Limits for moisture buffer

In Denmark, the perfect set point values for low-energy-storage is 13°C, 40% RH in February rising to 23°, 60% in August. These limits are given by the natural variation in the moisture content of the outside air. For such a climate control to work in practice, a 3 weeks moisture buffer capacity is needed to survive normal fluctuations from the monthly average value. Also, the thermal inertia must be large enough to even out daily variations in outside temperature. If controlled ventilation is used to take in outside air when it is by chance a benefit, the RH interval can be narrowed to 45% - 55% over the year. This has been proven to work at the Arnamagnean box (ref).

The Armamagnean climate is not fully low-energy, because it needs heating. However, unheated buildings can also be designed to keep a moderate climate. If the temperature is allowed to drift from 8°C in winter to 25°C, the RH will be perfectly stable at 50% all year round (fig. 1). Such temperature variation can quite easily be achieved by designing the building to take in sufficient solar heat through the roof and the south facade. Computer programmes will help choosing the thickness of the walls and the insulation. The air exchange rate need not to be very low to maintain a stable RH, but the moisture buffer capacity should still be large enough to level out episodes of unusual weather.

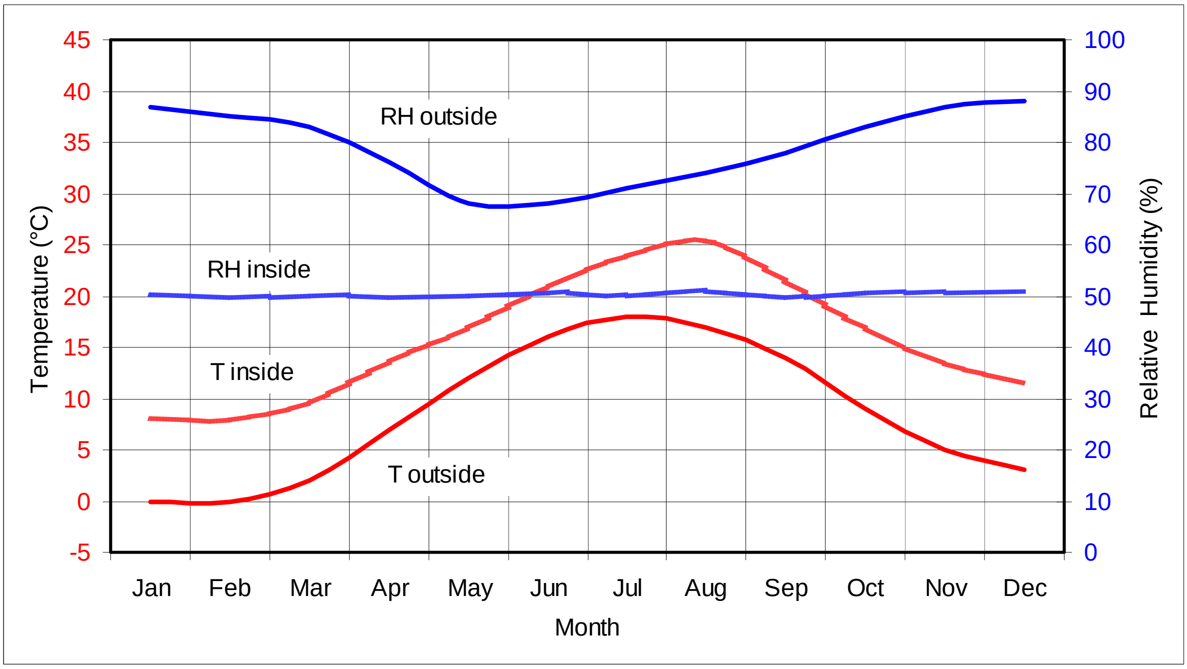


Figure 1. The climate over one year in a building heated only by solar radiation.

If a constant temperature is required, the situation is more complicated. To maintain a fairly stable RH, the moisture buffer capacity must now be large enough to even out the annual cycle in outside water vapour. For this to work, the building must have a very low air exchange rate of not more than 1 per day. A constant temperature of 18°C will be the natural set point, because at this temperature, the surplus of moisture in summer evens out the deficit of moisture in winter (fig.2). The total amount of moisture to transfer from summer to winter is approximately 250g/m3, equal to the area between the two curves in fig 3. Which material will do this, and how thick should the wall be?

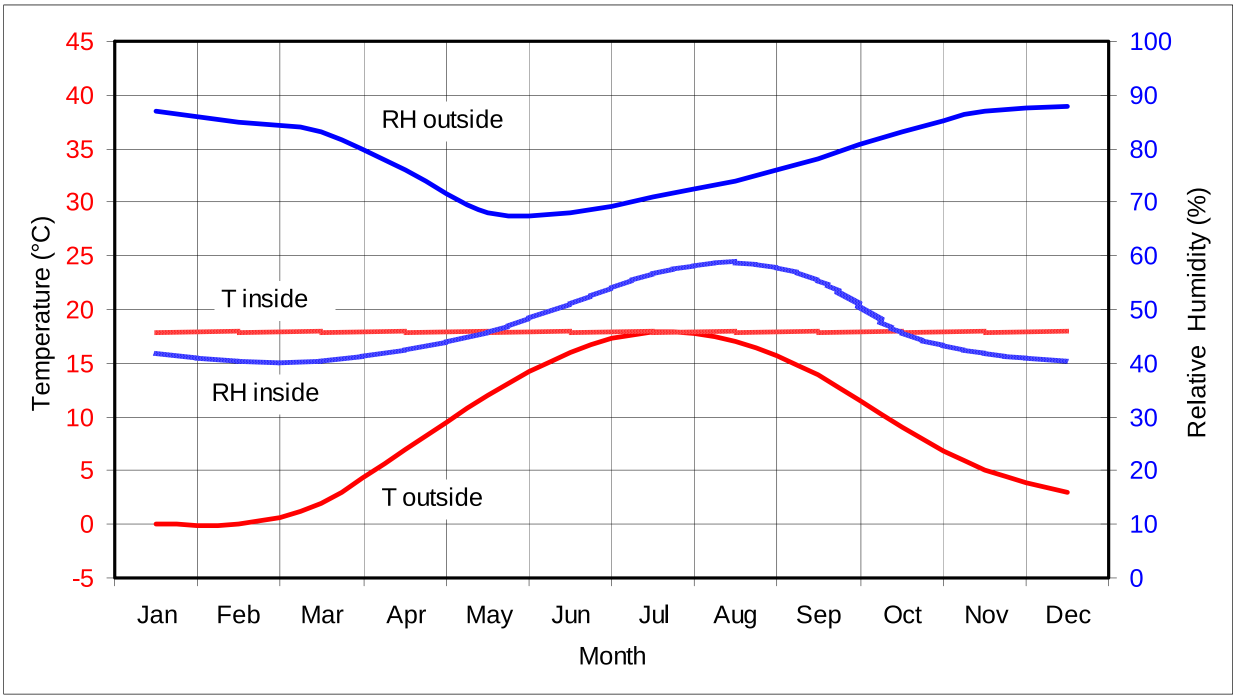


Figure 2. The climate over one year in a permanently heated building with full moisture buffer capacity.

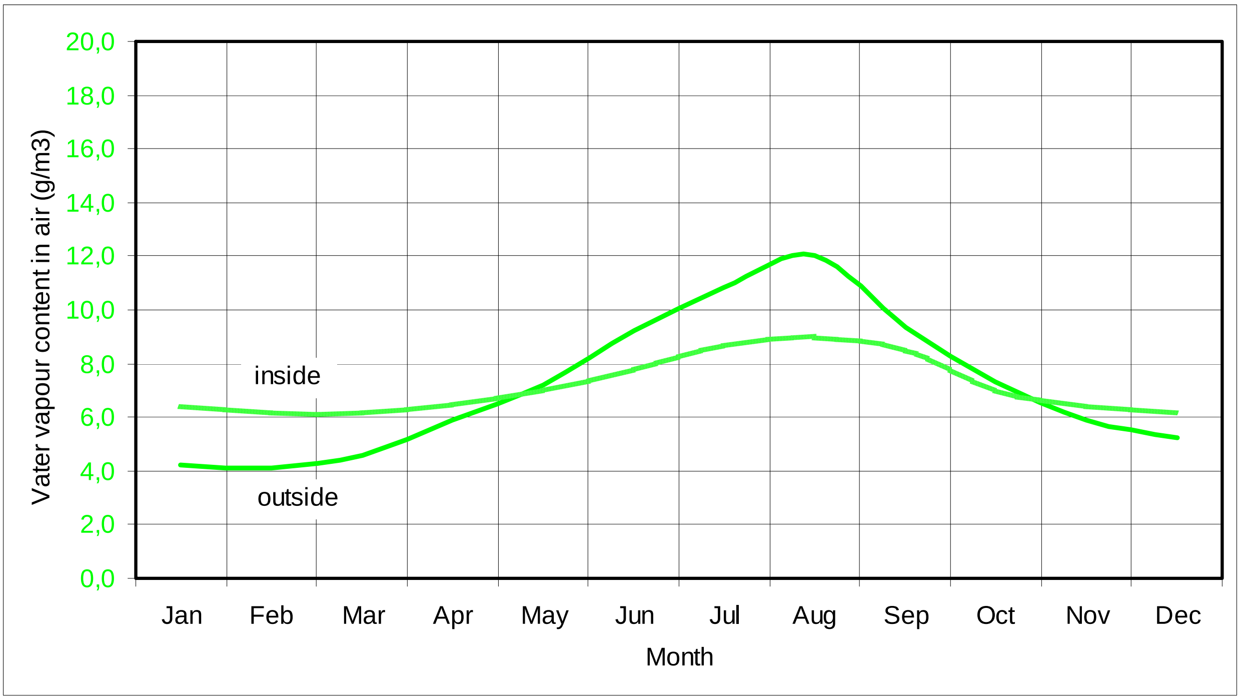


Figure 3. The water vapour content of the outside and inside air in a full buffered building. The area between the two graphs represents the amount of moisture which must be transferred from summer to winter by the moisture buffering walls

The moisture accumulation ability for various materials is given in table 1. This is a measure of the performance of the materials, calculated from the sorption isotherm and the diffusion coefficient. The penetration depth of a 365 days harmonic cycle between 40% and 60%RH is calculated next. This is the maximum thickness of a wall, which will be active during the year. The amount of moisture released or absorbed by this wall is given as 'available moisture'. A 100 mm thick concrete wall will release a little more than 1 kg of water, which is enough to buffer 4 m3 of air inside the storage. In fact, all the materials listed can in theory do the job, even if some has to be rather heavy! But the ratio of volume to area is quite different. One square meter of a 1 m thick brick wall will buffer only 4 m3 of air, whereas a ½ m thick wall of cross cut timber logs will buffer 28 m3 of air.

Material	Dry density	Effective moisture penetration depth	Moisture accumu-lation ability	Available moisture	Flux amplitude	Effec-tivity
	kg/m^3	mm	10^{-7} kg·/(m^2·Pa·s½)	kg/m^2	g/m^2 day	
Wood, pine, T	450	80	2,3	1,1	0,56	0,70
Concrete	2300	100	2,5	1,2	0,61	0,60
Clay	2050	288	4,3	2,0	1,05	0,36
Padfieldite	876	311	7,0	3,3	1,72	0,55
Wood, pine, ll	450	522	15,0	7,0	3,68	0,70
Porous lime silicate	510	584	5,1	2,4	1,25	0,21
Gypsum board	900	779	3,0	1,4	0,74	0,09
Canosmose	456	900	10,8	5,1	2,65	0,29
Brick	1600	1054	2,2	1,0	0,53	0,05

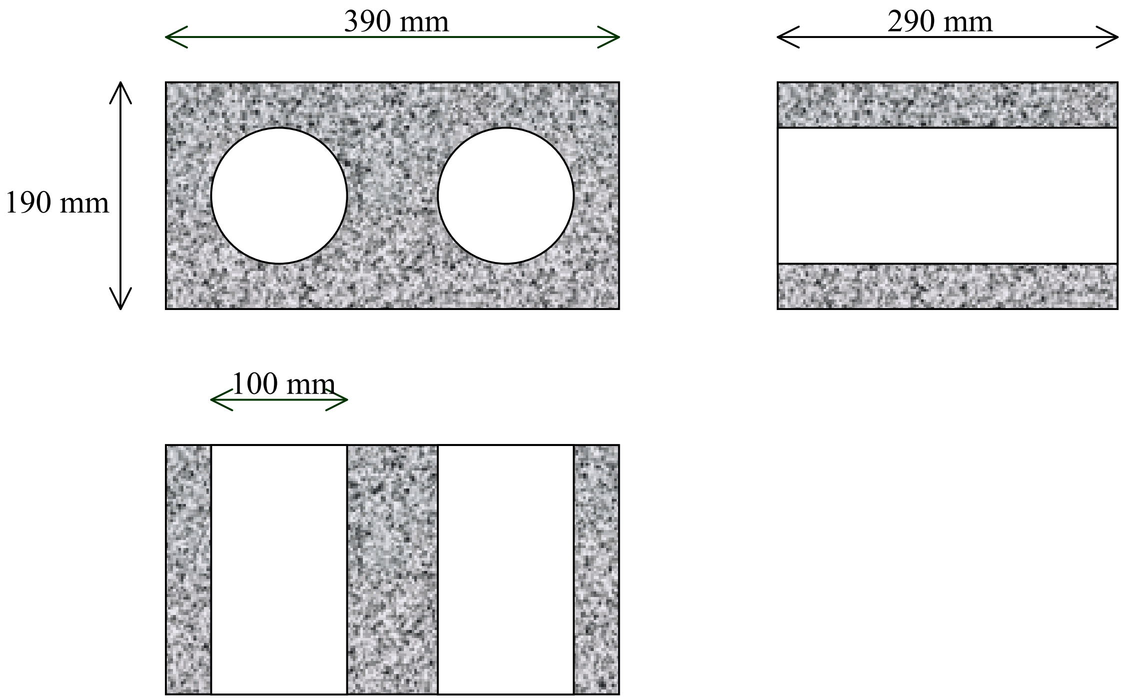
Table 1. Moisture buffer characteristics for various construction materials exposed to a one year cycle between 40 and 60 % RH at a constant temperature. Padfieldite is a mixture of perlite (expanded glass) and bentonite. Porous lime silicate is a commercial light weigh material called 'Celcon'. Canosmose is a mixture of sand, lime and hemp fibres. The calculations are displayed in appendix 1.

However, we cannot be sure if the moisture can escape fast enough at the right time. In January 3 g /m3 of water vapour is required every day to fill up the difference between the inside and outside air. To check this we need to calculate the amplitude of the vapour flux from the surface. The 5. column in table 1 gives the maximum speed of the moisture flux out of the wall surface. It becomes evident that only few materials will be able to release enough water vapour, at a reasonable surface to volume ratio. Assuming that one m2 wall must take care of one m3 air, 500 mm of end grain wood will be the only choice, followed by 900 mm of Canosmose. If a 2:1 surface to volume ratio is accepted, Padfieldite is also a possible choice, and this product need only to be 300 mm thick.

The ratio of flux amplitude to penetration depth gives the optimal choice of wall material. Wood is still the best, and it performs equally if the fibres are parallel or perpendicular to the surface. Solid concrete comes in second, because the penetration depth is only 100 mm. But the flux amplitude is too small. Padfieldite is almost as good as concrete and much better than canosmose. So from this point of view the porous clay is the best moisture buffer material. However, it takes two square meters of Padfieldite to buffer one cubic meter of air in a one year cycle. So either the room has to be small, 2,5 m in cubic measure, or the walls has to be designed with ribs, which will give more surface area.

The main difficulty when designing a moisture buffer wall is to get the moisture in and out fast enough. As stated above, most materials hold much more 'available moisture' than will ever come to use in long climate cycles. To overcome this disadvantage of solid walls, let us consider cavity walls or rather cavity structures. If a 300 mm Padfieldite wall consist of two layers of 100 mm with a 100 mm air gap between, the surface area increases by a factor of 3, whereas the amount of available moisture decreases with only 33%. There will still be enough water to buffer app. 4 m3 of air, and the flux amplitude is large enough to cope with 1,5 m3 air. We must make sure that the air gap is ventilated to the inside, but apart from this such cavity wall can be build of blocks with standard techniques.

The cavity wall principle can be turned 90° by making the walls of blocks with horinzontal holes connected to the inside. The size of the holes should be designed to allow the vapour diffusion to take place fast enough. This two dimensional calculation is not easy, but a computer program may give a solution. A geometry of 25 holes pr. square meter at a diameter of 100 mm and 300 mm deep will give two extra square meter of surface, which is exactly what we need to be able to build a storage with normal dimensions. If the material is pre-cast in blocks by the size 190 x 390 x 290 mm with two holes in each, the blocks will weigh app. 20 kg, which can be handled on the building site by the masons. The Padfieldite blocks will come to your town soon…..



Appendix 1

Density	ρ (kg/m3)
Water vapour permeability	δ (kg/Pa m s)
Moisture capacity	ξ (kg/kg) (the slope of the sorption isotherm at 40-60% rh)
Time periode for harmonic wave	t_p (s)
Vapour pressure amplitude	Δp (Pa) (200 Pa at 20°C in 40-60% wave)
Diffusivity parameter	$a_v = \delta/\rho\ \xi$
Effective moisture penetration depth	$d_p = \sqrt{a_v\ t_p / \pi}$ (mm) (37% amplitude)
Moisture accumulation ability	$\sqrt{\delta\ \rho\ \xi\ / p_s}$ ($kg/m^2\ Pa\ s^{½}$)
Available moisture	$\xi\ d_p$ (kg/m2)
Flux Amplitude	$\sqrt{2\ \delta\ \Delta p / d_p}$ (kg/m2 s)

Source: Carsten Rode and Karl Erik Hagentoft