TPO Update – 2001

René M. Dupuis, PhD, P.E.
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Thermoplastic roof membranes have been in use on commercial, industrial, institutional and governmental facilities for more than 25 years in the United States. The benefit of a welded lap (either by hot air or chemical) was recognized long ago as the superior feature of a thermoplastic membrane. We learned that unreinforced thermoplastic (such as plain PVC) did not give long-term performance when compared to reinforced PVC. There are a number of coated fabric products in use today that have PVC (or other thermoplastics) as the principal polymer present. They all, in one form or another, have a formulation that works. The first concern was performance; cost took a back seat for several of these products.

Today we have thermoplastic polyolefin (TPO) available, all reinforced. TPOs can demonstrate near EPDM-like resistance to weathering change if formulated and manufactured in a responsible manner. Unfortunately, cost cutting has set in, leaving performance to be assumed. The physical properties of TPO membranes can vary significantly with the type and amount of filler, fire retardants and UV stabilizers. We still do not have any ASTM standard on TPO roof membranes, due in part to the varied formulations that are possible.

TPO membranes have been used successfully below grade for more than 20 years. Early formulations also were used on several test roofs. Lap seaming was tricky back in the late 1970s; we could not keep early TPO roofs watertight, but the product weathered very well. Since these early membranes were black, the solar heat gain caused them to expand and contract with substantial force, causing the lap weld to fatigue and open up.

TPO roof membranes are the most robust thermoplastic material our roofs have ever seen. TPO materials have a high coefficient of expansion; worse yet, when TPO roof membranes contract, a sizable force is generated. The contractive force varies by manufacturer and formulation. For instance, EPDM, when it is brand new, generates a contractive force of 2 to 3 pounds/inch of width. PVC generates 4 to 6 pounds; prior to shattering, unreinforced PVC may generate 30 to 40 pounds/inch of width.

Our current generation of TPO roof membranes generates 10 to18 pounds/inch of width brand new. Thus the term "robust thermoplastic" means, in the author's opinion, a forceful response to temperature change. Does this make them difficult to weld and run out? Maybe. A lot depends on the manufacturer, the machine, the formulation and the color of the TPO membrane. The contractive force cited above occurs over a 100F temperature drop (70F to -30F).

Failure Mechanisms

Thermal and mechanical strain occurs in any mechanically fastened single ply; TPO membranes see more thermal strain than any other because of their high thermal response. TPO membranes can have a micro and macro failure zone. The micro failure zone occurs in the coating at the top of the reinforcement fabric. We already have seen small splits or cracks of this type occur due to several factors, including formulation and coating thickness. This type of failure, while micro in scale, can be troublesome since it can occur in a variety of places, but most often near the lap.

The macro failure zone is going to be adjacent to the lap seam due to repeated thermal and mechanical strain. Here the stress concentration occurs similar to a weld in structural steel. This is the predominant mechanical failure zone we anticipate from this class of membrane. Weathering failure is another matter.

Thickness of Weathering Surface

All reinforced single-ply membranes used in the market today have two minimum thickness properties that are important: minimum overall sheet thickness and minimum coating over the scrim or internal reinforcement. Historically, reinforced EPDM (ASTM D4637-96 Type II) had a 40-mil minimum sheet thickness with a 15-mil minimum coating over the scrim. Reinforced PVC (ASTM D4434-96 Type II) had a 45-mil minimum thickness with a 16-mil minimum coating over the scrim of fabric. Another product in use is Hypalon (ASTM D5019-96 Type I, Grade 2), which has a 40-mil minimum sheet thickness and an 11-mil minimum coating over the scrim.

The draft ASTM standard for TPO (Version #18H) proposes a minimum sheet thickness of 39 mils with a minimum coating over the scrim of 9 mils.

The variation of sheet thickness then ranges from 39 to 45 mils, with TPO the thinnest and PVC on the thick side. EPDM and Hypalon are in between at 40 mils. Minimum coating thickness variations are stark – 9 mils for TPO, 11 mils for Hypalon, 15 mils for EPDM and 16 mils for PVC.

A thicker top coating helps resist scuffing or damage from traffic. Weatherability is enhanced with a thicker top coating. For heat welding, a thicker top surface allows for fast and efficient welding, yielding more contact area of the lap to be welded. Thin top coatings leave a dimpled surface; the lap welds are a series of high points that have good bond, while the low point or valley may have lesser bond. Point-to-point contact is not good, nor does it leave you with any high-pressure resistance to water intrusion. It may be watertight, but it may not be able to take a hydrostatic head of 6 inches of water.

Thin top coatings weather differently than thicker coatings; ultra-violet radiation can do strange things since thinner coatings cannot benefit from heat sink.

Currently, there is a variation of coating thickness over the scrim amongst manufacturers. This variation can be 20 percent or more. If EPDM uses a 15-mil minimum coating over scrim and it is acknowledged to have the best weatherability as a single ply, why does TPO have a 9-mil suggested minimum? That is a good question. Certainly TPOs have to earn their weatherability reputation just as EPDM did; it takes DECADES of use to earn a solid reputation. It is true that the TPO coating is harder than EPDM and probably tougher in abrasion resistance. But can we justify a 50–60 percent reduction in this critical area of membrane design? Probably not, and some TPO manufacturers are making an effort in 2001 to bring this critical element (coating thickness over scrim) up into the 12- to 14-mil range.

Sheet Width

Many of the TPO membranes came onto the market with a 6-foot wide roll product. Now a number of manufacturers are using 8- and 10-foot wide sheets; another offers a 12-foot width. The reason for this, of course, is installation economy. Fewer seams mean faster installation and less labor. Time will tell, but this may be a shortsighted move. Robust thermoplastics are much better off with uniform attachment of more rows of fasteners to absorb and redistribute temperature-related movement. Of course wider sheets make wind-uplift resistance more difficult, as a single row of fasteners has to take up more load and transfer it to the deck.

Wide sheets of TPO are going to put more strain on the laps; fatigue may become an issue when wind and temperature change stresses the lap. We may be reaching the point of no return on wide sheet technology from the roof deck perspective. Older, rusted 22-gauge steel deck may have lost attachment to the bar joist (poor spot welds during construction). Thus we may have engineered the membrane and fastener system beyond the capability of an older steel roof deck that has seen water damage (corrosion), poor installation and maximum bar joist spacing. New construction is another matter as we can specify exactly what we want in deck attachment (mechanically fastened) for positive long-term uplift resistance.

Fire Ratings

All low-slope roofs need a fire rating; few if any unrated systems are allowed. TPO membranes can use halogenated or non-halogenated flame retardant (FR) additives to achieve a fire rating. A flame retardant also needs to chemically co-exist with UV stabilizers. For instance, halogenated FR additives such as bromine or chlorine are inherently high in acid level and environmentally unfriendly. The non-halogenated FR additives such as magnesium hydroxide or others may be alkaline, environmentally friendly and more expensive. Halogenated FR additives are needed for passing steeper-slope fire tests; most non-halogenated FR additives may not endure heavy fire testing.

One concern of halogenated FR additives is the long-term effect on UV stabilizers. Hindered amine light stabilizers offer excellent UV stability but can — after years of rooftop exposure — be degraded by the halogenated FR additive. Today, some manufacturers use halogenetad FR additives knowing that a measured service life is available, perhaps not as long as a non-FR sheet, but usable for its intended life.