A postscript to the article published in the 9th symposium of Nordic Building Physics, Tampere, Finland 2011. This postscript is co-authored by Morten Ryhl-Svendsen

Abstract

Unfired clay brick has been evaluated as relative humidity (RH) buffers for indoor spaces. Its response to a cyclic variation of RH has been measured and expressed in a unit for describing the buffer capacity, the 'buf' with symbol B. This is defined as the quantity of water vapour exchanged with the material, expressed as the volume of space which will experience the same change in amount of water vapour when exposed to the same RH cycle. One can regard the sum of the buffer values of the wall lining and the furnishing as a virtual (larger) volume to the room, into which water vapour from infiltration and internal generation has to disperse, with a consequently smaller RH variation. The buffer value is dependent on air velocity over the surface and on temperature, as well as on cycle period.

However, even the well ventilated perforated unfired brick reacts slowly to changing RH, having a buffer capacity nearly doubling from a one-day to a four-day humidity cycle then doubling again for a two week cycle. As the cycle lengthens the performance approaches that predicted from sorption measurements made on finely granular samples of the material.

A test of the B-value concept in a small room is the subject of this article, which is a postscript to the article by Tim Padfield & Lars Aasbjerg Jensen, 'Humidity buffering of building interiors by absorbent materials', Proceedings of the 9th Nordic Symposium on Building Physics, Tampere, Finland May 2011 pp 475 - 482.

The test room was 26 m^3 with an absorbent section of wall of 7.5 m^2 and an untreated (painted concrete) area of wall of 50 m^2. The measured air exchange rate was 0.125 per hour. The best fit with the observed long period variation in the RH was attained with a B-value of 100 for the brick, which is close to the value for the material as described in the earlier article.

Introduction

Padfield and Jensen [1] proposed a simple measure of the buffer capacity of a sorptive building material. The 'Buf' is defined as the volume of air which will experience the same change in RH when it absorbs as much moisture as unit area of the buffer surface when exposed to that change in RH. This B-value can be regarded as a virtual, larger room volume which will dilute the effects of infiltration of air and generation of moisture within the room. The B-values of all surfaces and furnishings in the room are additive. The B-value is time dependent, since for rapid changes of room RH only the surface layer of the buffer is involved, so the moderating effect is smaller. It is also temperature dependent, since the water sorption by materials is hardly affected by temperature while the RH of a cooler room space is more strongly increased by water vapour injection.

In this article we describe the performance of a room with a relatively small area of unfired brick humidity buffer.

The experimental room

Figure 1: The test room window is to the right of the archway. It faces west.

The room is made of concrete, plastered and painted. It has two outer walls with a west facing window (fig. 1). The volume is 26 m^3 and the surface area of wall is 56 m^3. 7.5 m^2 of the internal corner of this wall is covered with unfired brick, 110 mm thick. 2.5 m^2 of this buffer area is perforated to give a larger active surface area, the rest is unperforated and covered with a variety of porous finishes, such as lime wash (fig. 2). The measured air exchange rate is 0.125 per hour. The data logger is mounted in the centre of the room. There is no heating within the room but heat leaks in from the building to give a winter temperature which seldom falls below 10 °C. There is direct afternoon sunshine on the window, which is screened on the inside by a translucent curtain. The room is empty.

Figure 2: The inside corner of the room showing the perforated unfired brick and some areas with various experimental finishes, to reduce dusting.

The room climate

The room climate and the outside climate are shown in figure 3. This graph also shows the expected inside climate if the room were inert to moisture and had the measured air exchange rate. The slow air exchange combined with the thermal buffering by the structure moderates the spikiness of the RH but not nearly enough to provide a stable climate.

With a modest area of unfired brick, the predicted climate closely resembles the measured values (fig. 4). For this graph, the B-value of the unfired brick veneer was put at 100, which is approximately the value given for long term buffering in the earlier article.[1] The other surfaces in the room were given a B-value of 2, to allow some surface sorption onto the ancient flaking paint and concrete surfaces.

The simulation differs from the measured value in two respects. It is much smoother. This is because rapid fluctuations are not so effectively buffered – the B-value is considerably smaller for the daily variation. It would be possible to superpose the short term buffering on the long term 'deep' buffering but that spoils the simplicity of the B-value concept – that one chooses the B-value which suits the intended purpose of the buffering. In this case the purpose is storage of art in a room well filled with absorbent materials which will take care of the short term variation. Another reason the short term variation is not shown in the simulation is that the brick buffer moderates the RH at its surface. When that surface is at a different temperature to the data logger in the centre of the room, which receives diffuse sunlight in the afternoon, the room RH will be de-stabilised by the temperature difference between the air and the buffer surface.

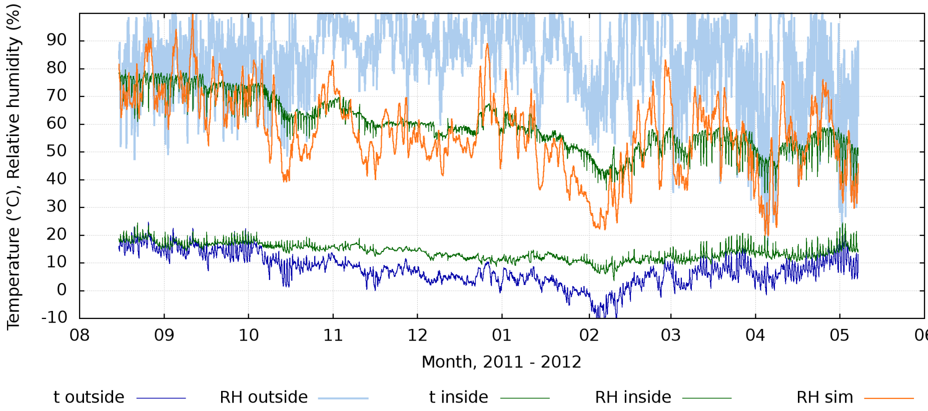

Figure 3: The measured climate inside and outside the test room with the predicted climate if the room surfaces were inert to water vapour. The slow air exchange moderates the spikes of RH but the indoor RH pattern follows the outside RH, modified by the temperature difference between inside and outside.

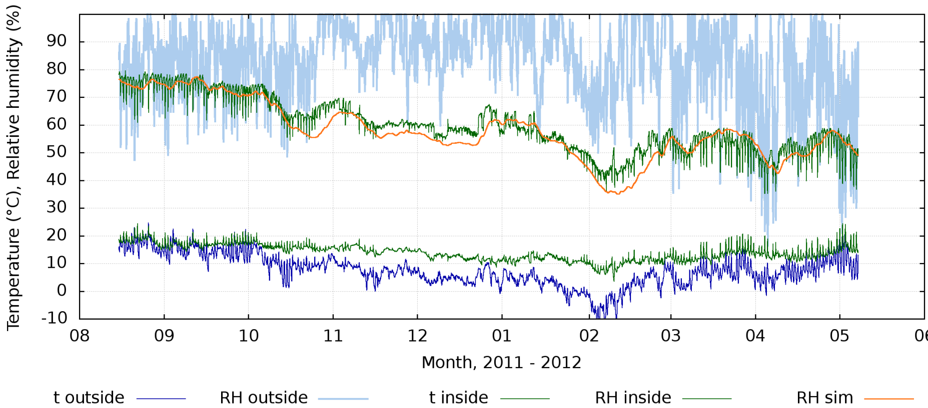

Figure 4: The measured climate inside and outside the test room with the predicted climate for the room buffered with unfired brick.

The other error in the simulation is more difficult to explain. The downward trend in RH is well matched by the simulation but the upswings are not. On the first occasion, in month 10, the temperature remains fairly constant, while the outside RH rises rapidly and the inside RH rises faster than predicted. On the second occasion, in month 7, there is a rise in temperature during the rise in room RH. We have no explanation for this behaviour.

Conclusion

The moisture buffer capacity of unfired brick, used as a wall material, or wall cladding, is sufficient to moderate the course of the RH in a room with a small air exchange rate, as can be achieved in an uninhabited store. The resistance to RH change caused by infiltration and by temperature change can be predicted from the air exchange rate, the outside water vapour concentration and the buffer value of the moisture-reactive components of the room walls and furnishing.

This passive RH buffering allows a considerable simplification of the air conditioning of museum stores and archives in temperate climates. In archives with abundant paper and cardboard it is possible to use just winter heating to a fixed temperature, relying on long term buffering to ensure that the RH does not rise significantly during the summer. For buildings holding non-absorbent material, wall cladding of unfired brick will not alone ensure a stable RH throughout the year but will be useful when combined with intermittent ventilation with outside air when, by chance, it is of suitable water vapour concentration to drive the inside space towards the set point. One can also envision climate control by solar powered dehumidification during the summer, with the winter climate controlled by buffering of both temperature and RH.

Acknowledgements

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References

[1] Tim Padfield & Lars Aasbjerg Jensen, 'Humidity buffering of building interiors by absorbent materials'. Proceedings of the 9th Nordic Symposium on Building Physics, Tampere, Finland May 2011 pp 475 - 482. Available online at:
www.conservationphysics.org/ppubs/
humidity_buffering_building_interiors_nsb2011.pdf

Appendix: the simulation program

```
# awk script for calculating Rh in buffered store. version 20120605
# data file measures every 30 mins so actual ach is halved for calculation
# buffered RH is appended to data file.
# usage: awk -f thisfilname datafile > outputfile

# functions for dew point,vapour pressure and g/m3
function svp(t) {return (610*exp(t/(t+238.3)*17.2694))}
function vp(t,rh) {return (svp(t)*rh/100)}
function w(t,rh) {return (log(vp(t,rh)/610.78))}
function dpt(t,rh) {return ((w(t,rh)*238.3)/(17.294-w(t,rh)))}
function gm3(t,rh) {return (vp(t,rh)*2.166/(t + 273.16))}
# difference in g/m^3 water vapour outside minus wv inside
function gm3d(tout,rhout,tin,rhin) {return (gm3(tout,rhout) - gm3(tin,rhin))}
function gm3toRH(t,g) {return (100 * g/(svp(t)*2.166/(t + 273.16)))}
#
# data columns: (1:date 2:time) $3:t_out $4:RH_out $5:t_in (6:RH_in)
# constant air change rate per hour

BEGIN {
       bvalue = 100 # unfired brick
       area = 7.5 # sq m
       bvalue2 = 2 # other surfaces
       area2 = 50 # sq m
       vol = 26 # cubic m
       actual_ach = 0.063 # 0.125 recalculated to half hourly
       tin = 17.0 # starting value
       h2o_inside = 11.0 # starting value g/m^3
       # calculate virtual ach
       ach = actual_ach * vol/(bvalue * area + bvalue2 * area2 + vol)
       }

# calculation for each row in data file (half hourly)
{
      h2o_inward = gm3($3,$4)*ach
      h2o_inside -= h2o_inside * ach
      h2o_inside += h2o_inward
      # constant temperature used for RH calculation
      # because B-concept only works for constant t
      rhin = gm3toRH(tin,h2o_inside)
      # use this rh and temperature now, to calc new h2o_inside
      h2o_inside = gm3($5,rhin)
      # set t now as basis for next hours calc.
      tin = $5
      # write input row and append buffered RH
      printf("%s ", $0)
      printf("%3.3g\n", rhin)
}
```