The Leaky Lake House:

Driving Rain Penetration & the Importance of a Proper Rain Screen

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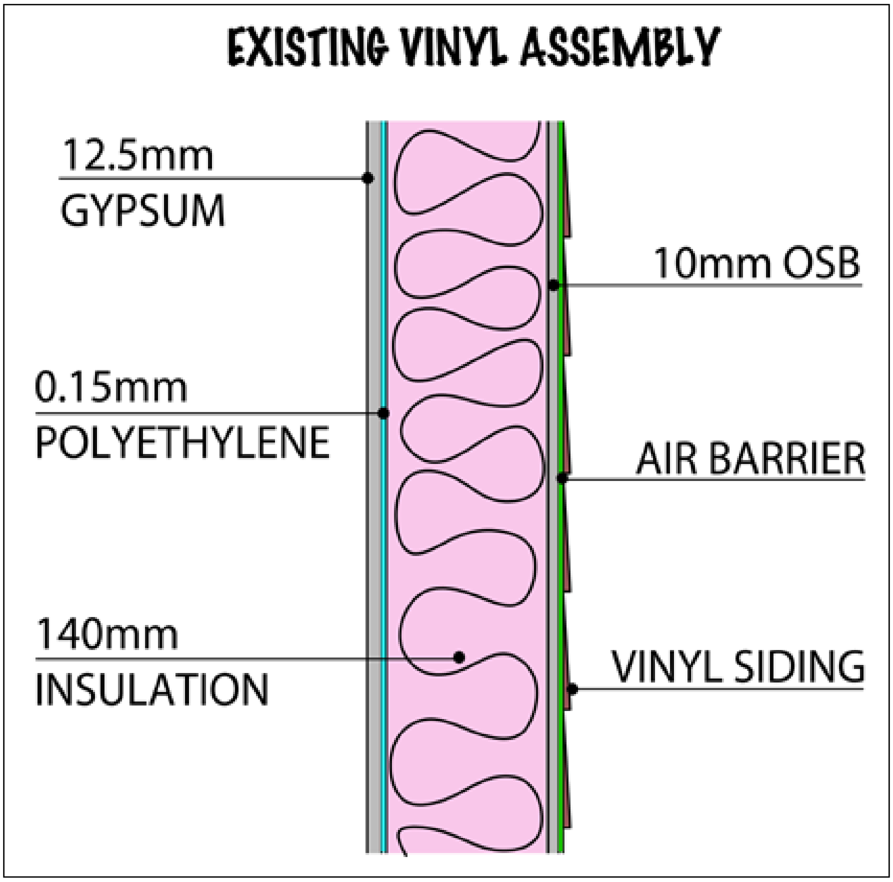
If you have ever seen the movie *The Lake House* (2006) starring Sandra Bullock and Keanu Reeves, you may recall it is a movie about reaching across time. Well, just like the movie, let's reach across time and begin by looking at the Lake House we first described in a *Pushing the Envelope Canada* article in the Fall 2015 edition. The article was entitled, *The Case of Misplaced Membranes, Rain Penetration & the Decay of Major Structural Members*.

In Part I, we reported that the home was built back in 1993 with nominal 2x6 framing. In June 2014, subsequent purchasers moved in and were living happily ever after in a home described by the realtor as "well-maintained" and a "10+" house! Well, three months later, a driving rain event occurred, and more than eight litres of water began pouring in through the south-east walls, which faced a large lake with a fetch of 20 kilometres (fetch is a nautical term that describes the length of water over which wind has blown). The Lake House had been sold to unsuspecting purchasers, and it leaked like a sieve.

The new homeowners had no idea that the house had long been suffering chronic rain penetration problems and was a major fixer-upper. They believed they were moving into a sound home! Why? All of the signs of rain penetration had been carefully concealed, hidden behind new drywall and paint! It wasn't until the arrival of a rainstorm with winds that rose to 60 kilometres per hour from the southeast that rainwater poured into the home. Since the original rain leakage, similar driving rain events have occurred between four and six times per year, mostly in the spring and fall. It wasn't until the driving rain came in September 2014 that the homeowners realized, "We have a problem."



The profile of the "repaired" wall assembly suffering rain penetration.

Thanks to some good building science investigations and some clever guidance and labour from a handyman formally trained by the school of hard knocks, the root causes of the rain penetration problems were identified. The walls that were performing badly were opened up and examined. They had been constructed, with repairs attempted, as shown in Figure 1 (on this page). The vinyl siding had been re-applied directly over the OSB sheathing that had been retrofitted with an impermeable peel-n-stick membrane, forming an air barrier and a water-resistant layer.

In a desperate attempt to keep the rain out of the wall, a contractor had removed the original vapour-permeable air retarding membrane and replaced it with a peel and stick membrane, a product intended for use as an ice and water shield on sloped roofs.

Sadly, the retrofitted wall was destined for failure in two possible ways: by concealed condensation due to vapour diffusion from the inside; or by driving rain penetration. Why? First, the peel-n-stick membrane was almost impermeable, and

A failed attempt to air-seal an electrical outlet.

it was on the cold side of the thermal control layer in a home located in ASHRAE Climate Zone 6. Even a crude hygrothermal analysis using hand calculations will show that the retrofitted wall will eventually fail through concealed condensation. However, since vapour diffusion is an extremely slow process, the wall had not yet had time to fail by vapour diffusion and condensation.

However, the wall did fail because of rain penetration. Although the peel-n-stick membrane was intended to keep water out, in fact, because of the way in which it was applied, it still let water in but didn't allow it to drain back out as easily as it had before. Rain penetration occurred because of air leakage and the lack of a pressure-moderated rain screen. Although the peel-n-stick membrane was an air barrier, it was not made continuous with any of the wall penetrations, including windows, sliding glass patio doors, and even electrical penetrations.

Although attempts were made to make the membrane continuous, most of the attempts failed. The photo on page 23 shows an example of the gobs of silicone sealant that were applied in vain to an electrical outlet that penetrated the membrane. As built, even a small hole in the sealant would still be a path for air pressure-driven films of water. Without the provision of a vented cavity and a proper rain screen, such a brute force caulking approach was doomed to fail, and it did.

In the photo on this page, you can see another poor detail for managing rainwater. Someone had attempted to direct water from the peel-n-stick membrane and onto the flashing surrounding a shaped window using duct tape, not flashing tape. After a few years in service, the duct tape had become dust tape. Further, following the removal of the shaped window, it was found that there was no air seal between the window frame and the air barrier.

Matters were made worse when no framing or header support for the shaped window were provided. This meant that the window flanges were merely nailed to the adjacent unsupported OSB sheathing and left unsealed. Since the OSB was largely unsupported, the window could deflect up to a centimetre or two in high winds, thereby causing the face-seal caulking to fail. Not surprisingly, water entered around the window despite the gobs of repair caulking, and the wood framing decayed.

Further, water running down from the shaped window penetrated the second-floor patio doors below and wet the supporting sill which formed the header of the first-floor patio door. The built-up header, spanning 2.7 metres and comprised of three nominal 2x10 spruce members, had decayed as well. As you can see in the photo on the top-left of the next page, the header is rotten. The outermost member lost all of its capacity and the middle member likely lost about 50 percent of its capacity. The innermost member, which had been kept dry by heat losses from the house, was only slightly decayed.

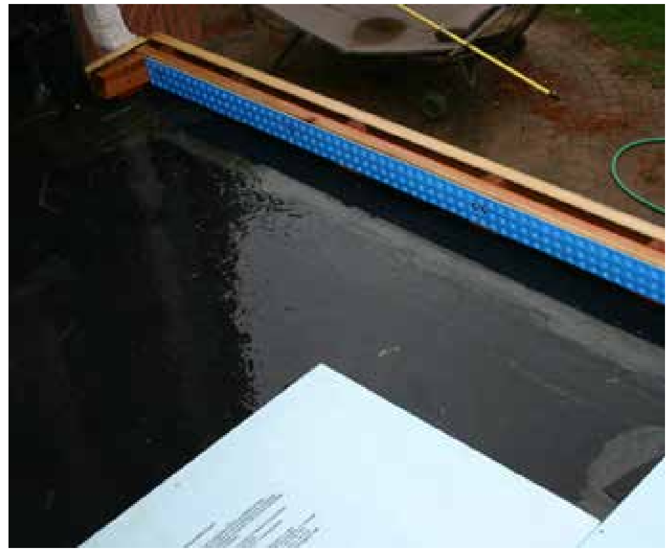
As we described in our first article a couple of years ago, to address the rain penetration issues, the vinyl siding and the peel-n-stick membrane were removed. The impermeable membrane was replaced with a vapour-permeable air barrier, and critical areas around windows and doors were air- and weather-sealed using various flashing tape products. Further, proper metal head flashings with end dams were installed.

The rotted and leaking sliding glass doors were replaced with new insulating glass units, which were designed and constructed specifically for driving rain exposure. The sliding glass panels of the new doors are on the outboard face of the fixed unit, and so when the wind blows, the same wind pressure that drives water inward, also pushes the sliding door more tightly against the seal: the higher the wind pressure, the better the seal. This is a great patio door design for resisting rain penetration, but it's not perfect. In the winter, the exterior track must be kept clear of ice and snow in order to keep the track from icing.

Having created a continuous air barrier, the next step in creating an effective rain screen was to add 25-millimetre pine board and batten siding. The siding was installed over 19-millimetre strapping, which was used to create an airspace. The board and batten siding was open to the air at the top and the bottom of the air space. As well, since the boards were rough sawn, a small air gap existed between the battens and the boards. Accordingly, the

An unsupported and unsealed shaped window.

The rotten header above a three-panel patio door.



Insulating the protected membrane roof.

air space behind the board and batten siding was well-vented and, therefore, pressure-moderated.

After constructing a proper rain screen, there was one more source of rain penetration that needed to be addressed. The original low-slope roof/deck adjoining the first floor and covering a portion of the walkout basement below was only 25 millimetres lower than the sill of the sliding patio doors. The roof was low-slope and wind could easily drive rain under the door and into the house. The existing roof/deck was covered with an exposed vinyl membrane, and the surface of the membrane was about 150 millimetres higher than the interior floor. Such a construction detail was just waiting to fail.

To address the roof/deck issues, the roof was first lowered about 300 millimetres, and a protected membrane roof was installed. An EPDM fully-adhered membrane was applied to 19-millimetre tongue-and-groove plywood that was supported by nominal 2x10 spruce joists. The membrane was integrated with the air barrier on the wall and became a part of

The board and batten siding has been partially completed.

the air, water, and vapour control system. Then, 100 millimetres of extruded polystyrene insulation was placed outboard of the roof membrane, while 100 millimetres of glass fibre insulation was used to thermally insulate the joist space. Since the EPDM membrane served as the vapour control layer as well, no polyethylene sheeting was applied on the interior. Instead, the ceiling joists were covered with 12.5-millimetre gypsum board that was painted with two coats of vapour-permeable latex paint.

By leaving out the interior polyethylene sheeting, small amounts of water entering the joist space through rain leakage or vapour condensation could still dry by vapour diffusion to the inside. In place of the polyethylene, a vapour-permeable membrane was used to protect the gypsum board from wetting. To date, no water has accumulated in the joist space. Although it is possible in very cold weather for condensation to form on the underside of the plywood roof sheathing, no water accumulation has occurred. This is likely because during the coldest months, the home has an indoor relative humidity below 25 per cent. Further, no rain has entered the low-slope roof assembly, either by gravity or driven by air pressure differences. Quality of both design and workmanship have ensured that rainwater stays out of the building.

For now, this is the end of the story. Phase II of the construction has been completed, and so far, it has not rained inside when it is raining outside. Phase III awaits. That phase will involve keeping the rain out of the masonry walls that are visible in the photo on the previous page. Those walls are leaking, too, and keeping the smaller amounts of rainwater out will be a tougher task for the future.

What lessons have we learned? Well, pressure-moderated rain screens really do work. In addition to constructing an outer rain screen, by providing a well-vented cavity that serves as a drainage plane, and by ensuring the air barrier is reasonably continuous, you can keep driving rain out. We have also been reminded that vapour diffusion is indeed a slow process. If you construct a wall with a double vapour barrier, you will mortally wound a wall in a cold climate, but it could be a very slow demise! Finally, we learned that the problems presented here, like most building science problems, are best solved when sound designs are implemented with the guidance and care of skilled hands. ■

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Covering the protected membrane roof with decking.