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Research & Development Highlights

96-206 Technical Series

Straw Bale Moisture Sensor Study

Introduction

Houses with straw bale walls are relatively rare in Canada, but many people have expressed interest in building this type of house, particularly in rural areas. The main advantages are the ease of construction, the high degree of wall insulation, and the environmental benefits of using an agricultural waste product as a building material. Most of the straw bale house construction in recent years has taken place in the US Southwest, an arid and temperate climate. While those houses have had few moisture problems, it is currently unclear whether straw bale construction will function equally well in places with long winters. The greatest concern is the possibility of moisture movement and accumulation in the straw bale walls. Moisture also accumulates in walls of houses with other types of insulation, but the moisture behaviour of those walls has been well established.

If a low cost moisture monitor could be developed, then it would be easy for straw bale homeowners or builders to track the moisture performance of their own dwellings. As more straw bale houses are constructed, monitoring would lead to an increase in knowledge about their performance in cold climates. If the straw bale walls perform well, then their construction could be encouraged. If moisture proves to be a problem, solutions could be explored.

Research Program

This study investigated easy-to-deploy, low-cost sensing methods to determine the moisture content of straw bales. The devices included electronic sensors, wood blocks, mechanical humidity gauges, etc. and a simple weighing procedure. The devices were placed in half bales that were tempered to various relative humidities, and then bagged in plastic to allow the straw and sensors to reach equilibrium. Straw moisture content was tested by oven-drying straw samples to equilibrium and comparing the weight loss during the drying procedure. Humidities were checked against a reference Hanna 8564 Thermohygrometer calibrated against NaCl (75.4% RH) and LiCl (11.1 % RH). A multimeter reading capacitance (1 pF accuracy for capacitive sensor) or a capacitance meter were employed to make measurements.

Findings

Initially the low cost electronic sensors now found in many RH meters and consumer applications were evaluated. Could the directly measured resistance of a resistive RH sensor or the capacitance of a capacitive sensor be measured by a common multimeter (voltmeter) and do the results correlate well with humidity levels? Three sensors were placed in 0.75" CPVC plumbing tubes to protect them from the straw.

The data from these experiments did not show that these sensors were suitable for this application. Each sensor tested appeared to have its own personality and therefore must be calibrated before and during use to be reliable. This quality suggested that these sensors would work better in a scientific or research environment rather than being used by homeowners.

A mechanical hygrometer was also tried out with an extension tube of CPVC pipe to see if this inexpensive monitoring device would be useful for straw bale monitoring. The results were not promising and the testing was terminated.

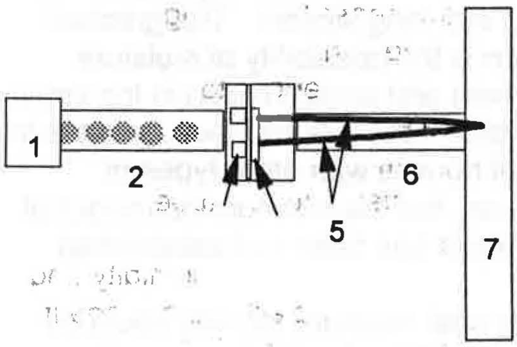
Three techniques which did work are described below. While the text gives specific instructions on how to duplicate the sensors, some variations would have little effect on the accuracy of the devices, such as the type and diameter of plastic pipe. The level of accuracy expected from these measurements is in the order of +/- 10% relative humidity, enough to distinguish a wet straw wall from a dry straw wall.

Electronic meters

Straw bales need to measured for temperature in addition to humidity. The commonly available Micronta RH meter was adapted for straw bale measurements by removing the sensor elements and putting it on extended leads. The humidity and temperature sensors were located away from the monitor (inside the straw bale) and the monitor located flush against the wall. See Figure 1.

The RH and temperature sensors (thermistor) in the Micronta are readily accessible and easily desoldered, then reconnected to the Micronta by means of wires. (If you are not familiar with the use of soldering tools, you may wish to ask a knowledgeable friend to do this operation.) The sensors were mounted inside a standard 18 mm CPVC plumbing tube (0.75 in. diameter) about 200 mm (8") away from the Micronta. In this way it was possible to cheaply and easily measure

Figure 1: Micronta remote sensing



1. Cap
2. Perforated CPVC pipe (covered with coffee filter)
3. Sensors
4. Mounting plate
5. Leads to display (wires)
6. CPVC tube
7. Micronta hygrometer

both temperature and humidity inside the bale on a continuous basis. The Micronta unit was opened, after removing the batteries, and the sensor and temperature elements desoldered carefully. To prevent damage the leads of each sensor element should be protected by holding them with pliers while desoldering. A standard soldering iron used for microelectronic circuits should be used. After desoldering, wires (about 200 mm or 8 inches long) are soldered to the Micronta board in the positions previously occupied by the sensor leads. The CPVC tube can then be permanently glued to the Micronta module (use epoxy).

The sensors are mounted on fish paper or electronic hobby board (sensor mounting plate). The paper or board is cut to fit inside the connector. The sensor leads are pushed through the paper or board and carefully soldered to the leadout wires from the Micronta (after pushing these wires through the sensor tube). After soldering, the sensor mounting plate is pushed into the connector and backfilled with a thick layer of epoxy to seal the mounting plate, strengthen it, and prevent diffusion of humidity between the sensor tube and the inlet diffusion tube.

The sensor measured both humidity and temperature as expected in the range from 35% to 90%. The fact that both temperature and humidity can be measured, and that RH is displayed continuously are advantages of this unit. The Micronta meters (two) both measured high (4-6 units at 70% RH) when compared to a reference meter. They need to be occasionally calibrated for accurate work and do not measure below 35% RH. Note that a simple calibration process is described in the free CMHC document "Measuring Humidity in Your Home".

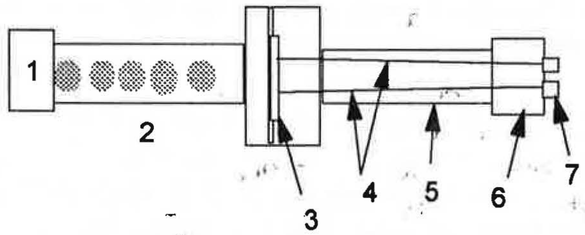
Wood Block Sensors

In theory the conductance of wood blocks should tell us something about the relative humidity in the straw bale and as a result something about the moisture content of the straw. Conductance is an easy measurement to make with a standard low cost wood block moisture meter. There is no mess, and sampling at many locations should be possible with little cost, time, or effort.

Blocks of balsa wood and white pine measuring approximately 50 mm X 75 mm X (3 mm to 25 mm) or 2" X 3" X (0.125" to 1" thick) were used in this study. Balsa was chosen because it is conveniently available in many dimensions, has a uniform grain, and is easy to cut. It is a delicate wood however and care must be exercised not to damage it.

Standard parts were used to make wood moisture probes. The wood moisture meter contacts the leadouts on the end cap of the moisture probe to make a measurement. Three probes made of CPVC plastic plumbing were prepared (as for the electronic sensors - 300 mm (12") long with holes in one end). The wood sensor is a 3 mm (0.125") thick round wood disc (balsa or pine) of 18 mm (0.75") diameter shaped to fit inside connector. Two holes are drilled in the wood sensor spaced 15 mm (0.6") apart, each fitted with a small stainless nut and bolt to hold the end of the electrical leadout wire. The leadout wires are connected to the wood sensor, the sensor is placed inside the connector and sealed in place by a thick backlayer of epoxy cement. The epoxy layer strengthens the wood sensor and seals it to prevent moisture movement between the inlet tube and the sensor tube. After the epoxy is hard the electrical wires are passed through the sensor tube and each is connected to the small stainless nut and bolt on the end cap. The

Figure 4: Wood moisture probe



1. End cap
2. Perforated CPVC pipe covered with coffee filter
3. Wood disk with screws
4. Wire leads to wall
5. CPVC pipe
6. End cap
7. Sensor contacts

nut and bolt are spaced to line up with the tips of the wood moisture meter.

The sensor was located at the centre of the bale. The length of the sensor tube can be adjusted for this purpose. There did not appear to be any problem with the materials used in terms of surface conduction along the CPVC plastic or between the leadout wires.

The experiments show that there is a good correlation between the conductivity of the wood blocks, the RH, and the straw moisture content. The blocks equilibrate after a time determined by the RH. As a matter of fact, cardboard, cloth, etc. all behave in the same manner. Most importantly, the conductivity of the straw itself correlates well with its own moisture content. See the graphs on the next page.

Below 55 %, the equilibration rate is slow. The block readily loses moisture if the bale is at a lower humidity but is slow to re-acquire moisture, if the humidity level in the bale increases but stays below 55%. Moisture content as measured by the wood moisture meter and by drying to constant weight correlate well. In fact, the two measurement methods even correlate when the block is not at equilibrium with the relative humidity in the airspace surrounding the block.

There may be some influence of temperature on response, but for the range of temperatures studied (13 C to about 28 C) the influence was small and difficult to determine. However, for measurements in winter, in cold climates, a temperature correction would be necessary. The temperature could be reasonably approximated from the inside and outside temperature, and the depth of the wood block in the wall.

In these tests, there did not appear to be any difference between the balsa and white pine. The depth of penetration of the wood moisture meter is a concern with softwood since the reading tends to increase with increasing penetration. An insulated probe (except for the tip) would simplify measurement or reduce the impact of this type of error (+/- 1% moisture) and these are commercially available.

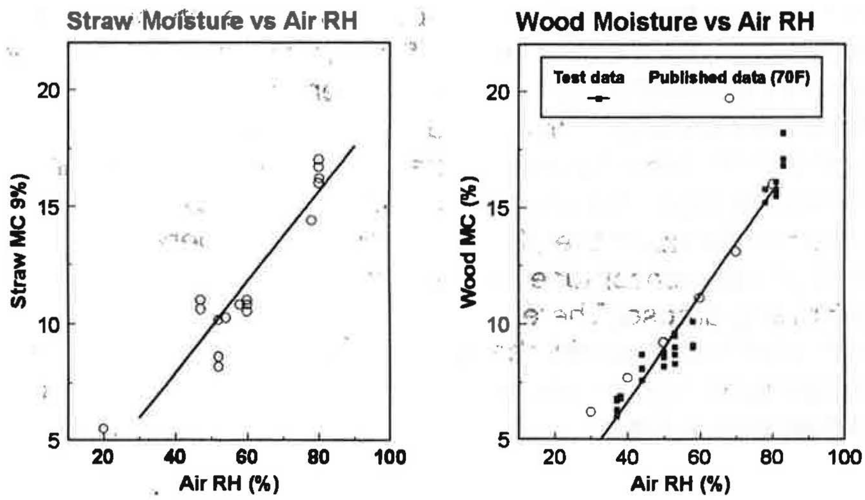
Instead of constructing these sensors, it may be possible to buy them ready-made with the leads attached. They are known as "Duff gauges". The drawback to wood sensors is the need for a wood moisture meter to take the readings, although one meter could be shared with other families in the vicinity to lower costs.

Straw as a humidity sensor

To establish the performance of the other sensors the moisture content of the straw was determined by weighing the sample after drying in an oven. An approximate 10 gram sample of straw was taken from the bale and wrapped in aluminum foil which was then perforated to allow moisture to escape while heating. The sample was carefully weighed (balance to 0.02 g) and placed in an oven at 120 C for 4-6 hours or until a constant weight was obtained. The difference in weights represents the moisture lost. The difference is expressed as a percentage of the dry weight. The foil and oven drying technique could be used for larger samples of straw, although the drying time may have to be extended for larger samples.

The straw only has to be dried the first time, to establish the weight at roughly 0% moisture content. First, weigh the foil in which you wrap the straw (F). Then wrap the straw in the foil, oven dry it, and weigh the straw and the foil together (FD). For each weighing thereafter, the moisture content is simply the sample weight (FS) minus the foil and dry straw weight, divided by the weight of dry straw (without the foil weight), or:

Moisture Content vs. Relative Humidity for Straw and Wood



resample the humidity. The sample must be left until it comes to equilibrium with the moisture content of the straw bale wall. The process can be repeated and the sample itself behaves like a sensor.

To simplify this procedure the sample could be placed in a standard plumbing tube perforated with holes at one end, the tube being located in the bale with a standard plumbing access port for removal. Once the sample is pushed to the end of the tube (perhaps with a string on it to aid in retrieval), the space between the opening and the sample should be filled up with insulation, perhaps something as simple as fibreglass in plastic bag. This insulation would have to be removed and re-inserted each time the straw is weighed.

Implications for straw bale builders

This project looked at several inexpensive means of monitoring straw bale moisture inside walls of straw bale houses. Three methods seem functional: the disassembly of a standard electronic household hygrometer, the use of wood blocks and a wood moisture meter, or the use of a weighed straw sample. All have some limitations or require some effort to undertake. All could provide a reasonable level of monitoring for less than $200, although to meet this price those using wood blocks would need access to a used or free wood moisture meter. The use of any of these techniques could alert homeowners to the presence of dangerously high moisture levels in their straw bale walls.

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Research Report:: *None available*
Research Consultant: *Instruscience Inc.*

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