
Moisture Barriers in Straw-bale Construction



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Summary: The Uniform Building Code requires the use of sheet moisture barriers underneath all exterior claddings to protect wood-frame structures from external moisture which may enter the building envelope and to separate plywood and plaster components structurally. Empirical and test data for bale walls, on the other hand, strongly indicate that equal or superior moisture protection exists without the use of sheet membranes.

The behavior of moisture in straw-bale construction differs **significantly** from wood-frame construction, and therefore different measures should be taken to control moisture within bale walls than those employed in wood-frame construction. The use of sheet moisture barriers may be harmful in bale construction, and runs counter to successful historical examples, current building practice, and results of empirical and test data. Sheet moisture barriers over straw are not required, and are sometimes expressly prohibited, by straw-bale building codes. Code officials who mistakenly require moisture barriers in contradiction of common industry practice and knowledge may become liable

for failures resulting from such requirements.

Moisture Behavior and Building Design

The behavior of moisture within buildings is complex and dependant upon several variables such as seasonal climate, site conditions, building usage, heating and cooling systems and wall construction. Moisture trapped within the building envelope (walls, floor or roofs) can cause degradation of wood or straw, and reduce the efficacy of insulation materials.

The composition of wood and straw are quite similar. Both consist largely of cellulose plus inorganic materials. At about 18% moisture content fungi which are present in wood and straw as spores become active and begin breaking down cellulose, creating what we know as dry rot. Below 18% the active fungi go dormant. Good building design prevents moisture accumulating in the building envelope from reaching levels where fungi will grow and multiply.

Moisture can enter a building envelope as vapor (gas) or as liquid water. With rare exceptions, moisture movement follows airflow. Reducing airflow is the first, and often the easiest, line of defense. Careful caulking and sealing, the proper installation of air and/or vapor barriers, and attention to detail will usually pay off in comfort, energy savings and moisture control. Additionally, wall assemblies should be designed which are self-maintaining and use the physics of the building system to greatest advantage.

Water at room temperature exists as liquid in clumps of about eighty molecules. As temperature increases, the molecules become excited and the clumps break up until individual molecules break away and become air-borne as vapor. In our "heating climate", vapor generally originates from inside a building as a result of cooking, washing and respiration. Because the inside of a building is warmer than the outside, and warm air has a higher vapor pressure than cold air, vapor will be driven through the interior wall surface and into the wall assembly. As the difference in temperature between the interior and exterior increases so does the pressure differential, and hence the quantity of vapor which will enter the wall. Houses heated in winter or cooled in summer are the most susceptible to problems cause by vapor migration.

Vapor is not a threat to wood or straw unless it condenses into liquid. Warm air is capable of holding more water vapor than cold air. When warm, moist air encounters cold air or cold surfaces, the warm air cools and the water vapor it carries condenses into water (like rain, dew, or fog on windows). The temperature at which condensation can occur, called the dew point, varies with the relative humidity of the air. This point is not always inside the wall, but in very hot or cold climates the dew point, and the potential for rain inside the walls, usually falls inside of a wall. Any vapor entering the wall will condense at the on the warm side of the next downstream surface from the dewpoint. This liquid may accumulate and create the conditions for dry rot to occur. Care should be taken in design construction, to minimize these pathways for moisture transport into and within the building envelope and to provide for the removal of

moisture from within the wall.

Moisture diffusing through in-tact wall surfaces (such as plaster or drywall) is insignificant compared to that entering as a result of air leakage through cracks, holes and voids in the building envelope. Special care should be taken to seal pipes, electric outlets and window and door openings in order to reduce airflow. In wood construction, convection currents within a wall can easily occur, and should be minimized using blocking and with the proper installation of insulation materials. In bale construction, plaster should be applied directly to the straw to avoid gaps behind paper and stucco which could create air channels. Voids between courses of bales should be solidly and firmly filled with straw, straw-clay or plaster.

A much greater threat to buildings in temperate climates comes from rainwater penetration of the building envelope. Wind-driven rain accounts for most moisture damage within wall systems. Careful attention to detail, sealing of all penetrations and control of crack and fissures are vital and cost-effective ways of preventing moisture from entering the envelope. Regular maintenance can reduce the possibility of failures over time.

Principles of Moisture in Bale and Wood-frame Walls

It should be recognized that no building system is perfect, and that some wetting will occur. Once moisture enters the building envelope where does it go? Can moisture be stored harmlessly within the wall assembly until drying can occur? The ability of a wall system to dry and store moisture, as well as its resistance to wetting, are of great importance in reducing its vulnerability to moisture-related damage and deterioration.

Storage Capacity. Although wood and straw are similar in organic composition, straw-bale and wood-frame walls differ significantly in structure, mass, weight and surface area, creating major differences in how moisture enters, leaves and travels within the wall.

Bale walls are made up of millions of individual straws that can absorb and disperse relatively large quantities of moisture. Compared to wood fiber, straw is loose, and provides greater opportunity for capillary movement and moisture storage. The mass of a bale wall is greater than wood-frame, and that material is more readily available for moisture transport and storage because of its low density and porosity.

Imagine, for instance, turning a hose on a straw bale. A great deal of water will be absorbed before runoff will occur. Now imagine turning a hose on a stack of studs and plywood--the water would begin to run off almost at once, and any water which would remain would collect in cracks and crevices.

Wood-frame structures, on the other hand, tend to concentrate moisture entering a wall into localized areas. The stud-wall matrix consisting of dense material (studs and plywood) alternating with voids or low-density material (air or

fiberglass), encourages moisture concentration. Moisture within a stud wall is commonly led along a few passageways within the wall: air channels, eddies and backwaters within cavities direct vapor laden air; and solid wood elements working with gravity concentrate the movement of water into certain limited areas within the wall. This channeling leads quickly to collections of water and localized areas of high humidity and subsequent rot, making it extremely important to minimize the amount of moisture entering a wood wall. Thus follows the widespread use of extremely tight air and vapor barriers to block moisture from entering wood frame walls.

This tendency of bales to absorb and disperse moisture works to protect the interior of the wall from high concentrations that would support fungal growth. Moisture entering a bale wall can be stored over the very great surface area of the straw itself and then be transpired back through the stucco when conditions permit.

Drying Ability. Sheet membrane systems are neither practical nor desirable for bale walls because they inhibit the unique ability of bale walls to store large quantities of moisture and to allow that moisture to efficiently dry to the outside. The permeability, density, and great surface area of straw bales within a wall allow the wall to transport and store moisture within the wall and then dry to the outside with relative efficiency. Problems with (and studies of) non-breathable stucco finishes have shown that the ability of any wall to dry is vitally important in protecting the wall from rot, and experience has shown that total reliance upon the integrity of sheet barriers for waterproofing is ill advised.

Redundant systems, which incorporate natural processes for moisture storage and drying, can greatly reduce the risk of failure. It is commonly accepted that the health and longevity of older bale structures, built without moisture barriers and often with highly permeable exterior finishes, is a result of the ability of bales to store and transpire moisture and thereby maintain safe levels of humidity. The most effective strategy for bale walls involves maximizing the potential for moisture storage and drying by taking advantage of the bales' capillary activity and large evaporative area.

Use of Sheet Moisture Barriers

The almost universal practice among straw-bale builders, in all climate zones, is to avoid the use of sheet moisture barriers or impermeable stuccos over the bales. Experience with straw-bale structures, in a variety of climates, indicates that these barriers are not necessary and may even be detrimental.

The introduction of a sheet moisture barrier, even a 'breathable' product, inhibits the natural transpiration of the bales and may create a surface for condensation to occur. Although products such as Tyvek transmit vapor, they block liquid moisture. Moisture being drawn to the surface by evaporation and capillary suction is blocked by such barriers and could collect at the membrane and cause rot. Condensation commonly occurs against such membranes when the sun strikes walls after a rain and vaporizes water within the stucco and straw

layers. This vapor can move into the wall through a moisture barrier such as Tyvek, and will condense into liquid as it travels deeper into the wall. When the liquid tries to leave through the exterior of the wall it cannot then exit through the waterproof barrier. On the other hand, a straw/stucco membrane without a sheet barrier allows both liquid transport and vapor diffusion, allows moisture to freely wick out of the wall assembly and evaporate.

Centuries of experience have shown that water will get inside building walls, either as condensed vapor or as water entering from the exterior. Because bale walls can accommodate accumulations of moisture which wood-frame walls cannot, and can transpire moisture with relative ease, common practice in bale construction has been to maintain a breathable external wall by avoiding the use of sheet barriers between stucco and straw.

Structural Advantages of a Direct Plaster/Bale Bond

There are significant structural advantages to eliminating sheet moisture barriers in straw-bale construction. When plaster is applied directly over the bales it forms a mechanical bond with the straw that is impressive in its strength and tenacity. Protruding straw fibers grip and reinforce the plaster, and the uneven surface of the bales provides a significant mechanical key. Because the straw behind the plaster has some flexibility, movement of the bales over time can be accommodated without transferring stresses to the plaster layer. (The strong bond between bales and plaster makes lath unnecessary for attachment, but it may be used as reinforcement for the plaster).

Because the stucco layer is the least flexible element of a bale wall system it will likely be the first to resist seismic and wind forces. The strength of this stucco shell is greatly enhanced by being keyed into, and supported by, the bale component. A network of thickened plaster is created at the bale joints, creating a 'waffle truss' that strengthens the stucco layer, and when stucco is used for both interior and exterior skin, a stress skin truss can be developed.

Experience has shown the value of redundant systems in building technology. Single-element systems, whether to handle moisture or to resist earthquakes, are often the first to fail. Stucco can and should be used as an important redundant structural component, and the strength of the stucco can be greatly increased by application directly to the bales without an intervening sheet barrier.

Conclusions

Good straw-bale design and construction technology inimizizes the possibility of water intrusion into the bale wall but maximizes the potential for drying. In practice, care should be taken to seal wall penetrations, both interior and exterior, and (in heating climates) to develop a tight interior shell while allowing moisture to diffuse to the outside. Sheet moisture barriers that block capillary action are not advised. Hydrophobic, vapor permeable sealers or plasters that allow evaporation may be applied to the exterior stucco, and are recommended in particularly wet conditions.



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