LOW-SLOPE ROOFS ARE ROTTING

By Dwight D. Benoy, PE, and Pamela Jergenson, CCS, CCCA

Low-slope roofs are rotting, resulting in major repair costs. Recently investigated roofs on three multifamily residential buildings had failed prematurely. All three buildings were less than ten years old and were located in a northern climate.

These buildings had similar nonventilated, low-slope roof assemblies utilizing wood trusses with a polyethylene vapor retarder on the bottom of the trusses covered with a gypsum ceiling. Blown-in fiberglass or cellulose insulation filled the truss space from the ceiling to the bottom of the roof deck. Oriented strand board (OSB) of ½-in. thickness was installed over the trusses as the roof deck. Rigid board insulation was installed over the OSB, followed by the roof membrane, which was a gravel-surfaced, built-up roof in one case; a ballasted EPDM single-ply membrane on another; and a mechanically fastened TPO single-ply membrane on the third (*Figure 1*).

There was no water intrusion evident in any of the buildings. A survey of the roof surfaces showed that they were in good condition. Occupants in two of the buildings reported that they thought they had a mold problem, which led to further investigation. Maintenance people walked on the third building roof and reported soft spots, which turned out to be locations where the OSB roof deck had lost its structural integrity due to moisture degradation.

Invasive inspection openings made into the roof assembly revealed the OSB decking was severely deteriorated in many areas, such that it could not support the roofing materials above. The top portion of the top cord of the wood trusses was also wet and rotted in some cases. The steel tie plates of the trusses were corroded. Framing lumber at the exterior walls in the truss space was also wet.

The polyethylene vapor retarder was turned down the vertical face of the exterior walls and lapped with the polyethylene vapor retarder of the wall, with the overlap sealed with plastic tape. At partition walls, the vapor retarder was attached to the vertical face of the top plate of the wall with a thin bead of adhesive. Overlaps in the ceiling vapor retarder were also sealed with plastic tape.

It was apparent that moisture-laden air migrated into the truss space and condensed in the upper reaches of the roof

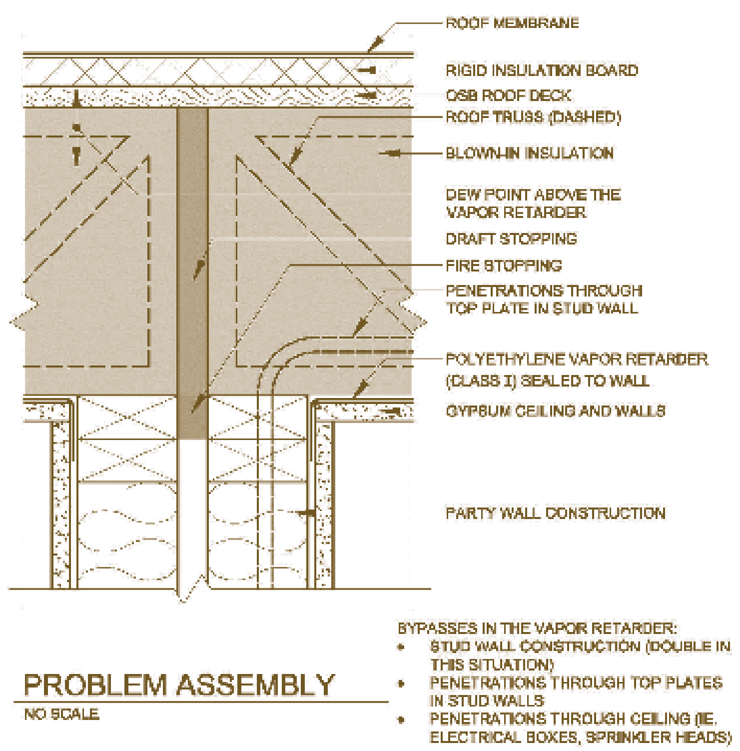

Figure 1 – Problem assembly.

Figure 2 – Rotted deck collapsed into truss space revealing rotted top chord of truss and corroded tie plates.

Figure 3 – Vapor retarder bypass at partition and party walls.

assembly. So how did this moisture-laden air get into the truss space and condense in quantities that caused such extensive damage? The vapor retarder should act to minimize the amount of moisture vapor from the interior of the building getting into this space. In the northern climate where these projects were located, the vapor drive in the winter is mainly from the warm interior to the cold exterior. The warm interior air carries moisture vapor that will condense on the surfaces that are below the dew point, the temperature at which condensation can occur.

The investigations found many bypasses in the vapor retarder that would allow the warm, moist interior air to migrate into the truss space (*Figures 2-5*). The party walls between apartment units, which were a double-stud wall

Figure 4 – Vapor retarder bypass at ceiling light electrical box.

Figure 5 – Vapor retarder bypass through top plate of partition wall.

Figure 6 – Leaky dryer and bathroom vent ducts in truss space.

construction, interrupted the continuity of the vapor retarder.

Likewise, any interior partition walls resulted in a discontinuity in the vapor retarder at the ceiling. This was exacerbated by the penetrations through the top plate of the wall by plumbing stacks and wiring. Penetrations through the ceiling, such as sprinkler heads and electrical boxes for light fixtures, were also found not to be sealed to the vapor retarder.

Two of the buildings had ducts from bathroom and dryer vents running through the truss space (*Figure 6*). Some of these ducts were not well sealed at the joints, which introduced very moist air directly into the space where condensation was most likely to occur.

The roof assembly would likely perform satisfactorily if the ceiling vapor retarder were perfectly constructed. However, in this type of construction, it was virtually impossible to perfectly construct a vapor retarder at the ceiling level due to all of the discontinuities. Ventilation of the truss space is not an effective option to manage the moisture. Unlike a steep-slope attic space, there is very little, if any, space to create airflow over relatively long distances.

Traditional methods for moisture analysis of the

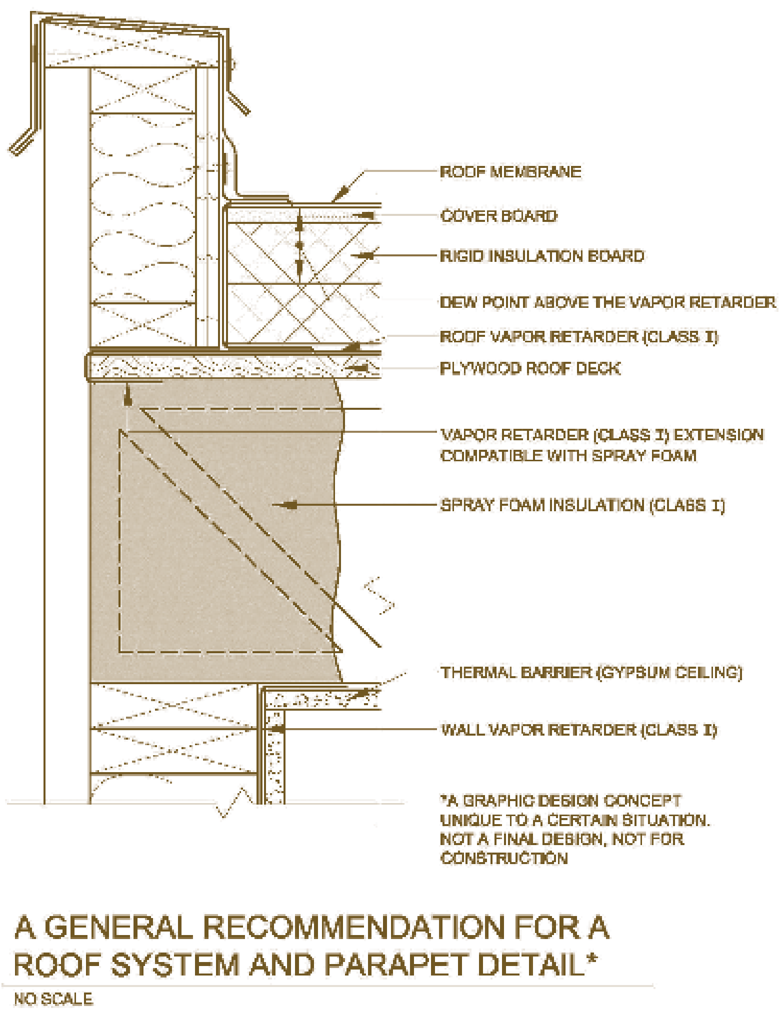

Figure 8 – Recommendation for a roof system and parapet detail.

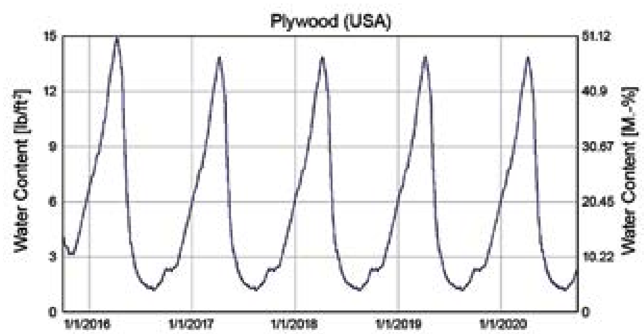

Figure 7 – Hygrothermal model graph of the roof deck in the roof assembly shown in Figure 1.

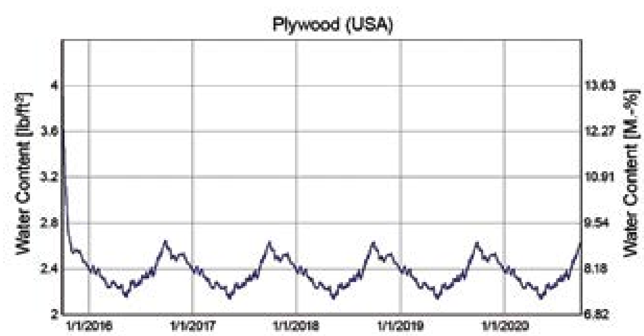

Figure 9 – Hygrothermal model graph of the plywood roof deck in the roof assembly shown in Figure 8.

exterior envelope, such as the dew point method, the Glaser diagram, and the Kieper diagram, are steady-state analysis tools. These methods have significant limitations due to the fact that wetting and drying cycles cannot be accurately analyzed when considering only a specific temperature at one moment in time. These tools neglect the moisture storage capacity in the building materials and the transient effects of vapor drive.

Hygrothermal modeling has become more widely used over the past 20 years to simulate the transient heat and moisture conditions in roof and exterior wall assemblies. Hygrothermal modeling, in contrast to the traditional methods, looks at heat and moisture conditions over time and can take into account a number of variables. Most importantly, it can show whether the system has a propensity for moisture to accumulate at levels that can result in rot, mold, and corrosion.

Figure 7 is the hygrothermal model graph of the roof deck in the roof assembly shown in *Figure 1*, assuming the presence of vapor retarder bypasses, over a five-year period. The water content of the roof deck exceeds 19% for about 40% of the year, peaking in April. Calculating the dew point using traditional methods by selecting temperature and humidity conditions in January may not have shown the potential problem of excessive moisture in the system that peaks in April. The moisture damage to the roof deck, as observed in the field, strongly correlates to the hygrothermal model results.

Perhaps the motivation to design an assembly as shown in *Figure 1* would be to minimize the insulation costs related to the energy code requirements of recent years. While the amount of insulation installed exceeds the code requirement, the material and labor to install it were less than a code-compliant insulation installed above the roof deck. Filling the truss space with noncombustible insulation also provided the opportunity to eliminate the need for firestopping and draftstopping as noted in the 2000 International Building Code (IBC) in force at the time these buildings were constructed.

A more constructible approach would be to install a vapor retarder on the roof deck level (*Figure 8*). Some insulation could be installed in the truss space, but most of the insulation would need to be installed above the vapor retarder so that the dew point occurs above the vapor retarder. Insulating above the roof deck with rigid board insulation would be more expensive than insulating with blown-in insulation in the truss space. However, eliminating condensation is less expensive than costly repairs after the fact.

Figure 9 is the hygrothermal model graph of the plywood roof deck in the roof assembly shown in *Figure 8*. This shows the moisture content of the plywood roof deck staying below 19% and actually drying out over time from its initial peak moisture content at the time of construction. Anecdotal observations of roofs similar to this design in place for 20 years or more substantiate the hygrothermal model results.

Installing the vapor retarder at the roof deck level affords a much better opportunity for achieving a complete vapor retarder. This would be a relatively easy way to provide continuity across party walls and to seal penetrations. The vapor retarder must also be continuous from the roof to the exterior walls. This might be accomplished by using spray foam insulation within the truss space at the exterior walls.

Recent investigations of three buildings in a northern climate clearly demonstrated the well-intended cost-saving measure to insulate within the truss space resulted in premature roof failure and expensive repairs. Those repairs included complete replacement of the roof covering and roof deck, along with repairs to the structural trusses and installation of new insulation. This was an expensive lesson from which we should all learn.

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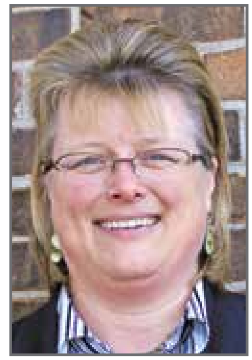

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