# *NOT* ALL INSULATION FACERS ARE EQUAL

**By Matt Dupuis, PhD, PE**

Many decades ago, we had a choice between two roofs: coal tar or asphalt. Fast-forward to today's roofing market. We have an overwhelming choice of membranes, fastening methods, and insulation types. However, if we focus on market shares for insulation, we see a clear domination by polyisocyanurate. This segment is vastly dominated by ASTM C1289 Type II, Class 1 insulation, faced with glass-fiber-reinforced cellulosic felt facers on both major surfaces of the core foam. We commonly refer to this product as a "paper facer."

In 2013 and 2014, the National Roofing Contractors Association (NRCA) and the Midwest Roofing Contractors Association (MRCA) joined together to sponsor independent research into the fundamental properties of water-based adhesives (WBA). One of the outcomes of this research was a common failure mode during laboratory peel-strength testing. This failure mode was cohesive failure within the paper facer.

This observed failure mode was not limited to the laboratory. In numerous roof system forensic investigations around North America, this cohesive failure within the paper facer of the polyisocyanurate was observed when elevated moisture levels were encountered in the roof system. Examples of peel failures can be seen in *Figures 1* and *2*.

Given the issues with cohesive facer failure seen in the lab, in field investigations, and from numerous industry

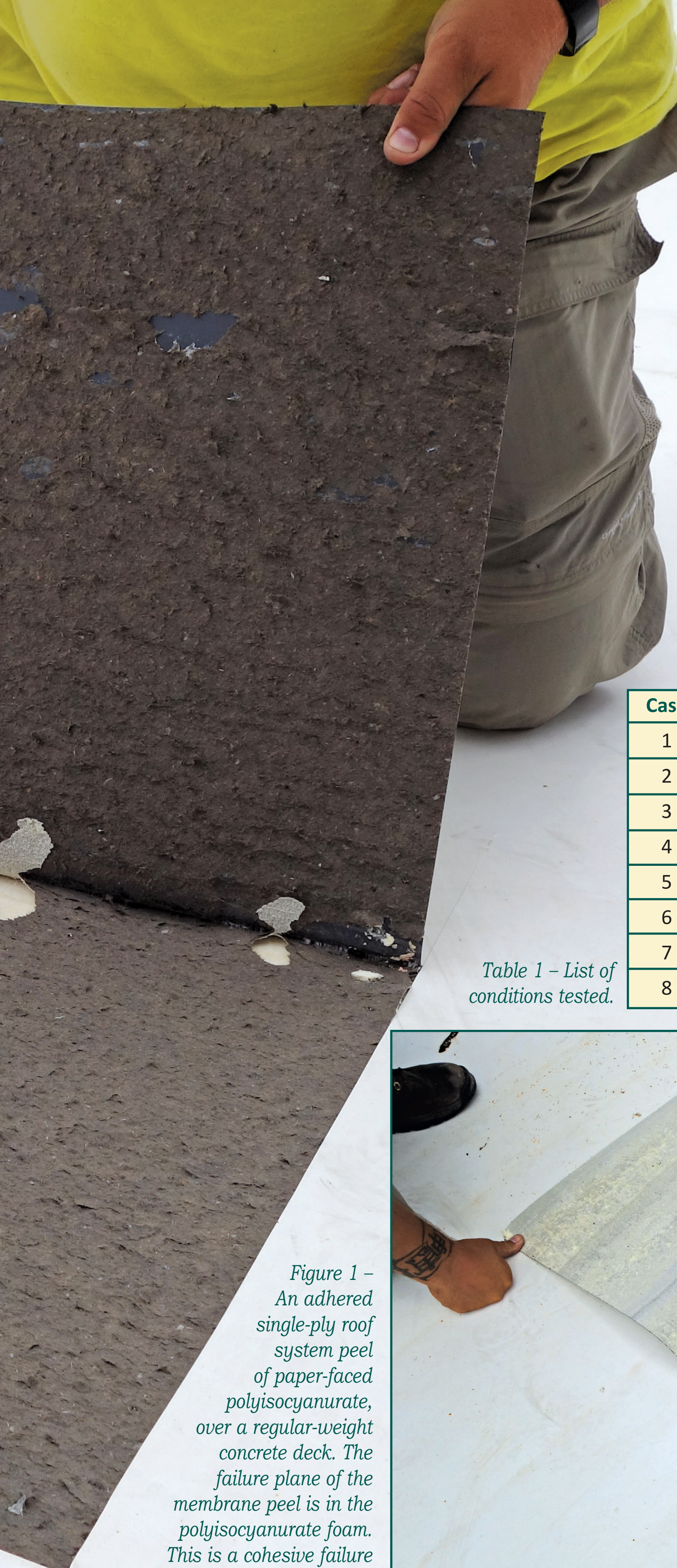

*Figure 2 – An adhered single-ply roof system peel of paper-faced polyisocyanurate, over a lightweight structural concrete deck. This roof is the same roof system configuration as in* Figure 1, *and from the same building. The difference here is that the portion of the building was constructed with lightweight structural concrete. This insulation system was laden with moisture, and the facer was wet to the touch. The failure plane is cohesive in the facer plane.*

reports, the Chicagoland Roofing Council sponsored research into the moisture sensitivity of polyisocyanurate facer strength. This research was presented at the 2015 Chicago Roofing Contractors Association Trade Show and Seminars and is detailed here.

The research protocol involved testing ASTM C1289 Type II, Class 1 "paper" facer versus Type II, Class 2, faced with coated polymer-bonded glass fiber mat facers on both major surfaces of the core foam, and commonly referred to as "coated glass" facers. Samples of each of these facer classes were procured from two manufacturers from the bulk-facer rolls before board production. In this study, the facers are treated as a class of product and not manufacturer-specific. Therefore, they are only reported as Manufacturer A and Manufacturer B.

These bulk-facer samples (paper and coated glass) from man-

| Case | Condition |
|---|---|
| 1 | Oven-dry (60°C/140°F) 24 hours |
| 2 | 30% relative humidity @ 73°F |
| 3 | 50% relative humidity @ 73°F |
| 4 | 70% relative humidity @ 73°F |
| 5 | 90% relative humidity @ 73°F |
| 6 | Immersed in water 24 hours (saturated) |
| 7 | Immersed 24 hours and oven-dried 24 hours |
| 8 | Immersed 24 hours and oven-dried 24 hours for 5 cycles |

*Table 1 – List of conditions tested.*

*Figure 1 – An adhered single-ply roof system peel of paper-faced polyisocyanurate, over a regular-weight concrete deck. The failure plane of the membrane peel is in the polyisocyanurate foam. This is a cohesive failure in the foam core.*

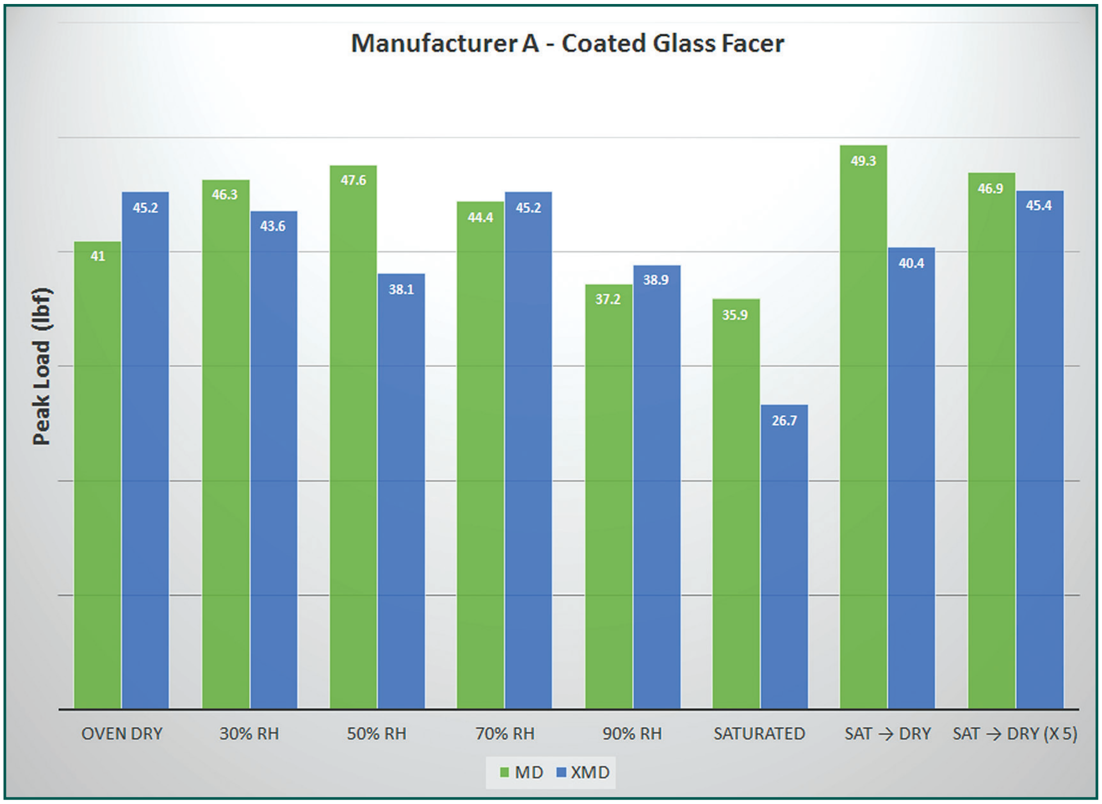


*Figure 3 – Tensile results for Manufacturer A coated glass facer.*

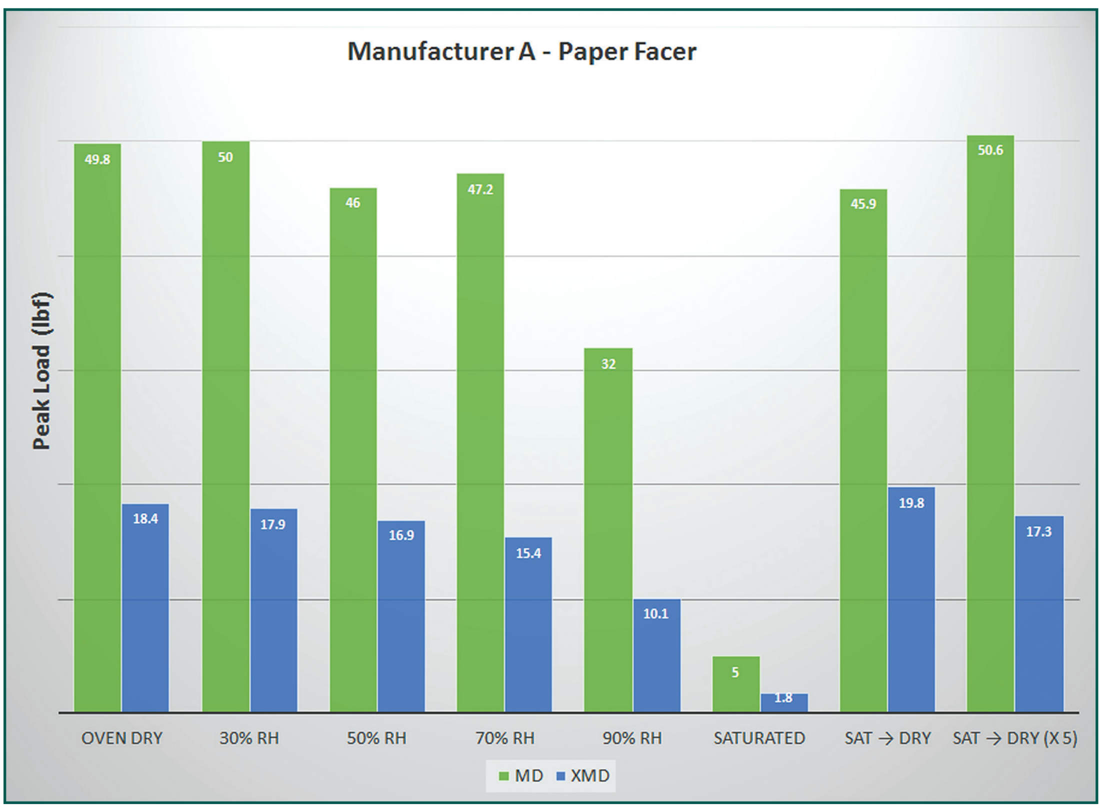


*Figure 4 – Tensile results for Manufacturer A paper facer.*

ufacturer A and B were cut into strips from both the machine direction (MD) and the cross-machine direction (XMD). To produce the different moisture contents in these specimens, they were allowed to equilibrate in different environmental conditions before testing.

In addition to equilibrium moisture levels, moisture cycling was investigated. This cycling is intended to investigate if either of these facers loses strength from moisture cycling. In so doing, we are broadly investigating the impact of seasonal moisture cycling and/or repetitive membrane leakage. A summary of conditions tested is listed in *Table 1*.

In all, 192 samples were prepared. Each sample, after appropriate moisture conditioning, was tensile-tested in an MTS load frame, utilizing pneumatic jaws with a crosshead speed of 1 inch per minute. The results of the tensile tests are presented in *Figures 3* through *6*.

After studying the results presented in *Figures 3* through *6*, we can begin to make some conclusions. The first conclusion is that the paper facers have different strengths in different directions. In engineering-specific terms, the paper facers are said to be nonisotropic when compared to the glass facers. This observation considers that the paper facers have about 25% of their MD strength in the XMD at all moisture levels. In contrast, the glass facers generally appear much closer to isotropic.

It can be said that the paper facers generally maintained a reasonable strength up to 70% relative humidity (RH). However, at 90% RH, a marked decrease in strength for the paper facers was seen. But consider that we are loading the paper facer with more and more water molecules as we increase humidity levels; however, until we reach the dew point inside the tiny capillaries and voids inside the material, we should not have liquid water inside the material. Yet we start losing tensile strength—a curious phenomenon that probably needs more examination. Finally, when the paper facer was satu-

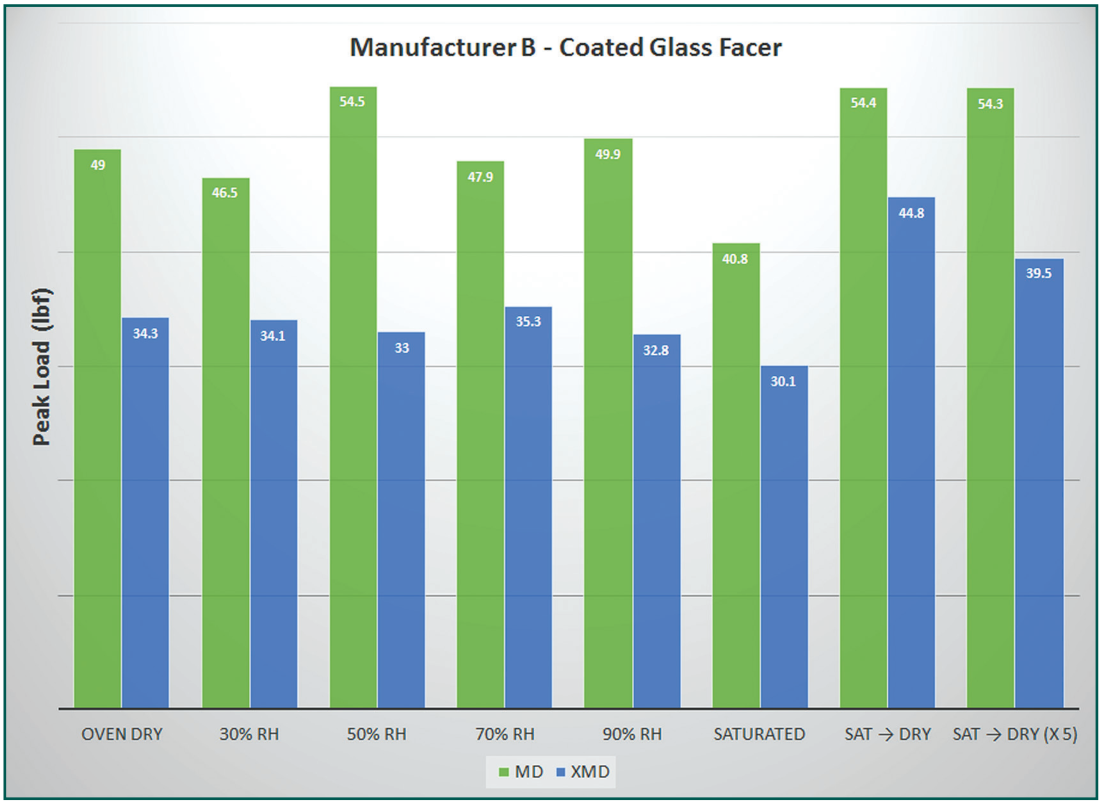


*Figure 5 – Tensile results for Manufacturer B coated glass facer.*

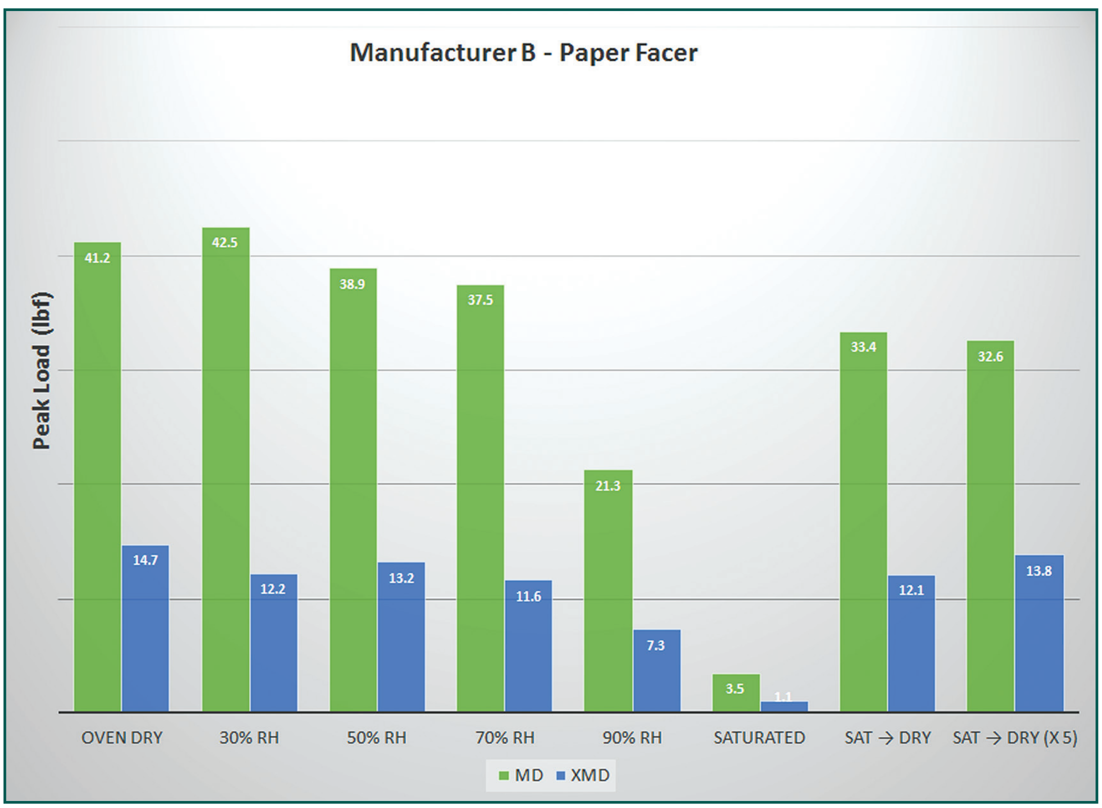


*Figure 6 – Tensile results for Manufacturer B paper facer.*

rated, tensile strength of the paper facer, in both directions, was extremely low. The lowest recorded tensile strength was just 1.1 pounds. This occurred, not surprisingly, at saturation.

It can be seen that the glass facers' tensile strength was relatively indifferent to differing moisture levels, even at saturation. This may imply that even a fully saturated glass-faced polyisocyanurate board can perform under service loads such as wind uplift.

Both glass and paper facers generally regained their original strength or better after being saturated and dried, even after five cycles.

In addition to the tensile data, moisture content, mass change over time, and readings with a Delmhorst meter were collected. To observe the mass change over time, special analytical balances are used. These balances are different for common laboratory balances in that they can be placed directly in the environmental chamber while maintaining the same accuracy. When in the chamber, we can collect data points with a computer as the samples sit in the chamber. This technique allows us to determine when equilibrium has been reached, considered when no more appreciable mass change occurs over a time period.

The mass change over time data for Manufacturer A's paper and coated glass facer is shown in *Figure 7*. What occurred in the chamber is interesting in that both facer types reached equilibrium within 2 to 4 hours of being placed in the chamber. Compared to most other roofing materials, this is very fast.

The data, to include moisture content at equilibrium and associated Delmhorst readings, are presented in *Figure 8*.

Taking into consideration the research done by the NRCA and MRCA into water-based adhesive performance on paper-faced polyisocyanurate and the research presented here, the one conclusion that should be evident is that ASTM C1289 Type II, Class 1 "paper" facers are poor performers with high moisture content.

However, as previously stated, polyisocyanurate insulation dominates the roofing industry insulation market. We have billions of square feet of installed roofs utilizing paper-faced polyisocyanurate. It must be conceded that a vast majority of these roofs are functioning as intended and presenting absolutely no problems. But there are the handful of roofs utilizing paper-faced polyisocyanurate, particularly those with the membrane adhered directly to the facer, that are presenting symptoms of a moisture-based failure. The appropriate question is, "Do we actually have a problem?"

The genuine concern with facer performance is wind uplift performance in an adhered system. In roof systems utilizing ballast or mechanical fasteners to resist wind uplift, the impact of facer strength under varying moisture contents has no implication, and thus is of no concern. But in the adhered system, we are at the mercy of the weakest link in the chain. If we are reliant on the paper facer at any level in the roof system for uplift resistance, we have a point of discussion.

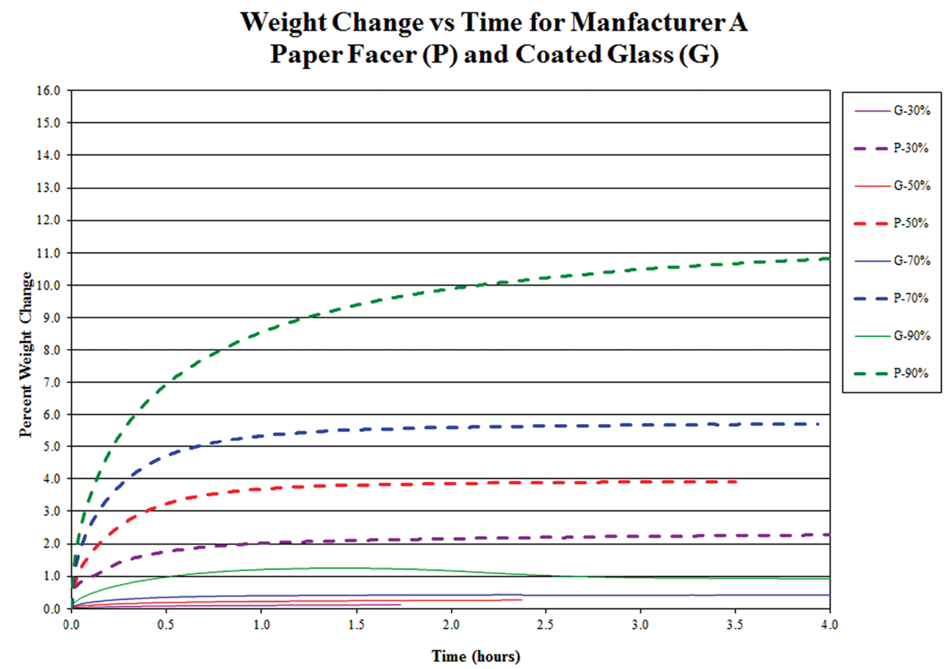


*Figure 7 – Mass data from facer samples placed in an environmental chamber.*

Consider structural design of buildings. When utilizing engineering industry guidance for building design, we take into account the end use of the building. In buildings that are part of vital public infrastructure, such as a hospital, or where failure would incur large losses of life, such as a sports arena, we utilize higher factors of

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| | Moisture Content (%) | | | | Delmhorst (BD 2000 Scale 1) | | | |
|---|---|---|---|---|---|---|---|---|
| Conditons | Glass-A | Paper-A | Glass-B | Paper-B | Glass-A | Paper-A | Glass-B | Paper-B |
| Oven Dry | 0.1 | 0.2 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30% RH | 0.15 | 2.35 | 0.15 | 2.74 | 0.0 | 0.0 | 0.0 | 0.0 |
| 50% RH | 0.27 | 3.92 | 0.28 | 4.23 | 0.0 | 0.0 | 0.0 | 0.0 |
| 70% RH | 0.43 | 5.72 | 0.44 | 6.57 | 13.6 | 8.1 | 13.4 | 9.9 |
| 90% RH | 1.25 | 10.92 | 0.95 | 13.85 | 20.6 | 16.0 | 20.3 | 22.0 |
| Saturated | 26.3 | 107.8 | 27.8 | 111.1 | 19.0 | 23.9 | 18.7 | 24.2 |
| Sat → Dry | -0.6 | -1.0 | -0.5 | -1.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| Sat → Dry (X 5) | -0.8 | -2.2 | -0.8 | -2.5 | 0.0 | 0.0 | 0.0 | 0.0 |

*Figure 8 – Moisture content percentage and associated Delmhorst meter readings for the facers and conditions in this study.*

safety in their design.

It seems reasonable to extend this concept to roof system design, in that if we design a roof system for a critical structure—say one that would fall under American Society of Civil Engineers' (ASCE's) designation from ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, Risk Category III or IV—we should consider designing a more conservative roof system.

Based on the research conducted by the NRCA and MRCA into water-based adhesives and the research the Chicagoland Roofing Council funded (which is reported herein), it would be reasonable to say membranes adhered directly to paper-faced polyisocyanurate insulation are not a conservative design. A more conservative choice would be to utilize coated glass facers in that same roof system design and avoid the potential for moisture-induced cohesive facer failure.

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