Figure 1: Sloped roof and overhangs protect the building from moisture accumulation.

Creating Redundancy in Building Envelope Design

By Scott Lockyear, P.E.

Wood frame construction has been utilized for centuries and has resulted in many of the most beautiful and durable structures around the world. Examples include Chinese temples built in the 12th century and Norwegian Stave Churches dating back to the 1300s. The longevity of these structures has been achieved through the use of durable materials and protection from the elements. As modern day building construction evolves with an increased focus on energy efficiency, it is of continuing importance that we understand how buildings perform when exposed to moisture from rain and snow.

This article covers the use of redundant water management strategies to protect buildings from moisture intrusion. Just like backing-up data on computers in case of a hard drive crash, a redundant building envelope can minimize damage in the case of sealant or caulking failures. This is important, since many sealant products used in commercial construction may only last two to five years depending on the exterior environment and product installation.

Roof Systems

One common technique is the use of pitched roof systems instead of flat roofs. In commercial construction, it is common for buildings to utilize flat roof systems with parapet walls. While these are ideal for providing partial concealment of roof top units and allow easy access for maintenance, they are also more susceptible to water ponding. Additionally, it is common in low-slope roof construction to omit overhangs, which increases the bulk water absorbed by the wall system. Overhangs and sloped roof systems, as shown in *Figure 1*, are effective tools to divert moisture away from buildings.

In 1996, a report was commissioned by the Canadian Mortgage and Housing Corporation to study the impact of overhang length on moisture related wall issues. Results from the study (*Figure 2*) clearly show that, as overhang length decreases, the likelihood of moisture problems in the wall cavity increases. Based on these numbers, a 2-foot overhang may reduce the likelihood of moisture intrusion by over 50 percent in exterior walls. If moisture is diverted from the walls, it also follows that breaches in the building envelope are less of an issue.

Another key element in diverting moisture away from walls is the use of a properly designed drainage system. One area where proper drainage is commonly overlooked is at the eaves where roofs and walls intersect. As shown in *Figure 3*, kickout flashing has been installed to guide roof runoff into the gutter without saturating wall cladding.

Balconies

Balconies can provide the same protection as roof overhangs, provided detailing is designed and constructed properly. Unfortunately, this protection may be negated if moisture is allowed to drain toward the building. Additionally, balconies are inherently more susceptible to moisture-related issues given their exposure to the elements along with relatively complex detailing requirements for flashing and connections.

One of the most common ways to protect balconies is with the use of membrane assemblies which divert moisture away from both the balconies and other exterior elements. These membranes commonly use plastic or elastomeric systems to provide protection. When these systems have a tear or are improperly detailed for drainage, underlying structural components can be readily wetted allowing for decay, rust, or spalling depending on the materials being utilized. To highlight how common failures are in waterproof membranes, some condominium homeowner associations (HOA) have language in their agreements transferring liability for moisture intrusion to the owner (*see sidebar*).

*Scott Lockyear, P.E. is a Technical Director for the WoodWorks initiative which provides free support to design professionals that want to utilize wood in commercial structures. He may be reached at **scott@woodworks.org**.*

SAMPLE HOA VERBIAGE

BALCONIES–All of the condominium balconies are coated with a waterproof membrane, which if properly cared for, will withstand the elements for many years. If you see a puncture in the balcony floor or if you see a water stain on the ceiling beneath a balcony, let our Property Manager know immediately. The following rules apply to all second floor balconies:

A. Potted plants must be on raised bases/plant stands with water catch basins (this allows air to circulate underneath); no plants may be placed directly on the balcony floor (over time, trapped water will damage the balcony surface)

B. Objects with sharp feet are not allowed on the balcony. Residents will be held responsible for any damage to the waterproof balcony floor/membrane that results from puncture(s) they cause.

Puncturing of membranes may occur when balcony handrails and posts or other items are improperly connected over lightweight concrete. Moisture may also circumvent the membrane protection entirely when proper detailing is not provided. This includes prematurely ending the membrane protection at the top of the deck edge, which leads to moisture exposure of the perimeter framing. When this occurs with untreated wood, decay as shown in *Figure 4* is likely.

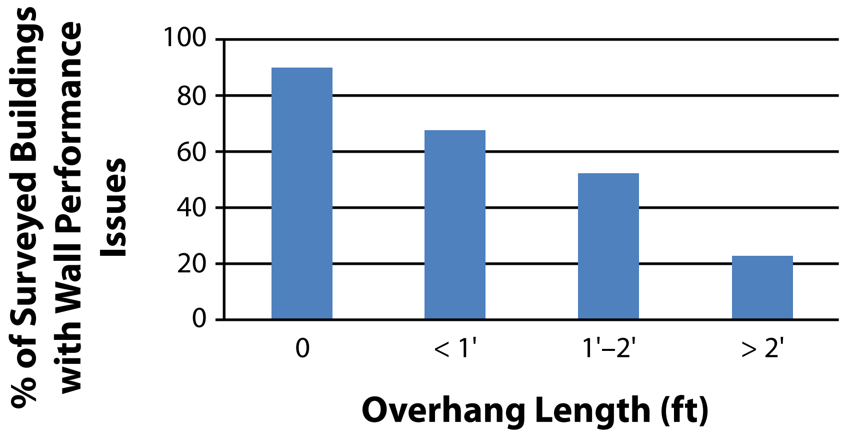

Figure 2: Effect of overhang length on wall performance.

Redundancy

Unfortunately, failures in membrane design and installations do occur, which creates a potential need for redundancy in the envelope design. Use of preservative treated wood components can provide this redundancy in exterior balconies. The concept of redundancy can also be used on breezeways where concrete toppings may act as a sponge for moisture. *Figure 5* is an extreme case, given that the protective membrane was completely omitted leading to premature failure. While the use of preservative treated wood will not prevent rusting of metal connectors and mold growth, it will protect structural members of the breezeway until the building envelope breach can be identified and repaired. Given the inherent risk of membrane failures, the situation in *Figure 5* could have occurred even with the membrane in place.

Figure 3: Kickout flashing.

If a redundant approach including the use of preservative treated wood is utilized, the designer should contact the plastic membrane and/or preservative wood manufacturer to ensure that chemical reactions will not occur between the plastic and the wood treatment.

Wall Systems

Even if overhangs and balcony areas are designed to divert moisture away, wall systems still need to provide protection from moisture intrusion. This is even more relevant in multi-story wood frame structures where

Figure 4: Decay at balcony edge where inadequate drainage provided led to decay.

Figure 5: Breezeway with no plastic membrane installed.

Figure 6: Reverse flashing at window.

Figure 7: Untreated wood beam with exposed end grain.

shrinkage of wood coupled with cladding (e.g., brick) expansion may put additional stresses on caulking and mortar intended to minimize moisture intrusion. Many articles have been written about shrinkage characteristics of wood along with expansion of brick. The Brick Institute of America's Technical Note 18A contains provisions for calculating expansion of brick, and the *Wood Handbook* published by the USDA Forest Products Laboratory has provisions for calculating shrinkage of wood. This should be a consideration when designing expansion joints of the building envelope.

With regard to wall systems, there is a litany of envelope choices available. Barrier systems are one option, with a long track record of success in existing European structures with thick stone walls that can dissipate moisture. One common barrier system is an exterior insulating finish system (EIFS). In these modern day wall systems where excess material is minimized, water may not dissipate if there is a building envelope failure which leads to moisture intrusion. In relatively simple wall systems with few penetrations, these systems may perform quite well.

Penetrations in the building envelope may result from windows, plumbing, or other systems critical to overall building performance. Proper design and installation techniques can be found in ASTM E2112–07 *Standard Practice for Installation of Exterior Windows, Doors and Skylights*. During installation, it is critical that common mistakes are avoided such as reverse flashing as shown in *Figure 6*.

As the number of penetrations increases, the probability of moisture intrusion past the barrier system also increases. This is due to the fact that caulking is relied upon to protect around these openings. High-density residential construction exterior walls often have multiple penetrations from windows and balconies. This has been identified as a concern in section 1408.1.1 of the 2009 *International Building Code* (IBC) where a drainage plane behind the EIFS in commercial buildings is required for residential occupancy. This was not required in previous versions of the IBC, leading to significant field issues.

Another option for building envelopes is drainage wall systems, which include brick veneer, cast stone, or EIFS with drainage. In drainage wall systems, the cladding provides a first layer of protection as well as a secondary drainage plane. With this strategy, small failures are less likely to cause issues; however, these systems do have a higher initial cost and do cost more to repair if there is an issue with installation. Additional considerations for drainage wall systems include proper application of weather barriers, and provision of a drainage plane gap between the wall and cladding along with a mechanism for water to exit such as weep holes in brick facades.

Untreated Wood

Another strategy is the use of untreated wood in semi-exposed applications. While untreated wood may perform well in exterior applications in certain climates, for the most part it needs to be protected to avoid significant weathering and/or decay. The easiest way to prevent issues with decay in exterior environments is to utilize decay-resistant or preservative treated wood in accordance with Chapter 23 of the IBC.

In some instances, for aesthetics, it may be desirable to utilize untreated wood at the building exterior where it is designed for minimal exposure to moisture. Section 2304.11.5 of the IBC provides guidance on the use of untreated wood and indicates that a roof, eave, overhang, or other covering, to prevent moisture or water accumulation on the surface or at joints between members, is required unless the building is located in a geographical area where moisture is not a concern.

One application where untreated wood is often used is rafter overhangs. When detailed properly, an untreated wood overhang may withstand many seasons of rain and snow. However, of particular concern is exposure of wood end grain to moisture. Trees inherently allow easy moisture transport along the grain. In a living tree, water absorbs through its roots and travels up the tree trunk to the limbs and leaves. When trees are cut into timbers, this same mechanism exists, allowing end grain to be more susceptible to uptake of moisture in exterior applications. When designing wood rafters, it is desirable to seal the end grain and situate the beams within the roof system to minimize exposure to wind-driven rain and draining water. When this does not occur, decay may result as shown in *Figure 7*. Exposed untreated wood may be utilized, provided it does not exceed moisture content of between 16 and 19 percent. Fortunately, wood in unexposed applications will have moisture content much lower than this unless a building envelope design failure occurs.

Conclusion

Before embarking on a wood frame design, it is important to consider materials and techniques which will lead to a redundant building envelope. Many internet resources are available for design and construction. When questions relating to wood frame construction arise, a useful resource is the WoodWorks website (**www.woodworks.org**). By clicking "search other wood associations," the WoodWorks search engine will guide you to resources from most of the wood industry associations in North America. By utilizing available design resources coupled with a redundant approach to the building envelope, it is possible to design and construct wood-frame structures that will stand for centuries to come.▪

This article was previously published in the December issue of *Wood Design Focus*. It is reprinted with permission.

References

Survey of Building Envelope Failures in the Coastal Climate of British Columbia, Canada Mortgage and Housing Corporation, 1996

2009 *International Building Code*, International Code Council, 2009

Technical Note 18A, *Accommodating Expansion of Brick*, Brick Institute of America

Wood Handbook, USDA Forest Products Laboratory, 2010