Feature

Not All It's Cracked Up to Be? Surface Fracturing of PVC and KEE Membranes

By Kade Gromowski, PE, RBEC, CBECxP

IT WAS 2018 the first time someone handed me a cellphone with a photo on it that baffled her: a PVC/KEE membrane, reportedly still under warranty, with numerous arc-shaped fractures around an underlying cover board fastener plate. As a consultant who practices in "hail country," the author is no stranger to seeing hail impacts to a PVC/KEE membrane, and it is well known that membranes can be fractured by hail at fastener plates. However, the arc-shaped fractures ringing the cover board fastener plate were subtly different from any hail damage I'd ever seen before.

Since then, I've now observed this surface fracturing phenomenon on numerous other PVC/KEE membrane roofs in Colorado, some as young as approximately two to three years in service. Not only has such fracturing kept popping up, it's something I've now seen at additional membrane locations on a given roof, including at stripping plies over edge metals, back sides of seams, corner bends of membranes, edges of underlying insulation, and areas where fully adhered membranes were creased during "butterfly" installation of the membrane. On every roof where this author has seen it, it has led to consternation. Is it hail damage, and if so, why does it not look like hail damage? Or is it due to something other than hail? For example, is there possibly something wrong with the membranes themselves?

PVC/KEE HAIL EVALUATION

Hail damage to a thermoplastic membrane is generally considered any fracture which compromises either the performance (watertightness) or service life of a membrane and is consistent with hail impacts in size, distribution, and characteristics. When hail impacts a thermoplastic membrane, it causes the back of the membrane to stretch. If a hailstone has sufficient energy, this stretching of the membrane can cause the underside of the membrane to tear or fracture. Often times, if the underside of the membrane is fractured, the top of the membrane will exhibit a corresponding fracture which is visible to individuals assessing the roof.

In general, it is widely accepted in the industry that hail fractures to thermoplastic membranes are most commonly spiral-shaped fractures, star-shaped or "crow's foot"-shaped fractures originating from a central point, or concentric circular fractures (**Fig. 1**). These fractures can allow water to infiltrate past the membrane due to their penetration through the membrane, which can lead to substrate deterioration or interior leaks. They also can allow water into the membrane's reinforcing scrim, which may shorten the service life of the membrane.

Due to the nature of the way hail impacts damage thermoplastic membranes, areas of unsupported membranes on roofs and membrane installed over fastener plates tend to be especially susceptible to hail impact damage. Unsupported membrane can stretch more readily, and therefore will often fracture more easily. In contrast, fastener plates directly under the membrane provide a "pinch point", where the hail impact may pinch the membrane

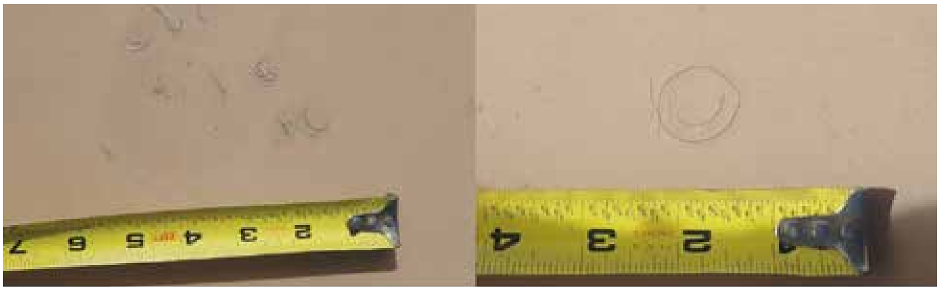

Figure 1. *Typical hail fracture shapes on a PVC/KEE membrane.*

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between the stone and the plate and cause membrane damage.

When there is a question if a thermoplastic membrane has been damaged by a hail impact, it is most common to perform test cuts of the membrane to review the bottom surface of the membrane. Fractures visible on the back side of the membrane that resemble hail impacts are most commonly determined to be hail related.

CASE HISTORY 1: THE DIFFICULTY WITH FASTENERS

This case history consists of two buildings located in the Colorado Springs area which were assessed by the author in May of 2022. Both buildings had a tan-colored PVC/KEE membrane manufactured by Manufacturer X. At Building A, the membrane was manufactured in 2009 and induction welded to the fasteners for the underlying substrate, and at Building B the membrane was manufactured in 2010 and mechanically fastened. Both roofs had a gypsum coverboard immediately beneath the roof membrane. The collateral evidence of the hail event on site included "spatter" marks (removal of oxidation) on the membrane surface and denting of on-site metals, both of which were consistent with approximately ¾-inch to 1-inch diameter hailstones.

On both buildings, arc-shaped fracturing was observed around the perimeters of the fastener plates for the coverboard and membrane fasteners (**Fig. 2**). The prevalence of these arc-shaped fractures at each fastener varied, but many of the fractures interrupted one another and did not correspond to the spatter marks on the membrane. They were therefore not consistent with hail impacts. At isolated unsupported areas of membrane on the roofs, fracture shapes consistent with hail impacts which coincided with spatter marks were observed.

Several test cuts were performed on the roofs to evaluate the observed fracturing. In general, it was found that the arc-shaped fractures around the fasteners did not extend to the bottom of the membrane (**Fig. 3**). No fractures or damage to the underlying substrate materials or their facers were observed.

There were a very limited number fasteners where a "pinch-type" fracture was suspected, due to more circular fractures visible on the membrane surface which corresponded to spatter marks on the roof surface. Test cuts at these locations showed that the "pinch-type" fractures were visible on the underside of the membrane, and therefore consistent with hail impacts, but that arc-shaped fractures on the same fastener did not extend through the membrane thickness (**Fig. 4**).

Figure 2. *Arc-shaped fractures that interrupt each other at a fastener plate.*

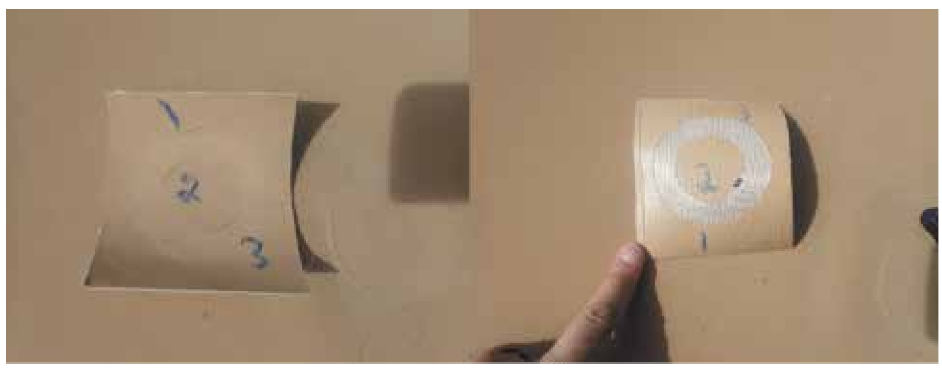

Figure 3. *Test cut at fastener plate; note fractures not present on membrane underside.*

Figure 4. *Pinch-type/"anvil strike" hail fracture on a membrane test cut, marked "3," visible on both top and bottom surfaces of membrane. Note that while the surface fracture marked "1" on the membrane is visible as an indentation on the bottom of the membrane, no actual separation of the membrane's underside was present at this location.*

It was ultimately recommended that the roofs be evaluated by Manufacturer X for warranty purposes, and if no warranty loss was identified, that they receive a waterproof coating. The coating was recommended in lieu of patching, as it was unlikely that the pinch-type hail fractures could be reliably differentiated from the arc-shaped fractures without performing test cuts. The most likely cause of the widespread arc-shaped fractures was determined to be weathering, stress-related, thermal-related, or a combination of these factors.

CASE HISTORY 2: IT ALL FALLS APART

The author was requested to evaluate eleven buildings located in the same city in eastern Colorado in March of 2024, with many of the buildings consisting of numerous roof areas having membranes of different ages. The membranes evaluated were all white-colored PVC/KEE membranes manufactured by Manufacturer Y and ranged in likely manufacturing date from 2008 to 2020. The membranes were fully adhered to the underlying substrate, and the substrate was most commonly a gypsum coverboard. At some roofs, the gypsum coverboard was fully adhered, whereas at other roofs the gypsum coverboard was mechanically fastened. The collateral evidence of the hail event on site included denting of on-site metals which was consistent with approximately ¾-inch diameter hailstones.

On all roof areas evaluated, including the membranes manufactured in 2019 and installed in 2020, very small diameter arc-shaped fractures were observed at the overlapping membrane of the seams throughout the roofs. These arc-shaped fractures coincided with the edge of the underlying membrane below, and commonly interrupted one another (**Fig. 5**). Similar fractures were observed at the edge metal stripping plies, above the underlying edge of the metal flashing (see Figure 5). In addition to the fracturing at the edges of seams and metals, arc-shaped fractures were observed at every coverboard fastener plate immediately below the membrane, and in the corner bends of the roof-to-wall transition (see Figure 5). In general, these arc-shaped fractures were most prevalent on roof membranes ranging in likely manufacturing age from 2008 to 2011, and directional conditions such as the roof-to-wall corner conditions were more prevalent on south-facing and west-facing surfaces. Test cuts at these fractures throughout the buildings assessed did not show any of these fractures extending to the membrane underside.

The wrinkle in this assessment came when numerous, widespread, consistently shaped fractures were observed on some roof areas with membranes whose manufacturing likely predated 2011. These circular-shaped fractures were generally 1/2-inch or less in diameter, and were consistent in distribution with hail impacts. However, test cuts at these fractures did not show fractures at the back sides of the membrane for these fractures, even when these fractures coincided with relatively vulnerable unsupported membrane areas (**Fig.6**). In addition, none of the fractures coincided with damage to the substrates or facer materials. So were they hail-related, or not?

It was recommended that the roofs be evaluated by Manufacturer Y for warranty purposes throughout the roofs, which this author understands to be ongoing at the time of the submission of this article. If no warranty loss is identified, this author has recommended that roofs exhibiting the widespread, circular fractures in the field of the roof receive a coating in response to these fractures, as hail cannot be ruled out as a cause for these fractures due to their distribution. However, it's unclear at this time if these fractures are hail related. If these fractures are truly hail-related, this assessment raises lingering questions: How could a membrane that is less than 15 years old be fractured by such small hailstones, why did those fractures not appear on the back of the membrane, and what, if anything, are the long-term implications for these fractures for the performance and service life of these membranes if they are not repaired?

Similar to the first case history, the arc-shaped fractures at seams, edge metals, corner bends, and fastener plates which were so prevalent throughout these roofs were not consistent with hail impacts, but were likely related to weathering, membrane stresses, thermal factors, or a combination of these causes.

WHAT IS A CONSULTANT TO DO?

The arc-shaped surface fracturing documented in these selected case histories, and on numerous other similar roofs besides, vastly complicates the assessment and maintenance of these roof membranes. This is particularly compounded by the fact that this author has also observed PVC/KEE membranes of similar ages from other manufacturers which do not exhibit this surface fracturing or potential susceptibility to relatively small diameter hail impacts.

At this time, this author has been unable to locate any industry resources that discuss the cause(s) of these arc-shaped surface fractures which are not consistent with hail impacts, although an age-related, stress-related, and/or thermal-related cause seem most likely given the

Figure 5. *Typical arc-shaped fractures at back of a seam (upper left), back of an edge metal flashing (upper right), a cover board fastener plate (lower left), and roof-to-wall corner bend (lower right).*

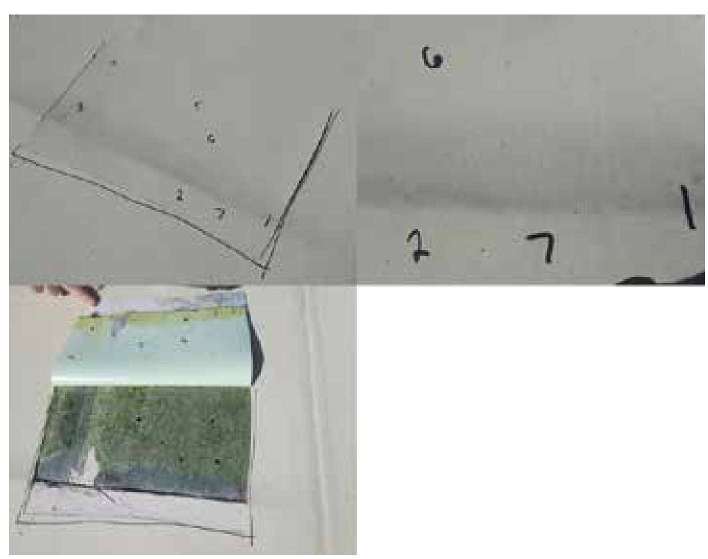

Figure 6. *Test cut at an unsupported membrane exhibiting small-diameter circular surface fractures, upper left. Close-up of surface fractures, upper right. No fracturing to cover board or back of membrane, lower left.*

locations where these fractures appear on roofs and that they appear to become more prevalent as membranes age. However, it's possible that there are causes resulting from the membrane formulations or manufacturing processes themselves, given that they have been observed on membranes as young as two to three years into their service lives. It begs the question: Are our membrane or testing standards too lenient? And if not, then why are some of our PVC/KEE membranes fracturing when they should still be within their anticipated service life?

In addition, it's unclear what, if anything, needs to be done about these arc-shaped surface fractures on a membrane that remains otherwise within its anticipated service life. These arc-shaped surface fractures don't generally extend through the membrane's full thickness, and they therefore typically do not allow water infiltration. In addition, most PVC/KEE membranes have "sealed scrims", and therefore often do not require cut edge sealants more commonly required on their TPO counterparts. So will widespread, arc-shaped fractures of the membrane surface to the membrane reinforcing scrim allow for potential long-term deterioration of the membrane, or not?

This author anticipates that additional research into these questions will be needed, and that it may be some time before the industry gets these answers.

REFERENCE

1. Haag Engineering Co. 2018. *Single-Ply Roofs Damage Assessment Field Guide*. Flower Mound: Haag Engineering Co.

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Special interest

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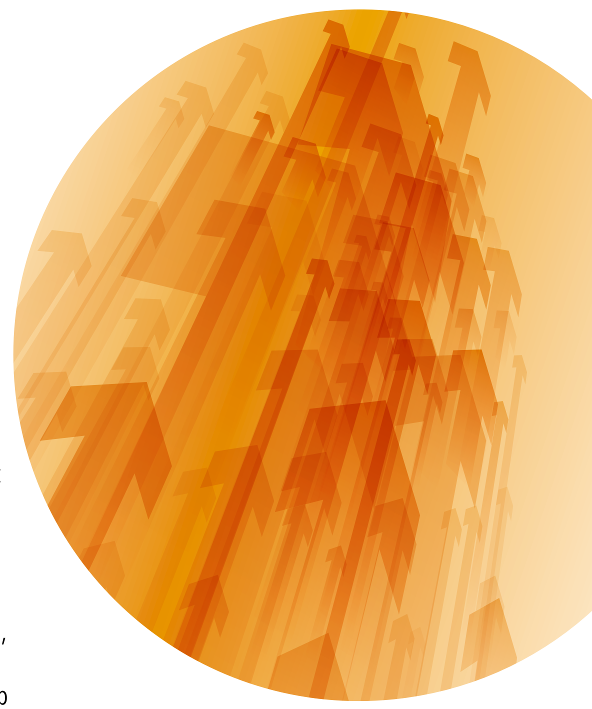

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IT'S NO SECRET that the climate is having an effect on the built environment.

Patrick Sisson at Bloomberg recounted how Glasgow's Science Centre opened with great fanfare in 2001, attracting people to its IMAX theater and exhibits on new technology. By 2018, the facility needed a new roof because its sealant, designed for cooler temperatures, had turned to black goo on a June day that reached 90 degrees Fahrenheit.

"The Science Centre's meltdown offered a particularly graphic illustration of the usually invisible toll that climate change can exact on buildings," Sisson wrote. "It's not just the brute impact of wind, flood, and hail; there's also the insidious, slow-motion damage triggered by weather that no longer matches the conditions for which the built environment was built.

"Longer, more severe heat waves degrade roofs and strain air conditioning and HVAC systems," Sisson continued. "Wild temperature swings bring thermal cycling that expands and contracts concrete and masonry walls, hastening cracks and water intrusion. Asphalt shingles, the most common covering on residential homes in the US, warp under unrelenting sun, while pavement buckles, steel rails kink, and siding suffers 'solar distortion.' Foundations can shift in drought or high temperatures, leading to cracked walls, burst pipes, and serious structural problems."

The costs are increasing. Real-estate analysis firm Trepp said repair and maintenance costs were up 30% last year in such major US markets as Dallas, San Francisco, San Diego, and Houston, while an Atlas Real Estate study showed the average repair cost in rental property shooting up from $290 per incident in 2018 to $501 in 2024.

"I'm paying more for the equipment, replacing it more often, paying more for water and energy, and I'm seeing decreased resiliency," said Christian Whitaker, global head of sustainable operations for international brokerage JLL. "Every time you have an outage event, it costs buildings money. And letting a building go into an unconditioned state in a heat wave means even more damage."

Jose Ramirez at real estate brokerage and services firm Savills zeroed in on the impact of climate change on roofs. "Think about roofs, which tend to get hotter than the surrounding air temperatures," he said. "Twenty or 30 years ago, they were built to withstand temperatures of 110 to 120 degrees. Now they're hitting 140 to 150 degrees. Imagine what that does for the lifetime of the roofs."