Wall Performance Summary

One of the largest challenges with earthen architecture is how to apply modern day standards, codes, rules and regulations to earthen wall assemblies, in particular the metrics for moisture and vapor performance. Available historical data [Keefe] demonstrates earthen buildings last for centuries longer than their modern day counterparts built using modern day standards, codes, and building science.

The vapor barrier problem

The gap between traditional and modern day building information seems to be most prevalent when it comes to vapor and moisture control, widened further when building science took a turn in the 1940's based on a scientific study. The study, considered questionable as it implemented the arbitrary definition of vapor barrier permeance at 1 US perm or less, did not take into account situations when walls perform better without them, such as in the case of strawbale [J. Straube]. It can be further argued that vapor barriers are a cold climate artifact, embedded into current building practices more from habit then from understanding of moisture physics [Rose].

Vapor barriers were originally intended to prevent building assemblies from getting wet. However, through incorrect use of vapor barriers, assemblies that have been getting wet have been prevented from drying by the same barrier, increasing moisture related problems [Lstiburek].

It is now standard across all North American codes to regard vapor transmission in assemblies as the main topic of concern. With regard to this concern one of the biggest outstanding issues is how a mass cob wall with high permeance and capillarity can function without becoming saturated and without the creation of a dew point within the wall assembly.

In a conventional wall assembly there will be a point, usually at the vapor barrier wherein one side is exposed to cooler air and the other side to the warmer moisture-laden air, where condensation occurs on the warm side. This is where the dewpoint is met, and water vapor transforms into liquid. The BC Building code tries to alleviate this issue by controlling the Relative Humidity (RH) inside the structure to stay around 35%. Humidity beyond this poses increased risk of condensation inside the wall cavity, which leads to moisture levels that support mold, rot and general decay.

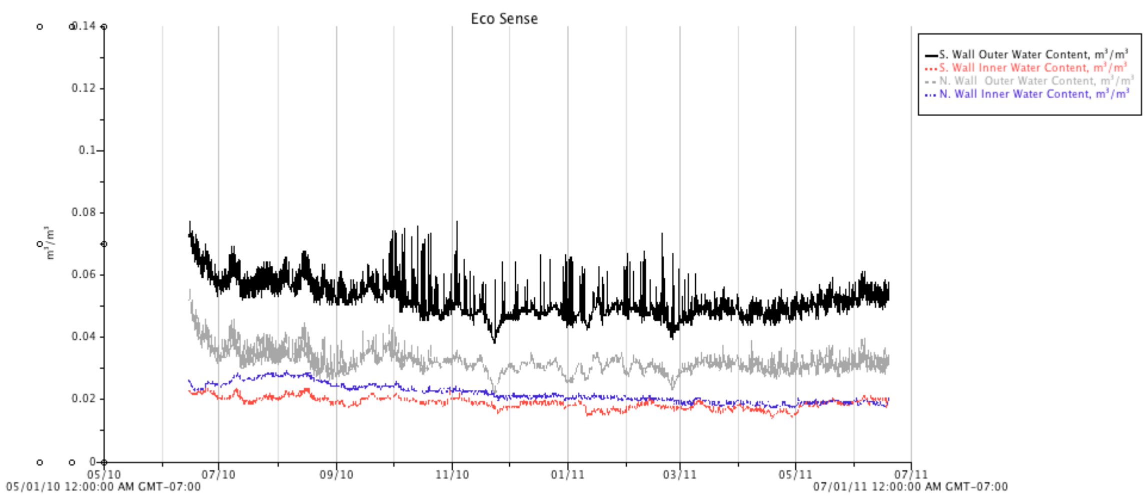
Cob Walls

One of the concepts building officials now struggle with is how cob walls absorb and release water vapor, particularly given generally higher humidity levels within the cob structure and thus greater vapor pressure on the earth wall assemblies. Conventional vapor transmission beliefs lead to the assumption that higher vapor pressure and humidity will continue to accumulate inside the cob wall. This lack of understanding commonly leads officials to assume that cob will achieve moisture content of 14% and beyond. This is untrue and can be illustrated with basic moisture physics and data monitoring.

The low equilibrium moisture content of earthen walls (0.4% to 6% by weight) combined with the ability of the walls to transmit moisture, actually keeps the timber elements with the earthen walls dry [Minke]. If designed properly, cob walls will wick and evaporate moisture, allowing moisture to evaporate before it weakens the structure. Natural earthen coatings do not inhibit this wicking effect, and in fact are porous enough to allow water to evaporate as readily as it is absorbed. Owing to ignorance, prejudices against loam (cob) are still widespread.

Moisture Content Data

The following graph shows the yearly levels of moisture content within the cob walls at Eco-Sense. The inside moisture content is very low, and the outer wall water content reaches a maximum of 7.73%.



Research has shown that clay straw mixes have a moisture equilibrium of between 0.4% – 6.0% [Minke]. The research data on the walls clearly documents that on the inside of the home, (the wall surface receiving the highest vapor pressures), the moisture level does not exceed 3%.

	m^3/m^3	Percentage
Max S. Inner Wall Water Content	0.0235	2.35%
Max N. Inner Wall Water Content	0.0293	2.93%
Max S. Outer Wall Water Content	0.0773	7.73%
Max N. Outer Wall Water Content	0.0555	5.55%

During the year of data collection, the exterior wall assembly temperature dropped below the outdoor dew point, a condition strongly avoided in conventional building. This occurred several times, evidenced not by a spike in moisture readings from the sensors as one would expect (due to presence of condensation), but by the readings of the temperature sensors and the outdoor RH/Temp sensor.

This means that that the walls did not experience condensation (which would be indicated by a dramatic increase in moisture content) but instead maintained a stable range of 5%-7% moisture content. The building science vapor research on dewpoints and condensation dictates that this is an impossibility, yet the earthen materials controlled the moisture levels, ensuring water content stayed well below the dangerous levels required for insect and fungal life as pointed out by Minke (> 14%).

It was also found that the granular porous characteristic of cob withstood the freeze and thaw cycles despite 5% moisture content, within the 5 cm of the exterior wall surface, without damage. This is very similar to the theory behind the performance of air-entrained concrete.

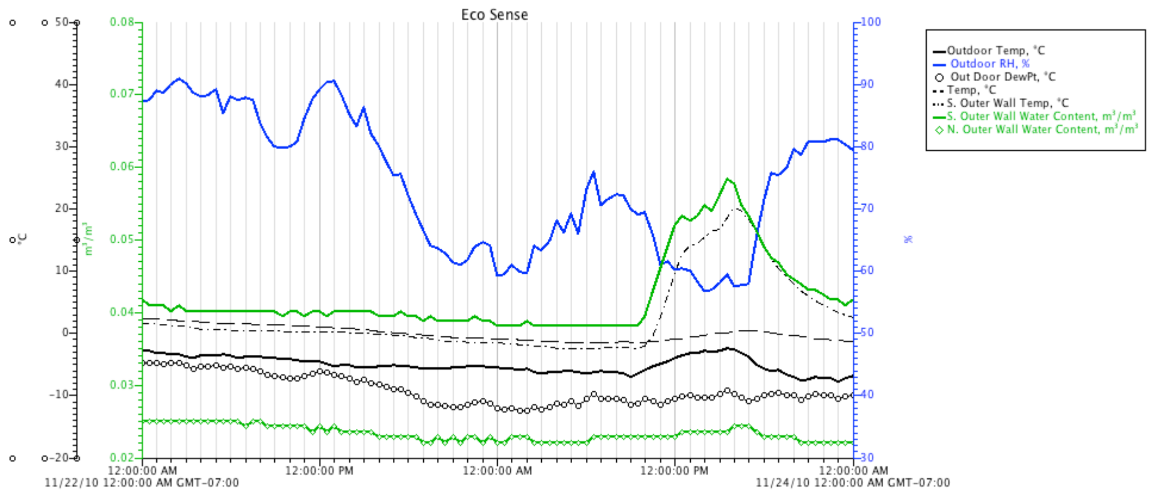


Figure 1 Sub zero characteristics

The Above graph shows characteristics when the exterior is at sub zero temperatures (-8°C) when the sun comes out. The North and South outer wall assemblies maintained similar temperatures, and their moisture content stayed firm, despite the low outside air temperature of <0°C, and wall temperature spike up of greater than 20°C.

Three important conclusions:

1. The subzero temperatures do not perceivably alter the walls moisture content level.

2. As the temperature rose, due to solar insolation on the surface of the wall, a dramatic shift occurred with the moisture in the wall. Moisture physics suggest that the moisture had the opportunity to flow out of the wall with the shift in temperature gradient. The warming and increase in vapor movement

would allow moisture to easily escape from the warm porous lime plaster surface, thus creating a capillary flow to the hot surface.

3. It was noticed that the surface of the wall was subjected to sub-zero temperatures earlier in the day, and then ranged over 20 C. In following days it stayed above freezing. In fact each day the sun was out the thermal mass of the wall absorbed and held onto some of its solar gain into the following day.

The significance of the third conclusion is that in conventional building science this would not translate into much of a difference in the temperature differential between inside and outside of the home, so heat flows and heat loss would continue. With the earthen mass wall heating up to such a degree, and the fact the wall assembly is one solid continuous mass, the inner wall would see the outer wall as warmer, and thus reverse the heat flows through the wall in response to the temperature gradient. Heat travels from warm to cold, so usually in the winter from inside to out, but in this case there would be a period where the flow in that direction would stop and reverse, thus making the wall perform as if it were actually of higher insulation value.

Dew Point Observations in exterior wall.

The following are snapshots of the outer wall assembly performance in relation to outside dewpoint and relative humidity. Of particular note is where the wall temperatures drop below the dewpoint. It is at these times that we would expect drastic changes in the moisture content in the walls. This does not happen. Instead moisture levels stay well within their narrow acceptable range.

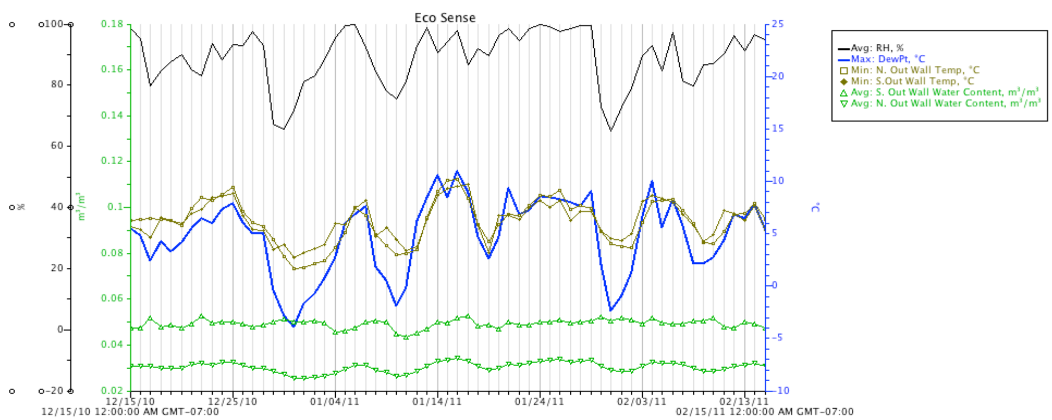


Figure 2 Winter Results

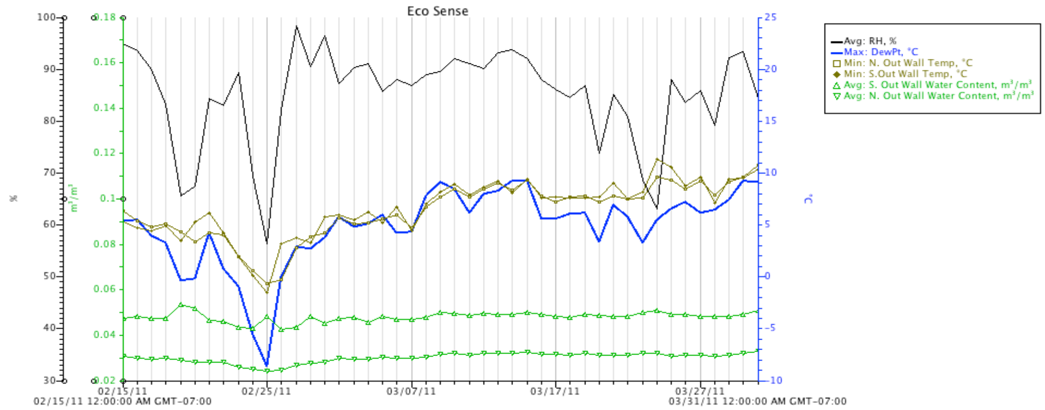


Figure 3 Spring Results

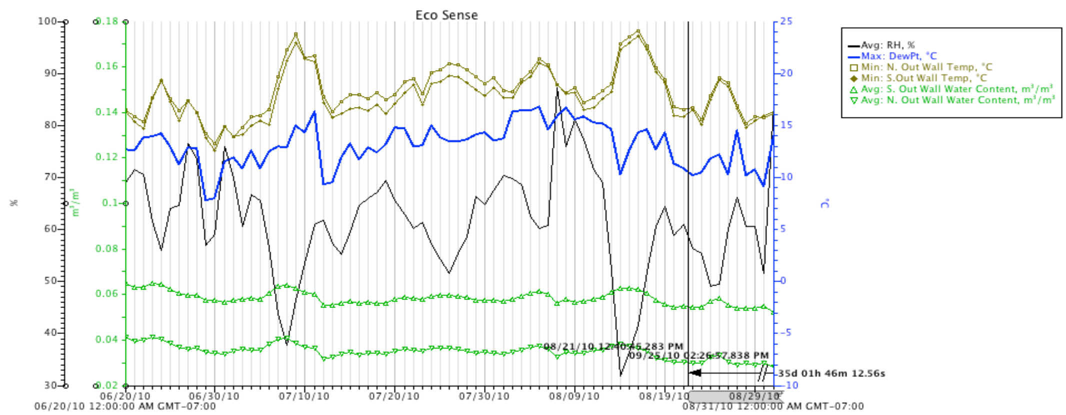


Figure 4 Summer results

The following graph demonstrates the range of the outdoor relative humidity (RH) in relation to that of the indoors, with the indoor RH a more stable line. It also shows the relationship between temperature and inner wall water content; moisture levels in the inner wall maintain a static level under 3%.

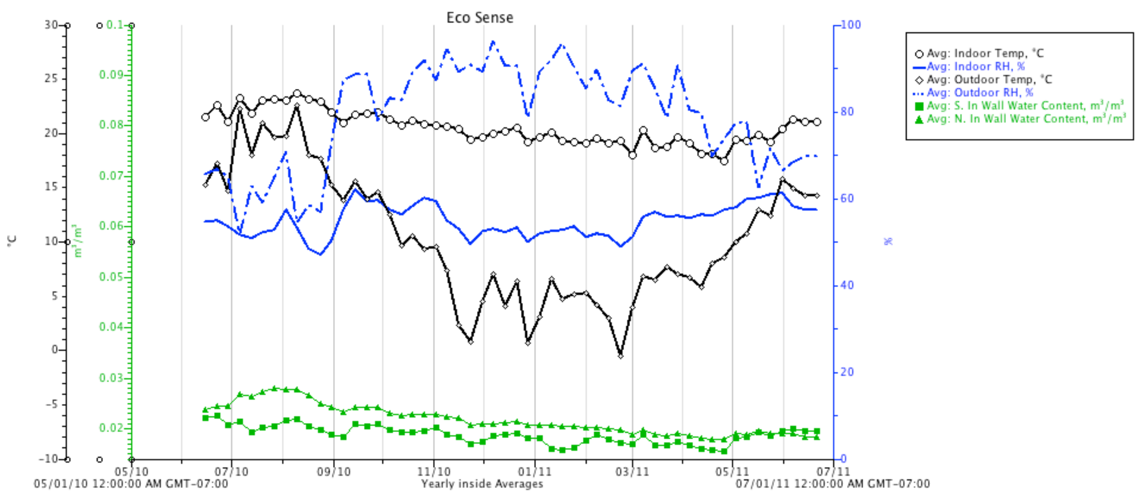


Figure 5 RH range

Relative Humidity ranges for the year.

The following graph shows the outdoor relative humidity variation for the year (min and max for each day), and shows the indoor RH (min and max). The key points of observation are the wide daily difference between the outside RH minimum and maximum and the corresponding very narrow range seen with the indoor RH. Also it is important to note the steady range of the indoor RH.

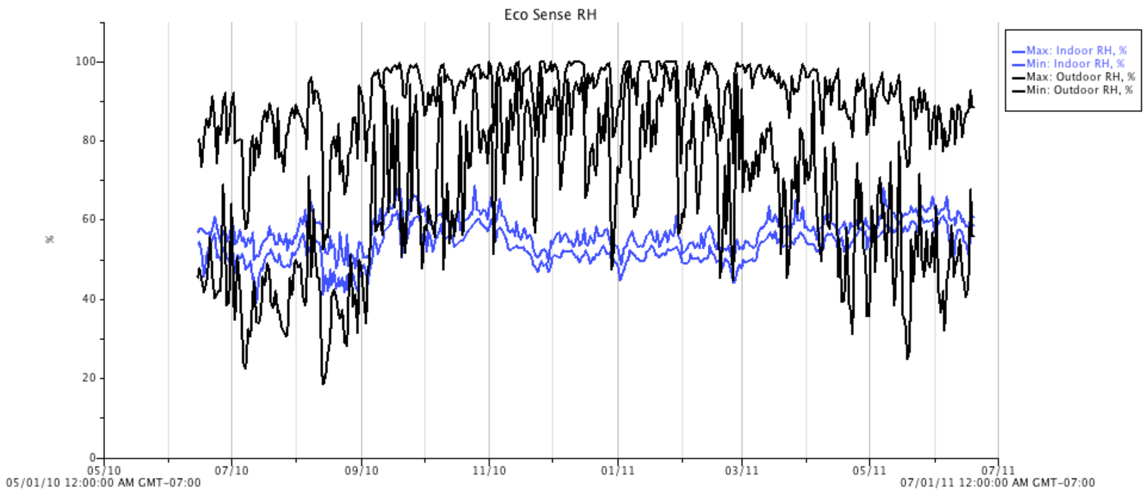


Figure 6 Outdoor annual RH variation

Indoor Dewpoint - relation to Inner Wall Temperature

In the BC Building code the issue over high humidity levels in the building is due to inside vapor condensing against a cool barrier. In conventional construction, insulation is used to attempt to knock down the temperature gradient (Delta T) on the cooler side of the vapor barrier. Water condenses to liquid at a dewpoint, and these barriers are the places where the dewpoint occurs in conventional building.

Below is a graph showing the homogenous temperature inside the cob dwelling in relation to the inner earthen wall assembly. The cob wall is a large thermal mass, and as demonstrated on the graph, this mass is a degree or so cooler than the inside temperature. The dewpoint for the inside is considerably lower and at no time do the inner walls come close to the dewpoint, (though as we have seen above with the outer walls, it is of little consequence even if it did).

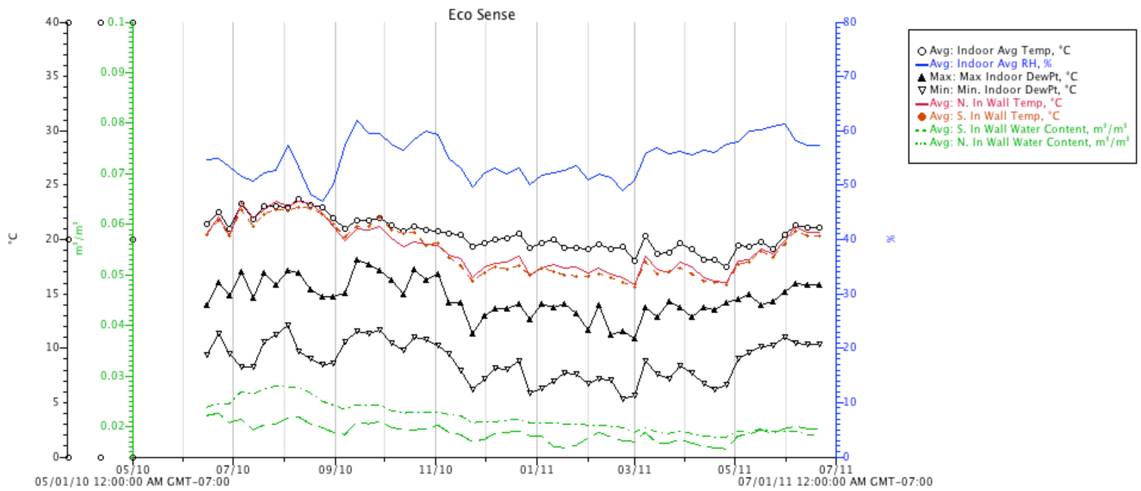


Figure 7 Temperatures

Initial Conclusions

The data collected for this project involves over 212,000 data points over a period of a year. These are just some of the initial observations from the research, observations that have previously been discussed about existing earthen homes for centuries, but have never before been seen in such exact measured detail.

What is very clear from the preliminary findings is that the cob wall functions drastically differently from the conventional systems that our Codes and regulations refer to. This clearly demonstrates why earthen buildings have lasted 5 to 7 centuries even in wet climates. It also demonstrates that the metrics used within the building code are too narrow to incorporate an unmeasured "different animal" and therefore shows why there has been hesitation from banks, insurance companies and building inspectors to allow such building projects. A previous lack of technical information and a steep new learning curve has caused hesitation at many levels.

The information on the energy performance analysis, combined with the performance of the wall system will hopefully lend credibility to these building methods as a safe alternative in a wet climate and seismically active area. A well designed and engineer earthen building is a sustainable, safe, and healthy option.

Note on Energuide rating:

To finalize this discussion, here a message from Peter Sunberg of City Green Solutions in Victoria when tasked with placing an Energuide rating on the home after 2 years of digesting the data:

> "The high level results from your home energy assessment are as follows:
>
> File number: 38WSD00859
> EnerGuide Rating: 77
> Blower Door Results: 2.12 ACH@50Pa

Equivalent Leakage Area of 684 sq cm

Your air leakage rates are exceptionally good. The EnerGuide rating of 77, unfortunately, does not accurately represent the innovative and tremendous energy efficiency of your home. The HOT2000 software and the ecoENERGY Retrofit Homes program in its existing form is not able to account for your particular solar heating system and utilized base load default assumptions for interior loads for electric appliances, lighting hot water and occupancy. Essentially this program is currently designed to provide a quick and cost effective energy assessment that meets the requirements of estimating energy consumption for typical homes/homeowners. The software is currently under revision to address many of these issues."

Notes

60 is the nanogram per second per square meter per pascal [ng/PA s m2] or 1 US perm (the US perm is defined as 1 grain of water vapor per hour, per square foot, per mercury), the number required to properly address vapor transmission.

References

2006 BC Building Code, 2006

Straube, J.F. *Moisture Properties of Plaster and Stucco for Strawbale Buildings*, Report for Canada Mortgage and Housing Corporation, June 2000

Minke, Gernot Building With Earth: Design and technology of a sustainable architecture, Birkhäuser, 2006.

Lstiburek, J; Understanding Vapour Barriers; Building Science Digest, BSD 106, 2006.

Keefe, Laurence: Earth building: methods and materials, repair and conservation, 2005