



Cellulose Insulation Moisture Performance in cold climate construction

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A well-insulated, airtight building envelope plays a major role in reducing the energy costs of homes in Interior Alaska. In the past 20 years, construction techniques have become much more energy efficient, with modern homes being better insulated and more airtight than their predecessors.

Safely managing moisture within the walls of well-insulated homes can be challenging, but the right wall design can balance both energy efficiency and durability. Key aspects of moisture management include controlling the flow of moisture and avoiding excess moisture retention within building envelope components. Cellulose insulation has several properties that could facilitate better moisture management, however, its performance in building envelopes in very cold climates (such as Interior Alaska) has not been extensively studied. This report presents preliminary findings related to the moisture performance of wall systems using dense-pack cellulose insulation.

Background

Traditional residential wood-frame wall construction (i.e. 2x6 or 2x4 stud walls with an interior vapor retarder) works in Interior Alaska for several reasons: a polyethylene vapor retarder limits moisture entry into the wall; moisture that condenses within the wall in the winter remains well below freezing; and the wall is vapor-permeable enough on the exterior that it can dry. When warmer temperatures arrive in spring, these walls tend to thaw and dry quickly to the exterior. Overall these characteristics generally minimize mold and moisture problems.

Adding exterior insulation changes these moisture dynamics. If enough exterior insulation is added to a wall assembly, the structural sheathing and framing will remain warm enough to avoid high relative humidity (RH) and condensation, improving overall moisture control. Adding an inadequate amount of exterior insulation is risky since it keeps the wall sheathing above freezing,

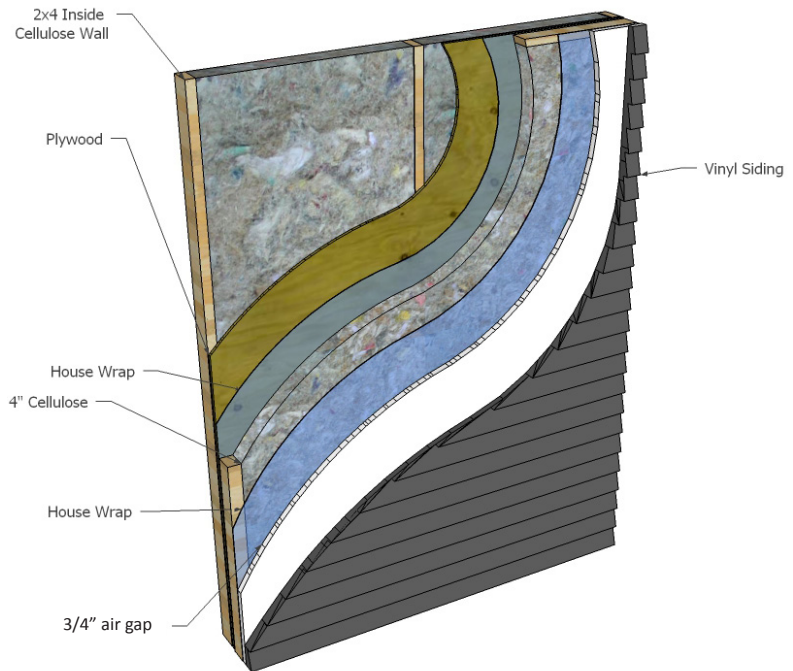


Figure 1. Wall section with stud cavity and exterior cellulose insulation. The wall was 8 inches thick with an R-value of approximately 29.

but still cold enough that the sheathing is at high RH, or reaches the dew point. Under these conditions, the sheathing will be able to absorb moisture, increasing the risk for mold growth. Exterior insulation, depending on the insulation type, can also limit the ability of the wall to dry to the exterior. Inadequate exterior insulation can both increase moisture loading within a wall and reduce its drying ability.

Cellulose insulation has material properties that may improve moisture control when used as stud cavity and exterior insulation. Dense-pack cellulose is less permeable to air flow than fiberglass batts, reducing the amount of moisture that migrates into the stud cavity. Additionally, cellulose is more permeable to water vapor than expanded or extruded polystyrene (EPS or XPS), which are commonly used as exterior insulation. Therefore, cellulose as an exterior insulation allows faster drying to the outside. Finally, cellulose has the



Table 1. Test Wall Properties

| Test wall | Framing | Vapor Retarder | Exterior Insulation | Interior insulation |
|-----------|---------|------------------------------|---------------------|------------------------|
| 1 | 2x6 | 6-mil polyethylene (Class I) | none | Cellulose (R-21) |
| 2 | 2x6 | Latex paint (Class III) | none | Cellulose (R-21) |
| 3 | 2x4 | Latex paint (Class III) | EPS (R-16) | Fiberglass batt (R-11) |
| 4 | 2x4 | Latex paint (Class III) | Cellulose (R-16) | Fiberglass batt (R-11) |
| 5 | 2x4 | Latex paint (Class III) | Cellulose (R-16) | Cellulose (R-13) |

ability to absorb and release water vapor, storing vapor that might otherwise condense on a colder surface. Together these properties allow cellulose to “buffer” moisture and moderate moisture levels within the wall, preventing large spikes in RH and retention of moisture that can cause damage.

Recently, CCHRC tested wall assemblies that used dense-pack cellulose instead of foam board for exterior insulation and cellulose instead of fiberglass batts for stud cavity insulation, as depicted in Figure 1. Researchers examined whether the cellulose could provide acceptable moisture control with less exterior insulation than otherwise would be required to avoid condensation on the sheathing during the heating season (see the sidebar on insulation ratios).

Study Method

CCHRC used the Mobile Test Lab (MTL) for 18 months starting in late 2011 to study the moisture performance of dense-pack cellulose in comparison to fiberglass- and EPS-insulated wall sections in the cold, dry Interior Alaska climate. A summary of the test walls is provided in Table 1. CCHRC studied two conventional 2x6 walls insulated with dense-pack cellulose, one with and one without a polyethylene vapor retarder. Three 2x4 walls had exterior insulation, no polyethylene vapor retarder, and a variety of insulation combinations. The three test walls with exterior insulation were set up with approximately the same R-value ratio of stud cavity versus exterior insulation.

The walls were made with standard construction techniques using painted gypsum board on the inside, 1/2-inch plywood sheathing, a weather and air barrier installed over the sheathing, and vinyl siding. On walls with exterior insulation, insulation was applied over the air barrier. All test walls had a 3/4-inch air gap between the siding and the sheathing or exterior insulation. None of the walls had the recommended amount of insulation outside the sheathing that would have kept the sheathing above the dew point for the entire winter.

During the first year of the study the RH inside the MTL averaged 40%, the temperature averaged 72°F, and the pressure was neutral. Toward the end of the study, a slight positive pressure was induced by mechanical ventilation to drive moisture into the walls. The pressurization was designed to mimic pressures on the uppermost floor of a house from stack effect or pressure that might come from an unbalanced ventilation system. The temperature, moisture content, and RH across the wall cavities were recorded.

Results

The figures on page 3 present the results from monitoring RH within each test wall of this study. As seen in Figure 2, the conventional walls performed as expected. The wall with no vapor retarder spent most of the winter above 80% RH, which is a generalized threshold for mold growth, while the wall with a vapor retarder rarely reached the threshold. The test walls with exterior insulation are shown in Figure 3. Those with exterior cellulose insulation had superior moisture performance than the wall with exterior EPS. The two walls with exterior cellulose oscillated around the 80% RH threshold during the winter. The wall with exterior EPS was well above the 80% RH threshold for both winters, but did not reach the dew point (100% RH). Upon tearing down the test walls, the wall with exterior EPS had small areas of visible mold growth. This observation supports the monitoring results and illustrates that condensation is not a necessary condition for mold growth.

The cavity insulation appeared to be a less significant factor for moisture control. While the wall with interior fiberglass batts had slightly higher RH during periods in the winter, its overall moisture performance was comparable to the wall with interior dense-pack cellulose. However, this comparison is not exact because the test wall with interior cellulose had a slightly higher R-value in the stud cavity, which should result in colder sheathing and higher RH values for the cellulose test wall. This may indicate that using cellulose insulation in

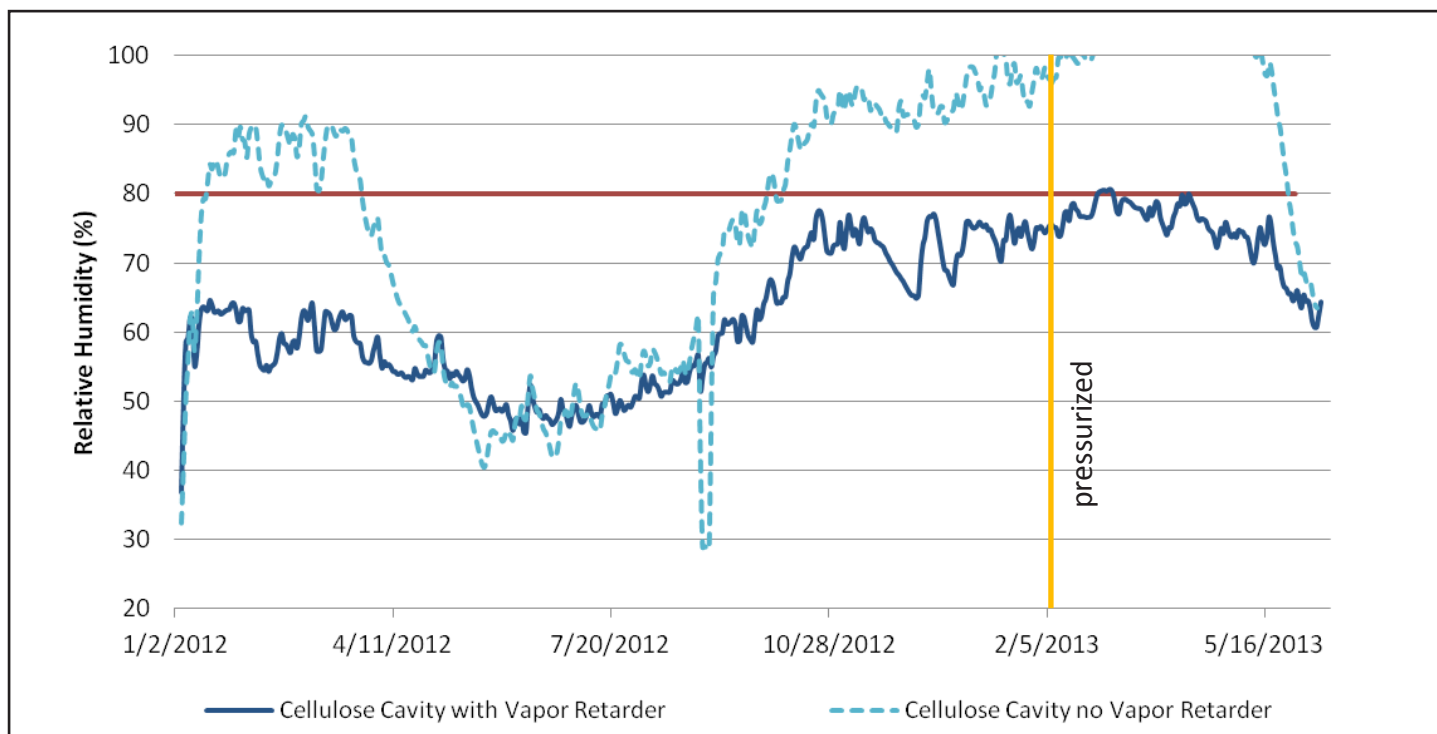


Figure 2. Relative humidity at the sheathing plane inside the stud cavity of test walls 1 and 2. The red line at 80% shows the lower limit where mold growth can occur. Humidity above 80% coupled with temperatures above 40° F allow for mold to develop on a surface. The vertical line in early February 2013 represents when a slight positive pressure was induced in the MTL.

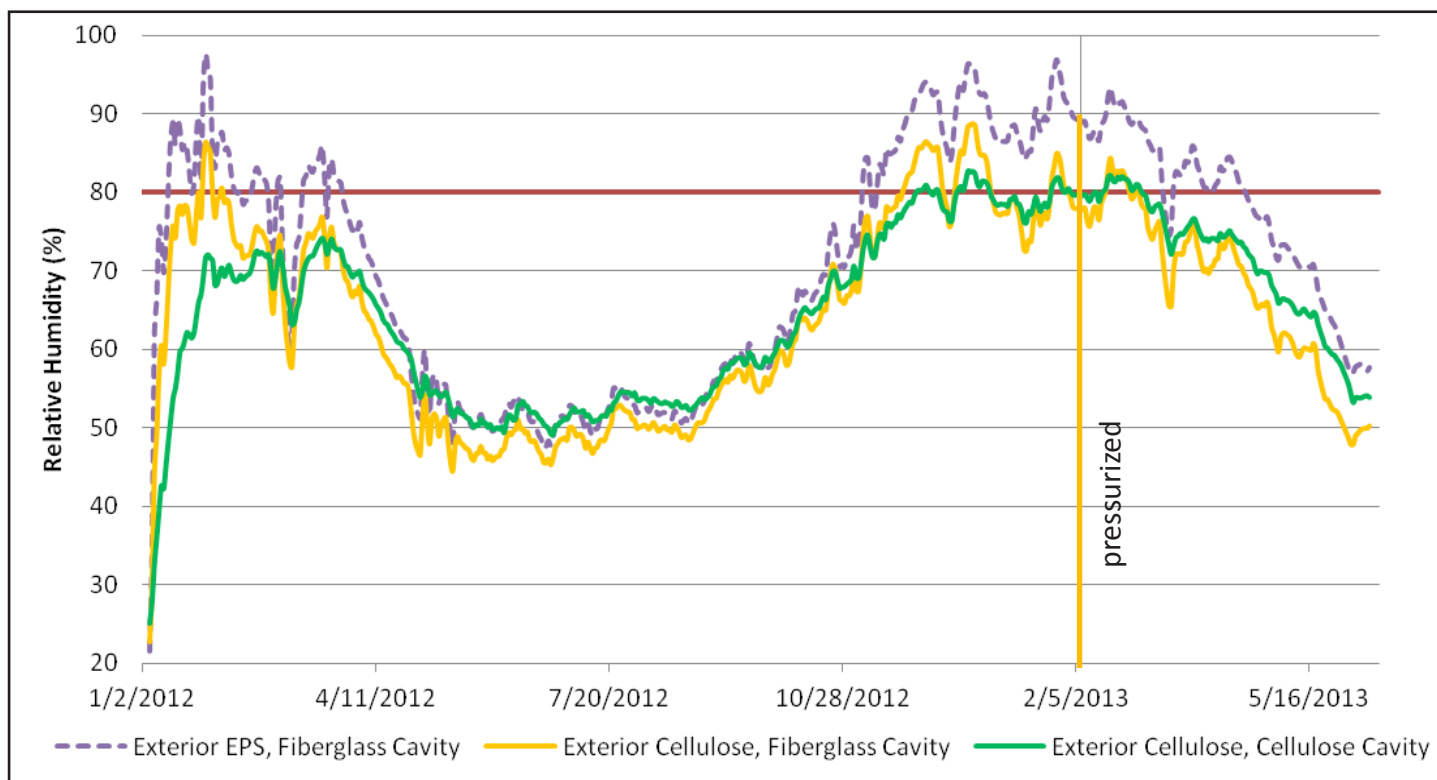


Figure 3. Relative humidity at the sheathing plane inside the stud cavity of test walls 3, 4 and 5. The red line at 80% shows the lower limit where mold growth can occur. Humidity above 80% coupled with temperatures above 40° F allow for mold to develop on a surface. The vertical line in early February 2013 represents when the MTL pressurization began.



Removing dense-pack cellulose from a test wall in the Mobile Test Lab.



The Mobile Test Lab includes 9 wall test bays with varying types and amounts of insulation. The interior conditions simulated a house, at 70° F and 40% relative humidity.

the stud cavity instead of fiberglass batts can slightly improve moisture control.

The results of this investigation and other studies on cellulose-insulated wall assemblies provide interesting options for exterior insulation beyond rigid foam board (also see Arctic Wall in right sidebar). Using dense-pack cellulose exterior to the sheathing provided better moisture protection than an equivalent R-value of exterior foam board insulation. The minimum amount of exterior cellulose required to provide ample moisture control in Interior Alaska is still undetermined, although this study indicates that it is probably less than the amount of rigid foam board insulation needed. CCHRC plans to continue studying this and other moisture and thermal properties of cellulose in future projects.

Exterior Insulation Ratios

This study deliberately used walls that do not meet the recommended ratio of interior insulation to exterior insulation. The recommendation for Fairbanks holds that at least 2/3 of the total insulation value of the wall should go outside the sheathing, which keeps the sheathing warm enough so moisture in the wall does not condense inside the wall cavity. For example, a 2x4 wall with R-13 cavity insulation would need at least R-26 insulation outside of the sheathing to meet the recommendation.

For this study, researchers designed walls that fell short of the recommendation in order to learn more about the moisture performance of cellulose and to gain a better understanding of the limits of the recommended 2/3 ratio. The walls presented in this study are not walls that CCHRC would recommend building.

Arctic Wall Report Highlights

The Arctic Wall is a super-insulated cellulose double wall designed by Fairbanks builder Thorsten Chlupp that CCHRC studied in 2012. The wall system provided ample moisture control without using a Class 1 vapor retarder by following these key rules:

- The airtight design manages the moisture movement into the wall
- The vapor-open wall allows for the absorption and release of moisture across large surface areas (i.e. the whole wall surface instead of leaks in a vapor barrier)
- Cellulose insulation provides the ability to buffer moisture

For more information visit cchrc.org/arctic-wall

Thank you to our funders

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