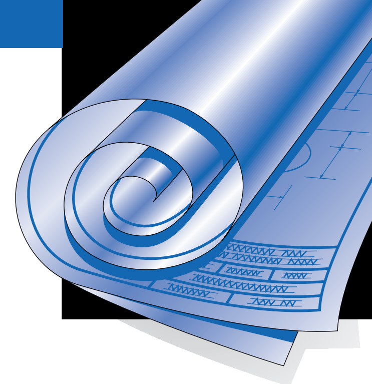

Moisture Control In Low Slope Roofs

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Wood roof construction can provide centuries of service life that is unaffected by the temporary exposure to wetting that may occur during construction. However, prolonged exposure to moisture in the roof cavity can cause fastener corrosion, condensation dripping in the occupied area, or wood decay in severe cases.

Low-sloped, panelized roof systems which are commonly used for commercial and industrial building in the western United States annually account for millions of square feet of roof construction. Unlike most pitched residential roofs which utilize a combination of vapor retarders and ventilation to minimize moisture in attic spaces, insulated low slope roofs typically involve little or no ventilation. Therefore, it is important for the designer, specifier and erector to understand the fundamentals and techniques for moisture control in low-sloped roofs, particularly when insulation is used below the roof.

Moisture Sources in Wood Construction

Wood is naturally porous and always contains some degree of moisture when used in construction. Moisture content is a measure of the total weight of moisture in the wood as a percentage of the oven-dried weight of the wood. Wood stores chemically bonded moisture in the cell walls (up to 30% moisture content) and "free water" in the cell cavities when moisture content is in excess of 30%. The moisture content of wood is very high in living trees where it can range from 60% to in excess of 120% (based on oven dry weight of wood). Wood production processes generally involve drying of the wood. The table below provides typical average moisture content values of wood products as manufactured.

Structural panels................6% typical
Glulam..............................12% typical
Lumber
  Green ....20 - 50% +
  Dry.........................19% or lower

Decay fungi growth in wood construction is prevented by maintaining moisture content levels below the threshold required for decay growth (approximately 20 to 25%). Protection of wood construction from decay fungi is discussed in *Engineered Wood Systems Technical Note* R495.

The moisture content of wood products during construction and in service will depend upon exposure to humidity and direct wetting. When protected from direct wetting, wood moisture content is primarily a function of the relative humidity, as shown in Table 1, although ambient temperature can also influence wood moisture content.

The time it takes for wood to equilibrate to a given humidity through drying or absorbing moisture is primarily a function of cross-sectional size and can be substantial for larger size lumber and glulam members.

Wetting During Construction

Wood components are subject to direct wetting from rain and snow during construction. Exposure to direct wetting leads to elevated surface moisture content over the short term and potentially to high moisture content throughout the entire wood member if exposure is prolonged. Because of their high ratio of surface area to volume, exposed structural wood panels may absorb considerable moisture during construction rain delays. Entrapment of moisture between an impermeable roof membrane above the wood panel and a vapor retarder below the panel may retard drying and prolong high moisture conditions in the roof.

TABLE 1

MOISTURE CONTENT AS A FUNCTION OF RELATIVE HUMIDITY

Relative Humidity (%)	Approximate Wood Moisture Content (%)
20	5
40	8
60	11
80	16
100	28

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Moisture from Condensation

Water vapor is always present in the air and may condense out of the air and onto any surface when the temperature of the surface drops below the dew point. This is a consequence of either moisture-laden air flowing to a region of lower temperature, or a reduction in surface temperature which is often a function of seasonal or nightly temperature drops in the roof envelope. The mechanics of heat and moisture transfer that govern wetting, drying and condensation in roof systems are complex, but follow basic physical laws that apply to all roof deck materials. Wood has an advantage relative to some materials due to its natural thermal resistance. This helps keep the deck warmer than the dew point. Wood also has the ability to absorb some degree of moisture before condensation occurs.

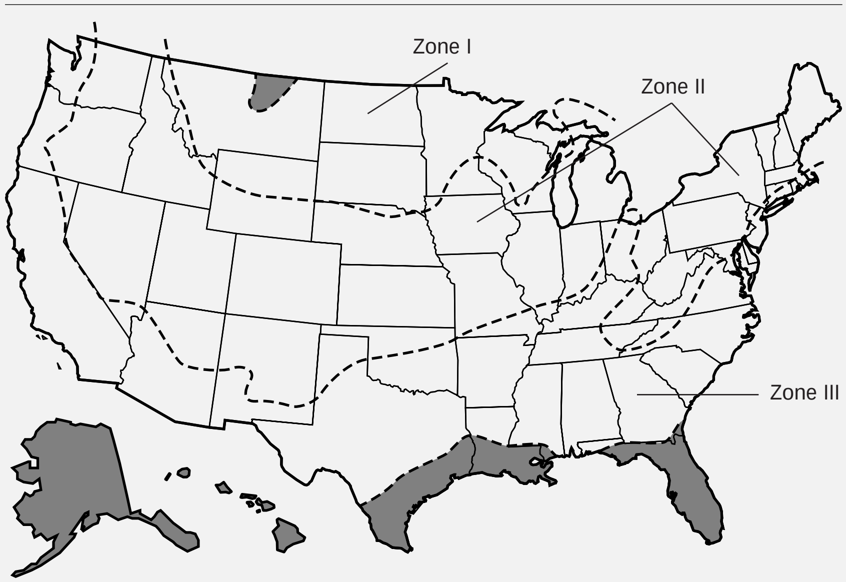
Control of condensation in wood construction is generally achieved with ventilation and vapor retarders (see APA Technical Note X485). Whereas this combination is readily facilitated in pitched roof construction, it is difficult to incorporate into low slope roofs. Therefore, it is especially important for the designer to consider the two primary factors that affect the condensation potential in a low slope roof – the temperature of the roof deck and the potential for water vapor accumulation.

Condensation Zones

Information published by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) contains a map of condensation zones that considers winter design temperature. Figure 1 is broken down into three zones where Zone I represents the coldest temperatures and therefore the highest condensation hazard. Although this map provides a general assessment, the condensation hazard may vary significantly within a zone. For example, within Zone III on the West Coast, the winter design temperatures of Los Angeles (40°) and San Francisco (38°) are higher than Portland (23°) and Seattle (26°).

FIGURE 1

CONDENSATION ZONES IN THE UNITED STATES
Zones include areas with approximate design temperatures as follows: Zone I, –20°F and lower; Zone II, 0 to –20°F; and Zone III, above 0°F. Shaded areas are outside Zones I and III.



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Accumulated Moisture

Moisture loads from natural infiltration or from occupancy can have a dramatic cumulative effect on the potential for condensation. Following is a list of examples of moisture loads from occupancy or naturally generated sources:

- Human occupancy. Each person generates about 0.1 lb. of moisture per hour. At 70°F and 50% relative humidity, the air in a 1,000-cubic-foot office room contains about 0.6 lb. of moisture. The cumulative effect of humans in high occupancy structures, such as offices, auditoriums, etc., can become a major source of moisture.
- Concrete slabs. During and after curing, concrete slabs can generate substantial moisture which is absorbed into the atmosphere. Thus if the slab is poured after the rod is placed, significant amounts of moisture can be absorbed by the roof framing.
- Soil in unoccupied buildings. Soil can generate over 12 lb. of moisture per hour per thousand square feet. Although not a common occurrence, one example of decay was observed in a wood structure which had bare soil in a closed building awaiting tenants. This structure had decay along a glulam which was at the high point of the building.
- Moisture generated from equipment such as propane-powered forklifts.

In order to prevent condensation, there must be a balance such that the cumulative moisture generated, whether from construction or occupancy, does not result in roof cavity humidity such that the surfaces in the roof cavity drop below the dew point temperature. Air humidity should be controlled through preventative measures such as air-to-air heat exchangers, ventilation or dehumidification. Control of roof temperature can also be provided by insulation on top of the roof deck or by limiting insulation below the roof deck so the roof sheathing temperature stays above the dew point.

Use of Vapor Retarders

Although vapor retarders in traditional ventilated roofs are a key feature in preventing condensation, it is widely recognized that their inability to prevent leakage can lead to high moisture conditions above the vapor retarder. The ASHRAE *Handbook of Fundamentals* contains the following information regarding the use of vapor retarders in low slope roofs:

"A vapor retarder in a conventional flat roof can trap moisture between the roof itself and the roof membrane. The decision of whether to use a vapor retarder depends on interior humidity and climate. The absence of a vapor retarder allows vapor to enter a roof during the heating season, but it also facilitates the removal of moisture from buildings with high humidity, where a large accumulation of frost or liquid condensation results in dripping. Where humidities are lower, the roof system may successfully store moisture through the heating season without problems."

The inability to effectively inhibit vapor from entry into the roof cavity results in increased moisture conditions during the winter. Roof systems are designed to accept some degree of moisture accumulation during the winter as long as it dissipates during spring and summer drying. In the drying season the moisture is driven downward into the building interior as the roof is warmed. The key concepts for acceptable performance for a "self-drying roof" are:

- That the system dissipates enough moisture during the drying season to reestablish an acceptable moisture equilibrium in the wood material.
- Peak moisture levels are low enough that condensation dripping does not occur.
- Cumulative time at conditions supporting decay is restricted such that decay is not supported.

The possibilities for progressive wetting during the cold seasons or for localized extreme wetting are hazards of a low slope roof. The problem becomes one of balancing the potential for moisture accumulation with the drying potential and, at the same time, avoiding any moisture spikes that may lead to condensation dripping or localized areas which may be prone to decay.

Under this scenario, it becomes clear how changes in energy design for buildings may have had a negative impact on the potential for condensation in low sloped roofs. One effect of increased insulation below deck in low slope roofs is reduced heat loss to the wood roof sheathing. Assuming no changes in the moisture vapor potential of the inside occupancy, the reduced temperature of the roof sheathing makes it more likely to become a condensation surface since its temperature may have dropped below the dew point of the air in the roof cavity.

Minimizing Moisture Loads In Low Slope Roofs

The following are recommendations to minimize moisture which can accumulate in low slope roofs.

During Design/Specification

- Provide positive roof slope (1/2:12 or more) to provide roof drainage. Sloped roofs also provide better opportunity for ventilating to the outside.
- Use glulam and dry framing lumber to minimize wood moisture which can become entrapped as the wood dries after construction.
- Provide as much ventilation for potential moisture "traps" as possible (e.g., cut back ends of reflective foil or batt insulation installed below the roof sheathing by approximately 1/2 inch).
- Where low design temperatures or high interior humidities are expected, consider the use of insulation above the wood deck to maintain wood temperatures above the dew point.
- Tests by Portland Cement Association indicate that concrete slabs with a vapor barrier (4-mil polyethylene), used in conjunction with a gravel layer that serves as a capillary break, effectively reduce moisture inflow (0.85 lb./day per 1,000 square feet) into a building. Similar tests using concrete slabs over bare soil had substantial moisture inflow (16 lb./day per 1,000 square feet at 2 months; 6 lb./day per 1,000 square feet when fully cured).
- Design for dissipation of occupancy moisture loads. Design the HVAC system to maintain indoor winter humidity at levels which will not lead to condensation. This can be achieved through dehumidification methods or air-to-air heat exchangers.
- For buildings with very high natural production of moisture (e.g., swimming pools, laundromats, processing plants that generate moisture, etc.), the use of preservative-treated wood construction may be necessary if other methods of moisture control are inadequate.

During Construction

• Install roofing over the wood deck as soon as possible after installation to protect from exposure to the elements.

• To reduce risk of condensation, delay installation of below-deck insulation and vapor retarder or provide ventilation until wood deck moisture content is below 18%. If using electrical moisture meters, be aware that the accuracy should be verified by direct calibration in structural wood panels.

• Provide ventilation to remove moisture generated during construction and from curing of concrete and gypsum jointing materials.

• If prolonged rain is anticipated during construction prior to roofing, consider the use of roof deck sealants or other cover.

During Service Life

• Provide proper maintenance of roof membrane to avoid localized wet spots due to leaks.

• Maintain HVAC systems to limit humidity below the dew point temperature.

• Monitor signs of excessive indoor humidity such as mold or condensation on windows. Such signs of high interior moisture may be indicative of conditions that could also cause condensation in the wood deck.

• Minimize irregularities and local discontinuities in wood panel surfaces to minimize roof leaks. Prevent nails, screws and other connectors from protruding above the surface of the roof deck.

Other Available Literature

APA Design/Construction Guide: *Residential & Commercial* (E30)

APA Data File: *Preservative-Treated Plywood* (Q220)

APA Technical Note: *Condensation – Causes and Control* (X485)

APA Design/Construction Guide: *Nonresidential Roof Systems* (A310)

EWS Technical Note: *Controlling Decay in Wood Construction* (EWS R495)

Other Reference Literature

ASHRAE *Handbook of Fundamentals*

USDA Wood Handbook: Wood as an engineering material (Ag. Handbook 72)

Tobiasson, Wayne. Condensation in low-slope roofs. United States Army Corps of Engineers. *Proceedings of Workshop on Moisture Control in Buildings*, September 25-26, 1984.

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