Building with Straw

The rebirth of interest in traditional construction techniques, in part a search for new sustainable construction approaches, means that many people are looking at "alternative" construction materials. Cobb, rammed earth, and straw bale are just a few of the approaches being revived. Each has its aesthetic and technical features. However, it is important to remember that each also has its technical and practical limitations.

Straw bale construction is an option that has attracted wide attention. Straw is a natural, affordable, and annually renewable building material that has been used to shelter people around the world for thousands of years. Straw bale is simply one of many options for more sustainable construction. Its use depends upon accessibility to surplus bales.

Building with bales is a North American approach that emerged with the invention of the horse-drawn baling machine in the 1880s. Perhaps the highest profile straw bale homes are a series of 100-year-old pioneer houses in Nebraska, a dry area.

It is important to recognize that there are significant differences between straw bale and standard frame construction. A major difference is the lack of a vapour barrier on the interior and the absence of exterior sheathing in straw bale. The parging and stucco are applied directly to the straw bale wall. As a result, moisture build-up is possible.

High and sustained levels of moisture can have negative effects in at least three ways. First, prolonged wetness could cause structural damage. Second, mould growth associated with cellulose-based materials can cause serious health problems. Third, high levels of moisture reduce straw's insulation value.

Do we know enough to build stuccoed straw bale houses anywhere? We think not. Straw bale should not be used where there are concerns with stuccoed wood frame buildings. That includes a lot of coastal areas.

Perhaps straw may rot no worse than wood when equally wet and warm, but a stuccoed straw bale is not as moisture-load tolerant. The drainability and breathability of most wood frame walls is generally much better.

Whether straw, cobb, rammed earth, or wood frame, we have to design building envelopes with the underlying thought that water will penetrate the exterior cladding, so the system should be able to accommodate incidental moisture. Water will get in, so it must be able to get out without damaging the structure.

Compared to standard frame construction, straw bale walls generally incorporate higher permeance (more "breathable") interior and exterior protective layers. Although breathability of a wall can refer either to air movement through the wall or moisture movement, it commonly refers to moisture diffusion and not air movement. Much theoretical discussion about straw bale houses centres on the healthfulness of this breathability, but there is not much information available on the subject. Most of the straw bale houses built to date are in warmer arid climates where moisture concerns are easier to deal with because of dry conditions. To satisfy regulatory authorities, technical research on straw bale construction has concentrated mainly on the structural capacity and thermal resistance properties of straw bales.

The high vapour permeability properties of a straw bale wall means that it has the capacity to absorb moisture, and diffuse this moisture to either the exterior or interior of a structure. However, this capacity must not be used as an excuse for inappropriate designs and applications. Remember that vapour diffusion through interior finishes, good vapour retarder or not, does not move large quantities of moisture into the wall. If there is wall moisture from indoors, it can be tracked back to air leaks moving air through the wall and driven by sustained pressure differentials

Although straw bale houses do not use a traditional vapour barrier, they must still be airtight. A straw bale house, when properly plastered outside with cement-based stucco, and inside with cement stucco or wet plaster, will not offer many air leakage points, unlike drywall which often has gaps under the trim details. In straw bale construction, it is the plaster finish that is the air barrier. But as in conventional frame construction, airtight detailing must be followed to achieve airtightness.

Airtightness tests of several Nova Scotia straw bale houses proved that air sealing techniques can be applied to any building material. The tightest house was built by owner/builders who had paid special attention to air sealing in such areas as the wall/ceiling junction, the light and plumbing penetrations into the attic space and the spaces

between the window units and the rough openings. However, it registered 3.13 air changes per hour (the R-2000 limit is 1.5 air changes).

Moisture issues in mainstream housing range from the common use of wet or unseasoned local lumber to foundation leakage, poor site drainage, drywall nail pops, leaks, floor squeaks, truss uplift and condensation problems. Poor installation of air and vapour barriers leads to deterioration of wall, ceiling and floor materials and finishes, excessive moisture in crawl spaces due to 'rising damp', and high humidity related to poor ventilation of living spaces. Straw builders have to deal with all of these issues plus ones that are specific to straw: liquid moisture penetration, potential freeze/thaw spalling of exterior stucco finishes resulting in water damage.

Generally, the moisture in a wall is outdoor moisture penetration. Entrapment of exterior moisture guarantees trouble when the straw is wetted, because straw dries slowly. The straw could stay too wet into the warm weather, and rot in a few years. Mould growth can occur at temperatures as low as -5°C, and at humidities as low as 62%, although the optimum temperature ranges from +20°C to +28°C, and at relative humidity (RH) levels of more than 95%.

Testing Straw Bale Wall Moisture Near the Exterior Plaster *by Habib John Gonzalez*
Monitoring Straw Bale Moisture *by Rob Jolly*
Moisture in Straw Bale Housing, Nova Scotia *S.H.E. Consultants*

Design Considerations

The prime design consideration must be to protect the straw from exterior wetting. When designs are inappropriate, straw bale walls can fail, even in dry, low precipitation climates. Successful designs incorporated combinations of the following strategies:

- the use of verandahs, oversize gables and overhangs for direct control of precipitation
- standard-size gables and overhangs with a combination of other factors including:
- protection afforded by topography and vegetation
- minimal wind driven precipitation
- infrequent exterior wetting accompanied by prolonged drying cycles
- cement-based parging used on exterior and interior
- bales elevated above grade to eliminate backsplash

Designs which produced borderline or unacceptable moisture readings included:

- minimal or no overhangs
- no capillary break between foundation parging and above grade stucco
- structures subject to extreme exterior wetting without drainage
- bales placed below-grade
- inadequate backsplash protection.
- northern exposures

The exterior of straw bale walls is faced with stucco, an absorbent material, which is intimately connected to thousands of tightly packed, poorly draining wicks - straws - embedded in it and leading inwards. When the construction is located in a region with frequent wind driven rains and weak drying conditions, there will be problems.

Because of the increasing interest in straw bale construction, the CMHC has supported the monitoring of several straw bale houses in various parts of the country. Results show that straw bale houses can be designed and built to function properly, but that moisture is also a concern.

Taking measurements in straw bales is not easy. Part of the CMHC studies involved assessing tools to make the measurements. Measuring the relative humidity inside a bale was one technique used. Another was inserting a block of wood with wood moisture pins. The assumption was that the wood would establish moisture equilibrium with the surrounding straw, so the readings would reflect the moisture content.

Although both measuring techniques have their limitations they do provide a reasonable indication of moisture content.

The straw bale houses examined were in a variety of climate zones: Southeast British Columbia, in the semi-arid region of the Okanagan Valley; in Alberta, on the west coast of Washington, as well as in Quebec and Nova Scotia. All buildings displayed seasonal and random fluctuations in moisture readings. Although daily variances in RH are not an indication of straw degradation, prolonged high RH values (over 85%) generally indicate a problem.

Walls seem to have two peak 'wet' times: one in late winter and one in late summer/early fall. This matches the pattern of moisture collecting in a house during the heating season, dispersing over the spring/summer when windows and doors are open and fewer moisture-producing activities are confined to the interior of the house. The summer peak, which is higher than the winter peak, is indicative of the higher absolute moisture levels experienced in the summer months.

The results suggest straw bale walls do not have any unique propensity for moisture retention, but some walls examined, especially north walls, had moisture content readings of 14%-17% during the summer months. These levels suggest borderline to unacceptable conditions. Walls with a southern exposure were generally much drier than walls with other orientations and could handle significantly more exterior wetting.

Two Alberta houses had sustained higher moisture readings and observed indicators that would be considered borderline acceptable. High moisture readings were accompanied by straw samples that were wet and decomposing. In both cases, the problems were the result of two or more design flaws.

The third questionable case was a straw bale house on the west coast of Oregon. The sustained high levels of moisture in the north wall were the result of high atmospheric humidity levels, and not from external wetting.

In one house, areas of damp, slowly rotting straw were found under poorly built windowsills, even under a three-foot roof overhang (but which was two stories above). Some water may also have seeped down from condensation on the indoor glass surface.

In another house, problem areas were one foot above the slab-on-grade. The straw was found to be damp, dark and musty, slowly rotting in a ten-year-old wall. The source of moisture was "rising damp" which is ground moisture wicking through the concrete slab-on-grade that did not have a polyethylene or other effective ground cover. The amount of water rising was greater than the amount of water that could dry, so the straw was rotting from the slab upward.

Houses in Pompeii had slate damp-proof courses near the base of all masonry walls; are we super-slow learners?

Is straw bale construction only for rural applications?

The image of straw bale houses with their thick walls being suited only to rural or large suburban properties is being challenged by Julia Bourke, a professor of architecture at McGill University. She recently completed her own straw bale house on an infill lot in downtown Montreal.

The house is a 2 x 4 timber frame structure with bales packed between the struts as insulating infill. The straw was covered with a 4 to 5 cm stucco coat inside and out.

Prior to installation, a straw bale must be tested ensure that its moisture content does not exceed 11 or 12%, and must be kept dry during construction.

Building code issues remain problematic, as not all building officials will be comfortable with straw bale construction and may require engineering sign-off. There is also the issue of bale size. Straw bales are large, so a wall can be up to 2 feet thick, which can result in less usable floor space on a small lot.

Air Leakage Areas

Most air leakage points found in the four Nova Scotia straw bale houses examined are the same as those found in conventionally built houses. They are not inherent to the process of straw bale construction, except that there seems to be a higher ratio of owner/builders to professional builders. (All four of the houses tested were owner-built). Major air leakage areas were:

- at some electrical outlets on exterior walls where interior plaster was cracked or pulled away from the electrical box.
- testing holes and/or 'truth windows' without glass in front of the exposed straw.
- at gaps/cracks at the top of wall to ceiling/rafter connection
- at window frames at the connection between the frame and the rough buck or straw where no silicone or latex caulking was used to seal the opening at the buck/stucco connection.
- at the connection between door bucks to door and/or window frames
- plumbing penetration through exterior wall and/or through slab
- a handmade door/latch
- an attic hatch
- HRV ductwork in attic (one house)
- potlights in ceiling penetrating to attic.

Are there advantages to straw bale construction?

The most controversial issue is affordability. Proponents suggest there is a cost advantage, but there is no real cost advantage in building with straw - apart from the fact that you can use unskilled labour for a great deal of the work. Costs can range from $50 to $75 per square foot, and depending on finishing details can run over $95 per square foot.

- While the bales go up quickly, the plastering process is slow and requires skill.
- If locally available, the raw materials may be relatively cheap to buy.
- Straw bales are sound proof, reducing noise from outside, and make a building feel very solid inside.
- Plastered straw bale construction has excellent fire resistance. Studies have shown that plastered straw bale walls provide a two-hour rating.
- It is aesthetically pleasing because you can round off or soften edges, and make things like wide casements.
- Dry straw walls can make for a healthy home because of the high insulation values. The natural materials do not off-gas synthetic products.