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Wood Durability

Research Report - 0997
1999
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Abstract:

"We have accepted that design and construction must be responsive to varying seismic regions, wind loads and snow loads. Yet we typically ignore temperature, humidity, rain and the interior climate." This article puts the durability of wood in the proper context—the environmental context in which we ask it to perform.

Wood Durability

The general principle of building durability has two components:

- Buildings should be suited to their environment; and the laws of physics must be followed.
- We tend to ignore the first and find the second inconvenient.

It is irrational to expect to construct the same manner of building in Montreal, Memphis, Monterrey and Miami. It's cold in Montreal, it's humid in Memphis, it's hot and dry in Monterrey and it's hot and wet in Miami. And that's just the outside environment. It is equally irrational to expect to construct the same manner of building to enclose a warehouse, a house or a health club with a swimming pool. The interior environment also clearly matters.

We have accepted that design and construction must be responsive to varying seismic regions, wind loads and snow loads. We also consider soil conditions and frost depth, orientation and solar radiation. Yet we typically ignore temperature, humidity, rain and the interior climate.

The concept of limit states should play a key role in building durability. In structural engineering, loads and load resistance are considered and limiting states such as deflection are specified.

We can apply a similar approach to building durability. We should consider rain, temperature, humidity and the interior climate as environmental loads with principal limiting states such as rot, decay, mold and corrosion. A damage function analysis is then used to determine whether a limit state such as mold growth is achieved.

With wood (and other materials) we seem to not understand or pay attention to the load part while complaining about the limiting states part.

In applying limit states design to durability, building enclosures and mechanical systems should be designed for a specific hygro-thermal region, rain exposure zone and interior climate class in addition to the previously mentioned structural loads:

Hygro-Thermal Regions

- Very Cold
- Cold
- Mixed-Humid
- Hot-Dry/Mixed Dry
- Hot-Humid

Rain Exposure Zones

- Extreme (above 60 inches annual precipitation)

- High (40 to 60 inches annual precipitation)
- Moderate (20 to 40 inches annual precipitation)
- Low (less than 20 inches annual precipitation)

Interior Climate Classes

I. Temperature moderated

- Vapor pressure uncontrolled
- Air pressure uncontrolled
  (warehouses, garages, storage rooms)

II. Temperature controlled

- Vapor pressure moderated
- Air pressure moderated
  (houses, apartments, offices, schools, commercial and retail spaces)

III. Temperature controlled

- Vapor pressure controlled
- Air Pressure controlled
  (hospitals, museums, swimming pool enclosures and computer facilities)

Let us examine constructing a house in Montreal, PQ. Montreal is in a very cold hygro-thermal region and a moderate rain exposure zone. Constructing a house typically involves a class II interior climate assuming no interior swimming pool. A Class II interior climate involves temperature control within several degrees and an interior relative humidity range of between 20 percent and 60 percent. Air pressures are typically moderated within a 5 Pascal range to allow safe operation of combustion appliances and to control contaminant transport. Attic assemblies are vented.

A design solution could involve an interior polyethylene vapor diffusion barrier and air barrier with unfaced fiberglass batt insulation installed in the cavities. A drainage plane of vapor permeable housewrap could be installed under a vinyl siding that allows for a drainage space to function in conjunction with the drainage plane. The sheathing could be a moisture diode such as plywood or OSB where the permeability of the sheathing varies with relative humidity and moisture content. A controlled ventilation system involving heat recovery would limit interior winter relative humidities.

This being a wood industry publication, the vinyl siding could be replaced with backprimed wood on a 6 to 8 mm spacer strip. Alternatively, the spacer strip and wood siding could be replaced with a manufactured wood siding with integral plastic "thumb tacks" on a coated back surface (assuming we could convince a manufacturer to actually produce such a product).

Moving the Montreal house to Boston, MA changes the hygro-thermal region and rain exposure zone. The interior polyethylene vapor diffusion barrier would be dropped in favor of a vapor diffusion retarder such as two coats of interior latex paint. The air barrier would now consist of the interior gypsum board glued to framing members. Backprimed wood siding would be installed over a thicker spacer strip (12 to 18 mm) to facilitate back venting of the cladding due to the more severe rain exposure. Either an exhaust only or supply only controlled ventilation system with out heat recover would be installed.

Moving the Boston house to Richmond, VA changes the hygro-thermal region once again and reduces the rain exposure zone. The vapor permeable housewrap would be replaced with a semi vapor permeable #30 felt and the spacing under the wood siding could be reduced back to the Montreal spacing range. Only a single coat of interior latex paint is applied as an interior vapor diffusion retarder. A supply only ventilation system would be installed.

Moving the Richmond house to Orlando, FL changes the hygro-thermal region. The supply only ventilation system would be supplemented with a dehumidifier to address the part load humidity issues. The attic would be constructed to be unvented and conditioned. Venting attics in hot-humid hygro thermal regions is a bad idea if mold and humidity control is considered important.

Finally, moving the Orlando house to Las Vegas, NV changes both the hygro-thermal region and the rain exposure zone. The backpriming and ventilation of the siding could be eliminated. Additionally, the dehumidifier is dropped and the #30 felt is replaced with a housewrap. If the mechanical system and ductwork are inside the conditioned space of the house, the attic could be vented ? otherwise the attic should be unvented and conditioned.

The preceding examples highlight some important design recommendations based on varying environmental loads:

- A polyethylene vapor diffusion barrier and air barrier should only be used in very cold hygro-thermal regions. If it is used in other regions it reduces drying potentials to the interior more than it reduces wetting potentials from the interior.
- Flow through design (drying to both the interior and exterior) should be applied in mixed-humid hygro-thermal regions.
- Vapor diffusion retarders should be installed on the exterior of assemblies in hot-humid hygro-thermal regions. Housewraps should not be used in these regions as they are too vapor permeable and not sufficiently water resistive.
- Roof assemblies should not be vented in hot-humid hygro-thermal regions.
- Backpriming of wood cladding is necessary except in low rain exposure zones.
- Backpriming and back venting of wood cladding are both necessary in high rain exposure zones.
- Pressure equalization and backpriming of wood cladding are recommended in extreme rain exposure zones.

Examining some recent failures in the context of limit states design can provide further insight on durability. Vancouver, BC has experienced some traditional stucco failures on wood frame condominium structures (an understatement if there ever was one) and Wilmington, NC has experienced some EIFS failures on wood frame single family dwellings (also an understatement).

Wilmington, NC is in a hot-humid hygro-thermal region with an extreme rain exposure. Vancouver, BC is in a mixed-humid hygro-thermal region with a high rain exposure. Wall assemblies in both locations used interior polyethylene as a vapor diffusion retarder that prevented drying towards the interior. Wall assemblies in both locations were effectively "face-sealed" in that they did not provide drainage of penetrating rain water back to the exterior. Wall assemblies in both locations were also effectively air tight due to the inherent nature of traditional stucco and EIFS. And finally, wall assemblies in both locations used cladding systems that were not back vented.

Traditional rain control systems rely on drainage planes or barriers. With drainage planes, building paper or a housewrap is installed shingle fashion underneath a cladding system to provide a method of shedding rain water that penetrates through the cladding system. With the barrier approach, a durable material such as masonry, stone or concrete is used as a storage reservoir to absorb penetrating rain water and then subsequently release the stored moisture to either the exterior or interior environment.

Both approaches have relied on significant energy flows (heat gains, heat losses and air flows: infiltrating, exfiltrating and interstitial) and permeable and semi-permeable materials in order to provide acceptable performance. Current construction practice has lead to a significant increase in thermal insulation levels and airtightness of wall assemblies resulting in a reduction in drying potential. Furthermore, the introduction of polyethylene film vapor barriers and impermeable and semi-permeable sheathings has lead to further reductions in drying potentials. This has been further exacerbated by the loss of water repellency of plastic housewrap materials due to increases in surface energy from contaminants such as surfactants. Although the rate of rain water entry or penetration into building assemblies has not significantly increased over the past 50 years, the rate of moisture removal from building assemblies has significantly decreased. The hygric balance has become skewed: the rate out is now significantly less than the rate in.

It has become obvious from our investigations, field research and laboratory testing that most wall assemblies leak rain water ? and furthermore that most wall assemblies have always historically leaked rain water. The reason that traditional wall assemblies have provided successful performance in the past, is that although rain wetting occurred, the rain wetting was followed by hygric redistribution and drying to both interior and exterior environments. Poorly insulated or uninsulated assemblies constructed in a leaky (to air) manner with vapor permeable materials (no polyethylene, vinyl wall coverings or foam sheathings) that did not loose their water repellency (no plastic housewraps) dried before problems arose.

EIFS failures in Wilmington, NC occurred for the following reasons: rain water that entered was not able to be removed because a secondary drainage mechanism did not exist ? no drainage plane coupled with a drainage space was provided. Additionally, the rain water that penetrated and was not drained, was absorbed by moisture sensitive materials (OSB, gypsum sheathing or plywood) that were unable to dry towards either the interior or exterior due to a lack of energy flows (including air flow) and the presence of impermeable and semi permeable materials. EIFS, like traditional stucco systems, are significantly more airtight than typical wall assemblies. No air flow, no drying due to air flow. EIFS assemblies are also more heavily insulated. No heat flow, no drying due to thermal gradient diffusion and concentration gradient diffusion. Additionally, most codes required the installation of interior vapor barriers. Drying mechanisms were further reduced by impermeable interior wall finishes such as vinyl wall coverings and semi permeable exterior foam insulation's and polymer based (PB) and polymer modified (PM) ? elastomerically coated laminas. The lack of permeable interior and exterior surfaces magnified the problems.

To fix EIFS, a drainage plane with a vented drainage space is necessary. This needs to be coupled with a drainage plane material that either allows no rain water penetration or that simultaneously sheds and absorbs rainwater while subsequently allowing the absorbed rain water to migrate to both the exterior and interior environments via diffusion, capillary and ventilation. And all this needs to be coupled with interior and exterior materials that are sufficiently vapor permeable to allow diffusion drying. Some EIFS manufacturer's recognize the need for drainage planes and vented drainage spaces. However, the required characteristics of drainage plane materials and vapor permeable and semi-vapor permeable interior surfaces are not yet recognized.

Traditional stucco failures in Vancouver, BC occurred for reasons that are similar (but not identical) to the EIFS failures in Wilmington, NC. Due to a lack of understanding, the use of two layers of building paper under traditional stucco was omitted. Historically, the use of two layers of building paper lead to wrinkling and debonding of the papers from the stucco basecoats resulting in a drainage space. The drainage space (albeit small and tortuous) coupled with traditional drainage plane materials (building papers that provided some absorption of rain water that penetrated at staples and nails) provided successful performance as long as redistribution and drying of moisture to the interior also occurred.

In Vancouver, single layers of building paper became the norm coupled with interior polyethylene vapor barriers and highly insulated air tight wall assemblies. Additionally, traditional building papers were replaced with plastic housewraps that bonded to stucco basecoats resulting in the elimination of the drainage space. The plastic housewraps were also sensitive to surfactants in the stucco basecoats and the OSB and plywood sheathings leading to a loss of water repellency. Where single layers of traditional building paper or plastic housewraps were used, drainage spaces were compromised and water was held at the building paper-stucco-sheathing interfaces leading to loss of water repellency of the building papers, rotting of the building papers, and ultimately to rotting of the sheathings and deterioration of the structural elements.

To fix traditional stucco, a similar strategy to the EIFS system fix described above is required: a drainage plane with a vented drainage space is necessary. This needs to be coupled with a drainage plane material that either allows no rain water penetration or that simultaneously sheds and absorbs rainwater while subsequently allowing the absorbed rain water to migrate to both the exterior and interior environments via diffusion, capillary and ventilation. And all this needs to be coupled with interior and exterior materials that are sufficiently vapor permeable to allow diffusion drying.

In both Vancouver and Wilmington we had the wrong type of building for the environment. Move these buildings to Edmonton or Denver, and a different result would have occurred.

About the Author

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