



TITLE: TPO Single-Ply Roof Systems: Performance and Service Life

DESIGNATION: IIBEC-TA-012-2016

OBJECTIVE: To present a general overview of information regarding the performance of thermoplastic polyolefin (TPO) single-ply membranes, to summarize general information related to the evolution of TPO single-ply roof membranes, and to provide general information to assist individuals with reviewing in-place existing conditions of TPO roof membranes.

A. BACKGROUND

A.1 ASTM SPECIFIED PROPERTIES

Thermoplastic polyolefin (TPO) single-ply membranes have been used in Europe since the 1980s and emerged in the U.S. market in the early 1990s. The first ASTM standard for TPO single-ply membrane was published in 2003 as ASTM D6878, *Standard Specification for Thermoplastic Polyolefin Based Sheet Roofing*. This specification covers flexible sheet made from thermoplastic polyolefin as the principal polymer, intended for use in single-ply roofing membranes exposed to the weather. The sheet shall contain reinforcing fabrics or scrims. The sheet shall be formulated from ethylene and higher alpha-olefin polymers, copolymers, and mixtures thereof, in amounts greater than 50%, by weight of the total polymer content suitably compounded to satisfy the physical requirements specified. The sheet shall be capable of being heat-welded, fused, or adhesively bonded to itself for making watertight field splices and repairs. Different tests shall be performed in order to determine the following physical properties of thermoplastic polyolefin sheets:

- Nominal Overall Thickness of Sheet (+15%, -10% tolerance)
- Coating Thickness Over Scrim
- Breaking Strength
- Elongation at Break
- Tearing Strength
- Brittleness Point
- Factory Seam Strength
- Weather Resistance (Xenon Arc Weatherometer – Black Panel 176°F [80°C])
- Properties After Heat Aging (Oven Temp 240°F [116°C] for 224 days)
- Ozone Resistance
- Linear Dimensional Change
- Water Absorption

At the time of issue of this Technical Advisory, the standard is published as ASTM D6878-13.

DISCLAIMER

This Technical Advisory is intended to serve only as a general resource and to identify potential issues for consideration by industry professionals. Each person using this Technical Advisory is solely responsible for the evaluation of the Technical Advisory in light of the unique circumstances of any particular situation, must independently determine the applicability of such information, and assumes all risks in connection with the use of such information. The materials contained in this Technical Advisory do not supersede any code, rule, regulation, or legislation and are not intended to represent the standard of care in any jurisdiction.

A.2 PERFORMANCE (ASTM) CHANGES

- The initial ASTM standard specified a minimum xenon arc (ultraviolet or UV) exposure of 5040 kJ/(m² • nm) at 176°F (80°C) without surface crazing/cracking as viewed at 7X magnification. Changes were made in 2006 that doubled the weathering requirement, which increased the exposure for TPO membranes from 5040 kJ/(m² • nm) to 10,080 kJ/(m² • nm). This UV exposure limit remains in the current standard. Along with that for black EPDM membranes, this exposure limit is the highest required by ASTM for all single-ply roof systems available at this time.
- In 2008, a clarification was made on the Water Absorption Test Method.
- In 2011, the duration for the Heat Aging test was increased from 670 hours (28 days) to 5376 hours (i.e., 224 days or 32 weeks). So an 800% increase in heat aging was implemented for TPO membranes of all thicknesses by withstanding 240°F (116°C) for 32 weeks without significant changes to the physical properties of the membrane. The minimum thickness of the top coating above the scrim for 45-mil-thick membranes was increased 25% from 12 mils to 15 mils in the 2011 standard.
- In 2013, the requirement for minimum thickness of top coating above scrim was again refined. The 2013 requirement states that the thickness over scrim on the weathering side shall be at least 30% of the overall thickness of the sheet, but in no case shall it be less than the minimum requirement of 15 mils. Consistent with this requirement, 45-mil-thick membrane sheets retain a minimum top coating thickness of 15 mils, whereas 60-mil-thick sheets need a minimum top coating thickness of 18 mils.
- The ASTM standard specifications for the commonly available, flexible, single-ply membrane materials (that is, TPO, EPDM, KEE, and PVC), contain rigorous requirements for subjecting test samples to xenon-arc (UV) exposure in a laboratory apparatus. The limiting material property values specified in the standards characterize the products to ensure that they possess the minimum quality for their intended purpose of functioning as a roofing membrane. The following provides key aspects of the xenon-arc exposures for these four single-ply membrane materials, as given in the respective ASTM standards:
 - TPO (ASTM D6878-13): Expose specimens to 10,080 kJ (total radiant energy of the exposure) at a wavelength of 340 nm at a black panel temperature of 176°F (80°C). The irradiance is 0.35 to 0.70 W/(m² • nm) at 340 nm.
 - EPDM (ASTM D4637-16): Expose black specimens to 10,080 kJ at a wavelength of 340 nm at a black panel temperature of 176°F (80°C). The irradiance is 0.35 to 0.70 W/(m² • nm) at 340 nm.
 - PVC (ASTM D4434-12): Expose specimens for 5000 hours at a wavelength of 340 nm at a black panel temperature of 145°F (63°C). The irradiance is set at 0.35 W/(m² • nm) at 340 nm. This exposure provides energy of 6300 kJ.
 - KEE (ASTM D6754-15): Expose specimens for 5000 hours at a wavelength of 340 nm at a black panel temperature of 145°F (63°C). The irradiance is set at 0.35 W/(m² • nm) at 340 nm. This exposure provides energy of 6300 kJ.

A.3 HISTORICAL INDUSTRY INFORMATION

- Western States Roofing Contractors Association (WSRCA) TPO Weathering Farm Study, initiated in 2000. Sixteen TPO roof membranes from four manufacturers were installed on subject buildings located in San Antonio, Texas; Las Vegas, Nevada; Anchorage, Alaska; and Seattle, Washington.

The TPO membranes from each manufacturer were installed on each of the subject buildings. A seven-year update was published in 2010 and a ten-year report was published in 2011.¹ This study generally concluded that 15 of the 16 TPO membranes performed satisfactorily and weathered well installed in various geographic climates. The only unexpected weathering effect observed consisted of micro-cracking and splits occurring at creases in one of the membranes.

- Midwest Roofing Contractors Association (MRCA) Technical Research Advisory.² This advisory indicated a possible concern with TPO membranes exposed to concentrated loads of elevated heat such as adjacent to reflective surfaces (i.e., glass curtainwalls, metallic equipment, etc.).
- “Evaluation of the Effects of Long-Term UV Exposure on Single-Ply Membranes” by Koontz and Erland.³ The ability of a single-ply membrane to maintain its initial physical properties over an extended period of time can be a predictor of performance. This 1½-year study evaluated the relative performance level of 11 single-ply membranes when subjected to long-term ultraviolet (UV) exposure in the lab. New samples of various single-ply membranes were collected from seven different single-ply manufacturers. The results of the study concluded that on average, the TPO membranes have a greater propensity for retaining physical properties when compared to PVC, KEE, and EV membranes. Substantial variations, however, were observed within the TPO group.
- “Accelerated Aging of Thermoplastic Polyolefin Membranes—Prediction of Actual Performance” by Taylor and Xing.⁴ This study focused on heat exposure of TPO membrane materials because past in-service performance seemingly showed that heat, and not UV, has been responsible for a large portion of the earlier failures observed for these products. The study design included a large sample size representing the broad extent of the TPO industry with samples taken, to the extent possible, from every TPO manufacturing plant. Heat exposure was the primary parameter studied, although some UV testing was carried out. The heat exposure was performed using an air-circulating oven at 275°F (135°C). The specimens were periodically removed from the oven, cooled to ambient temperature, and then weighed and bent over a 3-in. mandrel. Heat resistance was thus determined as weight loss and surface cracking. Among the findings, the authors concluded that large differences existed in the ability of the commercial products tested to resist weathering. They suggested that heat-aging failure should be defined in specifications as a function of weight change or surface cracking, or both.

B. CONDITIONS NOTED

B.1 CONDITIONS

Some of the early generations of TPOs experienced issues with “false” welds at lap seams and long-term field performance that was associated with the fire retardants incorporated into the polymer blend at that time. The occurrences of false welds were presumed more to be attributable to a lack of welding parameters for TPO membranes than for PVC membranes. The issues with the fire retardants were associated with the use of halogenated fire retardants, which have all now been replaced with environmentally friendly nonhalogenated components. However, current-generation TPOs reportedly incorporate enhanced weathering packages and modified fire retardants in the polymer blend, and these modifications have typically resulted in improved performance in the respective laboratory exposure testing. To date, indications also appear to reflect improved in-service performance of the current TPO membranes.

However, there may be certain products and/or applications in existence whose actual in-service performance may still be in question. Certain conditions on existing in-place TPO membranes on a variety of systems, applications, and substrates have been documented that suggest that precaution should be used when reviewing these types of systems and assessing the overall long-term performance of the membrane. There are certain signs or evidence that may indicate that a TPO membrane may be experiencing

premature degradation (as evident from the development of cracks, splits, chalking, checking, etc.). It is possible that upon initial rooftop inspection and from visual appearance, the membrane may appear to be fine, but upon closer visual inspection, characteristics (i.e., very small cracks/splits or pinholes in the top surfacing) may be evident that indicate the membrane is exhibiting initial evidence of deterioration. Further deterioration may manifest within a short time frame, and subsequent and routine inspections should be implemented. A variety of conditions are depicted in photographs, which are attached hereto, to provide information to assist individuals when reviewing these types of roof systems.

The industry appears to have correlated elevated heat (temperatures) to premature aging and some of the problems encountered with TPO membranes. In addition, installation of TPO membranes adjacent to highly reflective vertical surfaces that may result in elevated temperatures should be appropriately evaluated. However, the TPO membranes have exhibited generally good overall performance to UV exposure. It shall also be noted that some of the warranties provided by TPO manufacturers do not include in-place service temperatures in excess of 160°F (71°C).

B.2 MEMBER SURVEY

A basic survey of current Consultant members of IIBEC was performed, and results indicated that most members that responded had experienced some type of issue with TPO roof membranes. Most of the issues were associated with mechanically attached 45-mil-thick membranes compared to thicker membranes and also associated with the earlier generation of TPO membranes of 6+ years of age. The predominant observed problem was reported to be erosion or loss of the top surfacing of the TPO membrane. While this survey asked specific questions regarding personal experiences related to TPO single-ply membranes, it shall be noted that similar responses would also be expected for surveys related to other roof membranes/materials, and that there are TPO membranes that have performed successfully.

B.3 THICKNESS

The ASTM standard for TPO membranes, as similar to the ASTM standards for other single-ply roof membranes, allows a 10% negative variation in the thickness of the manufactured membrane. Consequently, a 45-mil membrane could have an actual overall thickness closer to 40 mils; and theoretically, a 60-mil thick sheet could be only 54-mils thick. The thickness above the scrim is also an important factor, as this is the material that will be subjected to the environmental elements. A review of manufacturers' literature indicates that the thickness of the TPO material above the scrim is typically 24 to 26 mils for 60-mil-thick membranes. This is greater than the minimum 18-mil thickness required for these membranes in ASTM D6878, as mentioned previously. The industry appears to have gravitated to a "consensus" recommendation that "thicker is indeed better," not only for TPO membranes, but also for all single-ply membranes, and that 60-mil and 80-mil-thick membranes are more often being specified and installed in lieu of thinner membrane options. Manufacturers have indicated that in the mid-1990s, 45-mil membranes accounted for two-thirds of all volume; and today, 60-mil membranes account for two-thirds of the volume.

C. RECOMMENDATIONS

- C.1 When performing inspections on TPO single-ply roofs greater than six years of age, special attention or closer visual inspections may be prudent, particularly in the case of membranes that are less than 60-mil thickness, and for areas subjected to excessive heat, water run-offs, and ponding. If evidence of initial signs of deterioration is observed, then more regular and more thorough inspections are recommended.
- C.2 Specifiers/designers should request confirmation that products proposed for use comply with the minimum requirements as outlined in the current ASTM standard, and should comply with the applicable design standards.

- C.3 Installation of TPO single-ply membranes should comply with current industry guidelines and the respective manufacturer's guidelines, with special emphasis on welding temperatures, proper techniques for probing welded lap seams, avoidance of creasing of the membrane, and other similar practices.

D. ATTACHMENTS

Representative photographs of documented TPO conditions are affixed in the appendix. (Note that the photos of the various conditions were recorded on 45-mil-thick membranes located in a hot-weather climate that were installed between 2000 and 2005.)

E. REFERENCES

- ¹ 10th-Year Update Report: TPO Roof Research and Testing Project; Western States Roofing Contractors Association (WSRCA); June 2011.
- ² "Rooftop Hot Spots: TPO and Localized High-Heat Issues," Midwest Roofing Contractors Association (MRCA), technical research advisory article, Martinsons, Jane, Editor, January/February 2011.
- ³ "Evaluation of the Effects of Long-Term UV Exposure on Single-Ply Membranes," Jim D. Koontz, and John Erland, *Interface*, IIBEC, Inc., May/June 2010.
- ⁴ "Accelerated Aging of Thermoplastic Polyolefin Membranes—Prediction of Actual Performance," T.J. Taylor and L. Xing, *Roofing Research and Standards Development: 8th Volume*, ASTM STP 1590, S. Molleti and W.J. Rossiter, Eds., ASTM International, West Conshohocken, PA, 2015, pp.139-152.



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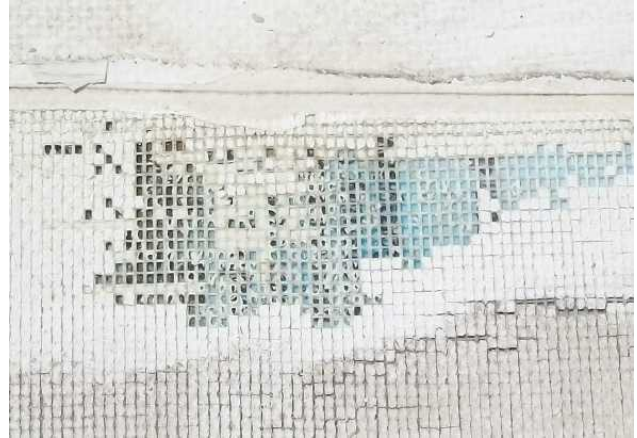
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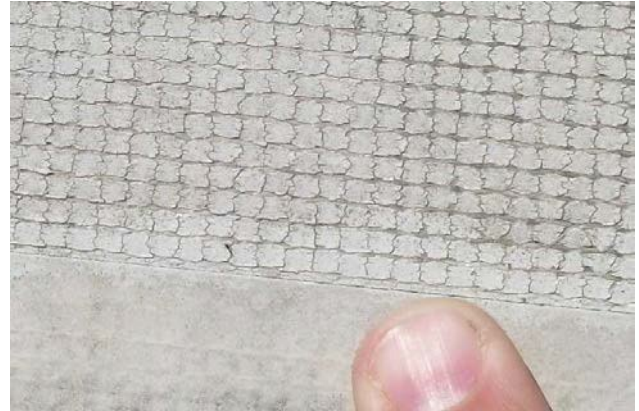


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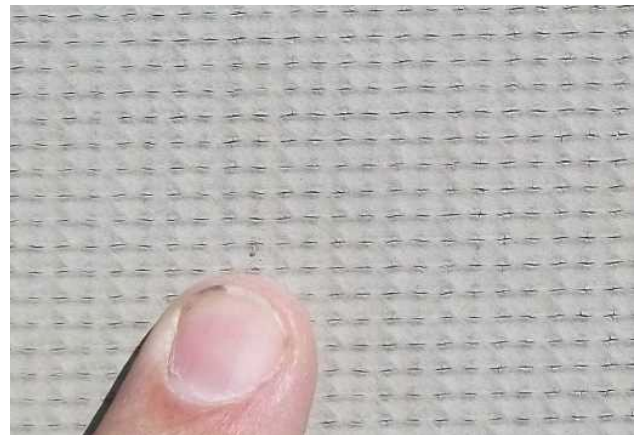
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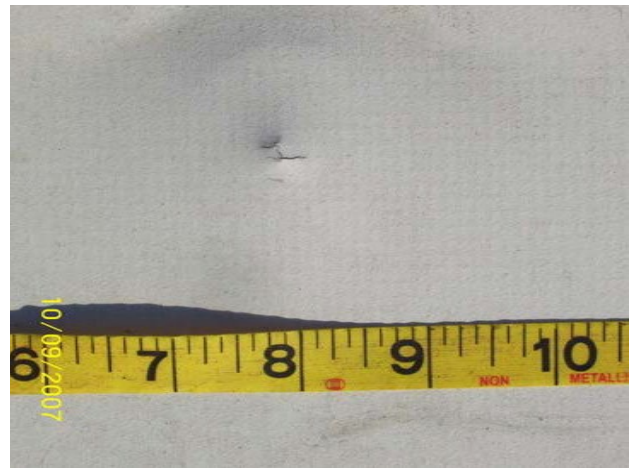
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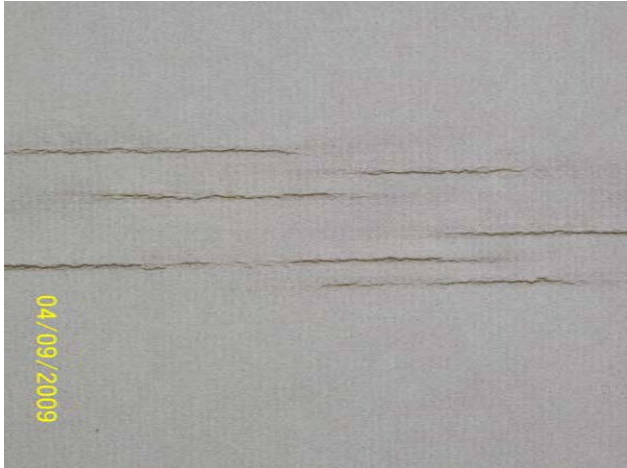


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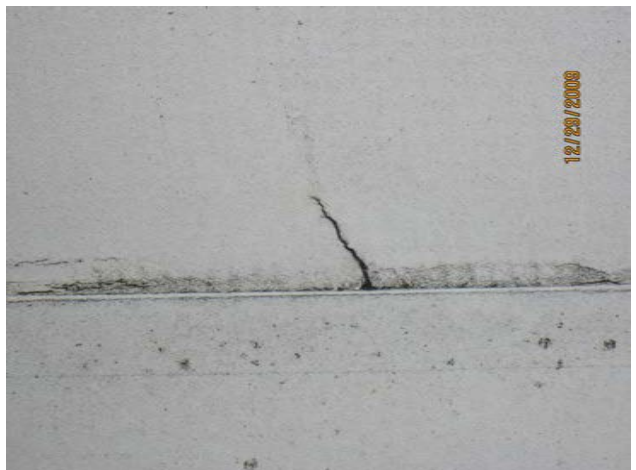
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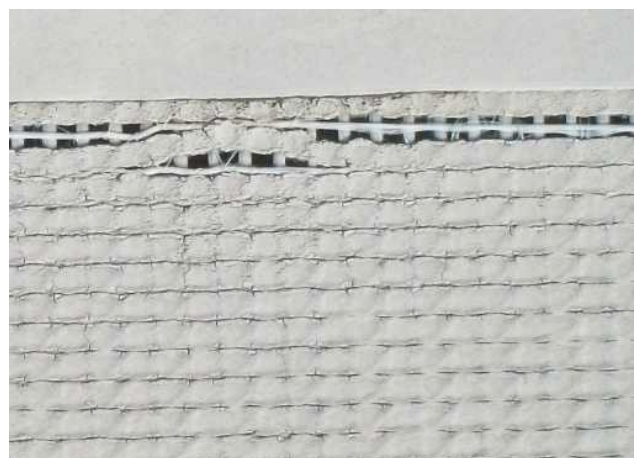
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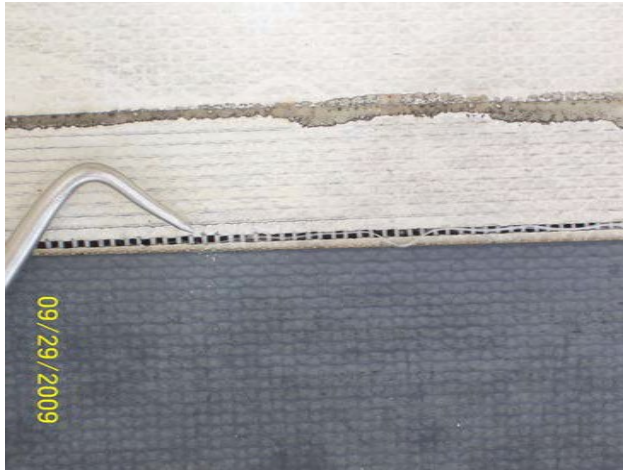


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