Air Barriers at the Roof Deck Improve Wind Resistance of Roof Systems

Research provides quantitative information

By Jim Kirby, AIA

Introduction

A roof system's primary function is to keep the elements–rain, snow, sleet, and hail for example–from entering a building. Roofing systems are also being asked to include a significant thermal layer, and be resistant to wind, fire, and hail. And roofing systems should perform those functions for a long time. To that end, the roofing systems need to be wind resistant and remain on the rooftop. Simply put, wind resistance is a key characteristic for long-term performance of roofing systems.

Physical Testing

Roofing system manufacturers rely on physical testing to determine key characteristics of roof systems. The key characteristics include: fire-resistance, impact-resistance, and wind-resistance. Each is determined by physical testing. Looking at wind resistance alone, there are a number of tests available to determine a roof system's wind-resistance included in the International Buidling Code (IBC). IBC Section 1504.4.1 lists three physical test methods – FM 4474, UL 580, and UL 1897 – that are allowed to be used to determine wind uplift resistance. In addition, there is a fourth physical test, which resides in the National Building Code of Canada (NBC). The NBC includes CSA A123.21 as the single physical test allowed to determine wind uplift resistance.

Wind Pressure

Wind pressure on a roof is a suction pressure–it acts upward and away from the roof. Wind is literally trying to pull the roof off of a building because of the negative pressure created. The suction / negative pressure acting on the roof increases as the wind speed increases. High winds can create significant negative wind pressure acting on the roof. This phenomena is also why airplanes stay up in the air–tthe air moving over the top of the wing creates lift (aka, suction or negative pressure). The same thing happens to a roof when the air moves very quickly over it–the large negative pressure is trying to lift the roof off of the building.

At the same time and in addition to the negative pressure above the roof, the roof is also pressurized from the underside by the air pressure inside the building. This is called internal pressurization. So when the wind blows, roof systems are being pulled off from above and pushed off from below. Perhaps unfortunately, but very importantly, these pressures are additive.

When determining the wind loads acting on a building, the possibility of a building being internally pressurized is taken into account. This characteristic is based on the overall design of the building enclosure. A building enclosure, based on specific calculation in ASCE 7, is considered to be "Enclosed" or "Partially Enclosed." This calculation is based on a number of parameters, including the ratio of the opaque facade elements to the overall area of doors and windows. It's more complex than stated here, but that's the concept. Simply put, an Enclosed Building allows very little wind to enter a building, and a Partially Enclosed building allows much more wind into the building. Buildings that have higher internal pressurization have design wind pressures that are higher, and therefore, the wind-resistance capacity of the roof needs to be larger.

Air Barriers

Air barriers at the roof deck can help prevent the internal pressures from getting to the roof system. The components of a roof system are themselves air barriers, but the overall roof system–because of joints and penetration openings in the roof deck–can allow internal pressure to reach the underside of the roof membrane. Figure 1 shows the potential pathways that internal air pressure can take to reach the underside of the roof membrane **without** an air barrier at the deck level.

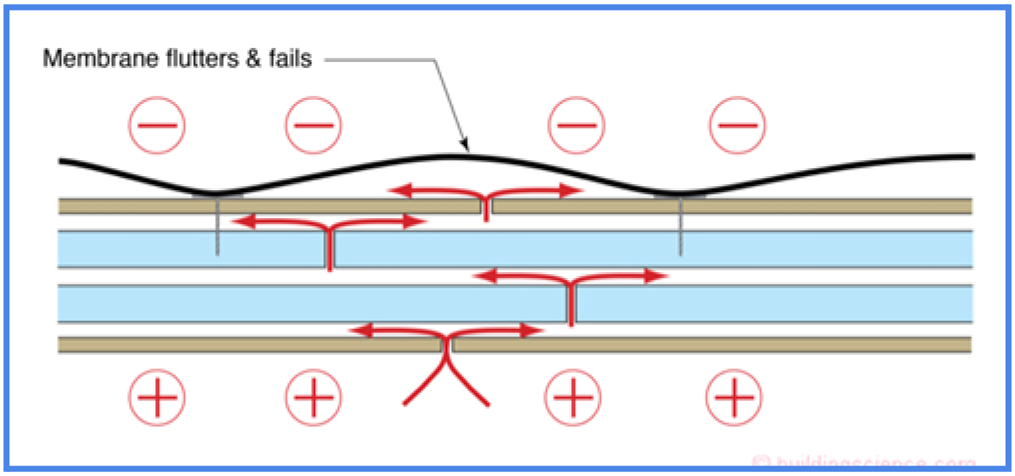

Figure 1: This figure shows the potential pathways that internal air pressure can take to reach the underside of the roof membrane. This graphic comes from "Roofs and Wind" by Joe Lstiburek, PhD, from ASHRAE Journal, October, 2020.

With an air barrier at the deck level, as shown in Figure 2, air can not get to the underside of the insulation or the underside of the roof membrane, so less total wind pressure affects the roof membrane.

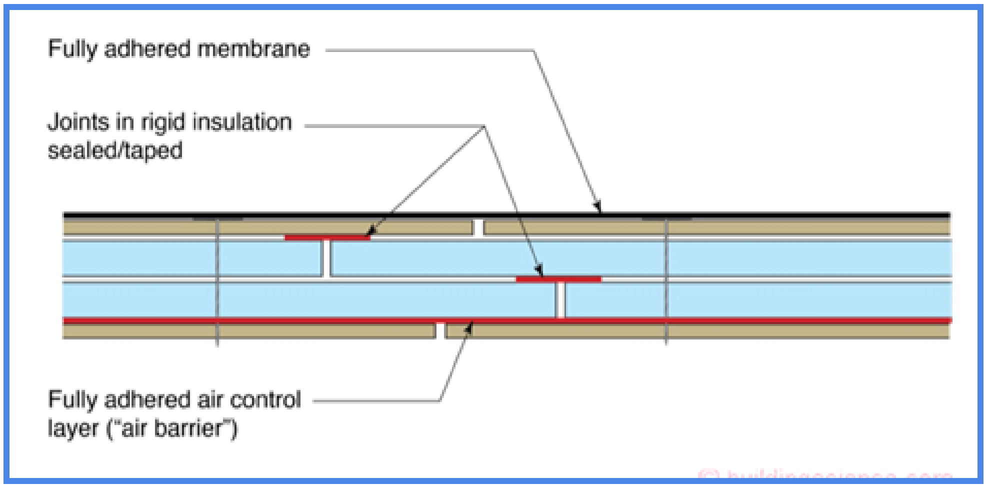

Figure 2: This figure shows the ability of a well-installed air barrier to prevent internal wind pressure from reaching the underside of a roof membrane. This graphic comes from "Roofs and Wind" by Joe Lstiburek, PhD, from ASHRAE Journal, October, 2020.

Quantitative Research Performed by National Research Council of Canada (NRC)

Research on air barriers and wind resistance was performed by the National Research Council of Canada (NRC). The NRC used the Canadian wind-resistance test method for this research. The research that was done by NRC shows that including an air barrier at the deck level (below the insulation layer) can result in roof systems with significantly greater wind resistance.

Increasing wind uplift resistance by inclusion of an air barrier is based on how well the air barrier blocks air intrusion from the interior of the building into the roof system. NRC's "AIR Movement Impacts on Roofing Systems [AIR] - Part 2" includes two important conclusions:

- A kraft-paper air barrier with taped seams at the roof deck reduced air intrusion by 97%
- Polyethylene and self-adhered films reduced air intrusion by 99.7%

If internal air can't get to the underside of the membrane, the additive component of internal pressurization is reduced to a large extent. To that end, in 2024, a compilation of NRC's research titled, "Three Decades of R&D Advancement in Roofing," was presented at the IIBEC Annual Trade Show and Convention in Phoenix in March 2024. The paper describes testing that was performed on a typical mechanically attached single-ply roofing system and the increased wind resistance capacity when an air barrier is installed at the deck level below the insulation. The paper states "...wind uplift resistance increased by 25% to 50% for systems with a VB [vapor barrier] than the systems without a VB." Figure 3 shows increases in wind resistance for systems tested by NRC. Importantly, it should be stated that the vapor barrier was installed to also act as an air barrier.

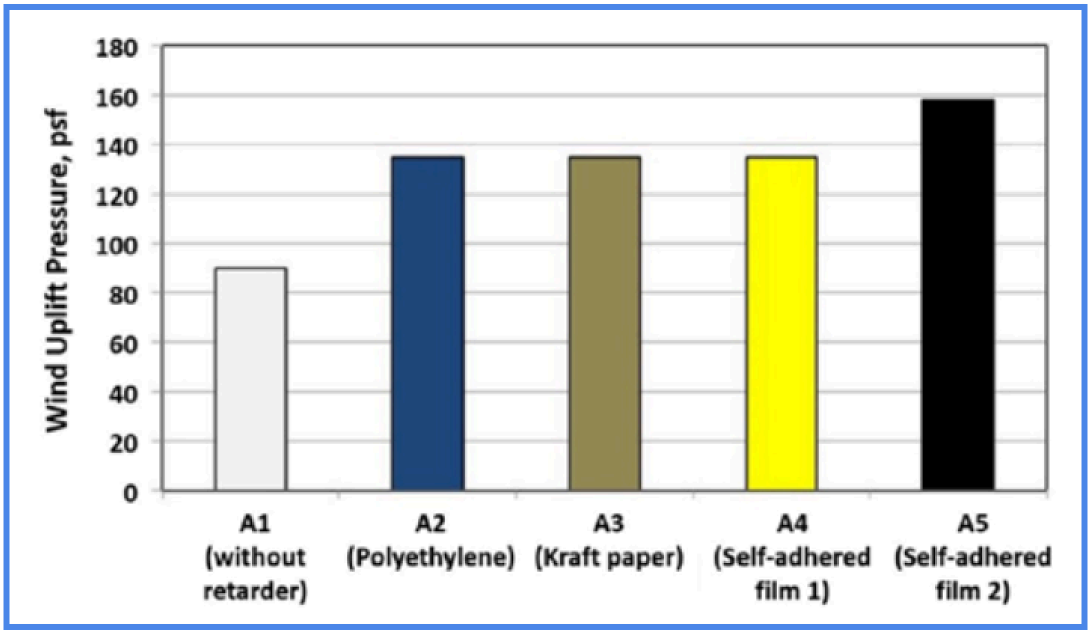

Figure 3: This figure shows the increases in wind resistance when an air barrier is installed above the roof deck. This graphic comes from "3 Decades of Scientific Advancement to the North American Roofing Community," Bas Baskaran, PhD, PEng, F-IIBEC, March 2024, Phoenix. Reproduced with the permission of the National Research Council of Canada, copyright holder.

Specifically, a mechanically attached membrane over 2 inches of insulation over a 22 gauge steel deck without an air barrier achieved a 90 psf uplift rating (A1). When an air barrier was included, the same mechanically attached system achieved a 135 psf uplift resistance with 3 types of air barriers (A2, A3, A4). This is a 50% increase in wind resistance capacity.

Conclusion

Air barriers have always generally been known to assist in reducing the wind loads acting on a roof system by removing the potential for internal pressures to reach the roof system. It turns out that is a correct assumption, and the NRC research provides quantitative data to not only support, but to validate the idea.