THE EFFECT EARTHERN PLASTERS AND EXTERIOR LIME STUCCOS HAVE ON CONTROLLING HUMIDITY AND TEMPERATURE IN BUILDING ENVELOPES

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ABSTRACT

Logged data of temperature and humidity were collected inside two test buildings, one constructed of compressed earth blocks (#2CEBs) and one of concrete masonry units (#4CMUs), with 1,120 ft^3 of interior space and identical roofs and floors. Without clay and lime plasters the #2CEB relative humidity varied 15%RH and temperature varied 4°F, #4CMUs humidity varied 33%RH and temperature varied 17°F. One year later with similar ambient conditions and clay interior plaster and lime exterior stucco #2CEBs humidity varied 16%RH and temperature varied 2°F. The #4CMUs humidity varied 14%RH and temperature varied 8.5°F. The drop in interior humidity in the CMUs can be explained by the phase change material (PCM) properties of the clay in the interior earthen plaster. The reduction in the interior temperature swing by half from the year before is hard to explain by just water's PCM interaction with clay. Lime has a low thermal conductivity and is a mineral of dual reflectivity index, effective in reflecting solar radiation. This reduces the radiant energy that can be absorbed and converted into thermal energy as sensible heat. Lime is also vapor permeable and allows moisture to escape permitting evaporative cooling. Earthen and lime materials have traditionally been used together to create not only beauty but also comfortable homes. This data shows that incorporating them in the buildings system minimizes the rise and fall of humidity and temperature in building envelopes. This reduces the amount of external energy needed to maintain comfortable living conditions.

KEYWORDS

hygroscopic, thermal conductivity, dual reflectivity index, vapor permeable, PCM

INTRODUCTION

Two test buildings were constructed outside of Del Rio, Texas to study the differences in relative humidity and temperature of conventional concrete masonry unit (CMUs) and compressed earth blocks (CEBs). The study also wanted to look at the effects of exterior lime stuccos and interior clay plasters in controlling humidity and temperature from one year to the next.

Background

In previous papers John Morony (1) has covered the ability of adobe or earthen building materials to act as humidity sinks inside a building envelope and thus control the amount of thermal energy in the air space.

> "The means for temperature moderation in adobe houses may come from the ease at which moisture enters and leaves permeable and hygroscopic soil in response to changing atmospheric conditions. The movement of moisture in and out of the adobe is more than a simple transfer of water. It is the transfer of latent heat that must take place when there is a phase change in water that raises or lowers the temperature of the building fabric."

The ability of unadulterated earthen material, (void of synthetic binders or coatings over them), to control the humidity swing over a 24 hour time period inside of an enclosed building envelope has also been observed in other studies. Tim Padfield (2) notes in his studies on water absorbent materials to control humidity in museums that, "Hygroscopic walls and ceilings give substantial stability to the indoor relative humidity (RH) in rooms which are ventilated at less than about one air change per hour."

The hygroscopic property of clay classifies it as a porous material and is subject to equilibrium moisture content. Gernot Minke (3) makes reference to this equilibrium moisture content in his book.

> "Loam [adobe] is able to absorb and desorb [release] humidity faster and to a higher extent than all other building materials. Therefore, it balances the indoor climate. Experiments at the *Institute Forschungslabor fur Experimentelles Bauen* (FEB) (Builders Research Institute) at the University of Kassel, Germany, demonstrated that when the relative humidity in a room was suddenly raised from 50% to 80%, unburnt brick [adobes] were able to absorb 30 times more humidity than burnt brick in a period of 2 days. Even when standing in a climatic chamber at 95% humidity for 6 months, adobes do not get wet and lose stability: neither do they exceed their equilibrium moisture content, which is about 5%-7% by weight."

These three studies clearly show that clay, in the earthen building material, is interacting with water vapor at the latent heat of vaporization. This type of phase change interaction has been sought out by the modern construction industry since the 1940s. Helmut E. Feustel and Corina Stetiu (4) in their paper on *Thermal performance for Phase Change Wallboard for Residential Cooling Application*, state "…that the use of PCM materials in plaster or other wall coverings allows the storage of high amounts of energy without significantly changing the temperature of the room envelope. As heat storage takes place inside the building, where loads occur, rather than externally, additional transport energy is not required." This interface enables clay to regulate the relative humidity and temperature in an enclosed building envelope. This effect has been noticed in many cultures that use earthen materials for building. It is not until recent times that it has been scientifically classified as a phase change phenomenon, Morony, (1).

This experiment was not limited to the effects of earthen plasters or adobes. Each of the test units was plastered with a traditional two coat exterior lime stucco and received a coat of limewash. Lime has many attributes that differ from ordinary portland cement (OPC) that has replaced traditional exterior lime stuccos. Lime is a breathable building material that has a high porosity and high permeability and thus permits evaporative cooling. Lime is a mineral of dual reflectivity and has a low thermal conductivity that limits the amount of solar/radiant energy that it absorbs. This in turn limits the amount of thermal energy that is transferred to the substrate and transferred to the interior building envelope as sensible heat. Unlike lime, OPC has a low porosity, low permeability, relatively low breathability and high thermal conductivity. Although OPC is made of lime and clay, their properties have been destroyed by the high burning temperatures associated with manufacturing portland cement.

Procedures

The two units in this study were constructed in the spring of 2005 at Quail Run subdivision in Del Rio, Texas.

Unit #2. A CEB building constructed of local site based soil using a portable compressed earth block machine that makes 10” x 14” x 4” building blocks making 14” walls. These blocks were mortared together with an adobe mortar that was made with the same soil the blocks are made of.

Unit #4. A CMU building constructed of conventional 8” x 16” x 8” CMU building blocks making 8” walls. They were mortared together with a portland cement mortar.

Both units have inside dimensions of approximately 10’ x 14’ x 8’ resulting in an internal volume of 1,120 ft^3 air space. The floors in each unit are unfinished earth. Roof construction consists of 2” x 8” rafters with ½” decking on the roof and ½” sheetrock on the ceilings. The ceiling cavity was insulated with R-18 fiberglass insulation and a white roofing membrane was applied to the flat roof. Each unit has an insulated exterior door which remained closed during testing periods. The first summer of testing, both units remained free of any interior plaster and exterior stucco. During the winter of 2005-2006 each building was stuccoed with two coats of exterior lime plaster that received one coat of limewash and both units received ½” of local site based earthen plaster on the interior. Data was then taken, over a 24 hour period, during a hot humid period the second summer that resembled the similar conditions of the previous summer.

Ambient humidity and temperature were recorded on a separate data logger.

Data Logging

VERITEQ data loggers, *Spectrum 2000*, were utilized inside the modules and set to record temperature and relative humidity every two hours continuously during the time of the experiment. Doors remained closed at all times. Temperatures were read to the nearest whole number. Data loggers were used in Unit #2, Unit #4 and outside (Ambient #5) to measure temperature and humidity during two testing periods: Relatively hot and humid time periods in June 2005 and then again in June 2006. Results from the first year’s data logging are recorded in ‘Fig. 1’ and second years in ‘Fig. 2’. Without clay and lime plasters the #2 CEB temperature varied 4° F and humidity varied 15% RH. The #4 CMUs temperature varied 17°F and humidity varied 33% RH. One year later with similar ambient conditions and lime exterior stucco and clay interior plaster, #2 CEB temperature varied 2° F and humidity varied 16% RH. The #4 CMU temperature varied 8.5° F and humidity varied 14% RH. In both the CEB and the CMU units the temperature variation from the first year to the second year and the CMU unit’s relative humidity variation were cut in half during the same test period. This data is in accord with other studies that have been done regarding the hygroscopic properties of clay and their ability to control humidity and temperature swings in a building envelope.

FIGURES

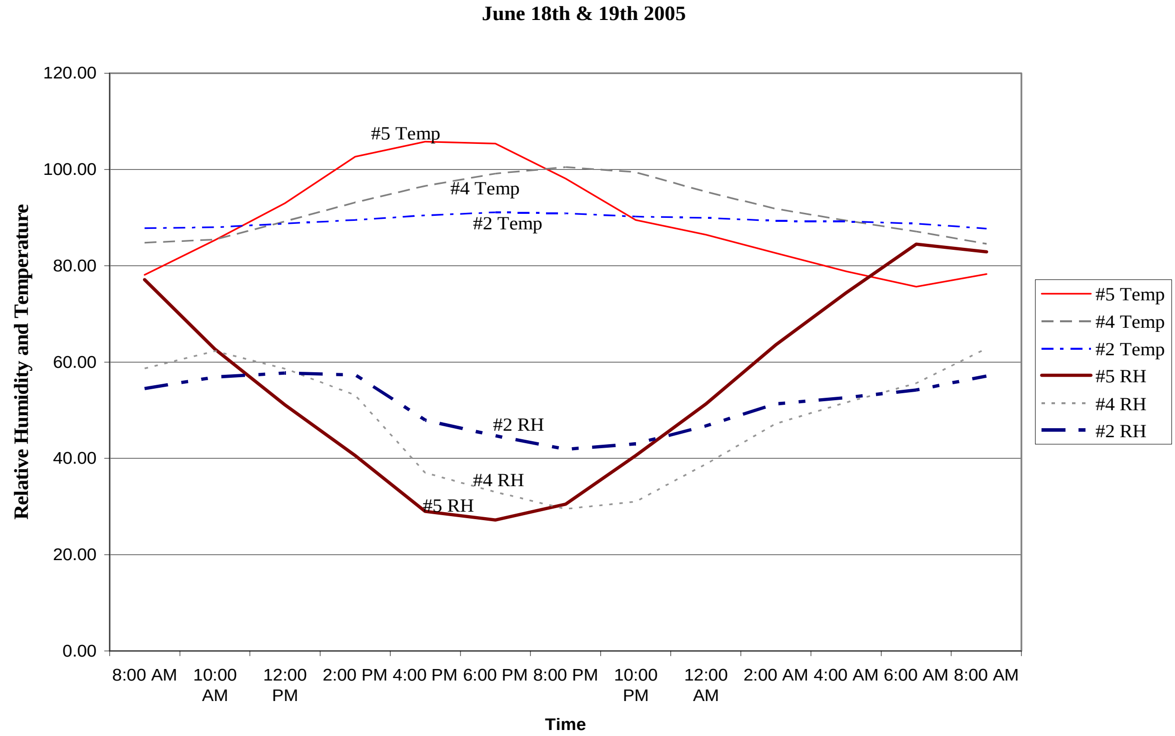

Figure 1. June of 2005 logged data for relative humidity and temperature for: #5 Ambient conditions, Unit #4 CMUs, and Unit #2 CEBs.

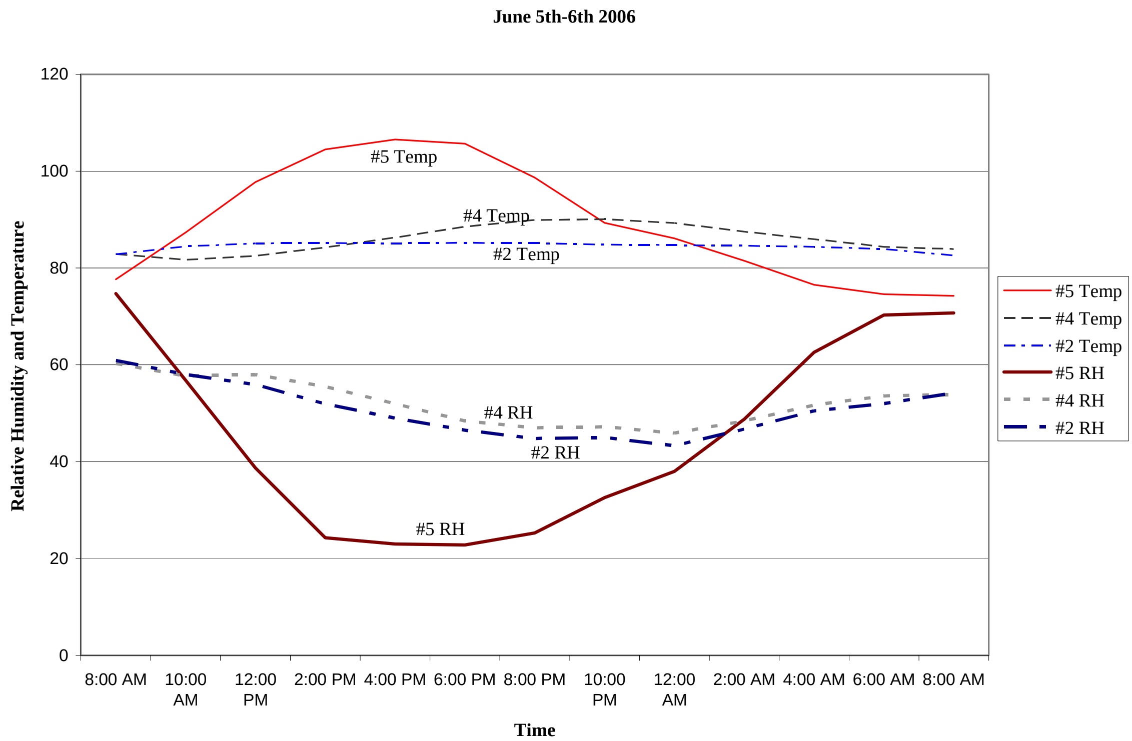

Figure 2. June of 2006 logged data for relative humidity and temperature for: #5 Ambient conditions, Unit #4 CMUs, and Unit #2 CEBs.

Discussion

The difference in the relative humidity and temperature in the #4 CMU test unit before and after lime stucco and earthen plaster were applied is dramatic. The hygroscopic properties of clay and how it is able to interact with the latent heat flux of vaporization of water could explain the dramatic drop in the humidity. However, the dramatic drop in the temperature is hard to explain with just the phase change properties of water and its interaction with the hygroscopic properties of clay. In the compressed earth block unit the humidity swing raised by 1% when the temperature swing was cut in half.

Looking at the properties of lime as a building material we find that it is a material with low thermal conductivity and is a mineral of *dual reflectivity index*. This makes the lime stucco more effective in reflecting solar radiation and absorbing less thermal energy from the ambient environment. This in turn limits the amount of thermal energy that is transferred to the substrate and transferred to the interior building envelope as sensible heat.

In a systems approach to buildings, earthen plasters can give us a hygroscopic material that is able to interact with the phase change of water at the latent heat flux of vaporization that the modern construction industry has been seeking out for more that 60 years. Lime exterior stuccos can give us an exterior coating that is effective at reflecting solar radiation and thermal energy. Lime stuccos have a successful history spanning hundreds of years where conventional portland cement based stuccos have a history of failure within decades.

Traditional earthen and lime building materials have been used extensively by humans all over the planet. Just recently have we been able to scientifically classify the benefits of these traditional building materials. The capability of these traditional materials to maintain comfortable living conditions inside a building envelope and to require less external energy to be imported is of utmost importance as the human race addresses energy consumption, CO2 emissions and moves forward.

ACKNOWLEDGEMENTS

I would like to thank John Morony and J. O. Stewart for providing the raw data on their experimental projects in Del Rio, Texas. Without the support of these two gentlemen this information would not be available to us.

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