RESEARCH HIGHLIGHT

Technical Series 00-103

Straw Bale House Moisture Research

INTRODUCTION

Straw bale houses do not have a long history in North America. There are isolated examples, but no large stock that is a sample for testing. Everything is new to some degree: designs, details, wall constructions, bale support, exterior coatings, code acceptance and so on. Researchers and builders do not know how well straw bale walls deal with moisture.What happens if you build with wet straw? Does it dry out over time? Is straw naturally better able to deal with water than building products such as wood? Will house humidity levels affect straw bale walls—especially during long Canadian winters? Would a vapour barrier help? If rain wets the stucco, does the straw underneath get wet? How do you keep the wall dry by a window when there is no drainage plane behind the stucco to carry the water away?

RESEARCH PROGRAM

CMHC commissioned research into moisture content of straw in walls and floors.The research included developing monitoring equipment, investigating moisture problems in older straw bale houses and monitoring moisture in the walls of new houses.

There was also laboratory research on stucco permeability and moisture uptake. CMHC reports the results in a *Research Highlight* 00-132 (order no. 62631).

MONITOR DEVELOPMENT

A contractor developed two inexpensive moisture content monitors. The devices are accurate enough for homeowners who want to track the condition of their houses. The contractor came up with two systems. The first one, an hygrometer, is a residential relative humidity sensor. The contractor took the hygrometer apart, buried the sensor inside the wall and mounted the hygrometer display on an interior wall. The second uses a wooden block.The block is buried inside the wall. Electrical leads from the block allow the moisture content to be read by wood moisture monitor.

It's simple to make both. CMHC has free plans for both in *Straw Bale Moisture Sensor Study, Research Highlight–Technical Series 96-206* or from CMHC's website at: http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/index.html#1996 “Homemade Straw-Bale-Moisture Meters” in the spring 1998 issue of *The Last Straw* suggested modifications to CMHC's designs.

FIELD TESTING

CMHC looked at the condition of several Quebec straw bale houses built in the 1980s. CMHC completed a study on the condition of straw bales used in floors—a technique sometimes called “waffle-slab”—of four structures. For both projects, researchers drilled through the stucco or concrete finish, took samples of the straw bales and analyzed them for moisture.

Using the inexpensive monitors, researchers tested moisture on four groups of recently built houses. The groups field-tested were:

- four houses in Nova Scotia
- four houses in Alberta
- exterior walls of nine houses in Alberta
- exterior walls of five houses in B.C.

RESULTS

Monitors

The field studies show that hygrometers and moisture content monitors have their place—and that both have limitations.

Hygrometers react more quickly than wood-block monitors.The easy-to-read display is continuous. It is perhaps too obtrusive for many homeowners.There are some questions about the ability of the sensors to survive in a damp environment. It is also questionable if this quick response means that homeowners understand their wall performance better.

Wood-block sensors require an instrument to read the moisture content of the wood block.The homeowner can reckon the straw moisture content from the wood block's moisture content.

Since moisture content changes more slowly than relative humidity, wood-block sensors may be a more realistic way to warn of danger to the straw.

Correction factors are available for the species of wood used for the block and for temperature.The research showed that most people do not correct the readings. The temperature correction is important. Because people did not use the correction factors, the research results during very cold periods may be out by several per cent.

Both hygrometer and wood block results are only an approximate response. It would be best to use the results as a moisture triage—the straw is definitely dry, definitely wet, or at risk and needing more monitoring or inspection.

Field Testing

Researchers investigated the Quebec houses in 1997. These houses were built differently than most current straw bale houses.The straw was mortared on all sides, like big bricks.The builder then applied stucco to the “bricks.” Louis Gagné pioneered this technique, which is the subject of several CMHC reports. The report about the 1997 research, *Pilot Study of Moisture Control in Stuccoed Straw Bale Walls*, is available from CMHC or on CMHC's website:

http://www.cmhc-schl.gc.ca/cmhc.html

The Pilot Study found several areas where the straw was wet and moldy, and concluded that:

> “. . . troubled zones in the straw all seemed explainable after the fact: moisture sources, paths and entrapments result in the net annual wetting regime approaching or exceeding the net drying regime; straw staying moist enough into the summer warmth is rotting.”

The study found no deterioration of the straw resulting from contact with the stucco.

The results of the investigation of straw in floors were discouraging.

Of the 12 samples, two in an occupied house were in the range of 20 to 30 per cent moisture content (MC). All the others exceeded 45 per cent. Some were as wet as 300 per cent moisture content; these samples showed liquid water in the cavities.

Current advice on preventing straw rot recommends keeping it under 20 per cent moisture content. Rot typically begins at 25 to 30 per cent moisture content. The collected core samples showed that in-floor environments are conducive to rot. All the samples showed at least some discolouration at the base of the concrete cavity; the straw was rotting from the bottom up.The longer the straw had been wet, the more developed the rot. Several bales had lost volume and subsided within the concrete cavity. In the worst case, a straw-insulated swimming pool, there was nothing but a pile of black compost in the base of the cavity. The waffle slab floor of a Montréal-area house is still being monitored with wood-block sensors. Straw moisture content varied between 14 and 22 per cent in the first year following construction.

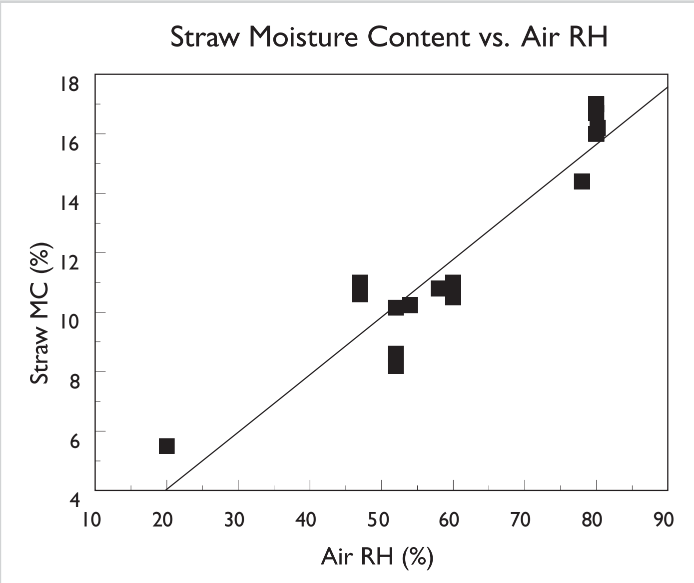
The four-house Alberta project had several wall locations monitored every three months for a year. Researcher Rob Jolly placed hygrometers in the middle of the bales in the four houses.

The test results are expressed as per cent relative humidity in the air in the bale. Most of the July readings were below 75 per cent, except for some values in the range of 75 to 85 per cent in bathroom walls. By October 1997, almost all results were in the 35 to 45 per cent range, with a few excursions into 50 to 60 per cent in traditionally wetter areas such as bathrooms. North walls also retained more moisture through the summer.The readings dropped to a low of 20 to 30 per cent in mid-winter and climbed back to 50 to 65 per cent in the summer of 1998.

Several hygrometers were placed in the straw just behind the exterior stucco.These exterior monitors showed high levels of humidity, up to 95 per cent, even when mid-bale monitors were showing much lower humidities. This suggests that the concept of a quick moisture redistribution in bale walls is probably not valid. The high humidity periods often followed one of Alberta's infrequent rains. The next round of Alberta house research was launched to determine the significance of this exterior straw wetting.

The Nova Scotia results showed similar trends. Researcher Shawna Henderson monitored the Nova Scotia houses using wood-blocks and wood-moisture meters. All readings, for the middle of bale walls, averaged 10 per cent wood moisture content in May and 12 per cent in July, with a few excursions above 15 per cent.

The September readings were generally lower than those at midsummer, at around 11 per cent. These wood moisture contracts in Nova Scotia are roughly the same as the air relative humidities as measured in Aberta. See the graph below for a conversion.



The highest reading—19 per cent—was at a site with a known history of water leakage. Mid-winter readings dipped to six to eight per cent with a gradual rise to the peak of the previous year occurring through spring and summer. On average, the north and east wall moisture content was slightly higher (one per cent indicated) than the moisture content of the south and west walls. There was no trend showing a wall position (high, mid or low wall) to be consistently higher. The Nova Scotia report, *Moisture in Straw Bale Housing*, Nova Scotia, is available from CMHC.

The mid-wall tests showed that few houses have high moisture levels inside the bale walls, except where there had been significant leakage. The research also showed that the monitors, while crude, provided useful information on the moisture content of the straw. The next round of tests was designed to see whether bale moisture contents might be higher just under the exterior stucco. It was at this location in the wall that Rob Jolly observed high relative humidities following a short rain storm, a condition that linge red for weeks despite a return to dry weather outside. The nine-house Alberta wall study included eight houses in that province and one house on the rainy West Coast. This time Rob used wood-block sensors with a wood-moisture meter. All monitors were placed close to the exterior stucco. The test results in the relatively dry Alberta climate showed a similar pattern to the two earlier studies, with peaks in June or July. Rob's conclusions are that straw bale walls do not exhibit any unique propensity for moisture retention. It is clear that straw bale walls can function, without incorporating an interior vapour barrier, in northern climates that receive mild to moderate amounts of precipitation.

In comparison to standard frame construction, straw bale walls generally incorporate higher perm (more breathable) interior and exterior protective layers. Within limits, a straw bale wall has the capacity to adsorb and absorb moisture, and diffuse it to either the exterior or interior of a structure. However, this capacity should not be used as an excuse for inappropriate designs and applications.

In specific terms, six of the nine structures in the nine-house Alberta study had moisture readings that could be considered acceptable (less than 14 per cent). Two Alberta structures had sustained readings and observed indicators that would be considered borderline to unacceptable. High moisture readings were accompanied by straw samples that were either decomposing or wet, or both. In both cases, these unacceptable readings and deleterious conditions resulted from two or more design flaws.

The third questionable case was on the West Coast. High and sustained levels of moisture in the north wall resulted only from high atmospheric humidity levels, and not from external wetting.

Design features which produced borderline or unacceptable moisture readings included two or more of:

- minimal or absent overhangs
- no capillary break between foundation parging and above-grade stucco
- structures subject to extreme interior wetting without drainage
- below-grade bales
- inadequate back splash protection
- northern exposure.

It is evident that the best way to guarantee dry walls is to prevent precipitation from hitting the exterior stucco. However, given the variety of successful wall systems and designs that were monitored in the Alberta survey, it is also apparent that numerous design strategies are both feasible and functional.

It is still unclear how appropriate straw bale construction is for high humidity and high precipitation climates. At the very least, extreme caution should be exercised when straw bale construction is used for walls with northern exposures in these types of climates. The five-house B.C. study, by Researcher Habib John Gonzalez, showed wood moisture contents typically less than 12 per cent.These houses were in the B.C. interior and not the wetter, coastal rain forest. Some higher concentrations were observed, for instance, following parging or in a location with a known leak. A lakefront house had somewhat higher spring readings—up to 14 per cent. Outside relative humidities were higher on this site than in the other four.

There is no consistent trend in the other houses of significant seasonal effects. If temperature corrections were applied to all the data, there might be up to two per cent change to the listed wood moisture contents, not a difference that would move moisture contents to being dangerously wet.

Habib summarizes his study by saying:

> "All of the buildings in this study did not use any form of barrier between the stucco and the straw bale walls. At most, first course wraps were used in some cases. Since 1995 I've been involved with over 30 straw bale construction projects in B.C., Alberta, the Yukon Territory, Washington and Idaho. Not one of the owner/builders or design professionals involved used any form of air or vapour barrier in their projects. In the field, this trend continues with the replacement of the first course wraps with stucco sealers to protect the bottom course bales from the splash back moisture. Sealers are fast and simple to apply and they let the stucco penetrate deep into the bales rather than sit on a composite of stucco wire and building paper sewn through the bales with baling twine. There is a clear consensus against the use of air and vapour barriers in baled fibre buildings."

IMPLICATIONS FOR STRAW BALE BUILDERS

Straw bale construction is still rapidly evolving, with changing details and materials. It is wise to monitor the condition of straw bale walls. The monitors developed are working adequately for this purpose and descriptions of the monitors are readily available through various sources.

Generally, the straw bale walls in the houses tested were usually dry enough to avoid rot, either at mid-bale location or even under the exterior stucco. However, if the wall sees an abundance of moisture through plumbing leaks, surface water or a lack of rain protection, some straw will begin to rot.

There is insufficient data, so far, on whether exterior treatments such as housewraps or surface sealers ensure low straw moisture content in walls. Opinions are readily available; there are not enough monitored houses to make conclusions. Straw in the bale walls in wet coastal climates will experience higher moisture contents. It is not yet clear whether this will lead to a significant wall failure rate.

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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