



TPO WEATHERING TEST ROOF IN LAS VEGAS, NEVADA.

Seven-Year TPO Report

An Update on Western States Roofing Contractors Association's TPO Weathering Farm Project

The following update describes highlights from some of the latest findings from WSRCA's TPO Research and Testing Project, which WSRCA is conducting on four different TPO roofing membranes with the participation of three U. S. TPO roofing manufacturers.

by: Chuck Chapman, WSRCA President; KC Barnhardt, WSRCA Low-Slope Committee Member; Jim Carlson, WSRCA Technical Advisor; Ana H. Delgado and Ralph M. Paroli, National Research Council of Canada; Randy Ober, Carlisle; Dwayne Wacenske, Firestone; Steve Moskowitz, Dow Roofing Systems (Formerly Stevens); Michael Ludwig and Stephen Elliott, Building Envelope Technology & Research's Technical Research Associates and Jim Carlson, Building Envelope Technology & Research's Technical Director and WSRCA's Technical Advisor.

Brief Background:

In a concerted effort to learn more about the weathering characteristics of TPO (thermoplastic polyolefin) single ply roof membranes, WSRCA began an in situ testing program during the year 2000. The program consisted of what may be referred to as weathering farms utilizing four test roofs, each incorporating the same four different TPO roofing membranes in order to study the effects of real-world weathering on TPO membranes in different Western United States climate regions. The membranes were installed in 2001/2002 and have been periodically inspected and tested. The most recent round of inspections occurred in 2009 in what is considered to be the seventh-year of aging of these membranes. Note that the roofs were not all installed on the

same date and some have aged slightly longer (i.e., months) than others.

The Western States Roofing Contractors Association TPO Roof Membrane In-Situ Testing and Research Program Protocol, created in 2000, states that the Project Purpose is to:

"Examine weathering characteristics of Thermoplastic Polyolefin (TPO) roof membranes by exposing them to various weather conditions of four distinctly different climatic regions in the Western United States."

Test Roof Locations Represent the Four Different Climatic Areas of the Western U.S.:

The test site locations were chosen because they represent four of the more diverse climatic regions of the Western United States.

General Highlights:

This TPO roofing research project is now in its 8th (and in the case of Seattle 9th) year of weathering (i.e., all roofs have aged for over seven years). Based on the visual field inspections, all of the roofs are generally performing well, even in the rather harsh exposure extremes at the different sites. Each site presents unique weathering conditions. For example, the Anchorage, Alaska roof has experienced low temperatures below -30°F, and weeks of being covered with snow and ice, to highs in the +80°F with sun; but not as much sun as the Las Vegas, Nevada site that normally has about 210 very intense sunny days per year and experiences roof-top temperatures in excess of 130°F. Seattle, although the climate is generally mild, experiences rain, some snow, little hail, but numerous days

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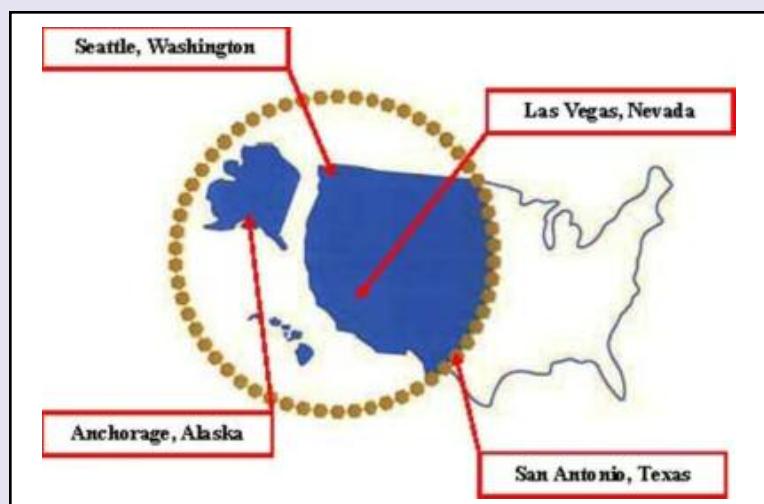


Figure 1. Test roof locations.

The locales and climates are: Las Vegas, Nevada, generally Hot and Dry; San Antonio, Texas, generally Hot and Humid; Anchorage, Alaska, generally Cold and Damp; Seattle, Washington, generally Moderate with Wet and Dry periods.

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and nights during fall, winter and spring where temperature fluctuations result in freeze-thaw conditions, and summer temperatures into the 90's F. The San Antonio, Texas roof, in addition to many very sunny, hot days has been subject to relatively severe hail storms.

In general, all seams are performing well. Contractors accompanied the task group during the inspec-

tions. Those seams that were observed to have unbonded were either re-welded during the inspection or were scheduled to be repaired within the following week. Performance of these repairs and the welding of the patches for the test cuts show that after seven years of aging, these membranes can be effectively welded to. All roofs are presently

leak-free and these 60 mil, white TPO membranes are so far showing good in-service performance.

Generally, the project is progressing well, with cooperation from all, including:

The participating contractors:

Snyder Roofing, Kyle King and

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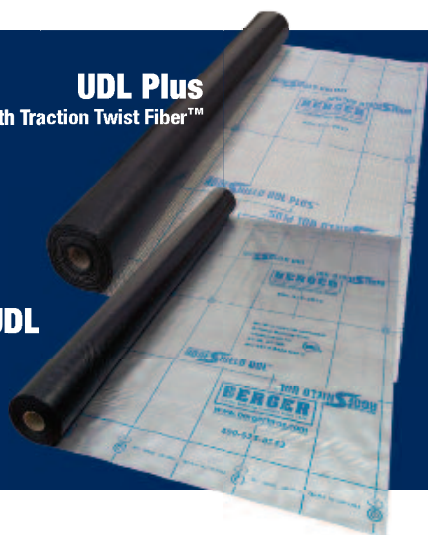
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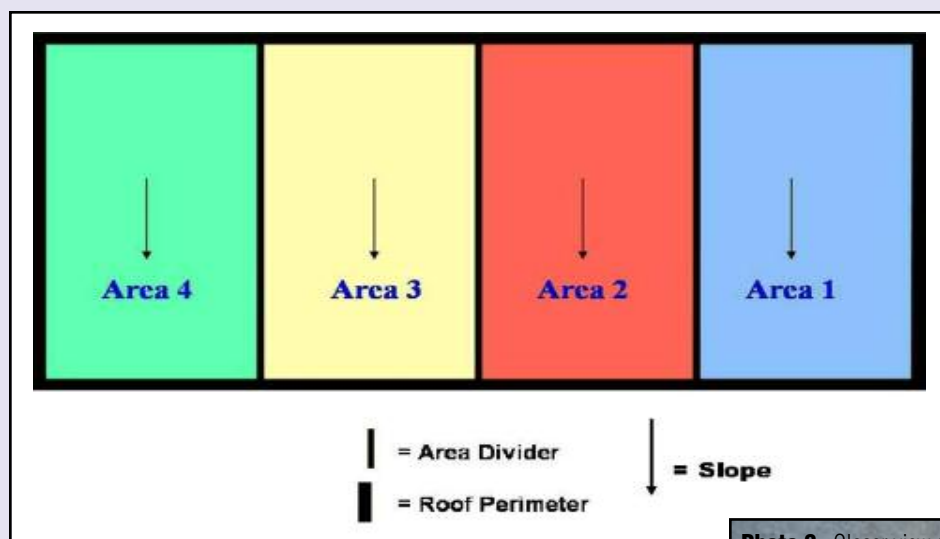


Figure 2. Roof Layout.

On-Roof Weathering and Testing is Unbiased, All Materials Are Blind-labeled:
The TPO membranes were blind labeled, and laid out similarly in each of the four test roofs.

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Tim Gardner of Snohomish, Washington;
RainProof Roofing, Curt Miller and Misty Stoddard of Anchorage, Alaska;
American Roofing, Eddie Spalten and Richard Higgs of San Antonio, Texas; and
Commercial Roofers, Inc., Dennis Conway of Las Vegas, Nevada

The participating manufacturers (in alphabetical order):

Carlisle Syntec Inc., with project representative, Randy Ober;
Dow Roofing Systems, represented by Steve Moskowitz
Firestone Building Products, represented by Dwayne Wacenske;
GenFlex Roofing Systems, whom withdrew during 2007; and

WSRCA's TPO Task Group:

KC Barnhardt, WSRCA Former President
Chuck Chapman, WSRCA President
Don Fry, Associate, WSRCA Vice President
Christian Madsen, WSRCA Senior Vice President
Michael Ludwig and Stephen Elliott, Research Associates and

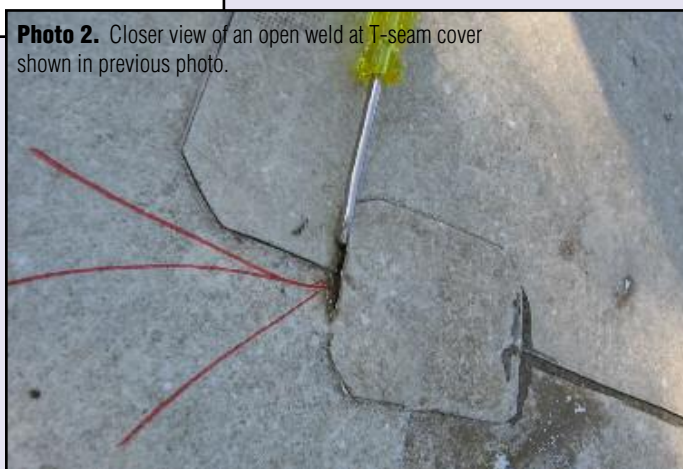


Photo 2. Closer view of an open weld at T-seam cover shown in previous photo.

Jim Carlson, WSRCA's Technical Advisor
Along with the skilled research personnel from the National Research Council of Canada (Institute for Research in Construction):
Ana H. Delgado, Research Council Officer, Building Envelope and Structure; and
Dr. Ralph M. Paroli, Director, Building Envelope and Structure.

Required Cooperation:

The joint TPO Task Group continues to work together, complementing each other by filling the voids in each other's knowledge and experience base. In this way the project has been kept on track in an unbiased manner. It is believed that this is the largest joint in-situ roof research and testing project ever taken on publicly by the roofing contractor sector of the industry, with approximately 470 squares of roofing weathering in view of the entire North American roofing industry.

This project is now entering the middle phase of the generally expected service life of a low-slope membrane roof system¹, and the following is a brief recap of the findings from the field and the laboratory.

Some Findings from the Field: Seam Integrity:

In general, all of the TPO membranes examined in the field to date have proven to maintain their seam quality.

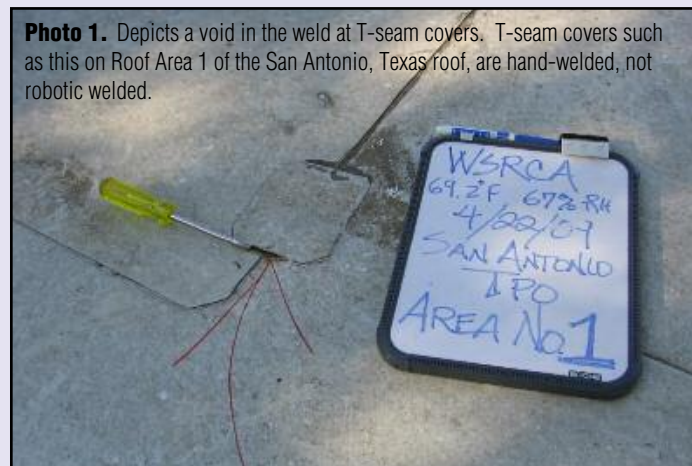


Photo 1. Depicts a void in the weld at T-seam covers. T-seam covers such as this on Roof Area 1 of the San Antonio, Texas roof, are hand-welded, not robotic welded.

All hot-air welded seams, which are randomly probed during the inspections, are proving to have great weld integrity. A few isolated, small voids were found during the most recent round of inspections. (See Photos No. 1 through 8.) A void was found in the weld at a T-seam cover on Roof Area 1, at the San Antonio, Texas site. In addition, a small void was observed at a field seam on San Antonio Roof Area 3, at the transition point between a hand-weld to a robotic weld, and at a hand-welded T-seam cover on that same Roof Area. A small void was also observed at a field seam on Seattle Roof Area 1 and at a penetration flashing boot on that same roof area.

These types of issues after 7 years appear to be relatively normal occurrences for single-ply roof membranes where there are hand-welded seams, and appear to be attributable to minor cold weld locations during application. A few other seam voids were observed, but were generally smaller than those depicted here. All robotic welds probed thus far on all four of the test roofs were found to be intact, except a few at the intersection where a hand-weld joined the start of a robotic weld.

Membranes Continue to Tighten:

As observed during previous years' field inspections and data collection, some tightening of the sheets, visible at a few locations as slight bridging at roof-to-wall intersections and some roof-to-area divider transitions appear to have gradually increased. (See Photos No. 9 and 10.) The tightening observed has been similar to what the North American roofing industry has experienced over the years with mechanically-attached single-ply roof



Photo 3. Depicts a small void in a seam at the transition point between the robotic welded field seam and the hand-welded portion close to the area divider curb. This location is on Roof Area 3 at the San Antonio site.

membranes, which can tighten as they age.

Initially, and up through the first year of weathering, some of the TPO membranes were somewhat loose or baggy with some apparent wrinkling. The San Antonio roof, which was installed a bit differently than the others (by first welding adjacent sheets then installing the mechanical fasteners), did not exhibit the fullness or looseness that the other three roofs presented during their first two or three years of service. It was noted that all of the roofs at their third-and fourth-year inspections, had

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tightened and were then generally quite smooth. The areas of minor bridging observed had been identified and marked, and they were monitored as this research and testing project progressed through its fifth year. The site visit, which was conducted for the fourth year roof survey at the San Antonio site, revealed that no additional tightening appeared to have occurred. However, the seventh-year inspection revealed slight, further tightening at a couple locations. Photos 9 and 10 depict an area of bridging membrane on San Antonio Roof Area 1, with marks applied during the most recent and two previous inspections.

Walk Pads:

The San Antonio test roof has a significant amount of on-roof equipment where manufacturer supplied walk pads were installed to protect the roof membrane from maintenance traffic. As observed on Roof Areas 1 and 2 of the San Antonio roof, walk

pads have degraded significantly since the 2007 inspection. (See Photos 11 through 14.) Walk pads on Roof Areas 3 and 4 appear to be in relatively serviceable condition. (See Photos 15 through 18) However, instances of apparent walk pad shrinkage were observed on Roof Area 3. (See Photos 16 and 17.) The shrinkage is evidenced by the diagonal wrinkles in the underlying roof membrane on both sides of the walk pad caused by the walk pad pulling on the membrane. Some of the walk pad material on Roof Area 3 is installed in fairly long runs and it is those longer sections where the

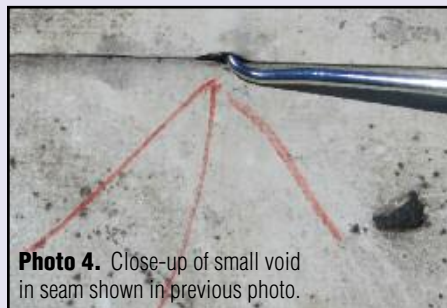


Photo 4. Close-up of small void in seam shown in previous photo.



Photo 5. Depicts a small void in a termination cover at Roof Area 3 of the San Antonio site.

shrinkage is noticeable. Note that the San Antonio roof is the only one where all four manufacturers' walk pads are well represented. It should be noted that new generation of walk pads by these manufacturers are much improved and are expected to provide longer service than those depicted here.

Potential Effects of Hard Creases in Membrane:

A small surface crack through the upper portion (i.e., top coating) of the membrane was observed during the seventh-year inspection of Roof Area 2 at the San Antonio, Texas roof. The crack occurred at a location where the membrane had originally been



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Photo 6. Close-up of void shown in previous photo.

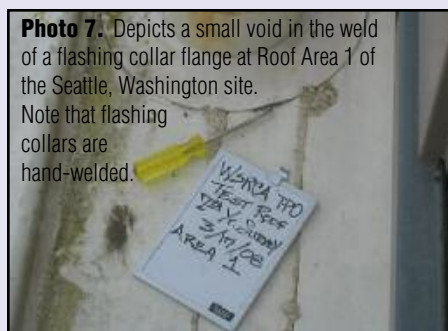


Photo 7. Depicts a small void in the weld of a flashing collar flange at Roof Area 1 of the Seattle, Washington site. Note that flashing collars are hand-welded.



Photo 8. Close-up of void in weld at flashing collar shown in previous photo.

creased during installation. (See Photos 19 and 20.) The red pointer in the photos indicates the crack location. Red arrows added to the photo indicate the crease. Note that the crack was repaired during the inspection. Note that at the time/era of this installation, it was common for the applicators to fold back the membrane and to crease it or to place weight on the fold to hold the membrane back. Manufacturers recognized that this may cause problems with TPO membranes and now discourage this practice.

Chalking:

Roof membranes were checked for chalking using the "black rag

test." Dust, rain, and debris can add to roof surface composition, however, this rag test showed minimal chalking or pickup on the cloth. It had been approximately three days since any significant rainfall. Very slight chalking was detected at most locations tested. Slight chalking is an indication that some weathering has occurred, but the amount observed appears minimal and to be expected in TPO roof membranes of this age. Note that precipitation had occurred on April 16th, 17th and 18th, with 0.11 inches falling on the 16th, 0.76 inches on the 17th and 0.60 inches on the 18th. A trace of precipitation was recorded on the 19th and the 20th and 21st were dry and sun-

ny, as was the day the test was performed.

Sealing of Cut Edges:

On the Seattle, Washington Roof in Roof Area 1, sealant applied at cut edges of some patches and flashings appears to be reaching the end of its useful service life and in a few locations it has separated and failed. The sealant appeared to be a type not recommended for use as cut-edge sealant that was applied at a repair location. (See Photo 24.) The type of failure observed appears to be similar to typical urethane-based sealant aging. Urethanes tend to lose their flexibility and elongation properties

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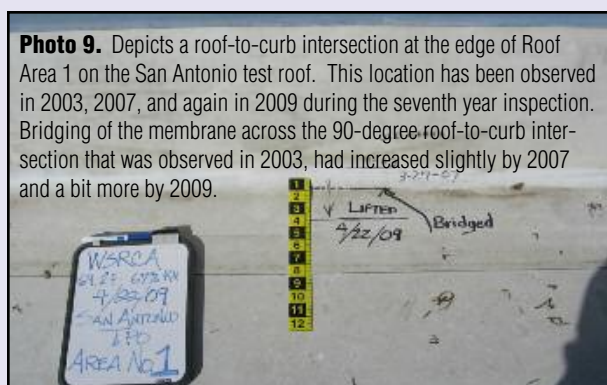


Photo 9. Depicts a roof-to-curb intersection at the edge of Roof Area 1 on the San Antonio test roof. This location has been observed in 2003, 2007, and again in 2009 during the seventh year inspection. Bridging of the membrane across the 90-degree roof-to-curb intersection that was observed in 2003, had increased slightly by 2007 and a bit more by 2009.

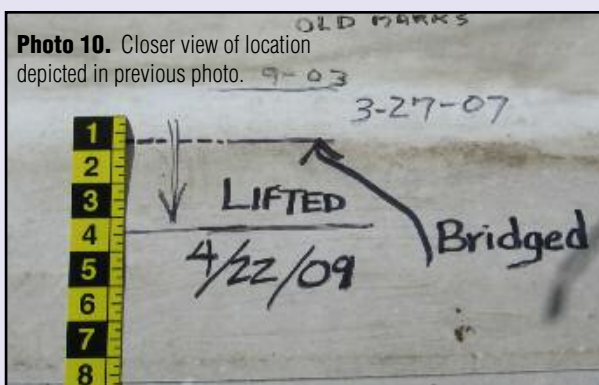


Photo 10. Closer view of location depicted in previous photo.



Photo 11. Depicts walkway pad degradation at Roof Area 1 of the San Antonio, Texas roof. The surface of the pad is cracked at numerous locations, likely due to ultraviolet degradation from sunlight.



Photo 12. Close-up of craze cracks in walk pad shown in previous photo.

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over time when exposed to natural ultraviolet radiation from the sun. It has been observed that these types of sealants can begin to craze and separate after seven to ten years of service and require replacement. Failure of the sealant at cut edges may make the exposed scrim at the edge susceptible to water absorption, which could lead to wicking and/or membrane damage. All purpose sealants are not recommended for sealing cut edges. For this reason, it is recommended that the manufacturer's cut edge sealant be used to seal all cut edges of the membrane that are exposed.

It should be noted that sealants on all roofing systems should be regularly inspected, maintained, and replaced as needed.

If an alternate sealant choice or selection is desired when sealing cut edges, ensure it is approved for this use by the roof membrane manufacturer.

Surface Characteristics and Color or Hue:

A uniqueness that was previously observed where the surface condition of some of the TPO roof membrane sheets appeared dirtier than others, apparently accumulating dust and air borne particulate differently than their neighboring sheets, appears to have eased somewhat in the seventh-year, as the membrane surfaces now appear to be generally cleaner than they were. This may be attributed to a change in the static charge of these



Photo 13. Depicts walk pad at Roof Area 2 of the San Antonio roof. The walk pad material has cracked and split through at numerous locations.



Photo 14. Close-up of splits in walk pad shown in previous photo.



Photo 15. Depicts walk pad on Roof Area 4 of the San Antonio roof with Roof Area 3 in background. Roof Area 4 walk pads appeared to be in serviceable condition at the seventh year of weathering.

assemblies over time and/or a change in the physical surface conditions due to weathering. It was also considered that weather conditions that existed just prior to the inspection, such as rain events could have had a cleaning effect as well. There



Photo 16. Depicts walk pad on Roof Area 3 of the San Antonio roof that has shrunk and pulled on the underlying membrane as evidenced by the diagonal wrinkles on either side of the pad.

are also basic differences in color and texture of the membrane surfaces between the different manufacturer's sheets that can account for variations

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Photo 17. Depicts another walk pad on Roof Area 3 that has shrunk.



Photo 18. Close-up of the surface of a Roof Area 3 walk pad reveals the material to be in serviceable condition other than the shrinkage issue.

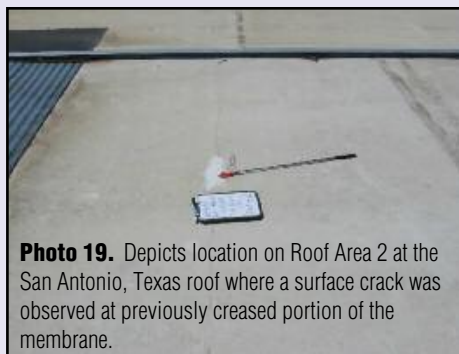


Photo 19. Depicts location on Roof Area 2 at the San Antonio, Texas roof where a surface crack was observed at previously creased portion of the membrane.

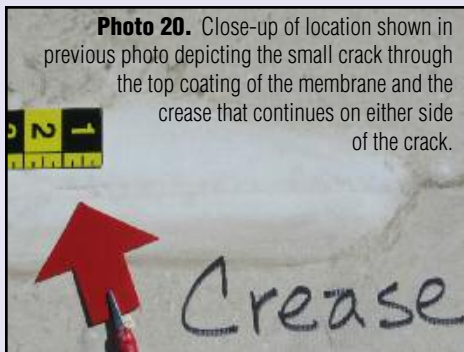


Photo 20. Close-up of location shown in previous photo depicting the small crack through the top coating of the membrane and the crease that continues on either side of the crack.



Photo 21. Depicts the black, cotton cloth/rag and the test area for the black rag test on Roof Area 4 of the San Antonio Roof. Photo taken on April 22, 2009.



Photo 22. Close-up of cloth after test showing whitish dust where it was rubbed on the surface of the membrane.

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in dust and dirt accumulation as well as slight, basic color differences, even on clean membrane surfaces.

Photo No. 25 is from the Seattle roof during the fifth-year inspection. Photo 26 is from a nearby location on the same roof during the seventh-year inspection. Both photos show Roof Area 1 on the left and Roof Area 2 on the right. Note that in the 30 days prior to the date of the fifth year inspection, there was approximately 3.16 inches total precipitation in the Seattle area, which was similar to previous years. That rainfall was relatively evenly distributed over that time period with the most rain in any one day measured at 0.22 inches. Similar conditions existed prior to the seventh year inspection, with 3.53 inches of precipitation in the 30 days preceding the inspection and that was also relatively evenly distributed

over that time period with the most rain in any one day measured at 0.18 inches.

Photo No. 27 is a close-up of unexposed membrane samples for Roof Areas 1 and 2, compared side by side, with Area 1 membrane on the left and Area 2 membrane on the right. Area 2 membrane appears rougher and of a slightly darker shade. Photos 28 and 29 show comparisons between unexposed Area 1 membrane and unexposed Areas 3 and 4 membranes respectively. Each unexposed membrane sample has its own uniqueness in color as well as surface texture. Note that the unexposed samples were taken from new rolls during original installation of the membranes and have been stored at Building Envelope Technology & Research's office. Similar samples are also stored at the offices



Photo 23. Depicts typical cut-edge sealant installed on Roof Area 3 of the Seattle, Washington roof.

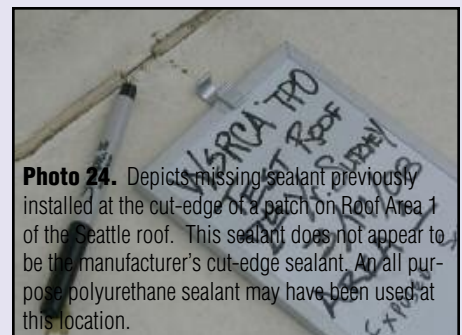


Photo 24. Depicts missing sealant previously installed at the cut-edge of a patch on Roof Area 1 of the Seattle roof. This sealant does not appear to be the manufacturer's cut-edge sealant. An all purpose polyurethane sealant may have been used at this location.

of Ralph Paroli and Ana Delgado at NRC and used for their comparison tests.

Solar Reflectivity:

Reflectivity measurements were obtained on the roofs during the third- and fifth-year inspections. Solar reflectivity measurements were conducted on both the uncleaned and cleaned weathered areas. (See Photos No. 30 and 31.) A comparison of two common cleaning methods were tested: Areas were wetted, scrubbed with stiff-bristle push brooms or long-handled brushes using a mild detergent and water solution, then rinsed, along with a side-by-side comparison of pressure rinsing/"washing." In nearly all cases, the carefully scrubbed areas produced a visually cleaner and a slightly more reflective surface.

However, even before cleaning, all of the TPO roofs far surpassed the reflectivity standard that has been set for three year old roof membranes by ENERGY STAR®. At all of the test roof areas, solar reflectivity improved after cleaning, but not as much as one would have thought by looking at the cleaned areas next to weathered areas of the membrane. This is due to the fact that 58% of the reflectivity component occurs in the non-visible portion of the solar spectrum.

This suggests that a roofing con-

tractor can install a TPO roof in areas of the country that have a standard for reflectivity, and he/she can be assured that under normal exposure conditions it will continue to meet the

Photo 25. Depicts Roof Areas 1 and 2 of the Seattle, Washington test roof. Photo taken on February 9, 2005 during the third year inspection. Note the beige color of the Roof Area 2 membrane on the right side of the photo, due to airborne dirt and dust accumulation.



current reflectivity standard after at least three years of weathering (depending on local conditions).

Reflectivity was not examined during the seventh-year inspections, however, it was noted that the mem-

Photo 26. Another view of Roof Areas 1 and 2 of the Seattle roof taken on March 17th, 2008, during the seventh year inspection. Roof membranes appear generally cleaner in this photo, with the exception of what appears to be some algae growth along the roof-to-curb intersection of Roof Area 1, on the left side of the area divider curb shown in the center of the photo.



brane surfaces appeared generally cleaner and lighter than they had at previous inspections and we suspect that reflectivity continues to meet or exceed the three year ENERGY STAR® standard, although there is currently no standard or requirement for reflectivity beyond the three-year mark.

Some Highlights of the Laboratory Testing Results:

Each of these four TPO membranes is quite different, visually no two are alike, not only in their surface texture and reinforcement profile telegraphing through the surface, but perhaps even their chemical make-up and compounding. However, following are some of the more interesting laboratory results.

Photo 27. Depicts unexposed TPO membrane samples from the new membrane rolls in 2001 that were installed on the Seattle, Washington test roof. The sample on the left is from the material installed on Roof Area 1 and the sample on the right is from the material that was installed on Roof Area 2.



Overall Thickness:

One of the tests performed is a measurement of the overall thickness of the membrane. All membranes were approximately 0.060 inches or "60 mils" nominal thickness when initially installed. To monitor potential changes, we measured samples of the test cuts in the laboratory. So far, the overall mil thickness of the sheets has varied a bit, as they continue to weather in the diverse climates. Measurements have been recorded greater than 0.060 inches, and others less than the specified as-new thickness. Thickness measurements are illustrated in Figure 4.

The variations in thickness mea-

Photo 28. Depicts an unexposed sample from the material that was installed on Roof Area 3 on the right side of the photo compared to the Roof Area 1 unexposed sample on the left.



Photo 29. Depicts an unexposed sample from the material that was installed on Roof Area 4 on the right side of the photo compared to the Roof Area 1 unexposed sample on the left.



surements are thought to be due to variations in the manufacturing process and the sampling procedures. However, these variations are within the tolerances for overall thickness as specified in ASTM 6878, Standard

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Specification for Thermoplastic Polyolefin Based Sheet Roofing. This standard provides minimum values and tolerances for new TPO roofing membranes.

Thickness of the TPO Membrane/ Coating Over the Scrim Reinforcing:

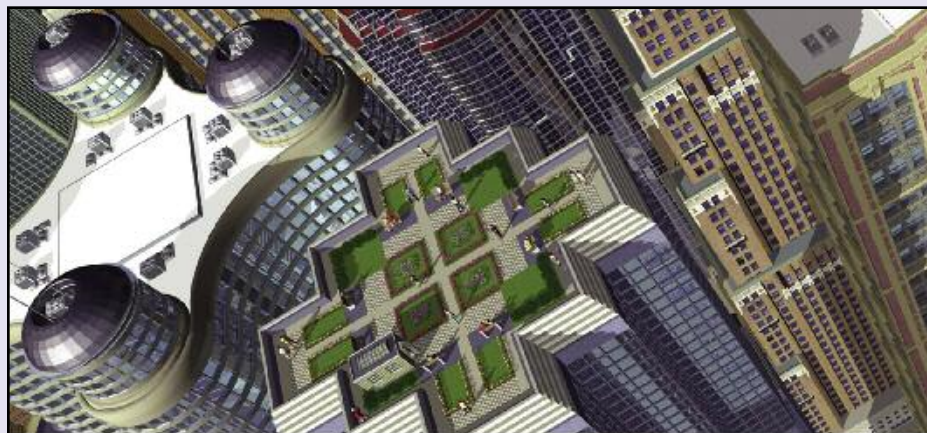
The thickness of the coating over the scrim reinforcing of the samples

measured during the seventh-year inspections do not show a definitive trend toward loss of material. Overall thicknesses changed only slightly or remained the same since the last tests were run in 2007 for the fifth-year inspections. Two notable changes in thickness over the scrim were observed, one in the sample taken from Roof Area 3 of the Seattle site and one from Roof Area 1 of the

San Antonio site.

Microscopic examination of the Seattle sample in Building Envelope Technology & Research's laboratory found that at this particular location the membrane had a thicker bottom layer than that observed in previous samples. (See microscopy image comparison in Photo 32.) The layer above the scrim was indeed thinner than measured on previous samples, but with the fact that the under layer is thicker came the thought that the thinness above the scrim may be an anomaly created during the manufacture of the membrane rather than definitive indication of a loss of material due to weathering.

Examination of the San Antonio samples shows the thickness over scrim to be slightly less on the sev-



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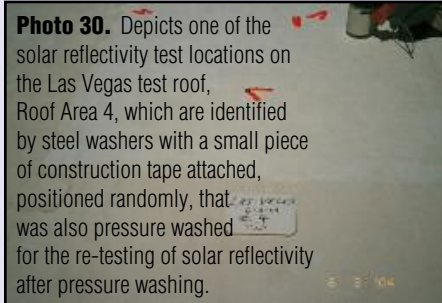


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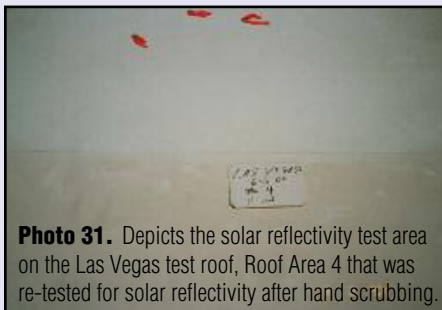
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enth-year weathered sample than on the unexposed sample. However, in the portion of the sample observed, the scrim appeared to be somewhat high within the weathering layer,



and again the measurement may be indicating a variation in how the sheet was manufactured rather than evidence of thickness loss due to weathering. In all the comparative microscopic review, only the Seattle Roof Area 3 measurement fell below the ASTM standard of 12 mils over the scrim after 7 years of weathering. It should be noted that test cuts are

WSRCA TPO WEATHERING FARM -- Refelectivity/Reflectance Testing																	
AGE OF ROOF	UNCLEANED ROOF AREA TEST COMPARISONS FROM REGIONAL LOCATIONS																AVERAGE
	Anchorage, Alaska				Las Vegas, Nevada				San Antonio, Texas				Seattle, Washington				
	ROOF AREA				ROOF AREA				ROOF AREA				ROOF AREA				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
New	0.870	0.780	0.793	0.860	0.870	0.780	0.793	0.860	0.870	0.780	0.793	0.860	0.870	0.780	0.793	0.860	
	Average: 0.826				Average: 0.826				Average: 0.826				Average: 0.826				0.826
9-Month	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.670	0.657	0.676	0.668	
													Average: 0.668				0.668
3-4 Year	0.720	0.595	0.603	0.626	0.693	0.721	0.654	0.701	0.589	0.625	0.537	0.595	0.683	0.605	0.618	0.656	
	Average: 0.636				Average: 0.692				Average: 0.587				Average: 0.641				0.639
5-6 Year	NA	NA	NA	NA	0.705	0.739	0.694	0.739	0.573	0.583	0.545	0.581	0.691	0.610	0.649	0.702	
					Average: 0.719				Average: 0.571				Average: 0.663				0.617
	Elapsed Change: - 0.190				Elapsed Change: - 0.107				Elapsed Change: - 0.255				Elapsed Change: - 0.163				0.187

	CLEANED ROOF AREA TEST COMPARISONS FROM REGIONAL LOCATIONS																
AGE OF ROOF	Anchorage, Alaska				Las Vegas, Nevada				San Antonio, Texas				Seattle, Washington				AVERAGE
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
New	0.870	0.780	0.793	0.860	0.870	0.780	0.793	0.860	0.870	0.780	0.793	0.860	0.870	0.780	0.793	0.860	
	Average: 0.826				Average: 0.826				Average: 0.826				Average: 0.826				0.826
9-Month	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
3-4 Year	0.774	0.680	0.681	0.723	0.746	0.761	0.742	0.783	0.729	0.686	0.692	0.723	0.713	0.628	0.669	0.732	
	Average: 0.715				Average: 0.758				Average: 0.708				Average: 0.686				0.716
5-6 Year	NA	NA	NA	NA	0.794	0.818	0.801	0.827	0.710	0.710	0.698	0.713	0.784	0.686	0.694	0.768	
					Average: 0.810				Average: 0.708				Average: 0.733				0.750
	Elapsed Change: - 0.111				Elapsed Change: - 0.016				Elapsed Change: - 0.118				Elapsed Change: - 0.093				0.109

taken from different areas of the test roofs, and the initial sheet thickness can vary from one location to another, which can affect the reported measurements/readings. This particular

finding may represent a manufacturing anomaly limited to just the portion of the membrane.

Photo 32 was taken in BET&R's laboratory with a digital camera

through a Leica microscope and shows a comparison between exposed and unexposed membrane for Roof Area 3 in Seattle. The

(Continued on Page 68)

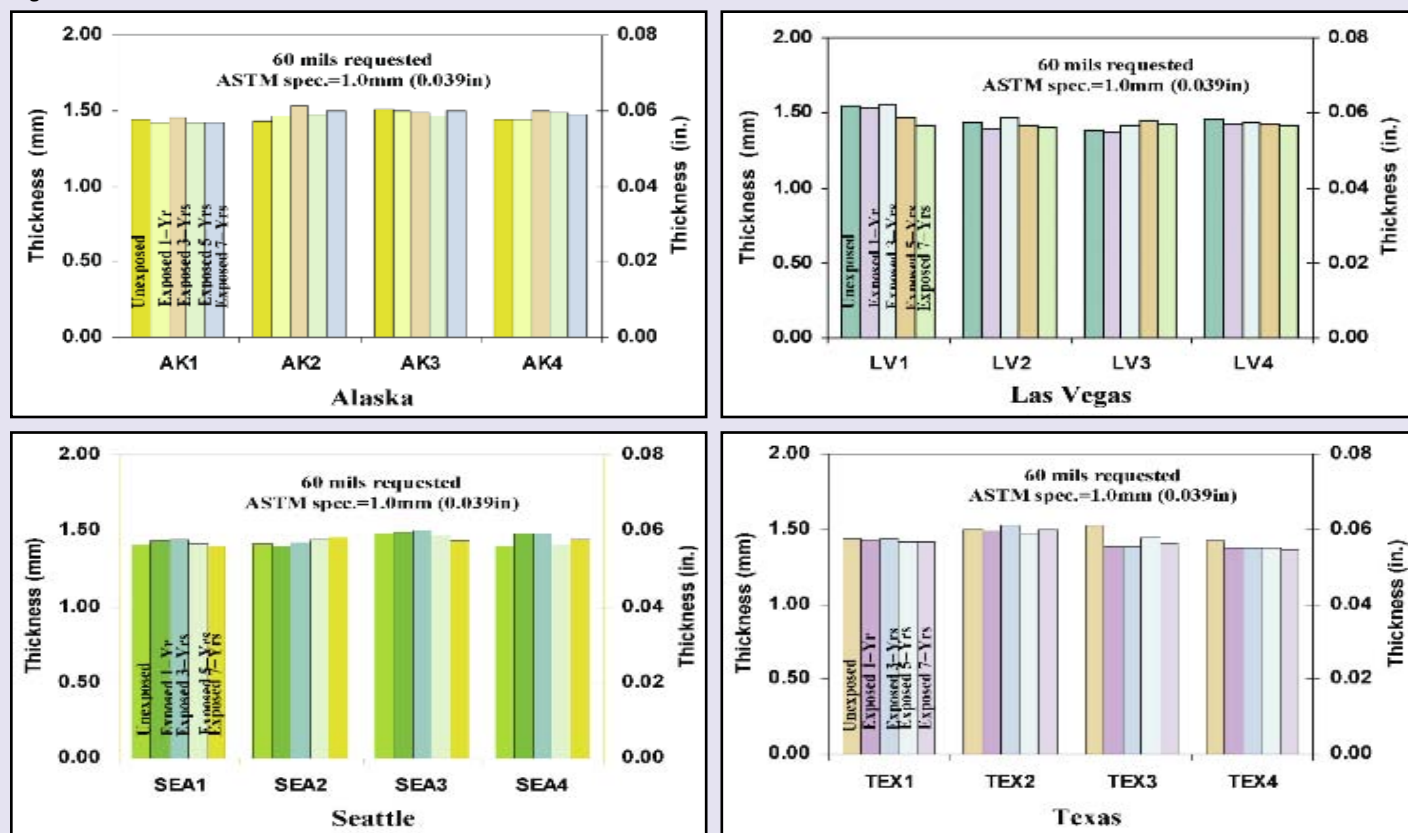
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Figure 4. Overall Thickness



Seven-Year TPO Report

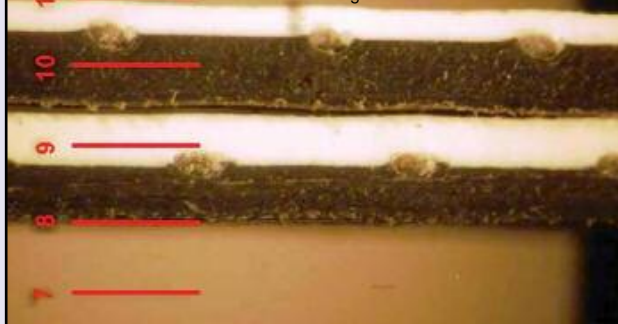
(Continued from Page 67)

exposed membrane is on top and the unexposed is on the bottom. Note the difference in thickness of the dark material below the scrim. The unexposed membrane shows the dark and light material approximately the same thickness, whereas the exposed membrane shows a very thick layer of the dark material and a quite thin layer of the white (i.e., weathering grade) material, which is the top, weathering surface of the membrane. The microscope's reticule appeared out of focus and has been drawn over in this photo and shows a rule marked in mil-

limeters. Both membrane samples measure a little less than 1.5 millimeters thick (approximately 58 mils).

It may be important to note that even though thicknesses have differed from some of the membrane test cuts, the measurements, with the one exception, fall within the ASTM standard, D6878-03. 2 (See Figure 5). However, note that this standard is not specific to thicker TPOs such as the 60

Photo 32. Photo taken through microscope. The microscope was set at 15X magnification. However, the actual scale changes depending on the size of the printed image. Therefore the scale can be determined by the millimeter reticule scale used in the image.



mil products. This WSRCA TPO Task Group and WSRCA's Low-Slope Committee recommend that the ASTM consider changing this standard to provide different classifications for each product thickness category.

The charts in Figure 6 show a comparison between overall thickness and thickness over scrim with arrows added to indicate Roof Area 3's seventh year data at the Seattle site.

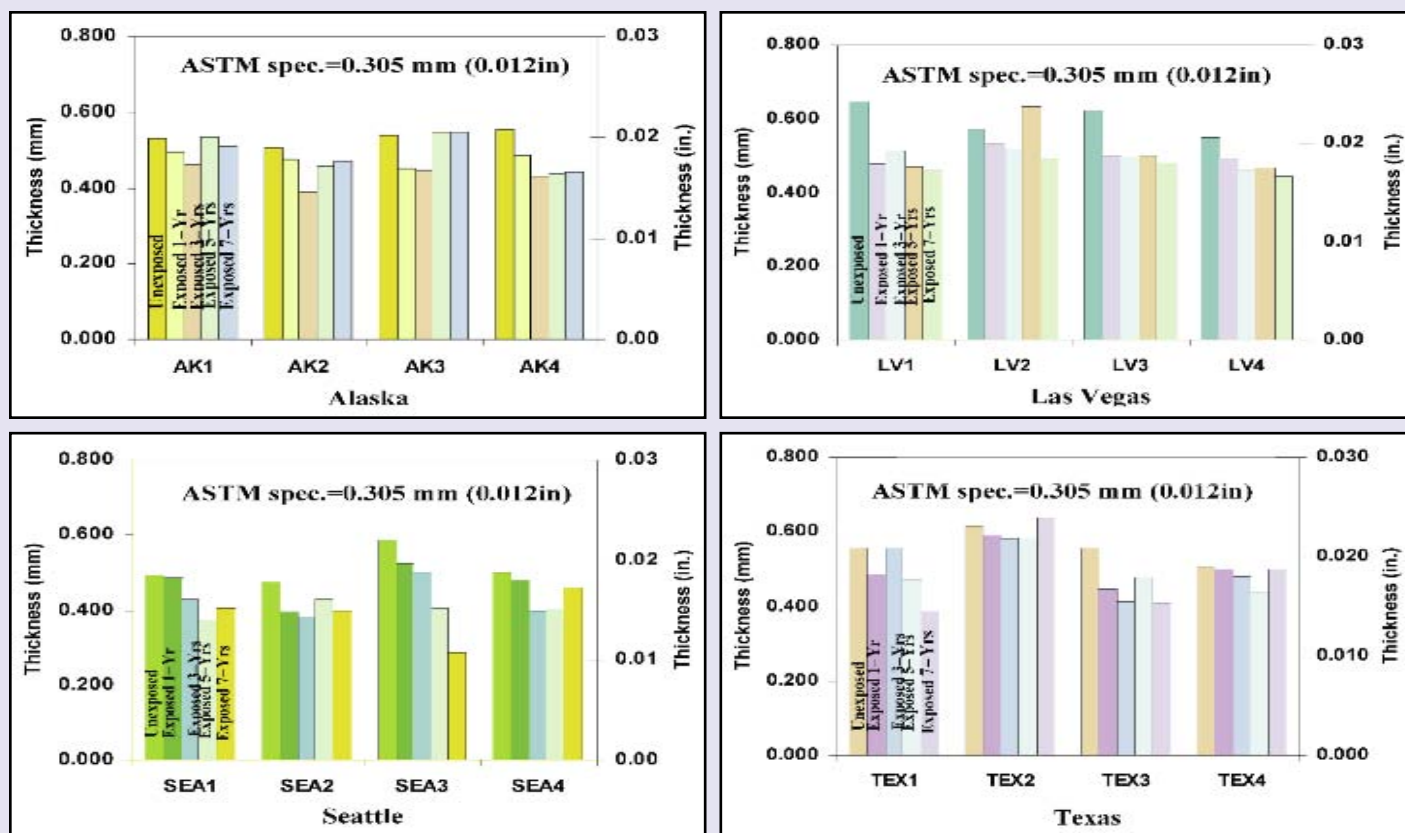
Linear Dimensional Stability Changes:

The membrane samples were measured for linear dimensional stability

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Figure 5: Thickness, coating over scrim.



changes in the first, third, fifth and the seventh year. After small changes were observed in the first year, the linear dimensional stability in both the machine direction and the cross direction appears generally unchanged.

Water Absorption:

Another test that is being run with each of the membrane test cuts is the water absorption test. Research carried out on a separate project indicated a correlation between the longevity of some roofing membranes and their degradation with age and tendency to absorb more water overtime. A working theory is that the higher the water absorption, the potentially more likely it is that

the membrane is yielding to the effects of weathering and the surface is degrading.

The results of the latest round of testing for water absorption indicate that the weather surface of the samples remains resistant to water absorption after seven years exposure.

Breaking Strength:

The breaking strength was tested on the membrane samples taken during the seventh year's inspections. In general, there was no significant difference between the unexposed membrane and that from the seven years of service in the field. It appears that so far, exposure has not affected the breaking strength of the membrane at

the locations tested. Test results for breaking strength are illustrated in Figures 7 and 8.

ASTM D6878 specifies the Grab Method for measuring the breaking strength and elongation of TPO roofing membranes. However, due to the limited size of the samples that were collected for this project, the Grab Method could not be used. In its place, a Strip Method was used. The values from the Strip Method should not be correlated to the Grab Method.

Elongation at Break:

Membrane samples were tested for elongation at break both at the fifth-year and the seventh-year investigation. Elongation at break of

(Continued on Page 70)

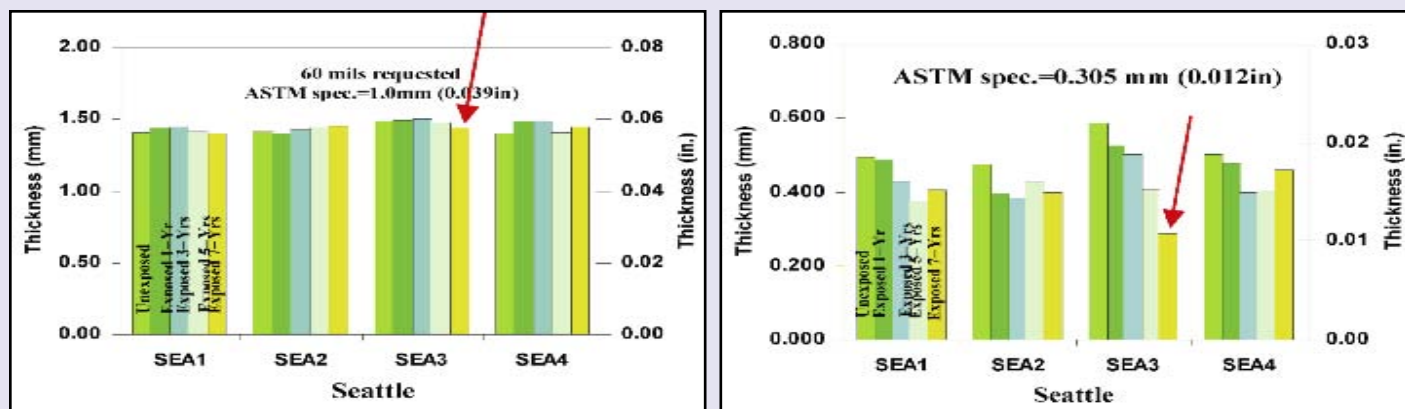


Figure 6. Comparison of thickness overall and thickness over scrim.

Figure 7. Breaking strength for 0-7-years for AK and LV samples – MD and XD.

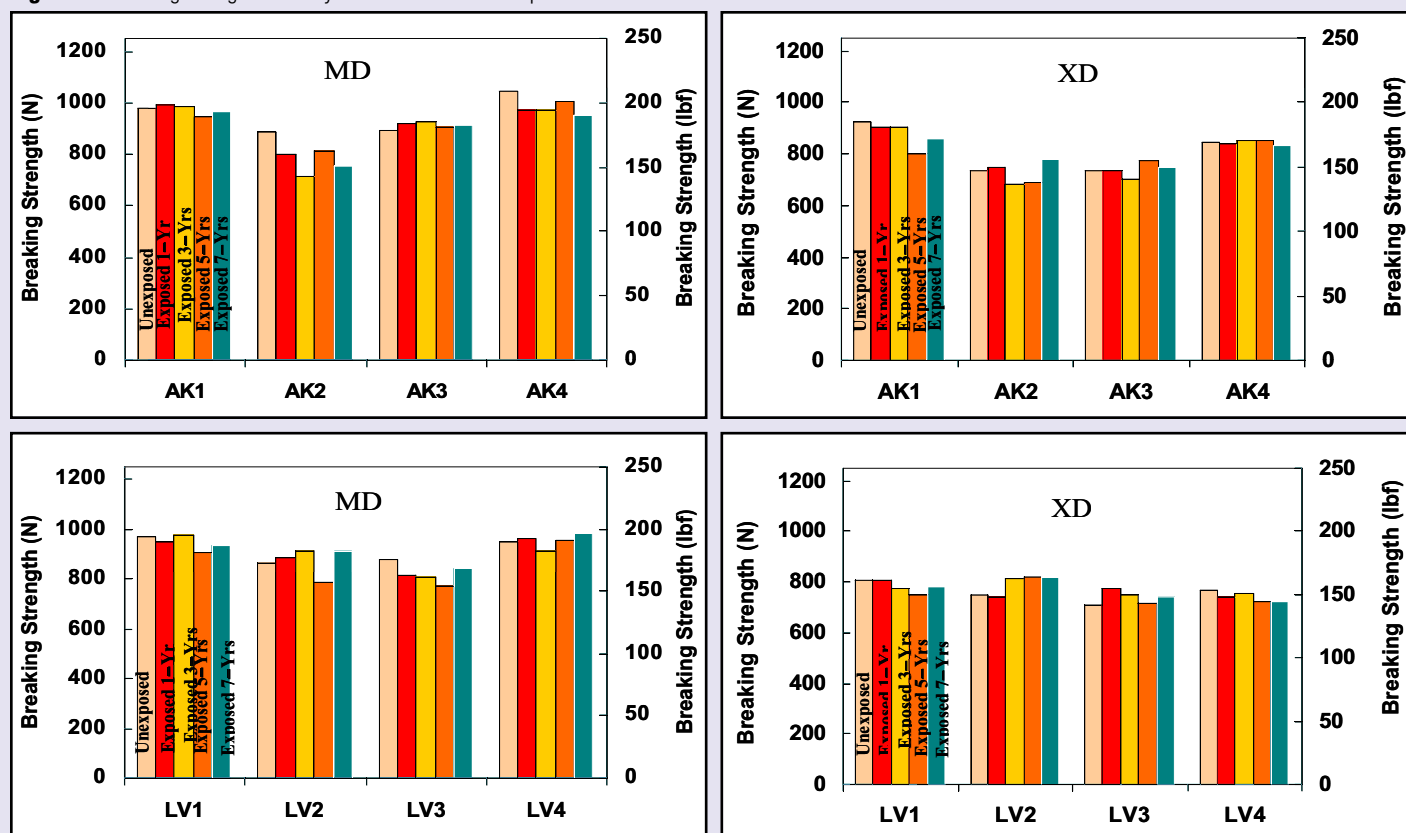
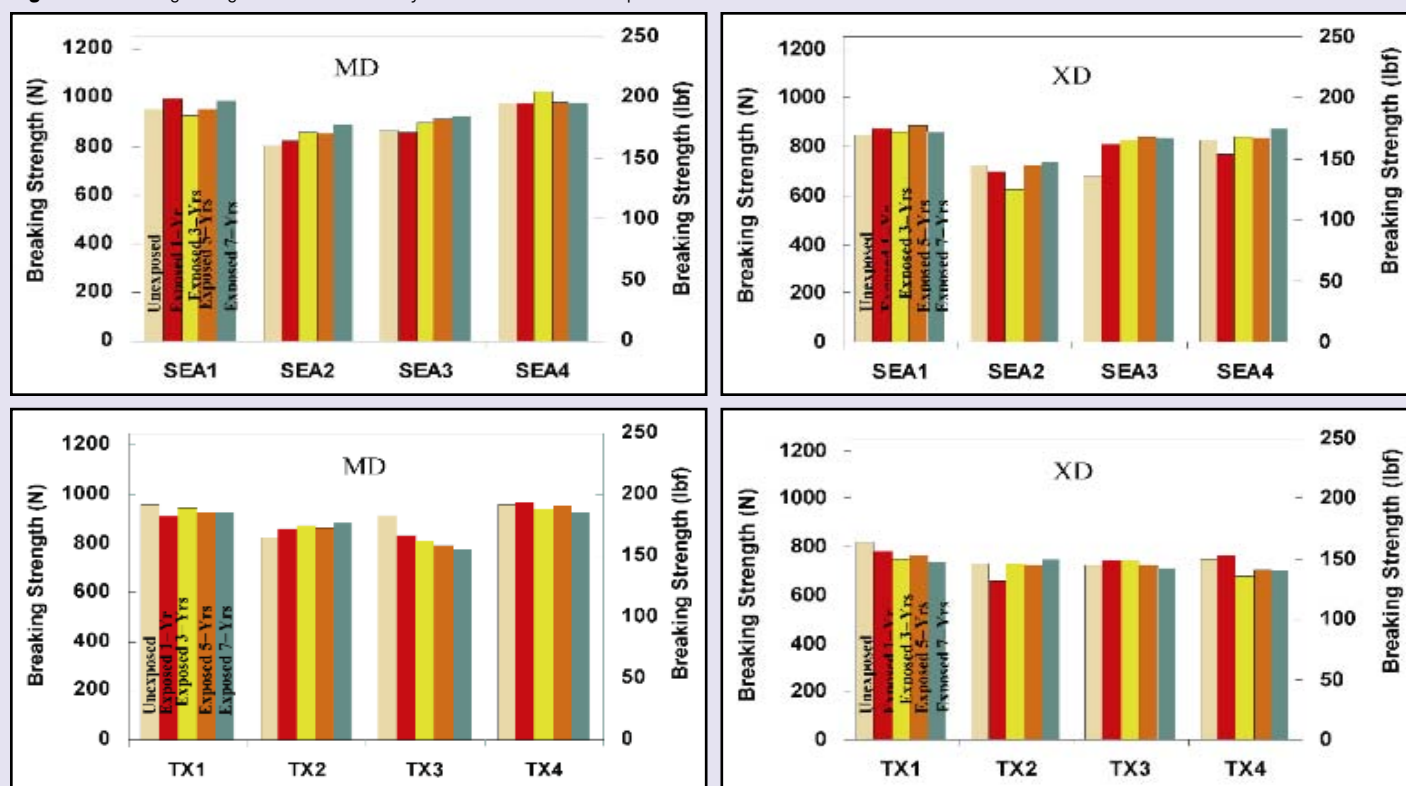


Figure 8. Breaking strength between 0- and 7-years for SEA and TX samples – MD and XD.



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all seventh-year samples was between 22% and 35% in both directions using the Strip Method. Slight changes have been detected but it

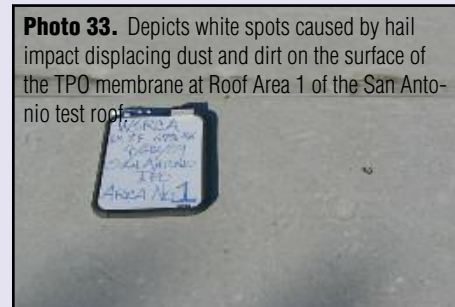
should be noted that these are minimal, are considered insignificant and do not affect membrane performance.

Glass Transition Temperature:

The unexposed membrane samples were tested in the lab as well as field-exposed samples from the third-, fifth-, and seventh-year inspections for all four regions and all four roof areas of each region for their glass

transition temperature. Note that the unexposed samples were taken from new rolls in 2001/2002 at the time of installation and have been stored in the lab to be used for comparison studies. The glass transition temperature is the temperature at which the polymers in the membrane can no longer move relative to each other and this creates a condition resulting in brittleness and breakage if the membrane is bent.

In general, the tests show the glass transition temperature rising, but by only 1 or 2 degrees Celsius from that which the membranes had when compared to the initial data; and in general, this change had occurred by the first year's inspection and has remained relatively steady since. The test has a tolerance of ± 2 degrees



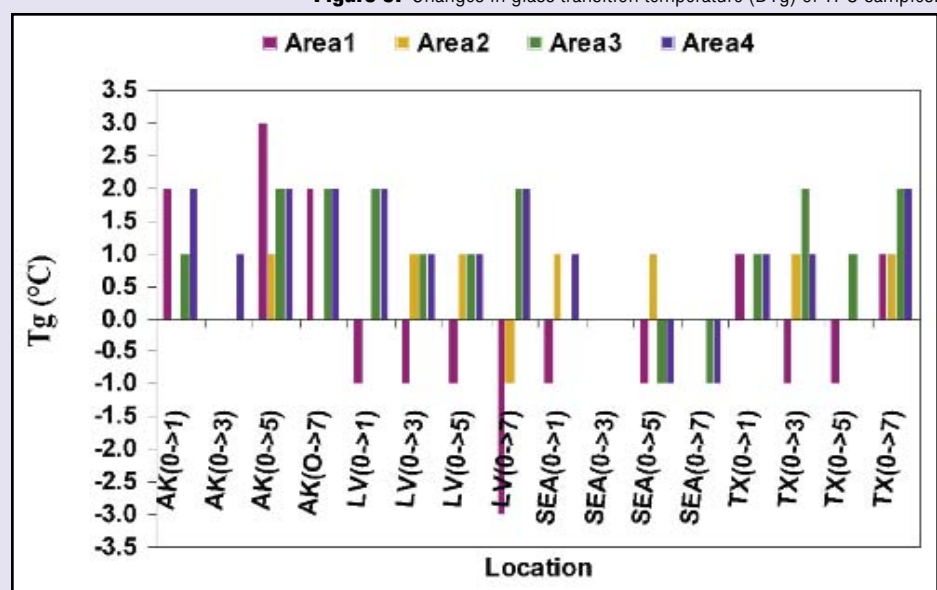
Celsius and so these minor changes appear to be insignificant. Glass transition temperature will continue to be tested and monitored in future at the ten-year inspection. Results of the seventh-year glass transition testing are summarized in Figure 9.

Other Items of Note:

A tactile examination reveals a detectable difference in the seventh-year samples from San Antonio and



Las Vegas Roof Areas 1 and 2 as compared to the unexposed samples, previous years' samples and even as compared to the seventh-year samples from Seattle and Anchorage Roof Areas 1 and 2. The samples from San



Antonio and Las Vegas feel somewhat harder and stiffer, likely indicating there are slight changes occurring due to the warmer climates' temperature, sun and heat loading. It may be that changes are occurring to all of the membranes but they are noticeable on Roof Areas 1 and 2 in the hotter climate regions. However, the changes seem slight and do not appear to represent any sort of failure.

Hailstone Impact:

When the inspection team arrived in San Antonio for the seventh-year roof survey, there had reportedly been relatively recent hail storms in the area. Once on the roof, evidence of hail having impacted the roof was observed. Don Frye, a WSRCA board member and Texas roofing contractor, who accompanied the inspection team, reported that many roofs in the area had been badly damaged by hail, and was surprised to see this TPO roof undamaged. For instance, light-colored spots approximately 1/4 to 3/4 inch in diameter were observed throughout the membrane's surface and closer examination revealed the light spots to be areas where there was less dirt and dust accumulation. (See Photos 34 and 35.) The theory is that hailstone impact had "blasted" away the coating of dirt and dust in these spots. Other evidence of hail was also observed as dented cooling fans at on-roof HVAC units. (See Photo 36.) Note: Historically, for hail

impacts on low-slope roofing membranes, the size of the marks left at hail impact sites are generally smaller than the hail stone itself, therefore it can be assumed that hailstones larger than 3/4 inch in diameter were among those that impacted this roof.

Membrane test cut samples including some of the white spots were removed from the roof and sent for testing to NRC-CNRC. In the laboratory the samples were observed and photographed through a scanning electron microscope. Then the samples were cleaned and observed, and photographed through the microscope again. The surface of the membrane within the white spot area appeared somewhat smoother than that outside the white spotted areas indicating hail impact may have slightly compressed the material upon the hail's impact.

Micro cracks were observed in some of the images but the cracks were reported by laboratory personnel to be very minute, ranging from 2 to 4 micrometers (μm). For a perspective on how small this is, note that the average width of a human hair is reported to be approximately 80 μm . Photo 37 is a scanning electron microscopy image copied from NRC-CNRC's draft report depicting an area within one of the white spots on a membrane sample from San Antonio Roof Area 3 after cleaning. Note the scale at the lower right of the image marks off 10 μm .

(Continued on Page 72)

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It appears that the membrane was undamaged by the hail impacts.

Recommendations:

Bridging/Tightening:

The WSRCA TPO Task Group has decided to continue to monitor this item.

Walk Pads:

The failed walk pads are no longer properly protecting the underlying membrane and should be replaced. Unfortunately replacement will require cutting and patching the

underlying roof membrane. Please note: The participating manufacturers have made changes to their walk pad composition and design since this study was started. Reportedly, longer service life and stability can be expected from the newer walk pads.

The roof walkway pads installed on Roof Area 3, which have clearly shrunk and impinged strain onto the underlying membrane, should also be replaced, and again this must include cutting and patching the underlying membrane. It was observed that this walk pad material is darker than the roofing membrane and this may be

contributing to the problem by allowing the walk pads to gain higher on-roof temperatures. The problem seems to be exacerbated where it is installed in long runs. However, a walk pad needs to be able to perform well, regardless of the length of walkway that is required.

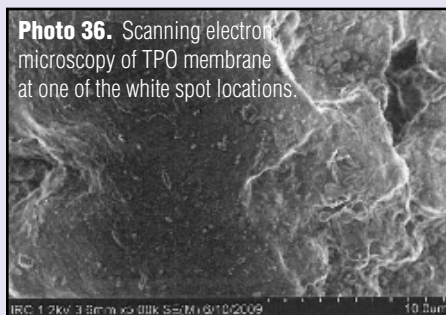
Cut-Edge Sealant:

Sealant installed at cut-edges should be repaired where it has degraded, eroded, is missing or has failed as observed on Roof Area 1 of the Seattle, Washington test roof. Sealant should be replaced with the manufacturer's supplied cut-edge sealant.

Conclusion:

The WSRCA TPO Roof Research and Test Project results have been presented in great detail over the years, in written form, and during three different WSRCA annual Conventions/Expositions. The facts have been provided as the Task Group has learned more about these four exam-

(Continued on Page 74)



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ple 60 mil white TPO roof membranes. All physical properties and visual observations will continue to be observed by the WSRCA TPO Task Group. WSRCA believes these items and others are important to be monitored.

WSRCA's Low-Slope Committee, the assigned TPO Task Group, and WSRCA in general intend to continue monitoring the findings from the field and the laboratory testing — through the next round of test cuts and testing, which will be done after the 10th year of the project.

After seven years of service, the membranes at all Roof Areas appear to be weathering quite well on the four WSRCA TPO Weathering Farm test sites. This suggests that when TPO roofing is considered for a project, that white, 60 mil TPO membranes are a reasonable alternative to other single-ply roof membrane systems. WSRCA will continue to monitor and inspect these roofs and report

the findings with another round of inspections scheduled for 2011, after the 10th year of weathering.

One of the problematic issues, brought to light during this study, has been the lack of ASTM standards for single-ply roofing membranes relating to the varying thicknesses of the roofing membranes available on the market. WSRCA's Low-Slope Committee recommends that the ASTM standards be refined to add classifications related to membrane thicknesses [e.g., 45, 60 and 80, etc.], including standards for thickness over scrim, and perhaps include a series of simple physical data or performance values, which may relate to weathering and aging, so roofing industry professionals can better estimate expected service life of roofing membranes.

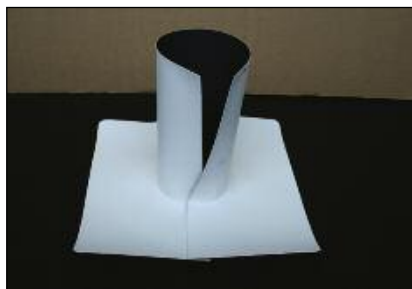
WSRCA believes that the measurement of thickness over scrim is critical to the expected life of the membrane. Each gauge or thickness of

reinforced single ply membrane should have a different standard not a single standard covering all thicknesses such as exists today.

WSRCA welcomes others to conduct similar full-scale roofing and waterproofing research. It should be noted that, to the best of our knowledge, no other roofing material has undergone such an independent, thorough, and long-term full-scale study as WSRCA has diligently conducted here with TPO. WSRCA continues to encourage membership in the Association, and welcomes new members, so this and other important roofing and waterproofing research can be funded, progress in an unbiased fashion, for the benefit of the Western roofing and waterproofing community as well as the industry at large.

1 Carl G. Cash, "The Relative Durability of Low-Slope Roofing," Proceedings from The Fourth International Symposium on Roofing Technology (1997): 119

2 As noted in the original article, ASTM 6878 was not yet finalized at the time the test roofs were installed, but shortly thereafter it was, as ASTM 6878-03. Subsequent revisions to ASTM D6878 in 2006 and 2008 did not change the specification for thickness of the coating over scrim or overall thickness.



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