In the recently published Nuralite Flat Roof Design Guide V2, on page 51, we wrote:

> *"Some PVC/KEE membranes are installed in New Zealand in dark colours and as thin as 1.1mm. This makes the membrane especially vulnerable to heat stress, punctures, or UV damage. With less than 0.4mm covering the reinforcing, it will not take much plasticiser migration for an issue to arise.*
>
> *Experience suggests that the thicker the membrane the better and, with plastic membranes, the lighter the colour the better."*

Nuralite stands by this statement. For clarity, we would add that it applies to all thermoplastic membranes such as TPO, TPE, PVC or KEE. This discussion document has been written because the statement above has been queried so we see a need for further explanation. This technical document will educate the reader so they can make an informed decision in future.

A thermoplastic roofing membrane is made up of a reinforcing scrim encased on both sides by a substance such as TPO (Thermoplastic Polyolefin), TPE (Thermoplastic Polyolefin Elastomer), PVC (Polyvinyl Chloride) or KEE (PVC modified by Ketone Ethylene Ester).

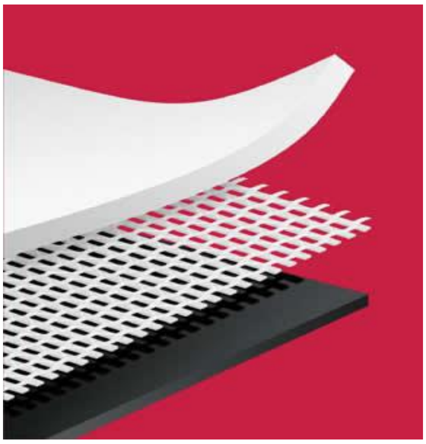

Figure 1. Thermoplastic sheet buildup (exploded view)

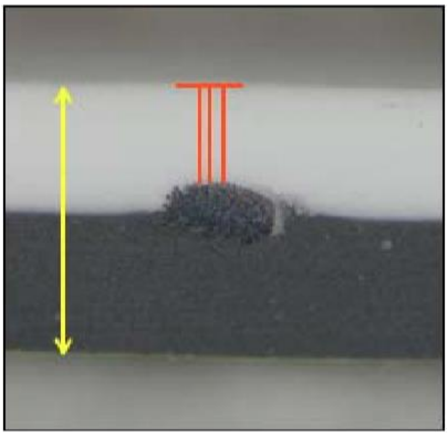

Figure 2. Difference between total thickness (yellow arrow) and thickness above scrim (orange lines)

In essence, the scrim provides the membrane with its skeleton while the substance is the flesh.

In comparison to other single layer membranes, the common feature of thermoplastic membranes is that sheets are hot-air welded together (rather than glued) to provide a permanent seal.

The potential risk with thin[1] thermoplastic membranes:

In his paper discussing what is meant by puncture resistance and comparing the performance of various types of weldable single-ply membranes, Building and Roofing Science Advisor for GAF Tom Taylor PhD importantly concludes that;

> *Low-speed, hand-held demonstrations purporting to show high puncture resistance can be misleading. A membrane that appears to perform well in a marketing test may perform poorly in an approved test method using high-speed impact."[2]*

Further to his extensive research and testing, Taylor also surmises that;

> *"…thinner sheets can be more easily punctured by falling sharp objects regardless of the reinforcement fabric…"[3].*

Our experience and long-term in-service history supports these conclusions also. More substance above the scrim provides body to the membrane. While using a membrane with more thickness above the scrim may cost more, it will mitigate future potential problems as thicker membranes offer greater protection not only against damage but also weathering and solar radiation.

The following images provide evidence of failures illustrating what happens if a membrane has poor puncture resistance on site.

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[1] Thin in this context is defined as less than 1.5mm or less than 0.7mm thickness above scrim.
[2] Puncture Resistance of Thermoplastic Single-Ply Roofing Membranes, Bhalwalkar & Thomas, January 2015
[3] PVC vs. KEE: What are the Pros and Cons? - GAF Blog , July 2015

Figure 3. Seven patches in this area – Material 1.1mm, Age approx. 3 years.

Figure 4. At least 12 patches in this area - Material 1.1mm, Age approx. 3 years.

Figure 5. Three patches (of 6 on the roof). Material 1.2mm, age 2 years

Low puncture resistance provides a risk for maintenance traffic especially. If the membrane is easy to damage, although a penetration can be patched, damage may have occurred to the building during the time before the hole is identified and repaired. The biggest challenge is that any entrapped moisture will potentially create issues in future in the form of blisters.

Recommendation

Nuralite recommends the top ply of the membrane to be a minimum of 0.7mm thickness above the scrim for superior durability.

The potential risk with dark thermoplastic membranes

In early 2010, the Midwest Roofing Contractors Association's ("MRCA") Technical and Research Committee published an advisory paper on TPO. They noted that:

> *"…information is being circulated in the industry indicating that high solar loading and elevated temperature lead to the premature exhaustion of anti-aging components such as antioxidants, UV absorbers and heat and light stabilizing compounds within TPO. This could lead to the breakdown of the sheet in affected areas."*[4]

It was noted that:

> *"…higher heat loads occur in situations such as reflections from nearby wall surfaces, HVAC units and neighbouring taller buildings."*[5]

While the MRCA research was focussed on TPO, we believe the findings are cautionary for all types of thermoplastic membranes.

Nuralite contends that the membrane colour is a key contributor to high solar loading as the temperature difference between a light and dark membrane is significant.

To illustrate the impact of colour on thermoplastic membranes, Nuralite conducted a simple experiment. Five samples of different coloured membrane were left outside in direct sunlight on a fine Auckland day from 9.30am to 2.30pm. Each hour the membrane temperature was measured.

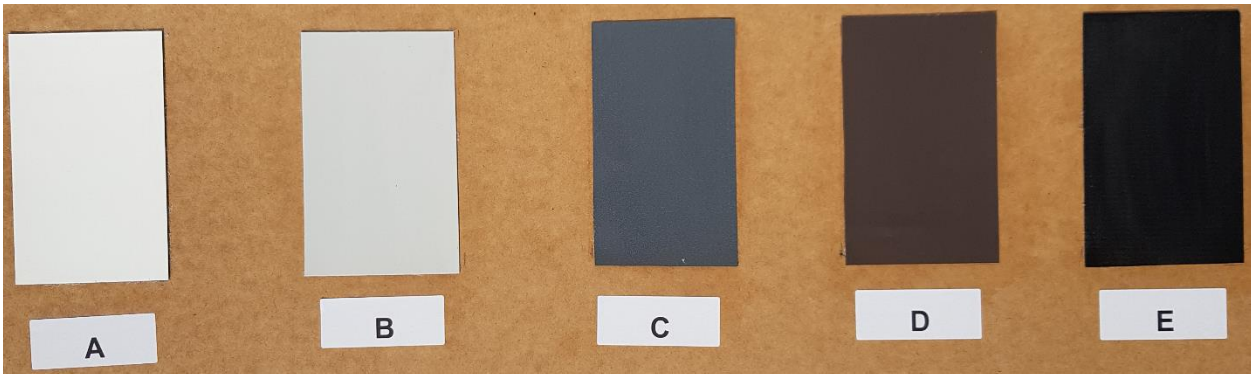
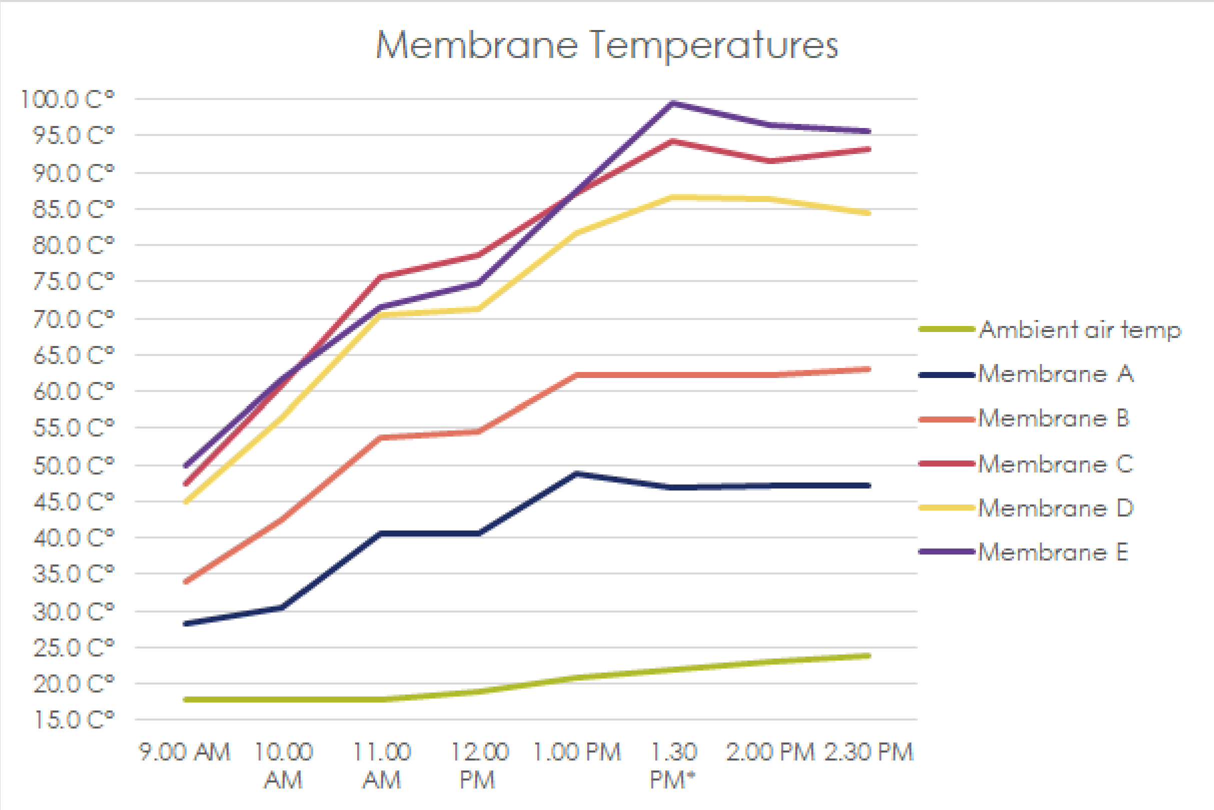


Figure 6. Membranes on test panel

[4] T.J.Taylor and L. Xing, "TPO Membranes, UV and Heat Aging. What are the latest findings?," MRCA 61st Annual National Conference, Indianapolis, October 28 - 29, 2010 cited in CEU: Evaluating Real-World Performance of Field Aged TPO Roofs

[5] CEU: Evaluating Real-World Performance of Field Aged TPO Roofs

SinglePly heat test		12/03/2021	Nuralite, 60D Leon Leicester Avenue, Auckland				
Time	Ambient air temp	Membrane A	Membrane B	Membrane C	Membrane D	Membrane E	Notes
9.00 AM	18.0 C°	28.2 C°	34.1 C°	47.6 C°	45.0 C°	49.8 C°	
10.00 AM	18.0 C°	30.6 C°	42.4 C°	60.8 C°	56.4 C°	61.8 C°	
11.00 AM	18.0 C°	40.6 C°	53.7 C°	75.7 C°	70.6 C°	71.5 C°	
12.00 PM	19.0 C°	40.6 C°	54.7 C°	78.6 C°	71.3 C°	74.8 C°	
1.00 PM	21.0 C°	48.8 C°	62.2 C°	87.3 C°	81.8 C°	87.5 C°	
1.30 PM*	22.0 C°	46.8 C°	62.3 C°	94.2 C°	86.7 C°	99.6 C°	*solar noon
2.00 PM	23.0 C°	47.1 C°	62.2 C°	91.6 C°	86.4 C°	96.6 C°	
2.30 PM	24.0 C°	47.3 C°	63.1 C°	93.1 C°	84.4 C°	95.7 C°	



The 3 darker colours grew significantly (50%) warmer than the white or light grey membranes.

With an increased temperature we can expect:

- greater expansion and contraction causing the substrate adhesion to be stressed,
- softening of the membrane, which will make damage or penetration easier,
- premature exhaustion of anti-aging components such as antioxidants, UV absorbers and heat and light stabilising compounds, and ultimately
- breakdown of the sheet.

The following photos evidence this concerning issue - a dark membrane by an upstand with the coating over the scrim being negligible. These photos are of New Zealand roofs that are less than 5 years old. The materials had all been used successfully overseas, however they have not performed in these situations in the New Zealand climate.

Figure 7. Membrane in sole of gutter appears deteriorated compared to upstand. Material 1.1mm, Age approx. 3 years.

Figure 8. Membrane blistering from heat from upstand reflection. Material 1.2mm, Age approx. 4 years

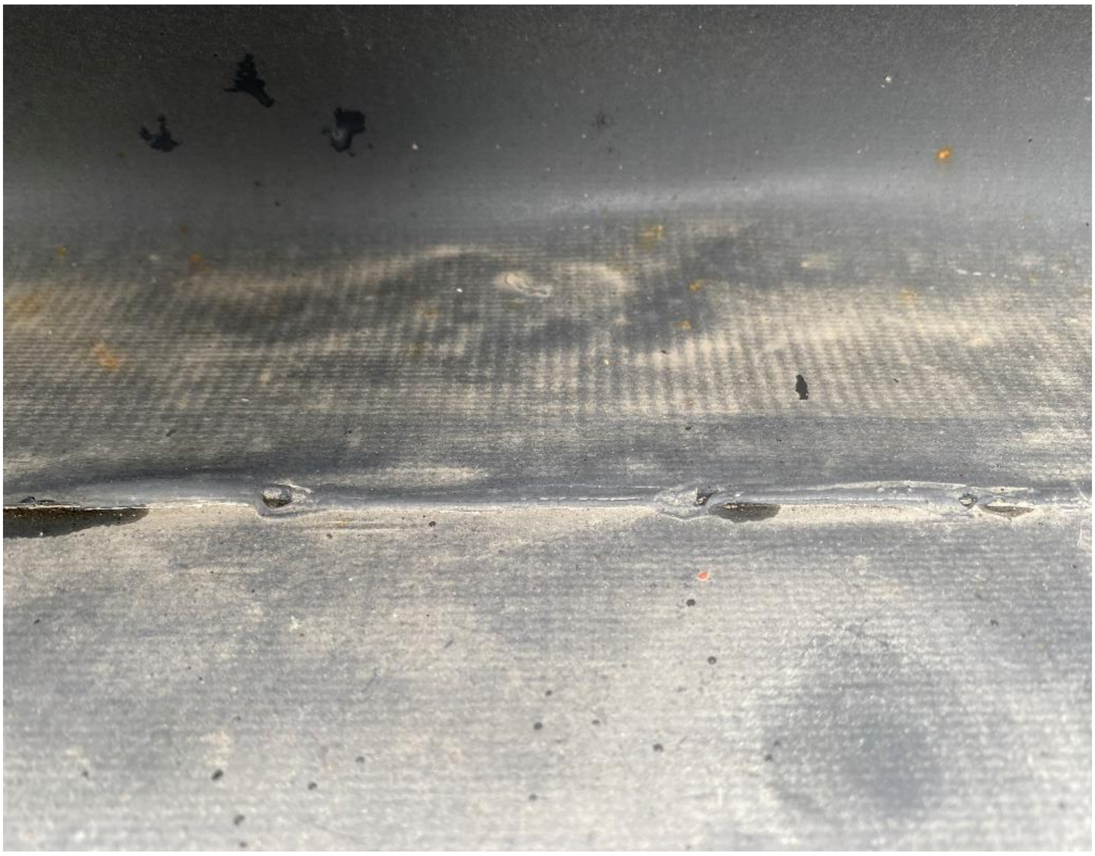


Figure 9. Closeup of membrane in sole of gutter, Material 1.1mm, Age approx. 3 years.

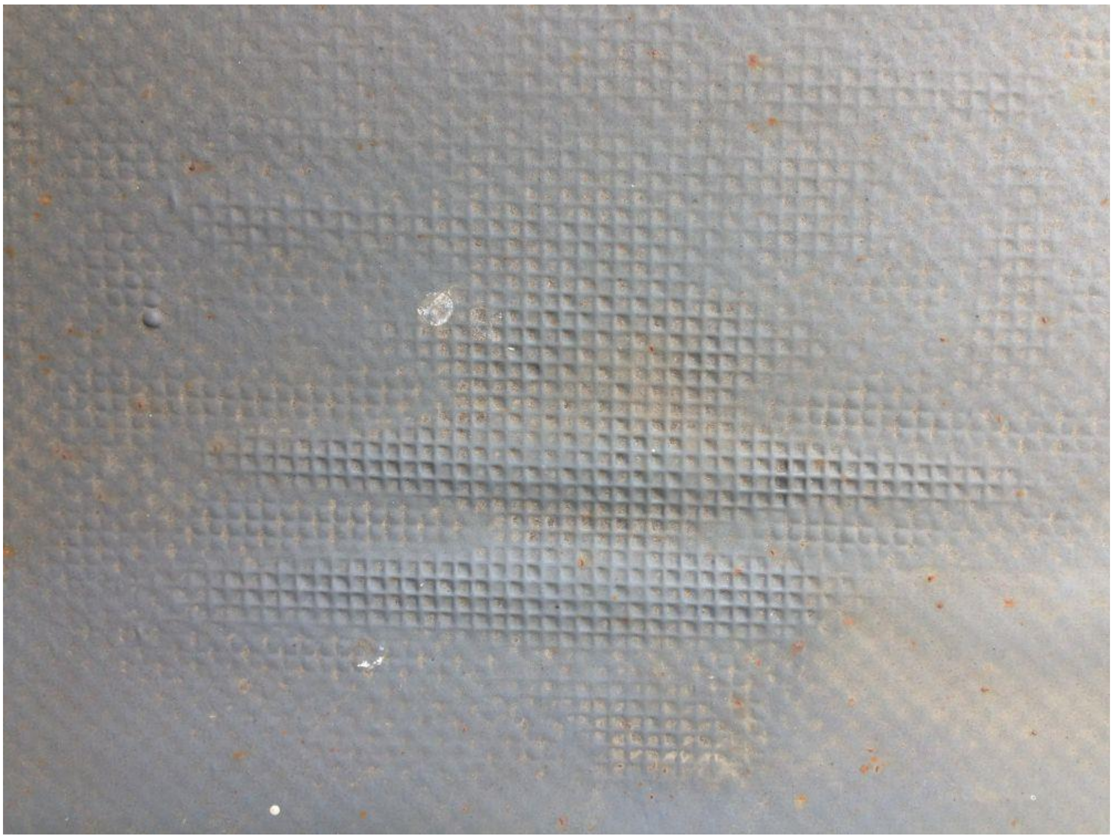


Figure 10. Close up, Material 1.2mm, Age approx. 4 years.

Once there is no material above the reinforcing scrim it would be considered that the product has failed and is no longer watertight.

An additional note is that Figures 5 & 7 show the membrane debonding from the substrate. While poor installation may also be a contributor, this can also be caused as a result of the membrane putting a high load on the adhesive due to thermal movement.

Recommendation

Nuralite recommends that thermoplastic membranes should be installed using light colours such as white or light grey to increase longevity of performance.

Conclusion

Nuralite Waterproofing has over 55 years' experience as suppliers in the membrane industry.

During this time we have learnt a lot about the technical capabilities of different membrane types, with robustness and durability being the key attributes a client needs to create buildings that provide long term, superior performance.

We maintain that the thicker the membrane, the better and, with plastic membranes, the lighter the colour the better. This view is supported by the international technical research referenced in this document as well as the photographic evidence from New Zealand projects.

Final Recommendation

All projects using a thin, dark thermoplastic membrane should be inspected to confirm they are performing as expected. Remedial action should be taken to address any issues. Steps should be taken to ensure the warranty conditions are met and remain current (i.e. annual maintenance inspections should be documented).

References

The source information/references for these statements are:

- http://blog.gaf.com/pvc-vs-kee-what-are-the-pros-and-cons/
- http://iibec.org/wp-content/uploads/2015-01-bhawalkar-taylor.pdf

from Thomas J Taylor, PhD, who is the Building & Roofing Science Advisor for GAF, and

- https://www.buildingenclosureonline.com/articles/89233-ceu-evaluating-real-world-performance-of-field-aged-tpo-roofs