	52	23	75.1	71.7283	0.0000	-	0.97
	55			71.735	0.0067		0.98
3rd drying	59	60	7.0	71.0893	0.0000	71.0922	0.07
	62			71.0922	0.0029		0.07
3rd wetting	65	23	75.8	71.7336	0.0000	-	0.97
	69			71.758	0.0244		1.01
4th drying	73	60	7.0	71.1134	0.0000	71.1160	0.10
	76			71.116	-0.0026		0.11
4th wetting	80	23	75.3	71.7343	0.0000	-	0.98
	83			71.7371	0.0028		0.98

Table A. 22- Water content during the drying/wetting cycles at 75%RH (repeatability), using oven-drying at 60°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)		
1st drying	0	23	76.9	67.2497	0.0000	66.5600	1.04		
	3	60	7.0	66.5663	-0.0110		0.01		
	6			66.5553	-0.0154		-0.01		
	7			66.5509	-0.0209		-0.01		
	8			66.5454	-0.0203		-0.02		
	9			66.546	-0.0201		-0.02		
	10			66.5462	-0.0286		-0.02		
	13			66.5377	-0.0228		-0.03		
	15			66.5435	-0.0223		-0.02		
	31			66.544	-0.0063		-0.02		
	34			66.5600	0.6451		0.00		
	1st wetting			38	23		75.4	67.2114	0.0017
41				67.2131	-0.6443	0.98			
2nd drying	45	60	7.0	66.5671	0.0000	66.5643	0.01		
	48			66.5643	-0.0028		0.01		
2nd wetting	52	23	75.2	67.1896	0.0000	-	0.95		
	55			67.1991	0.0095		0.96		
3rd drying	59	60	7.0	66.5991	0.0000	66.5975	0.06		
	62			66.5975	-0.0016		0.06		
3rd wetting	65	23	77.3	67.2018	0.6043	-	0.96		
	69			67.2111	0.0093		0.98		
4th drying	73	60	7.0	66.6178	-0.5933	66.6177	0.09		
	76			66.6177	-0.0001		0.09		
4th wetting	80	23	75.7	67.1945	0.5768	-	0.95		
	83			67.2017	0.0072		0.96		

Table A. 23- Water content during the drying/wetting cycles at 97%RH, using oven-drying at 60°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)		
1st drying	0	40	99.2	50.9103	0.0000	49.3575	3.15		
	3	60	7.0	49.354	-0.0131		-0.01		
	6			49.3409	-0.0055		-0.03		
	7			49.3485	-0.0039		-0.02		
	8			49.3501	-0.0077		-0.01		
	9			49.3463	-0.0061		-0.02		
	10			49.3479	-0.0049		-0.02		
	13			49.3491	-0.0043		-0.02		
	15			49.3497	-0.0049		-0.02		
	31			49.3491	0.0035		-0.02		
	34			49.3575	1.0015		0.00		
	1st wetting			38	23		96.6	50.3555	0.0000
41				50.4982		0.1427		2.31	
2nd drying	45	60	7.0	49.3741	-1.1241	49.3789	0.03		
	48			49.3789	0.0048		0.04		
2nd wetting	52	23	96.6	50.349	0.0000	-	2.01		
	55			50.4719	0.1229		2.26		
3rd drying	59	60	7.0	49.4068	0.0000	49.4090	0.10		
	62			49.409	0.0022		0.10		
3rd wetting	65	23	97.4	50.3942	0.0000	-	2.10		
	69			50.6694	0.2752		2.66		
4th drying	73	60	7.0	49.4373	0.0000	49.4278	0.16		
	76			49.4278	-0.0095		0.14		
4th wetting	80	23	98.5	50.5289	0.0000	-	2.37		
	83			50.7201	0.1912		2.76		

Table A. 24- Water content during the drying/wetting cycles at 23%RH, using oven-drying at 105°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	105	0.0	51.6734	0.0000	51.3918	0.55
	3			51.4017	-0.2717		0.02
	6			51.3921	-0.2813		0.00
	8			51.3906	-0.2828		0.00
	9			51.3945	-0.2789		0.01
	10			51.4083	-0.2651		0.03
	31			51.3897	-0.2837		0.00
	34			51.3918	-0.2816		0.00
1st wetting	38	23	23.6	51.5856	0.0000	-	0.38
	41			51.5885	0.0029		0.38
2nd drying	45	105	0.0	51.3889	0.0000	51.3896	-0.01
	48			51.3896	-0.1960		0.00
2nd wetting	52	23	23.4	51.591	0.0000	-	0.39
	55			51.5931	0.0075		0.39
3rd drying	59	105	0.0	51.3972	0.0000	51.3901	0.01
	62			51.3901	-0.1955		0.00
3rd wetting	65	23	23.7	51.5838	0.0000	-	0.37
	69			51.6046	0.0190		0.41
4th drying	73	105	0.0	51.3947	0.0000	51.3897	0.01
	76			51.3897	-0.1959		0.00
4th wetting	80	23	24.8	51.5847	0.0000	-	0.38
	83			51.5887	0.0031		0.38

Table A. 25- Water content during the drying/wetting cycles at 53%RH, using oven-drying at 105°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	105	0.0	68.7403	0.0000	68.1374	0.88
	3			68.1487	-0.5916		0.02
	6			68.1433	-0.5970		0.01
	8			68.1393	-0.6010		0.00
	9			68.142	-0.5983		0.01
	10			68.1603	-0.5800		0.03
	31			68.1362	-0.6041		0.00
	34			68.1374	-0.6029		0.00
1st wetting	38	23	54.1	68.6226	0.0000	-	0.71
	41			68.6313	0.0087		0.72
2nd drying	45	105	0.0	68.1346	0.0000	68.1379	0.00
	48			68.1379	-0.4847		0.00
2nd wetting	52	23	54.3	68.614	0.0000	-	0.70
	55			68.618	-0.0046		0.71
3rd drying	59	105	0.0	68.1277	0.0000	68.1268	-0.01
	62			68.1268	-0.4958		-0.02
3rd wetting	65	23	54.7	68.6135	0.0000	-	0.70
	69			68.6181	-0.0045		0.71
4th drying	73	105	0.0	68.1288	0.0000	68.1136	-0.01
	76			68.1136	-0.5090		-0.03
4th wetting	80	23	54.9	68.6015	0.0000	-	0.68
	83			68.6103	-0.0123		0.69

Table A. 26- Water content during the drying/wetting cycles at 75%RH, using oven-drying at 105°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	105	0.0	75.7083	0.0000	74.8148	1.19
	3			74.8202	-0.8881		0.01
	6			74.8239	-0.8844		0.01
	8			74.8207	-0.8876		0.01
	9			74.8234	-0.8849		0.01
	10			74.8362	-0.8721		0.03
	31			74.8121	-0.8962		0.00
	34			74.8148	-0.8935		0.00
1st wetting	38	23	75.3	75.5826	0.0000	-	1.03
	41			75.5934	0.0108		1.04
2nd drying	45	105	0.0	74.8145	0.0000	74.8112	0.00
	48			74.8112	-0.0033		0.00
2nd wetting	52	23	75.1	75.5568	0.0000	-	0.99
	55			75.5735	0.0167		1.01
3rd drying	59	105	0.0	74.8022	0.0000	74.8048	-0.02
	62			74.8048	0.0026		-0.01
3rd wetting	65	23	75.8	75.5599	0.0000	-	1.00
	69			75.5846	0.0247		1.03
4th drying	73	105	0.0	74.8079	0.0000	74.7975	-0.01
	76			74.7975	-0.0104		-0.02
4th wetting	80	23	75.3	75.5538	0.0000	-	0.99
	83			75.5619	0.0081		1.00

Table A. 27- Water content during the drying/wetting cycles at 75%RH (repeatability), using oven-drying at 105°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	105	0.0	66.3120	0.0000	65.5231	1.20
	3			65.5374	-0.7746		0.02
	6			65.5176	-0.7944		-0.01
	8			65.5272	-0.7848		0.01
	9			65.5297	-0.7823		0.01
	10			65.5445	-0.7675		0.03
	31			65.5146	-0.7974		-0.01
	34			65.5231	-0.7889		0.00
1st wetting	38	23	75.4	66.213	0.0000	-	1.05
	41			66.2163	0.0033		1.06
2nd drying	45	105	0.0	65.5231	0.0000	65.5207	0.00
	48			65.5207	-0.6923		0.00
2nd wetting	52	23	75.2	66.1951	0.0000	-	1.03
	55			66.2108	-0.0022		1.05
3rd drying	59	105	0.0	65.5164	0.0000	65.5221	-0.01
	62			65.5221	-0.6909		0.00
3rd wetting	65	23	77.3	66.2015	0.0000	-	1.04
	69			66.2172	0.0042		1.06
4th drying	73	105	0.0	65.5153	0.0000	65.5075	-0.01
	76			65.5075	-0.7055		-0.02
4th wetting	80	23	75.7	66.1989	0.0000	-	1.03
	83			66.2118	-0.0012		1.05

Table A. 28- Water content during the drying/wetting cycles at 97%RH, using oven-drying at 105°C, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	40	99.2	56.7493	0.0000	55.0936	3.01
	3	105	0.0	55.0893	-1.6600		-0.01
	6			55.1093	-1.6400		0.03
	8			55.0911	-1.6582		0.00
	9			55.0966	-1.6527		0.01
	10			55.1112	-1.6381		0.03
	31			55.0956	-1.6537		0.00
	34			55.0936	-1.6557		0.00
1st wetting	38			23	96.6	56.2113	0.0000
	41	56.3649	0.1536	-	2.31		
2nd drying	45	105	0.0	55.0946	-1.1167	55.0925	0.00
	48	55.0925	-1.1188	0.00			
2nd wetting	52	23	96.6	56.1847	-0.0266	-	1.98
	55	56.3216	0.1103	-	2.23		
3rd drying	59	105	0.0	55.0883	-1.1230	55.0648	-0.01
	62	55.0648	-1.1465	-0.05			
3rd wetting	65	23	97.4	56.1768	-0.0345	-	1.97
	69	56.4769	0.2656	-	2.51		
4th drying	73	105	0.0	55.0694	-1.1419	55.0564	-0.04
	76	55.0564	-1.1549	-0.07			
4th wetting	80	23	98.5	56.3164	0.1051	-	2.22
	83	56.5099	0.2986	-	2.57		

Table A. 29- Water content during the drying/wetting cycles at 23%RH, using vacuum-drying, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)		
1st drying	0	23	24.0	71.8250	0.0000	71.6015	0.31		
	3	23 (Vacuum 2)	2.0	71.7241	-0.1009		0.17		
	9			71.6101	-0.2149		0.01		
	13			71.5971	-0.2279		-0.01		
	20			71.5898	-0.2352		-0.02		
	31			71.5926	-0.2324		-0.01		
	34			71.6015	-0.2235		0.00		
	1st wetting			38	23		23.6	71.7936	0.0000
41				71.7986	0.0050	-	0.28		
2nd drying	45	23	2.0	71.6243	0.0000	71.6138	0.03		
	48	71.6138	-0.0105	0.02					
2nd wetting	52	23	23.4	71.7923	0.0000	-	0.27		
	55	71.796	0.0037	-	0.27				
3rd drying	59	23	2.0	71.6389	0.0000	71.6311	0.05		
	62	71.6311	-0.0078	0.04					
3rd wetting	65	23	23.7	71.7996	0.0000	-	0.28		
	69	71.7998	0.0002	-	0.28				
4th drying	73	23	2.0	71.6651	0.0000	71.6573	0.09		
	76	71.6573	-0.0078	0.08					
4th wetting	80	23	24.8	71.8005	0.0000	-	0.28		
	83	71.8018	0.0013	-	0.28				

Table A. 30- Water content during the drying/wetting cycles at 53%RH, using vacuum-drying, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	56.1	52.7765	0.0000	52.435	0.65
	3	23 (Vacuum 2)	2.0	52.5309	-0.2456		0.18
	9			52.4426	-0.3339		0.01
	13			52.4349	-0.3416		0.00
	20			52.425	-0.3515		-0.02
	31			52.4287	-0.3478		-0.01
	34			52.435	-0.3415		0.00
1st wetting	38			23	54.1	52.7472	0.0000
	41	52.7497	0.0025	0.60			
2nd drying	45	23	2.0	52.4522	0.0000	52.4418	0.03
	48	(Vacuum 2)	52.4418	-0.0104	0.01		
2nd wetting	52	23	54.3	52.7475	0.0000	-	0.60
	55	52.7482	0.0007	0.60			
3rd drying	59	23	2.0	52.4766	0.0000	52.4675	0.08
	62	(Vacuum 2)	52.4675	-0.0091	0.06		
3rd wetting	65	23	54.7	52.7561	0.0000	-	0.61
	69	52.7554	-0.0007	0.61			
4th drying	73	23	2.0	52.4804	0.0000	52.4738	0.09
	76	(Vacuum 2)	52.4738	-0.0066	0.07		
4th wetting	80	23	54.9	52.7511	0.0000	-	0.60
	83	52.7535	0.0024	0.61			

Table A. 31- Water content during the drying/wetting cycles at 75%RH, using vacuum-drying, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.4	66.0854	0.0000	65.4421	0.98
	3	23 (Vacuum 3)	4.0	65.6645	-0.4209		0.34
	9			65.4592	-0.6262		0.03
	13			65.4314	-0.6540		-0.02
	20			65.434	-0.6514		-0.01
	31			65.4372	-0.6482		-0.01
	34			65.4421	-0.6433		0.00
1st wetting	38			23	75.3	66.0373	0.0000
	41	66.0384	0.0011	0.91			
2nd drying	45	23	4.0	65.4826	0.0000	65.4734	0.06
	48	(Vacuum 3)	65.4734	-0.0092	0.05		
2nd wetting	52	23	75.1	66.0201	0.0000	-	0.88
	55	66.0291	0.0090	0.90			
3rd drying	59	23	4.0	65.4978	0.0000	65.4895	0.09
	62	(Vacuum 3)	65.4895	-0.0083	0.07		
3rd wetting	65	23	75.8	66.0334	0.0000	-	0.90
	69	66.0531	0.0197	0.93			
4th drying	73	23	4.0	65.5166	0.0000	65.5112	0.11
	76	(Vacuum 3)	65.5112	-0.0054	0.11		
4th wetting	80	23	75.3	66.0349	0.0000	-	0.91
	83	66.0375	0.0026	0.91			

Table A. 32- Water content during the drying/wetting cycles at 75%RH (repeatability), using vacuum-drying, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	76.9	54.0705	0.0000	53.5711	0.93
	3	23 (Vacuum 3)	4.0	53.7445	-0.3260		0.32
	9			53.5845	-0.4860		0.03
	13			53.5645	-0.5060		-0.01
	20			53.5647	-0.5058		-0.01
	31			53.5702	-0.5003		0.00
	34			53.5711	-0.4994		0.00
1st wetting	38			23	75.4	54.0425	0.0000
	41	54.0432	0.0007	0.88			
2nd drying	45	23	4.0	53.6172	0.0000	53.6007	0.09
	48	(Vacuum 3)	53.6007	-0.0165	0.06		
2nd wetting	52	23	75.2	54.0379	0.0000	-	0.87
	55	54.044	0.0061	0.88			
3rd drying	59	23	4.0	53.6289	0.0000	53.6195	0.11
	62	(Vacuum 3)	53.6195	-0.0094	0.09		
3rd wetting	65	23	77.3	54.0486	0.0000	-	0.89
	69	54.0531	0.0045	0.90			
4th drying	73	23	4.0	53.6306	0.0000	53.6252	0.11
	76	(Vacuum 3)	53.6252	-0.0054	0.10		
4th wetting	80	23	75.7	54.0445	0.0000	-	0.88
	83	54.0473	0.0028	0.89			

Table A. 33- Water content during the drying/wetting cycles at 97%RH, using vacuum-drying, for earth plaster.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	40	99.2	53.7279	0.0000	52.2246	2.88
	3	23 (Vacuum 1)	1.0	52.3255	-1.4024		0.19
	9			52.2248	-1.5031		0.00
	13			52.2109	-1.5170		-0.03
	20			52.22	-1.5079		-0.01
	31			52.2305	-1.4974		0.01
	34			52.2246	-1.5033		0.00
1st wetting	38			23	96.6	53.2737	0.0000
	41	53.4218	0.1481	2.29			
2nd drying	45	23	1.0	52.2794	0.0000	52.2755	0.10
	48	(Vacuum 1)	52.2755	-0.0039	0.10		
2nd wetting	52	23	96.6	53.261	0.0000	-	1.98
	55	53.3827	0.1217	2.22			
3rd drying	59	23	1.0	52.2995	0.0000	52.2944	0.14
	62	(Vacuum 1)	52.2944	-0.0051	0.13		
3rd wetting	65	23	97.4	53.2681	0.0000	-	2.00
	69	53.5827	0.3146	2.60			
4th drying	73	23	1.0	52.3334	0.0000	52.3277	0.21
	76	(Vacuum 1)	52.3277	-0.0057	0.20		
4th wetting	80	23	98.5	53.4684	0.0000	-	2.38
	83	53.6322	0.1638	2.70			

Hemp concrete

Table A. 34- Water content during the drying/wetting cycles at 23%RH, using oven-drying at 60°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	60	7.0	31.3171	0.0000	30.7014	2.01
	3			30.8604	-0.4567		0.52
	6			30.7565	-0.5606		0.18
	7			30.7323	-0.5848		0.10
	8			30.7472	-0.5699		0.15
	9			30.7436	-0.5735		0.14
	10			30.7426	-0.5745		0.13
	13			30.7134	-0.6037		0.04
	15			30.7197	-0.5974		0.06
	31			30.681	-0.6361		-0.07
	34			30.7014	-0.6157		0.00
	1st wetting			38	23		23.6
41		31.2195	0.0237	1.69			
2nd drying	45	60	7.0	30.8037	0.0000	30.7826	0.33
	48			30.7826	-0.0211		0.26
2nd wetting	52	23	23.4	31.1738	0.0000	-	1.54
	55			31.191	0.0172		1.59
3rd drying	59	60	7.0	30.8545	0.0000	30.8463	0.50
	62			30.8463	-0.0082		0.47
3rd wetting	65	23	23.7	31.1611	0.0000	-	1.50
	69			31.1794	0.0183		1.56
4th drying	73	60	7.0	30.8901	0.0000	30.8857	0.61
	76			30.8857	-0.0044		0.60
4th wetting	80	23	24.8	31.16	0.0000	-	1.49
	83			31.1713	0.0113		1.53

Table A. 35- Water content during the drying/wetting cycles at 53%RH, using oven-drying at 60°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	60	7.0	35.9969	0.0000	34.7558	3.57
	3			34.9689	-1.0280		0.61
	6			34.823	-1.1739		0.19
	7			34.8052	-1.1917		0.14
	8			34.8128	-1.1841		0.16
	9			34.8161	-1.1808		0.17
	10			34.8074	-1.1895		0.15
	13			34.7893	-1.2076		0.10
	15			34.8007	-1.1962		0.13
	31			34.7558	-1.2411		0.00
	34			34.7729	-1.2240		0.05
	1st wetting			38	23		54.1
41		35.9365	0.0295	3.40			
2nd drying	45	60	7.0	34.9653	0.0000	34.9525	0.60
	48			34.9525	-0.0128		0.57
2nd wetting	52	23	54.3	35.9151	0.0000	-	3.34
	55			35.9461	0.0310		3.42
3rd drying	59	60	7.0	35.0968	0.0000	35.0876	0.98
	62			35.0876	-0.0092		0.95
3rd wetting	65	23	54.7	35.9483	0.0000	-	3.43
	69			35.9796	0.0313		3.52
4th drying	73	60	7.0	35.1810	0.0000	35.1662	1.22
	76			35.1662	-0.0148		1.18
4th wetting	80	23	54.9	35.9569	0.0000	-	3.46
	83			35.9943	0.0374		3.56

Table A. 36- Water content during the drying/wetting cycles at 75%RH, using oven-drying at 60°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)				
1st drying	0	23	77.4	32.4734	0.0000	30.7497	5.61				
	3	60	7.0	30.898	-1.5754		0.48				
	6			30.7626	-1.7108		0.04				
	7			30.7469	-1.7265		-0.01				
	8			30.7621	-1.7113		0.04				
	9			30.7782	-1.6952		0.09				
	10			30.779	-1.6944		0.10				
	13			30.7543	-1.7191		0.01				
	15			30.7579	-1.7155		0.03				
	31			30.7263	-1.7471		-0.08				
	34			30.7497	-1.7237		0.00				
	1st wetting			38	23		75.3	32.3215	0.0000	-	5.11
				41				32.3553	0.0338		5.22
2nd drying	45			60	7.0	31.0008	0.0000	30.9890	0.82		
	48			30.989	-0.0118	0.78					
2nd wetting	52	23	75.1	32.328	0.0000	-	5.13				
	55			32.3614	0.0334		5.24				
3rd drying	59	60	7.0	31.1442	0.0000	31.1312	1.28				
	62			31.1312	-0.0130		1.24				
3rd wetting	65	23	75.8	32.3519	0.0000	-	5.21				
	69			32.417	0.0651		5.42				
4th drying	73	60	7.0	31.2278	0.0000	31.2238	1.55				
	76			31.2238	-0.0040		1.54				
4th wetting	80	23	75.3	32.3774	0.0000	-	5.29				
	83			32.4149	0.0375		5.42				

Table A. 37- Water content during the drying/wetting cycles at 75%RH (repeatability), using oven-drying at 60°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)				
1st drying	0	23	76.9	31.2643	0.0000	29.5428	5.83				
	3	60	7.0	29.7308	-1.5335		0.64				
	6			29.5649	-1.6994		0.07				
	7			29.553	-1.7113		0.03				
	8			29.5684	-1.6959		0.09				
	9			29.5776	-1.6867		0.12				
	10			29.5747	-1.6896		0.11				
	13			29.5523	-1.7120		0.03				
	15			29.5691	-1.6952		0.09				
	31			29.5265	-1.7378		-0.06				
	34			29.5428	-1.7215		0.00				
	1st wetting			38	23		75.4	31.1527	0.0000	-	5.45
				41				31.1882	0.0355		5.57
2nd drying	45			60	7.0	29.8026	0.0000	29.7862	0.88		
	48			29.7862	-0.0164	0.82					
2nd wetting	52	23	75.2	31.1564	0.0000	-	5.46				
	55			31.1956	0.0392		5.59				
3rd drying	59	60	7.0	29.9511	0.0000	29.9438	1.38				
	62			29.9438	-0.0073		1.36				
3rd wetting	65	23	77.3	31.2013	0.0000	-	5.61				
	69			31.2457	0.0444		5.76				
4th drying	73	60	7.0	30.0536	0.0000	30.0460	1.73				
	76			30.046	-0.0076		1.70				
4th wetting	80	23	75.7	31.2178	0.0000	-	5.67				
	83			31.261	0.0432		5.82				

Table A. 38- Water content during the drying/wetting cycles at 97%RH, using oven-drying at 60°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)		
1st drying	0	40	99.2	40.4005	0.0000	33.4239	20.87		
	3	60	7.0	33.4289	-6.9716		0.01		
	6			33.3009	-7.0996		-0.37		
	7			33.3139	-7.0866		-0.33		
	8			33.3461	-7.0544		-0.23		
	9			33.3463	-7.0542		-0.23		
	10			33.3713	-7.0292		-0.16		
	13			33.3761	-7.0244		-0.14		
	15			33.3916	-7.0089		-0.10		
	31			33.3842	-7.0163		-0.12		
	34			33.4239	-6.9766		0.00		
	1st wetting			38	23		96.6	37.2517	0.0000
41				37.7545		0.5028		12.96	
2nd drying	45	60	7.0	33.7835	-3.9710	33.7705	1.08		
	48			33.7705	-0.0130		1.04		
2nd wetting	52	23	96.6	37.2662	0.0000	-	11.50		
	55			37.7271	0.4609		12.87		
3rd drying	59	60	7.0	33.9820	0.0000	33.9684	1.67		
	62			33.9684	-0.0136		1.63		
3rd wetting	65	23	97.4	37.245	0.0000	-	11.43		
	69			37.9649	0.7199		13.59		
4th drying	73	60	7.0	34.1336	0.0000	34.1373	2.12		
	76			34.1373	0.0037		2.13		
4th wetting	80	23	98.5	37.3154	0.0000	-	11.64		
	83			37.8365	0.5211		13.20		

Table A. 39- Water content during the drying/wetting cycles at 23%RH, using oven-drying at 105°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)				
1st drying	0	23	24.0	28.1017	0.0000	27.0844	3.76				
	3	105	0.0	27.1771	-0.9246		0.34				
	6			27.1035	-0.9982		0.07				
	8			27.1129	-0.9888		0.11				
	9			27.122	-0.9797		0.14				
	10			27.1608	-0.9409		0.28				
	31			27.0836	-1.0181		0.00				
	34			27.0844	-1.0173		0.00				
	1st wetting			38	23		23.6	27.6133	0.0000	-	1.95
				41				27.6415	0.0282		2.06
2nd drying	45			105	0.0	27.0864	0.0000	27.0727	0.01		
	48	27.0727	-0.0137			-0.04					
2nd wetting	52	23	23.4	27.5775	0.0000	-	1.82				
	55			27.6042	0.0267		1.92				
3rd drying	59	105	0.0	27.0478	0.0000	27.045	-0.14				
	62			27.045	-0.0028		-0.15				
3rd wetting	65	23	23.7	27.5508	0.0000	-	1.72				
	69			27.5829	0.0321		1.84				
4th drying	73	105	0.0	27.0511	0.0000	27.0119	-0.12				
	76			27.0119	-0.0392		-0.27				
4th wetting	80	23	24.8	27.5437	0.0000	-	1.70				
	83			27.5616	0.0179		1.76				

Table A. 40- Water content during the drying/wetting cycles at 53%RH, using oven-drying at 105°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	56.1	27.2479	0.0000	25.7715	5.73
	3	105	0.0	25.8473	-1.4006		0.29
	6			25.8092	-1.4387		0.15
	8			25.8251	-1.4228		0.21
	9			25.8212	-1.4267		0.19
	10			25.8419	-1.4060		0.27
	31			25.7774	-1.4705		0.02
	34			25.7715	-1.4764		0.00
1st wetting	38			23	54.1	26.8152	0.0000
	41			26.8537	0.0385		4.20
2nd drying	45	105	0.0	25.8290	0.0000	25.8078	0.22
	48			25.8078	-0.0212		0.14
2nd wetting	52	23	54.3	26.7895	0.0000	-	3.95
	55			26.8238	0.0343		4.08
3rd drying	59	105	0.0	25.8083	0.0000	25.8008	0.14
	62			25.8008	-0.0075		0.11
3rd wetting	65	23	54.7	26.7748	0.0000	-	3.89
	69			26.8139	0.0391		4.04
4th drying	73	105	0.0	25.8475	0.0000	25.7996	0.29
	76			25.7996	-0.0479		0.11
4th wetting	80	23	54.9	26.7535	0.0000	-	3.81
	83			26.7909	0.0374		3.96

Table A. 41- Water content during the drying/wetting cycles at 75%RH, using oven-drying at 105°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.4	34.6785	0.0000	32.3182	7.30
	3	105	0.0	32.3642	-2.3143		0.14
	6			32.3501	-2.3284		0.10
	8			32.3739	-2.3046		0.17
	9			32.3745	-2.3040		0.17
	10			32.3933	-2.2852		0.23
	31			32.3111	-2.3674		-0.02
	34			32.3182	-2.3603		0.00
1st wetting	38			23	75.3	34.2024	0.0000
	41			34.2684	0.0660		6.03
2nd drying	45	105	0.0	32.4264	0.0000	32.4195	0.33
	48			32.4195	-0.0069		0.31
2nd wetting	52	23	75.1	34.1475	0.0000	-	5.66
	55			34.2192	0.0717		5.88
3rd drying	59	105	0.0	32.4196	0.0000	32.4211	0.31
	62			32.4211	0.0015		0.32
3rd wetting	65	23	75.8	34.1375	0.0000	-	5.63
	69			34.2385	0.1010		5.94
4th drying	73	105	0.0	32.4805	0.0000	32.4238	0.50
	76			32.4238	-0.0567		0.33
4th wetting	80	23	75.3	34.1517	0.0000	-	5.67
	83			34.2013	0.0496		5.83

Table A. 42- Water content during the drying/wetting cycles at 75%RH (repeatability), using oven-drying at 105°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.2	31.5717	0.0000	29.3468	7.58
	3	105	0.0	29.4305	-2.1412		0.29
	6			29.3911	-2.1806		0.15
	8			29.3913	-2.1804		0.15
	9			29.3963	-2.1754		0.17
	10			29.4245	-2.1472		0.26
	31			29.3519	-2.2198		0.02
	34			29.3468	-2.2249		0.00
1st wetting	38			23	75.4	31.1475	0.0000
	41	31.2014	0.0539	6.32			
2nd drying	45	105	0.0	29.4635	0.0000	29.4422	0.40
	48	29.4422	-0.0213	0.33			
2nd wetting	52	23	75.2	31.0996	0.0000	-	5.97
	55	31.1614	0.0618	6.18			
3rd drying	59	105	0.0	29.4662	0.0000	29.4676	0.41
	62	29.4676	0.0014	0.41			
3rd wetting	65	23	77.3	31.1129	0.0000	-	6.02
	69	31.1852	0.0723	6.26			
4th drying	73	105	0.0	29.5242	0.0000	29.4859	0.60
	76	29.4859	-0.0383	0.47			
4th wetting	80	23	75.7	31.1246	0.0000	-	6.06
	83	31.1804	0.0558	6.25			

Table A. 43- Water content during the drying/wetting cycles at 97%RH, using oven-drying at 105°C, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	40	98.5	34.0557	0.0000	26.7142	27.48
	3	105	0.0	26.6068	-7.4489		-0.40
	6			26.6324	-7.4233		-0.31
	8			26.6997	-7.3560		-0.05
	9			26.71	-7.3457		-0.02
	10			26.746	-7.3097		0.12
	31			26.7031	-7.3526		-0.04
	34			26.7142	-7.3415		0.00
1st wetting	38			23	96.6	29.8119	0.0000
	41	30.2134	0.4015	13.10			
2nd drying	45	105	0.0	27.0022	0.0000	26.9741	1.08
	48	26.9741	-0.0281	0.97			
2nd wetting	52	23	96.6	29.8608	0.0000	-	11.78
	55	30.172	0.3112	12.94			
3rd drying	59	105	0.0	27.1489	0.0000	27.1635	1.63
	62	27.1635	0.0146	1.68			
3rd wetting	65	23	97.4	30.0048	0.0000	-	12.32
	69	30.4513	0.4465	13.99			
4th drying	73	105	0.0	27.3533	0.0000	27.3073	2.39
	76	27.3073	-0.0460	2.22			
4th wetting	80	23	98.5	30.1421	0.0000	-	12.83
	83	30.4825	0.3404	14.11			

Table A. 44- Water content during the drying/wetting cycles at 23%RH, using vacuum-drying, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	24.0	31.2412	0.0000	30.9524	0.93
	3	23 (Vacuum 2)	2.0	31.1359	-0.1053		0.59
	9			30.9928	0.0000		0.13
	13			30.9656	-0.0272		0.04
	20			30.949	-0.0438		-0.01
	31			30.9223	-0.0705		-0.10
	34			30.9524	-0.0404		0.00
1st wetting	38			23	23.6	31.2230	0.2302
	41			31.2334	0.2406		0.91
2nd drying	45	23	2.0	31.0113	0.0000	30.9839	0.19
	48	(Vacuum 2)		30.9839	-0.0274		0.10
2nd wetting	52	23	23.4	31.2255	0.0000	-	0.88
	55			31.2341	0.0086		0.91
3rd drying	59	23	2.0	31.0586	0.0000	31.0452	0.34
	62	(Vacuum 2)		31.0452	-0.0134		0.30
3rd wetting	65	23	23.7	31.2389	0.0000	-	0.93
	69			31.2422	0.0033		0.94
4th drying	73	23	2.0	31.0854	0.0000	31.0776	0.43
	76	(Vacuum 2)		31.0776	-0.0078		0.40
4th wetting	80	23	24.8	31.2531	0.0000	-	0.97
	83			31.2533	0.0002		0.97

Table A. 45- Water content during the drying/wetting cycles at 53%RH, using vacuum-drying, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	56.1	31.0913	0.0000	30.4071	2.25
	3	23 (Vacuum 2)	2.0	30.7418	-0.3495		1.10
	9			30.4782	-0.6131		0.23
	13			30.434	-0.6573		0.09
	20			30.4085	-0.6828		0.00
	31			30.3726	-0.7187		-0.11
	34			30.4071	-0.6842		0.00
1st wetting	38			23	54.1	31.1178	0.0000
	41			31.1327	0.0149		2.39
2nd drying	45	23	2.0	30.5574	0.0000	30.5135	0.49
	48	(Vacuum 2)		30.5135	-0.0439		0.35
2nd wetting	52	23	54.3	31.1527	0.0000	-	2.45
	55			31.1688	0.0161		2.51
3rd drying	59	23	2.0	30.6572	0.0000	30.6410	0.82
	62	(Vacuum 2)		30.641	-0.0162		0.77
3rd wetting	65	23	54.7	31.2027	0.0000	-	2.62
	69			31.2165	0.0138		2.66
4th drying	73	23	2.0	30.7169	0.0000	30.7167	1.02
	76	(Vacuum 2)		30.7167	-0.0002		1.02
4th wetting	80	23	54.9	31.2323	0.0000	-	2.71
	83			31.2493	0.0170		2.77

Table A. 46- Water content during the drying/wetting cycles at 75%RH, using vacuum-drying, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.4	40.0455	0.0000	38.3801	4.34
	3	23 (Vacuum 3)	4.0	39.2324	-0.8131		2.22
	9			38.5116	-1.5339		0.34
	13			38.4128	-1.6327		0.09
	20			38.394	-1.6515		0.04
	31			38.3517	-1.6938		-0.07
	34			38.3801	-1.6654		0.00
1st wetting	38	23	75.3	39.9793	0.0000	-	4.17
	41	39.9917	0.0124	4.20			
2nd drying	45	23	4.0	38.6748	-1.3169	38.5496	0.77
	48	(Vacuum 3)	38.5496	-0.1252	0.44		
2nd wetting	52	23	75.1	39.9698	1.4202	-	4.14
	55	39.9989	0.0291	4.22			
3rd drying	59	23	2.0	38.7780	0.0000	38.7605	1.04
	62	(Vacuum 3)	38.7605	-0.0175	0.99		
3rd wetting	65	23	75.8	40.027	1.2665	-	4.29
	69	40.0728	0.0458	4.41			
4th drying	73	23	4.0	38.8737	-1.1991	38.8605	1.29
	76	(Vacuum 3)	38.8605	-0.0132	1.25		
4th wetting	80	23	75.3	40.0703	1.2098	-	4.40
	83	40.0856	0.0153	4.44			

Table A. 47- Water content during the drying/wetting cycles at 75%RH (repeatability), using vacuum-drying, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	23	77.2	30.9840	0.0000	29.7395	4.18
	3	23 (Vacuum 3)	4.0	30.3799	-0.6041		2.15
	9			29.8412	-1.1428		0.34
	13			29.7668	-1.2172		0.09
	20			29.7477	-1.2363		0.03
	31			29.711	-1.2730		-0.10
	34			29.7395	-1.2445		0.00
1st wetting	38	23	75.4	30.9728	0.0000	-	4.15
	41	30.9883	0.0155	4.20			
2nd drying	45	23	4.0	29.9842	0.0000	29.8947	0.82
	48	(Vacuum 3)	29.8947	-0.0895	0.52		
2nd wetting	52	23	75.2	30.9926	0.0000	-	4.21
	55	31.0133	0.0207	4.28			
3rd drying	59	23	2.0	30.0875	0.0000	30.0518	1.17
	62	(Vacuum 3)	30.0518	-0.0357	1.05		
3rd wetting	65	23	77.3	31.0406	0.0000	-	4.37
	69	31.0645	0.0239	4.46			
4th drying	73	23	4.0	30.1509	0.0000	30.1324	1.38
	76	(Vacuum 3)	30.1324	-0.0185	1.32		
4th wetting	80	23	75.7	31.0666	0.0000	-	4.46
	83	31.0854	0.0188	4.53			

Table A. 48- Water content during the drying/wetting cycles at 97%RH, using vacuum-drying, for hemp concrete.

	Days	T (°C)	RH (%)	Mass (g)	Δmass (g)	mo (g)	w (%)
1st drying	0	40	98.5	32.8154	0.0000	31.255	4.99
	3	23 (Vacuum 1)	1.0	32.0247	-0.7907		2.46
	9			31.3137	-1.5017		0.19
	13			31.2499	-1.5655		-0.02
	20			31.2527	-1.5627		-0.01
	31			31.2311	-1.5843		-0.08
	34			31.255	-1.5604		0.00
1st wetting	38	23	96.6	34.4826	0.0000	-	10.33
	41			34.7978	0.3152		11.34
2nd drying	45	23	1.0	31.6093	0.0000	31.5652	1.13
	48	(Vacuum 1)		31.5652	-0.0441		0.99
2nd wetting	52	23	96.6	34.4788	0.0000	-	10.31
	55			34.7456	0.2668		11.17
3rd drying	59	23	1.0	31.8213	0.0000	31.8128	1.81
	62	(Vacuum 1)		31.8128	-0.0085		1.78
3rd wetting	65	23	97.4	34.4955	0.0000	-	10.37
	69			34.9407	0.4452		11.79
4th drying	73	23	1.0	31.9746	0.0000	-0.0142	2.30
	76	(Vacuum 1)		31.9604	-0.0142		2.26
4th wetting	80	23	98.5	34.6089	0.0000	-	10.73
	83			34.9081	0.2992		11.69

III. Difference in water content, for dry and wet mass, during the drying/wetting cycles

Compacted earth

Table A. 49- Difference in water content during the drying/wetting cycles, using oven-drying at 60°C, for compacted earth.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	12.10	0.00	0.00	16.76	0.00	0.00	17.06	0.00	0.00	16.78	0.00	0.00	16.76	0.00	0.00
	1	12.10	0.00	-0.01	16.77	0.01	0.03	17.07	0.01	0.06	16.79	0.01	0.08	16.78	0.01	0.07
	2	12.11	0.01	0.08	16.79	0.02	0.13	17.08	0.02	0.14	16.81	0.02	0.14	16.79	0.03	0.16
	3	12.11	0.01	0.09	16.79	0.03	0.17	17.09	0.03	0.18	16.82	0.04	0.22	16.81	0.05	0.27
Wet mass (75%RH)	Cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	0.68	0.00	0.00	1.23	0.00	0.00	1.90	0.00	0.00	1.79	0.00	0.00	3.65	0.00	0.00
	1	0.53	-0.15	-21.80	1.07	-0.16	-12.84	1.64	-0.26	-13.63	1.65	-0.14	-7.92	3.32	-0.33	-9.08
	2	0.50	-0.18	-25.94	1.06	-0.16	-13.38	1.62	-0.27	-14.44	1.64	-0.15	-8.52	3.26	-0.39	-10.64
	3	0.42	-0.25	-37.52	1.08	-0.14	-11.72	1.67	-0.23	-12.21	1.69	-0.10	-5.46	3.76	0.10	2.79
4	0.49	-0.19	-27.65	1.09	-0.14	-11.53	1.66	-0.24	-12.70	1.67	-0.12	-6.62	3.37	-0.28	-7.67	

Table A. 50- Difference in water content during the drying/wetting cycles, using oven-drying at 105°C, for compacted earth.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	16.62	0.00	0.00	16.71	0.00	0.00	16.83	0.00	0.00	17.50	0.00	0.00	14.61	0.00	0.00
	1	16.62	0.00	0.02	16.72	0.00	0.02	16.82	-0.01	-0.04	17.51	0.01	0.06	14.61	0.00	0.00
	2	16.62	0.00	0.01	16.71	0.00	-0.01	16.81	-0.01	-0.07	17.50	0.00	0.02	14.61	0.00	-0.02
	3	16.62	0.00	0.01	16.71	0.00	-0.02	16.80	-0.02	-0.13	17.49	0.00	-0.02	14.60	-0.01	-0.06
Wet mass (75%RH)	cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	0.99	0.00	0.00	1.51	0.00	0.00	2.12	0.00	0.00	2.02	0.00	0.00	3.92	0.00	0.00
	1	0.66	-0.33	-33.11	1.18	-0.34	-22.20	1.72	-0.40	-19.00	1.79	-0.23	-11.34	3.48	-0.43	-11.03
	2	0.65	-0.34	-34.65	1.14	-0.37	-24.73	1.61	-0.51	-24.19	1.76	-0.26	-12.76	3.36	-0.55	-14.11
	3	0.63	-0.36	-36.36	1.16	-0.35	-23.03	1.62	-0.50	-23.57	1.77	-0.25	-12.33	3.69	-0.23	-5.84
4	0.62	-0.37	-37.33	1.14	-0.37	-24.38	1.55	-0.57	-26.68	1.68	-0.35	-17.09	3.38	-0.54	-13.67	

Table A. 51- Difference in water content during the drying/wetting cycles, using vacuum-drying, for compacted earth.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	16.92	0.00	0.00	16.55	0.00	0.00	16.91	0.00	0.00	16.37	0.00	0.00	14.68	0.00	0.00
	1	16.93	0.01	0.04	16.55	0.01	0.05	16.93	0.02	0.12	16.39	0.02	0.13	14.71	0.03	0.20
	2	16.94	0.02	0.11	16.57	0.02	0.13	16.94	0.03	0.17	16.40	0.03	0.17	14.72	0.04	0.29
	3	16.95	0.02	0.15	16.58	0.03	0.18	16.95	0.04	0.24	16.41	0.03	0.20	14.73	0.05	0.37
Wet mass (75%RH)	cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	0.51	0.00	0.00	1.04	0.00	0.00	1.59	0.00	0.00	1.54	0.00	0.00	3.52	0.00	0.00
	1	0.44	-0.07	-13.21	0.95	-0.09	-8.71	1.44	-0.15	-9.26	1.44	-0.10	-6.39	3.31	-0.21	-5.83
	2	0.43	-0.08	-15.41	0.95	-0.09	-8.47	1.44	-0.15	-9.41	1.44	-0.10	-6.63	3.24	-0.27	-7.79
	3	0.43	-0.08	-15.18	0.99	-0.05	-4.70	1.49	-0.10	-6.25	1.46	-0.08	-5.16	3.67	0.15	4.38
4	0.44	-0.07	-13.56	0.99	-0.05	-4.76	1.46	-0.13	-8.07	1.46	-0.08	-5.12	3.33	-0.19	-5.27	

Earth plaster

Table A. 52- Difference in water content during the drying/wetting cycles, using oven-drying at 60°C, for earth plaster.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	53.92	0.00	0.00	65.47	0.00	0.00	71.04	0.00	0.00	66.56	0.00	0.00	49.36	0.00	0.00
	1	53.93	0.01	0.01	65.49	0.02	0.03	71.06	0.02	0.02	66.56	0.00	0.01	49.38	0.02	0.04
	2	53.95	0.03	0.06	65.52	0.05	0.08	71.09	0.05	0.07	66.60	0.04	0.06	49.41	0.05	0.10
	3	53.97	0.05	0.09	65.54	0.07	0.10	71.12	0.07	0.11	66.62	0.06	0.09	49.43	0.07	0.14
Wet mass (75%RH)	Cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	0.42	0.00	0.00	0.76	0.00	0.00	1.11	0.00	0.00	1.04	0.00	0.00	3.15	0.00	0.00
	1	0.34	-0.08	-18.94	0.69	-0.08	-10.00	0.98	-0.13	-11.35	0.98	-0.05	-5.31	2.31	-0.83	-26.54
	2	0.33	-0.09	-20.96	0.68	-0.08	-10.84	1.01	-0.10	-8.76	0.96	-0.08	-7.34	2.26	-0.89	-28.23
	3	0.34	-0.08	-20.04	0.69	-0.07	-9.32	1.01	-0.10	-8.76	0.98	-0.06	-5.60	2.66	-0.49	-15.51
4	0.34	-0.08	-19.95	0.68	-0.08	-10.22	0.98	-0.13	-11.42	0.96	-0.07	-6.96	2.76	-0.39	-12.25	

Table A. 53- Difference in water content during the drying/wetting cycles, using oven-drying at 105°C, for earth plaster.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	51.39	0.00	0.00	68.14	0.00	0.00	74.81	0.00	0.00	65.52	0.00	0.00	55.09	0.00	0.00
	1	51.39	0.00	0.00	68.14	0.00	0.00	74.81	0.00	0.00	65.52	0.00	0.00	55.09	0.00	0.00
	2	51.39	0.00	0.00	68.13	-0.01	-0.02	74.80	-0.01	-0.01	65.52	0.00	0.00	55.06	-0.03	-0.05
	3	51.39	0.00	0.00	68.11	-0.02	-0.03	74.80	-0.02	-0.02	65.51	-0.02	-0.02	55.06	-0.04	-0.07
Wet mass (75%RH)	Cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	0.55	0.00	0.00	0.88	0.00	0.00	1.19	0.00	0.00	1.20	0.00	0.00	3.01	0.00	0.00
	1	0.38	-0.17	-30.15	0.72	-0.16	-18.08	1.04	-0.15	-12.86	1.06	-0.15	-12.13	2.31	-0.70	-23.22
	2	0.39	-0.16	-28.52	0.71	-0.18	-20.29	1.01	-0.18	-15.09	1.05	-0.15	-12.83	2.23	-0.78	-25.83
	3	0.41	-0.13	-24.43	0.71	-0.18	-20.27	1.03	-0.17	-13.84	1.06	-0.14	-12.02	2.51	-0.49	-16.45
4	0.38	-0.16	-30.08	0.69	-0.19	-21.56	1.00	-0.20	-16.39	1.05	-0.15	-12.70	2.57	-0.43	-14.46	

Table A. 54- Difference in water content during the drying/wetting cycles, using vacuum-drying, for earth plaster.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	71.60	0.00	0.00	52.44	0.00	0.00	65.44	0.00	0.00	53.57	0.00	0.00	52.22	0.00	0.00
	1	71.61	0.01	0.02	52.44	0.01	0.01	65.47	0.03	0.05	53.60	0.03	0.06	52.28	0.05	0.10
	2	71.63	0.03	0.04	52.47	0.03	0.06	65.49	0.05	0.07	53.62	0.05	0.09	52.29	0.07	0.13
	3	71.66	0.06	0.08	52.47	0.04	0.07	65.51	0.07	0.11	53.63	0.05	0.10	52.33	0.10	0.20
Wet mass (75%RH)	Cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	0.31	0.00	0.00	0.65	0.00	0.00	0.98	0.00	0.00	0.93	0.00	0.00	2.88	0.00	0.00
	1	0.28	-0.04	-11.81	0.60	-0.05	-7.85	0.91	-0.07	-7.31	0.88	-0.05	-5.47	2.29	-0.59	-20.36
	2	0.27	-0.04	-12.98	0.60	-0.05	-8.29	0.90	-0.09	-8.75	0.88	-0.05	-5.31	2.22	-0.66	-22.96
	3	0.28	-0.04	-11.28	0.61	-0.04	-6.18	0.93	-0.05	-5.02	0.90	-0.03	-3.48	2.60	-0.28	-9.66
4	0.28	-0.03	-10.38	0.61	-0.04	-6.73	0.91	-0.07	-7.45	0.89	-0.04	-4.65	2.70	-0.18	-6.37	

Hemp concrete

Table A. 55- Difference in water content during the drying/wetting cycles, using oven-drying at 60°C, for hemp concrete.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	30.70	0.00	0.00	34.77	0.00	0.00	30.75	0.00	0.00	29.54	0.00	0.00	33.42	0.00	0.00
	1	30.78	0.08	0.26	34.95	0.18	0.52	30.99	0.24	0.78	29.79	0.24	0.82	33.77	0.35	1.04
	2	30.85	0.14	0.47	35.09	0.31	0.91	31.13	0.38	1.24	29.94	0.40	1.36	33.97	0.54	1.63
	3	30.89	0.18	0.60	35.17	0.39	1.13	31.22	0.47	1.54	30.05	0.50	1.70	34.14	0.71	2.13
Wet mass (75%RH)	Cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	2.01	0.00	0.00	3.57	0.00	0.00	5.61	0.00	0.00	5.83	0.00	0.00	20.87	0.00	0.00
	1	1.69	-0.32	-15.85	3.40	-0.17	-4.87	5.22	-0.38	-6.85	5.57	-0.26	-4.42	12.96	-7.92	-37.93
	2	1.59	-0.41	-20.48	3.42	-0.15	-4.09	5.24	-0.36	-6.50	5.59	-0.23	-3.99	12.87	-8.00	-38.32
	3	1.56	-0.45	-22.36	3.52	-0.05	-1.39	5.42	-0.18	-3.27	5.76	-0.06	-1.08	13.59	-7.29	-34.91
4	1.53	-0.47	-23.68	3.56	-0.01	-0.21	5.42	-0.19	-3.39	5.82	-0.01	-0.19	13.20	-7.67	-36.75	

Table A. 56- Difference in water content during the drying/wetting cycles, using oven-drying at 105°C, for hemp concrete.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	27.08	0.00	0.00	25.77	0.00	0.00	32.32	0.00	0.00	29.35	0.00	0.00	26.71	0.00	0.00
	1	27.07	-0.01	-0.04	25.81	0.04	0.14	32.42	0.10	0.31	29.44	0.10	0.33	26.97	0.26	0.97
	2	27.05	-0.04	-0.15	25.80	0.03	0.11	32.42	0.10	0.32	29.47	0.12	0.41	27.16	0.45	1.68
	3	27.01	-0.07	-0.27	25.80	0.03	0.11	32.42	0.11	0.33	29.49	0.14	0.47	27.31	0.59	2.22
Wet mass (75%RH)	Cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	3.76	0.00	0.00	5.73	0.00	0.00	7.30	0.00	0.00	7.58	0.00	0.00	20.03	0.00	0.00
	1	2.06	-1.70	-45.24	4.20	-1.53	-26.70	6.03	-1.27	-17.37	6.32	-1.26	-16.64	13.10	-6.93	-34.61
	2	1.92	-1.84	-48.90	4.08	-1.65	-28.73	5.88	-1.42	-19.46	6.18	-1.40	-18.44	12.94	-7.09	-35.38
	3	1.84	-1.92	-51.00	4.04	-1.68	-29.40	5.94	-1.36	-18.64	6.26	-1.32	-17.37	13.99	-6.04	-30.16
4	1.76	-1.99	-53.09	3.96	-1.77	-30.95	5.83	-1.48	-20.22	6.25	-1.33	-17.59	14.11	-5.93	-29.58	

Table A. 57- Difference in water content during the drying/wetting cycles, using vacuum-drying, for hemp concrete.

		RH (%)														
		23			53			75			75r			97		
Dry mass	cycles	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo	dry mass	Δdry mass	Δm/mo
	0	30.95	0.00	0.00	30.41	0.00	0.00	38.38	0.00	0.00	29.74	0.00	0.00	31.26	0.00	0.00
	1	30.98	0.03	0.10	30.51	0.11	0.35	38.55	0.17	0.44	29.89	0.16	0.52	31.57	0.31	0.99
	2	31.05	0.09	0.30	30.64	0.23	0.77	38.76	0.38	0.99	30.05	0.31	1.05	31.81	0.56	1.78
	3	31.08	0.13	0.40	30.72	0.31	1.02	38.86	0.48	1.25	30.13	0.39	1.32	31.96	0.71	2.26
Wet mass (75%RH)	Cycles	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m	m75%RH	Δmass	Δm/m
	0	0.93	0.00	0.00	2.25	0.00	0.00	4.34	0.00	0.00	4.18	0.00	0.00	15.18	0.00	0.00
	1	0.91	-0.03	-2.70	2.39	0.14	6.05	4.20	-0.14	-3.23	4.20	0.01	0.35	11.34	-3.85	-25.34
	2	0.91	-0.02	-2.46	2.51	0.25	11.33	4.22	-0.12	-2.80	4.28	0.10	2.35	11.17	-4.01	-26.44
	3	0.94	0.00	0.35	2.66	0.41	18.30	4.41	0.07	1.64	4.46	0.27	6.47	11.79	-3.39	-22.33
4	0.97	0.04	4.19	2.77	0.52	23.09	4.44	0.10	2.41	4.53	0.34	8.15	11.69	-3.49	-23.01	

IV. MBV test

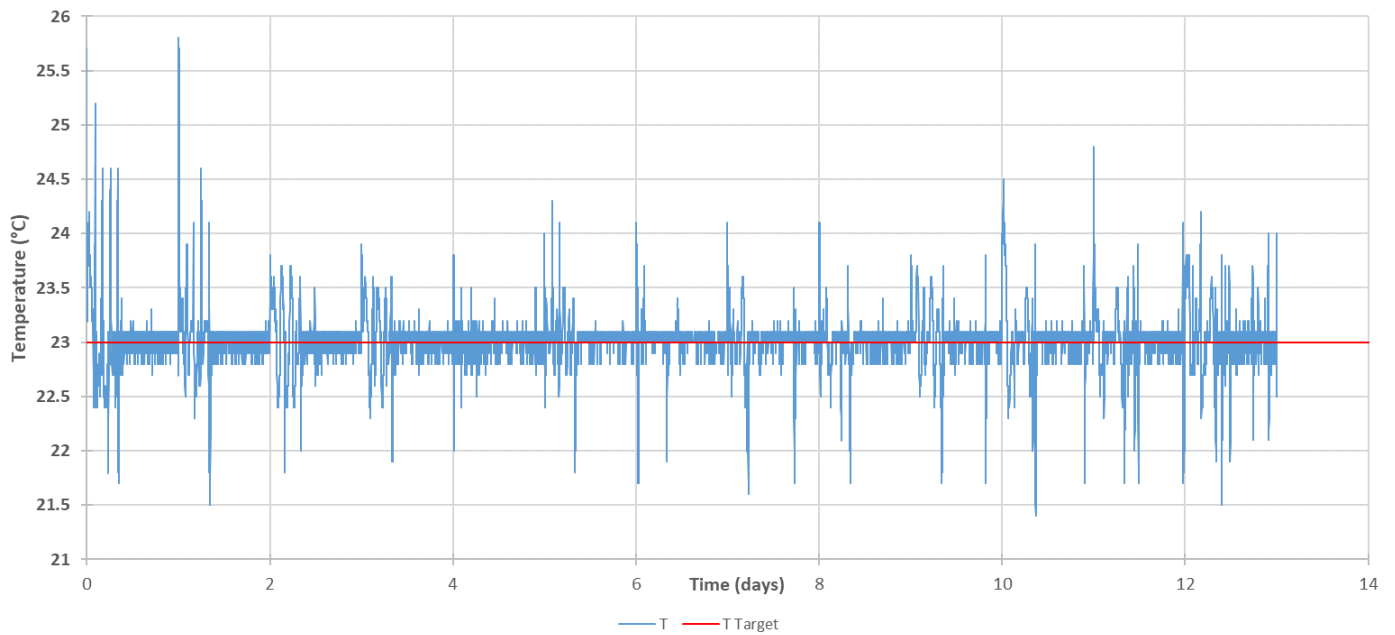


Figure A.1- Temperature measured experimentally in MBV cycle, for 13 days.

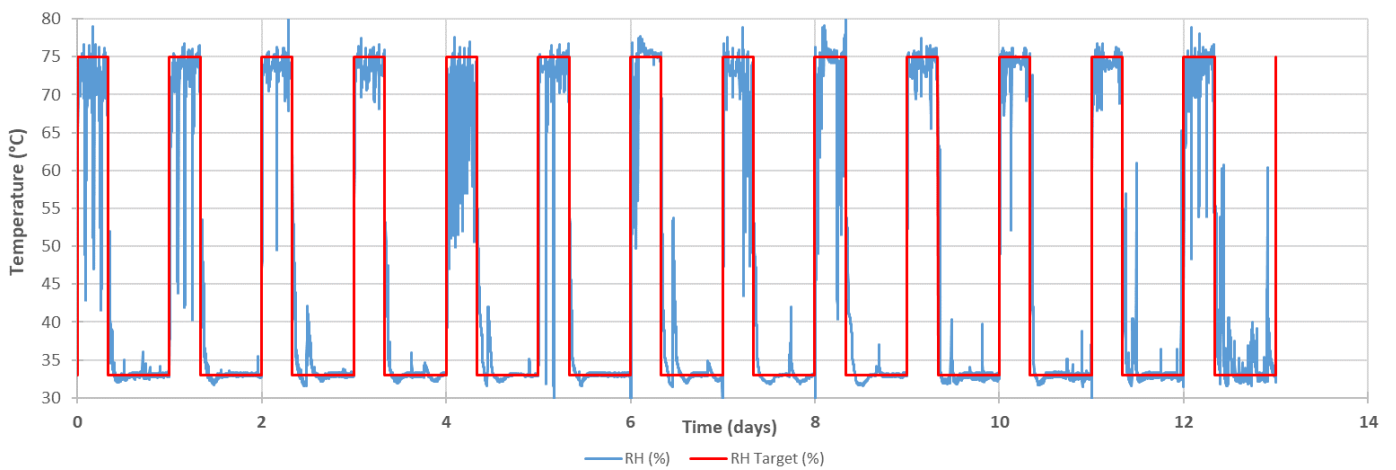


Figure A.2- Relative humidity measured experimentally in MBV cycle, for 13 days.

Compacted earth

Table A. 58- Difference in moisture uptake per square meter, before and after the drying cycles, using oven-drying at 60°C, for compacted earth.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
CE 2	9h30	0	69.16	0.00	69.05	0.00
	11h30	2	69.19	27.44	69.07	17.67
	13h30	4	69.20	40.02	69.08	27.02
	15h30	6	69.21	52.49	69.09	35.34
	17h30	8	69.22	60.29	69.10	44.69
	9h30	24	69.17	5.51	69.05	-2.08
CE 3	9h30	0	67.49	0.00	67.37	0.00
	11h30	2	67.51	28.58	67.39	17.67
	13h30	4	67.53	42.20	67.40	31.18
	15h30	6	67.54	54.88	67.41	40.54
	17h30	8	67.55	62.16	67.42	49.89
	9h30	24	67.49	4.05	67.37	1.04

Table A. 59- Difference in moisture uptake per square meter, before and after the drying cycles, using oven-drying at 105°C, for compacted earth.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
CE 1	9h30	0	71.36	0.00	71.03	0.00
	11h30	2	71.39	27.13	71.05	17.67
	13h30	4	71.40	39.60	71.06	28.06
	15h30	6	71.41	52.07	71.07	36.38
	17h30	8	71.42	59.45	71.07	43.66
	9h30	24	71.37	5.82	71.03	2.08
CE 6	9h30	0	68.02	0.00	67.73	0.00
	11h30	2	68.04	27.96	67.75	19.75
	13h30	4	68.06	40.95	67.75	28.06
	15h30	6	68.07	53.74	67.76	37.42
	17h30	8	68.08	61.64	67.77	46.77
	9h30	24	68.02	3.33	67.73	1.04

Table A. 60- Difference in moisture uptake per square meter, before and after the drying cycles, using vacuum-drying, for compacted earth.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
CE 4	9h30	0	65.49	0.00	65.47	0.00
	11h30	2	65.51	27.44	65.49	19.75
	13h30	4	65.52	39.71	65.50	30.14
	15h30	6	65.54	52.70	65.51	41.58
	17h30	8	65.54	60.29	65.52	49.89
	9h30	24	65.49	1.04	65.47	-5.20
CE 5	9h30	0	68.50	0.00	68.50	0.00
	11h30	2	68.53	25.57	68.52	18.71
	13h30	4	68.54	37.52	68.53	29.10
	15h30	6	68.55	49.68	68.54	39.50
	17h30	8	68.56	56.44	68.55	48.85
	9h30	24	68.51	1.87	68.50	0.00

Earth plaster

Table A. 61- Difference in moisture uptake per square meter, before and after the drying cycles, using oven-drying at 60°C, for earth plaster.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
EP 1.2	9h30	0	691.90	0.00	690.87	0.00
	11h30	2	692.15	20.37	691.08	17.11
	13h30	4	692.26	29.34	691.20	26.89
	15h30	6	692.36	37.49	691.29	34.23
	17h30	8	692.46	45.63	691.40	43.19
	9h30	24	691.93	2.44	690.87	0.00
EP 2.3	9h30	0	380.64	0.00	380.01	0.00
	11h30	2	380.90	21.19	380.22	17.11
	13h30	4	381.03	31.78	380.35	27.71
	15h30	6	381.14	40.74	380.45	35.86
	17h30	8	381.21	46.45	380.56	44.82
	9h30	24	380.66	1.63	380.03	1.63

Table A. 62- Difference in moisture uptake per square meter, before and after the drying cycles, using oven-drying at 105°C, for earth plaster.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
EP 1.1	9h30	0	673.72	0.00	671.53	0.00
	11h30	2	673.96	19.56	671.72	15.48
	13h30	4	674.06	27.71	671.84	25.26
	15h30	6	674.17	36.67	671.93	32.60
	17h30	8	674.26	44.00	672.03	40.74
	9h30	24	673.75	2.44	671.54	0.81
EP 2.2	9h30	0	371.80	0.00	370.27	0.00
	11h30	2	372.06	21.19	370.47	16.30
	13h30	4	372.20	32.60	370.61	27.71
	15h30	6	372.31	41.56	370.72	36.67
	17h30	8	372.41	49.71	370.82	44.82
	9h30	24	371.83	2.44	370.27	0.00

Table A. 63- Difference in moisture uptake per square meter, before and after the drying cycles, using vacuum-drying, for earth plaster.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
EP 1.3	9h30	0	736.44	0.00	735.04	0.00
	11h30	2	736.68	19.56	735.23	15.48
	13h30	4	736.79	28.52	735.34	24.45
	15h30	6	736.89	36.67	735.44	32.60
	17h30	8	736.98	44.00	735.55	41.56
	9h30	24	736.47	2.44	735.03	-0.81
EP 2.1	9h30	0	371.98	0.00	371.09	0.00
	11h30	2	372.26	22.82	371.29	16.30
	13h30	4	372.39	33.41	371.44	28.52
	15h30	6	372.52	44.00	371.52	35.04
	17h30	8	372.61	51.34	371.64	44.82
	9h30	24	371.99	0.81	371.10	0.81

Hemp concrete

Table A. 64- Difference in moisture uptake per square meter, before and after the drying cycles, using oven-drying at 60°C, for hemp concrete.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
HC 3	9h30	0	591.76	0.00	590.07	0.00
	11h30	2	592.34	30.74	590.51	23.32
	13h30	4	592.59	43.99	590.77	37.10
	15h30	6	592.77	53.53	590.93	45.58
	17h30	8	592.95	63.07	591.13	56.18
	9h30	24	591.85	4.77	590.08	0.53

Table A. 65- Difference in moisture uptake per square meter, before and after the drying cycles, using oven-drying at 105°C, for hemp concrete.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
HC 2	9h30	0	565.49	0.00	554.75	0.00
	11h30	2	566.07	30.74	555.19	23.32
	13h30	4	566.36	46.11	555.41	34.98
	15h30	6	566.59	58.30	555.66	48.23
	17h30	8	566.79	68.90	555.86	58.83
	9h30	24	565.67	9.54	554.81	3.18

Table A. 66- Difference in moisture uptake per square meter, before and after the drying cycles, using vacuum-drying, for hemp concrete.

	Hours	Time (h)	First MBV test		Last MBV test	
			mass (g)	$\Delta m/m^2$ (g/m ²)	mass (g)	$\Delta m/m^2$ (g/m ²)
HC 1	9h30	0	774.68	0.00	777.70	0.00
	11h30	2	775.24	29.68	778.16	24.38
	13h30	4	775.47	41.87	778.43	38.69
	15h30	6	775.67	52.47	778.62	48.76
	17h30	8	775.83	60.95	778.82	59.36
	9h30	24	774.79	5.83	777.75	2.65

Table A. 67- Difference in Moisture Buffering Value resulting from drying cycles, for compacted earth.

	Drying method	Before drying cycles			After drying cycles			ΔMBV (g/(m ² .%RH))
		Δm (g)	A (m ²)	MBV (g/(m ² .%RH))	Δm (g)	A (m ²)	MBV (g/(m ² .%RH))	
CE 1	oven-drying at 105°C	0.057	0.00096	1.4	0.042	0.00096	1.0	0.4
CE 2	oven-drying at 60°C	0.058		1.4	0.043		1.1	0.4
CE 3	oven-drying at 60°C	0.060		1.5	0.048		1.2	0.3
CE 4	vacuum-drying	0.058		1.4	0.048		1.2	0.2
CE 5	vacuum-drying	0.054		1.3	0.047		1.2	0.2
CE 6	oven-drying at 105°C	0.059		1.5	0.045		1.1	0.4

Table A. 68- Difference in Moisture Buffering Value resulting from drying cycles, for earth plaster.

	Drying method	Before drying cycles			After drying cycles			Δ MBV (g/(m ² ·%RH))
		Δ m (g)	A (m ²)	MBV (g/(m ² ·%RH))	Δ m (g)	A (m ²)	MBV (g/(m ² ·%RH))	
EP 1.1	oven-drying at 105°C	0.540	0.01227	1.0	0.500	0.01227	1.0	0.1
EP 1.2	oven-drying at 60°C	0.560		1.1	0.530		1.0	0.1
EP 1.3	vacuum-drying	0.540		1.0	0.510		1.0	0.1
EP 2.1	vacuum-drying	0.630		1.2	0.550		1.1	0.2
EP 2.2	oven-drying at 105°C	0.610		1.2	0.550		1.1	0.1
EP 2.3	oven-drying at 60°C	0.570		1.1	0.550		1.1	0.0

Table A. 69- Difference in Moisture Buffering Value resulting from drying cycles, for hemp concrete.

	Drying method	Before drying cycles			After drying cycles			Δ MBV (g/(m ² ·%RH))
		Δ m (g)	A (m ²)	MBV (g/(m ² ·%RH))	Δ m (g)	A (m ²)	MBV (g/(m ² ·%RH))	
HC 1	vacuum-drying	1.150	0.01887	1.5	1.120	0.01887	1.4	0.0
HC 2	oven-drying at 105°C	1.300		1.6	1.110		1.4	0.2
HC 3	oven-drying at 60°C	1.190		1.5	1.060		1.3	0.2

V. Water content in temperature steps for sorptions isotherms

Table A. 70- Water content and water vapour partial pressure in sorption isotherms, at different temperatures, for compacted earth.

T (°C)	RH target (%)	RH exp. (%)	w (%)	pv (mbar)
10	23	28.1	0.62	3.37
	53	60.3	1.13	7.24
	75	79.9	1.64	9.59
	97	99.2	4.38	11.90
23	23	25.1	0.54	7.03
	53	57.2	1.04	16.02
	75	78.6	1.54	22.01
	97	99.2	4.03	27.78
40	23	21.6	0.42	15.98
	53	50.7	0.91	37.52
	75	75.2	1.40	55.65
	97	99.2	3.52	73.41
23	23	24.0	0.51	6.72
	53	56.1	1.04	15.71
	75	76.9	1.54	21.53

Table A. 71- Water content and water vapour partial pressure in sorption isotherms, at different temperatures, for earth plaster.

T (°C)	RH target (%)	RH exp. (%)	w (%)	pv (mbar)
10	23	28.1	0.38	3.37
	53	60.3	0.73	7.24
	75	79.9	1.00	9.59
	97	99.2	3.61	11.90
23	23	25.1	0.33	7.03
	53	57.2	0.66	16.02
	75	78.6	0.92	22.01
	97	99.2	3.42	27.78
40	23	21.6	0.27	15.98
	53	50.7	0.57	37.52
	75	75.2	0.85	55.65
	97	99.2	2.88	73.41
23	23	24.0	0.31	6.72
	53	56.1	0.65	15.71
	75	76.9	0.93	21.53

Table A. 72- Water content and water vapour partial pressure in sorption isotherms, at different temperatures, for hemp concrete.

T (°C)	RH target (%)	RH exp. (%)	w (%)	pv (mbar)
10	23	28.1	1.04	3.37
	53	60.3	2.47	7.24
	75	79.9	4.38	9.59
	97	99.2	14.63	11.90
23	23	25.1	0.91	7.03
	53	57.2	2.33	16.02
	75	78.6	4.34	22.01
	97	99.2	15.18	27.78
40	23	21.6	0.75	15.98
	53	50.7	1.96	37.52
	75	75.2	3.86	55.65
	97	99.2	4.99	73.41
23	23	24.0	0.93	6.72
	53	56.1	2.25	15.71
	75	76.9	4.18	21.53

Table A. 73- Water content in each temperature step, at different relative humidities, using estimated water content from the samples dried in vacuum, for compacted earth.

		Vacuum - drying	Oven-drying at 60 °C (vacuum estimation)	Oven-drying at 105 °C (vacuum estimation)				
RH (%)	T (°C)	w (%)	w (%)	w (%)	Waverage (%)	wmax (%)	wmin (%)	wmax-wmin (%)
23	10	0.621	0.621	0.621	0.621	0.621	0.621	0.000
	23 (1st stage)	0.542	0.538	0.536	0.539	0.542	0.536	0.006
	40	0.424	0.426	0.421	0.424	0.426	0.421	0.005
	23 (2nd stage)	0.510	0.518	0.511	0.513	0.518	0.510	0.008
53	10	1.134	1.134	1.134	1.134	1.134	1.134	0.000
	23 (1st stage)	1.037	1.046	1.031	1.038	1.046	1.031	0.015
	40	0.913	0.918	0.891	0.907	0.918	0.891	0.027
	23 (2nd stage)	1.041	1.044	1.030	1.038	1.044	1.030	0.014
75	10	1.639	1.639	1.639	1.639	1.639	1.639	0.000
	23 (1st stage)	1.539	1.534	1.544	1.539	1.544	1.534	0.010
	40	1.404	1.386	1.403	1.398	1.404	1.386	0.018
	23 (2nd stage)	1.538	1.560	1.541	1.546	1.560	1.538	0.022

Table A. 74- Water content in each temperature step, at different relative humidities, using estimated water content from the samples dried in vacuum, for earth plaster.

RH (%)	T (°C)	Vacuum - drying	Oven-drying at 60 °C (vacuum estimation)	Oven-drying at 105 °C (vacuum estimation)	Waverage (%)	Wmax (%)	Wmin (%)	Wmax-Wmin (%)
		w (%)	w (%)	w (%)				
23	10	0.378	0.379	0.378	0.378	0.379	0.378	0.000
	23 (1st stage)	0.331	0.326	0.321	0.326	0.331	0.321	0.010
	40	0.268	0.262	0.267	0.266	0.268	0.262	0.006
	23 (2nd stage)	0.312	0.309	0.311	0.311	0.312	0.309	0.003
53	10	0.727	0.727	0.727	0.727	0.727	0.727	0.000
	23 (1st stage)	0.664	0.666	0.668	0.666	0.668	0.664	0.004
	40	0.573	0.594	0.594	0.587	0.594	0.573	0.021
	23 (2nd stage)	0.651	0.661	0.669	0.661	0.669	0.651	0.018
75	10	1.003	1.003	1.003	1.003	1.003	1.003	0.000
	23 (1st stage)	0.923	0.928	0.935	0.929	0.935	0.923	0.012
	40	0.855	0.861	0.850	0.855	0.861	0.850	0.011
	23 (2nd stage)	0.932	0.940	0.933	0.935	0.940	0.932	0.008

Table A. 75- Water content in each temperature step, at different relative humidities, using estimated water content from the samples dried in vacuum, for hemp concrete.

		Vacuum - drying	Oven-drying at 60 °C (vacuum estimation)	Oven-drying at 105 °C (vacuum estimation)				
RH (%)	T (°C)	w (%)	w (%)	w (%)	Waverage (%)	wmax (%)	wmin (%)	wmax-wmin (%)
23	10	1.044	1.044	1.044	1.044	1.044	1.044	0.000
	23 (1st stage)	0.910	0.898	0.897	0.902	0.910	0.897	0.013
	40	0.746	0.733	0.722	0.734	0.746	0.722	0.024
	23 (2nd stage)	0.933	0.935	0.927	0.932	0.935	0.927	0.008
53	10	2.473	2.473	2.473	2.473	2.473	2.473	0.000
	23 (1st stage)	2.335	2.344	2.355	2.345	2.355	2.335	0.020
	40	1.959	1.997	1.986	1.981	1.997	1.959	0.038
	23 (2nd stage)	2.250	2.299	2.328	2.293	2.328	2.250	0.078
75	10	4.382	4.382	4.382	4.382	4.382	4.382	0.000
	23 (1st stage)	4.336	4.363	4.371	4.357	4.371	4.336	0.035
	40	3.857	3.875	3.926	3.886	3.926	3.857	0.069
	23 (2nd stage)	4.185	4.252	4.256	4.231	4.256	4.185	0.071