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STRAW BALE HOUSING:

APPROPRIATE FOR EASTERN NORTH AMERICA, OR LONG-TERM POTENTIAL HEALTH CONCERN?

Sound ecological principles call for constructing housing which is affordable, safe and ecological. This means using basic materials which are obtained locally at reasonable price, are long lasting, are not overly bulky and difficult to handle, do not take up excessive space, will not deteriorate into harmful substances, or harbor pests, may be recycled, are not overly combustible or fire hazards, are easily maintained, and are attractive to residents and visitors alike. Some materials fit this bill better than others, both in a given location on the landscape and within a bioregion. Certain types of straw have proven to be excellent building materials in areas where they are abundant, or even considered as waste products, especially in agricultural areas of the West where the prevailing dry conditions typically do not encourage mold growth, and where other native wood materials may be absent or expensive. Straw kept dry can be an excellent insulating material, about R-2 per inch thickness, compared to about R-3.5 for fiberglass insulation.

Appalachian Conditions

With the advent of the new horse-drawn hay and straw baling equipment at the end of the 19th century, resourceful farmers in the Sand Hills of western Nebraska created well-insulated houses on the Great Plains, using the abundant natural straw resources available to them. But all building materials and shelter designs must be selected based on their performance, availability, and durability in a given bioregion. We review some Appalachian conditions for such construction.

Availability

Straw typically needs to be imported into this bioregion because Appalachia is not usually considered as a wheat or other small grain-growing region. The material must be brought in through expensive transportation means — a practice that is not quite synchronized with the ecological principle of building with native materials.

Climate Conditions

Appalachia and other parts of the Eastern North America are quite humid, especially in summer, and these climate conditions of high precipitation, high humidity, and high temperatures may provide optimum conditions for mold that could readily cause indoor air quality degradation leading to severe health problems for residents with respiratory ailments and allergies, and also lead to suppression of immune system functioning.

Expense

Imported straw bales would take up costly roofing area and floor space for the sake of insulation. The same or higher R-values can be obtained far more economically by use of other biologically derived materials, i.e., compressed straw, without using up as much of the building's footprint. This is especially true for smaller buildings (those under 1,000 square feet where one-fifth or more of the floor space could be consumed with the straw bale walls alone).

Ease in Construction

An appropriate technology principle is ease in construction by the owner-builder. Nebraska-style straw bale construction, where the walls are expected to be load bearing and support the roof system, can be quite tricky (more so than log or other wood-frame structures), and thus may require some expertise which may have to be sought out. Community-oriented "bale wall raisings" can utilize some unskilled labor and mimic traditional barn raisings.

Other Building Materials

In Appalachia, our overwhelmingly abundant natural resource for building is sustainably harvested wood — as logs, rough cut lumber, and cordwood — all readily available at relatively low costs along with other local materials such as stone and clay. Often older and substantial structures are available for deconstruction and can be ready sources of salvaged, reused, and recycled materials that can be refashioned into sturdy and healthy housing.

Inherent Insulation Value

As for its insulation value, dry straw is rated at about R-2 per inch thickness, compared to about R-3.5 for fiberglass insulation. With moisture absorption (perhaps due solely to ambient high relative humidities), the insulating value of straw falls dramatically.

Questions to Answer

Before undertaking the construction of a straw bale building we urge every prospective owner-builder to consider the follow questions related to *affordability*, *ecological soundness*, and *health and safety* — the three legs of a good housing project.

Is Constructing a Straw Bale House Good Ecology?

The answer depends on where one is standing — which bioregion one is speaking about. A western resident who wants an inexpensive material will find straw as a waste product of many western grain growing agricultural areas that is – most unfortunate for air quality and global warming — typically burned for disposal. When used in the bioregions where it is grown, there is little transportation cost involved. The same thing can be said in the dry Great Plains with relation to abundant wheat straw and lack of trees.

The story in Eastern North America may be quite different. Straw is not always readily available, and has other well-established uses such as for mulching. To bring the straw bales to an Eastern U.S. building site requires transportation costs due to the sheer bulkiness of the bales. At the same time less expensive locally available native materials are typically able to be found quite close by (salvaged and recycled building materials, stone and all types of wood products). ***The clear point here is what building materials work for one bioregion may not be automatically suitable for other bioregions.*** Building residential structures out of materials for which long term performance data are unavailable may be risky business.

Is a Straw Bale House affordable?

Again, the answer depends on local and bioregional circumstances as does all sound housing questions. If people are building small efficient homes with a concern for conservation of natural resources, then maximizing the amount of useable floor space becomes a major factor. And the percentage of wall area in a small straw bale home can take up considerable space, thus putting external pressure on an owner-builder to build a bigger dwelling to obtain an economy of scale. Unfortunately, this would be a false economy since large buildings take more resources to heat, cool and maintain.

Let us illustrate affordability by this example. A modest 25 by 40 feet (1000 square foot) rectangular house would have roughly 2 feet on all sides consumed by the footprint of the straw bale wall. Thus the usable floor footage is 21 by 36 feet or 756 square feet. The roof design should include a 2 feet overhang on all perimeter walls, and so total roofing area (1,276 square feet) includes much unused space because of the wall thickness. Note: a cordwood building's exterior walls with structural support are typically one foot thick and thus would contain over ten percent more usable floor space. If compressed 4-inch straw were used as insulation material in the exterior walls, some additional 150 square feet of floor space could be obtained.

Can moisture and ambient relative humidity affect straw bale construction performance?

A Kentucky farmer was told that people were building straw bale housing and she asked in wonderment, "Are they crazy?" She was not speaking of the sturdiness of the building, but of the mold problems on straw and hay which Eastern North American farmers are quite aware of in this humid climate. Straw and hay are both ideal media for mold growth due to high relative humidities and warm summer temperatures.

What are some of the experiences and observations of researchers looking at moisture and mold issues with straw bale construction outside of the primarily dry western climates?

Aprovecho Research Center has completed construction of a two-story straw bale dormitory in Cottage Grove, Oregon. Aprovecho's mission statement reads: "to provide a basis for scientific research on appropriate technologies and techniques for simple and cooperative living, and to serve an educational role in disseminating information on such technologies and techniques."

A $52,000 grant from the Oregon Department of Agriculture paid for the architectural services, helped to cover some of the building costs, and perhaps most importantly, funded a University of Oregon research project to determine moisture levels in the bales once the building was completed. The goal of the project is to scientifically determine if straw bale construction is a viable alternative in the moist climate of the Pacific Northwest.

In 1999 Dean Still, a researcher with the Aprovecho Research Center wrote about their experimental straw bale dormitory in Oregon's Willamette Valley, "OUR STRAWBALE DORM: 2 YEARS LATER: Can straw work in our soggy wet coast climate?"

"Straw absorbs moisture directly from the air when the dew point is not reached. In other words, bales become moister even when the relative humidity (RH) stays below 100%. A relative humidity of 70% equals approximately 20% moisture content. At 20% moisture content most organic material starts to degrade, such as grains, wood, dried meat and straw. The sensors near the outside of our bales showed an average above 20% moisture content that closely follows the external relative humidity.

— No one seems to know if straw bales will degrade at 85% relative humidity while at 40°F. They do know that bales will start to decompose at a relative humidity of 85% at 70°F. *Stacybotrys atra*, which causes Farmers' Lung disease, develops at a relative humidity of 92% at 70°F. But some cellulose molds will grow slowly at temperatures as low as 27°F! As far as I know, we are in a gray area of knowledge here.

— Only time will tell if the straw will degrade in this very wet and cloudy climate. Farmers, who have stored straw in our valley for decades warned us that it would eventually rot. Straw kept in their big, dry barns only lasts about five years here before popping the strings, after swelling from increased moisture content, and showing evidence of mold. But no one knows if the same will be true for straw heated inside a wall. Perhaps studies like those on the Aprovecho dorm will eventually shed light on straw's usefulness as an insulation even here in the wet and wild Northwest. (The report from the University of Oregon on moisture monitoring in the bale walls concludes that, while relative humidity levels were high in the bales it will take further years of study to determine whether rot will or will not occur.

There is one case in Nova Scotia, where a new home was built with stucco applied directly to the straw bales. In less than a year, the bales on the lower course of the north wall did indeed suffer permanent damage. The report recommends either huge overhangs or an impermeable membrane between stucco and straw." **Source:** http://www.efn.org/~apro/strawbale.html

In personal communication with the Dean Still, he states: **"My opinion is that if the relative humidity is above 70% for long periods perhaps another [building] approach might be warranted."**

Typical Appalachian and Eastern North American annual relative humidities are in the 70% range, e.g., Asheville's annual average relative humidity is 73.5%, and the annual average precipitation is 47.59 inches.

As noted in Oregon's Willamette Valley, the rainfall moisture and humidity come in the cool winters, whereas in the Eastern North America, precipitation and high humidity are found during the warm summer months – conditions that are well documented for mold, mildew, and other fungal growth.

As Lou Host-Jablonski, AIA, an architect with Design Coalition in Madison, WI has noted: "My concern with straw bale in this [Wisconsin's] humid climate is the potential for real moisture problems and structural issues…. The trouble is the [untreated] straw can get wet and grow mold, and be a big problem as a structural material. To grow mold you need air, moisture, the right temperature, and the micro-organisms." **Source:** <http://designcoalition.org/features/lansing/interview.htm>

As Bob Platts, P.E. from Ottawa, Ontario, Canada who has investigated about 16,000 houses across Canada, including a 14,000-house cross-section done with infrared thermography notes:

"Strawbale construction proponents must not take false comfort from the cellulose similarities with well-researched wood-frame housing. Straw may rot no worse than wood when equally wet and warm, but stuccoed strawbale is not as "moisture load" tolerant: the drainability and breathability of most wood-frame walls is perhaps a whole order better. That's one strong reason why we have two-hundred-year-old wood-frame houses, even wrongly-insulated, looking to shelter the next and still next generations.

Even the much-forgiving wood-frame house can be brought down by trouble-prone detailing, high wetting/poor drying climates, and hard-driving usage (excessive indoor relative Humidity [RH], and flueless). Add in stucco exterior finish to that kind of mix, and rot is what you've got. Wood-frame housing can easily be built and run to last, but it does take some thought; stuccoed strawbale takes redoubled thought.

Do we know enough to build stuccoed strawbale houses practically anywhere? We think not…."

Source: *The Last Straw*, "A Threat To Strawbale Housing," Issue #22, Spring 1998 by Bob Platts, P.E. - Ottawa, Ontario, Canada

In the report, "WETTED BUILDING MATERIALS SPROUT MOLD IN 48 HOURS EVEN AT LOW RELATIVE

HUMIDITY," researchers Elliott Horner, Phil Morey, and Bryan Ligman report that mold colonies grew on water-damaged materials within 48-72 hours even at 44%-45% relative humidity (RH), though growth was slower.

They note that high relative humidity (RH) and condensation can readily promote the growth of mold, which is omnipresent indoors and outdoors. When mold contamination begins to occur, the mold species that tend to proliferate indoors often produce mycotoxins that make people ill. Indoor environmental quality professionals and others know that building materials must be dried quickly to head off potentially serious mold contamination. But how quickly must that drying be done, and how low must the RH be to stymie mold growth?

The researchers work for Air Quality Sciences, Inc. of Atlanta, Georgia. Horner, Ph.D., is director of the firm's microbial laboratory; Morey, Ph.D., CIH, is vice president of microbiology and indoor air quality (IAQ); and Ligman is a manager for building investigations. Horner presented the research team's findings at "IAQ 2001, Moisture, Microbes and Health Effects: Indoor Air Quality and Moisture in Buildings" in San Francisco, California, in November 2001. The conference was organized and sponsored by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
Source: http://www.repp.org/discussion/greenbuilding/200201/msg00400.html

Don Fugler of the Canadian Mortgage Housing Corporation (CMHC) has done extensive moisture testing in straw bale walls across Canada, and remarks:

"(On the west coast of British Columbia) high and sustained levels of moisture in the north (straw bale) wall resulted only from high atmospheric humidity levels, and not from external wetting."

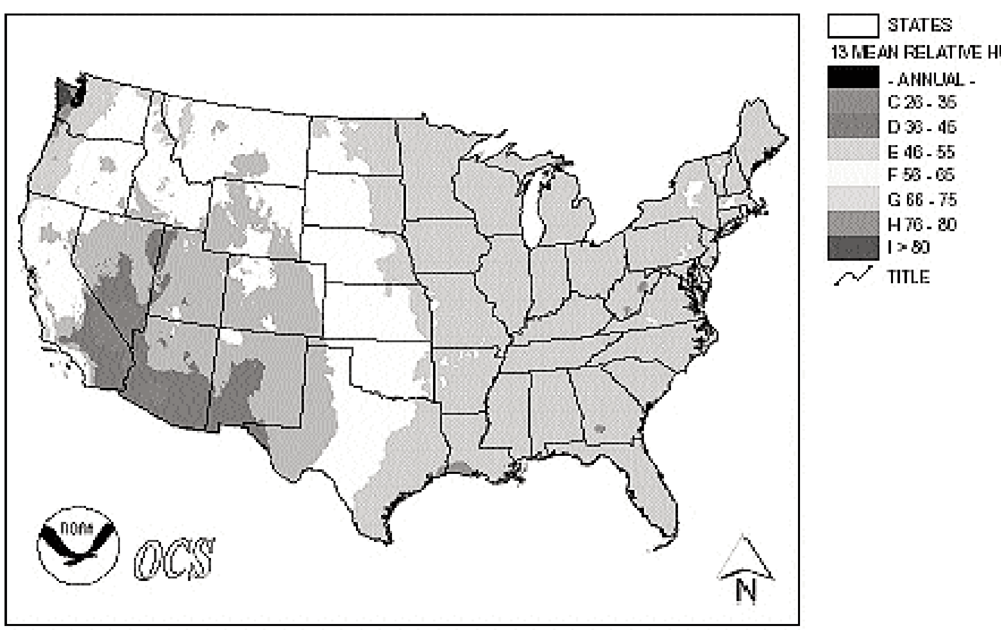
"Straw under very wet conditions (100% relative humidity) will have a moisture content of 35% or more. Some molds can grow at relative humidities of as low as 65%, although there is more risk in the range of 85% and up. The current advice on bale moisture contents is tentative, based on some research in existing straw bale houses and on the agricultural data. If the straw is at a dry-basis moisture content of 15% or less, there is no risk of mold. If the straw moisture content exceeds 25%, it is likely that mold has been growing. Quick drying of the bales, or removal, is encouraged. Ensuring that bales are under 15% moisture content (MC) before they are stuccoed will result in a reasonably dry wall to begin. Straw between 15 and 25% MC may be in some danger, depending upon the circumstances."
Source: Don Fulger, Straw Bale House Moisture Research, Technical Series 00-103 Research Highlights, June, 1997,CMHC

Given this data, with relative humidities of between only 43% and 72%, the moisture content of the straw bale wall would be within the range of where mold would be assumed to have already been growing. This range of relative humidities is frequently surpassed in Eastern North American and Appalachian climate conditions, and would represent a potentially particular threat during the hot and humid summer months.

For maps of the United States and Canada showing relative humidities for City, State or ZIP Code, see:
http://www.wunderground.com/US/Region/US/Humidity.html

Health Considerations with Straw Bale — Indoor Air Quality and Mold

As some of the experience of residents living in straw bale homes begins to come in, some respiratory ailments and allergies are being reported in humid parts of Appalachia and the Eastern North America as an aspect of degraded indoor air quality. Actually this revelation does not come unexpectedly. Straw bale walls are typically



designed to allow moisture to enter and to escape – to breathe. Molds will readily grow where there is sufficient relative humidity and moisture content in the straw. In contrast, compressed strawboard which is first heated to 300 degrees Fahrenheit is not known to have mold problems because once compressed into a sturdy board it does not tend to pick up moisture.

Indoor house mold is called the "Asbestos of the 21st Century" and more and more homes are beginning to show signs of being affected. This is especially true since most modern structures are designed to be air tight for efficient cooling in summer and heating in winter. With increasing climatic changes and global warming, builders are emphasizing more mechanical air handling systems, and the heating, ventilating, air conditioning (HVAC) ducts may begin to increasingly harbor mold in neglected ventilation systems. Mold problems in this age cannot be underestimated.

Canadian mold and fungal specialist, Dr. David Miller has extensive training and experience in both agricultural and residential mold problems and identification, and has noted, "one of the most notorious molds, *stachybotrys atra*, prefers straw over most anything else. *Stachybotrys* is universally recognized as a danger to human health (respiratory and immune system). It has been implicated in infant deaths in Cleveland from pulmonary bleeding. After he was told that researchers assumed there will not be a significant mold problem without water (or condensation) present in the straw, Dr. Miller agreed with this assumption, to some extent, but re-iterated that it is critical to keep *stachybotrys* out of indoor air. One step is to avoid materials like straw that *stachybotrys* prefers, Dr. Miller remarked.

Source: Don Fugler, Canadian Mortgage Housing Authority posting to strawbale list serve, strawbale@crest.org

"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."

Source: Don Fugler, Canadian Mortgage Housing Authority, posting to strawbale list serve, strawbale@crest.org

Conclusions

We are spending as much as 90% of our lives indoors, as the American Lung Association has noted, so we will have to be increasingly mindful of our indoor air quality.

Most of the published research data on moisture and mold on straw bale wall construction is coming from Canada and the Pacific Northwest, and the performance of straw bale construction in the high precipitation, hot and humid summers in Eastern North America is an unknown quantity.

Also, the concern is that any indoor air quality deterioration due to mold forming on straw bale walls may not show up for 10-12 years – a length of time that has scarcely been reached for any Eastern straw bale buildings.

It is for these reasons that we would offer a note of extreme caution and concern for building with the breathable straw bale design in the Eastern region of North America.

If others have experience with straw bale construction in Eastern North America – either positive or negative – we invite them to share their observations and experiences so that the future updates of this Technical Paper might include additional data and experience.

Until then, Dream Globally, and Build Locally for a sustainable and healthy future in each and every bioregion!

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