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FINAL REPORT
ON
2013-2014 BROAD SAMPLING
TPO TEST PROGRAM

Sponsored By:

GAF BUILDING MATERIALS CORPORATION INC.

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Submitted by:

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Forward

Structural Research, Inc. (SRI) was commissioned to conduct an independent study of 060 white TPO membrane currently produced by GAF, Carlisle, Firestone and Johns Manville (JM) in the January 2013 to January 2014 time span. SRI was to independently procure representative TPO roll samples from the open market through distributors or roofing contractors. Five rolls of white TPO were to be procured from each plant if possible; each roll was to have a different manufacturing date. This included 2 plants each for GAF, Carlisle and Firestone; JM had one TPO plant.

Sampling and Procurement of TPO Roll Goods

A plot of the geographical locations of white 050 and 060 TPO roll samples procured and date of manufacture are shown at the end of this report.

In addition to standard white 060 TPO, the test sampling included rolls of GAF Extreme White 050 and 060 rolls, each with a different date of manufacture. The TPO membrane procured for this test totaled 45 rolls broken out as follows:

- 10 Rolls Carlisle White 060 TPO
- 10 Rolls Firestone White 060 TPO
- 10 Rolls GAF Standard White 060 TPO
- 5 Rolls GAF Extreme 50
- 5 Rolls GAF Extreme 60
- 5 Rolls Johns Manville White 060 TPO

Additional rolls of some TPO materials were received as a broad approach was used to procure individual product. However, the testing protocol used was that the first five rolls of any specific TPO product received were to be used in the comparative testing reported herein.

Test Method Summary

Generally the ASTM D6878 – 11a guidelines were followed for heat aging, lamination strength, accelerated weathering and thickness over scrim. Specific detail of each test sequence used is as follows:

1. Heat Aging - used ASTM D573 with test run at 275°F (135°C); weight change was monitored to 0.001 gram accuracy during heat aging of 2" x 6" samples. Cracks were checked by mandrel bend over a 3 inch diameter solid round section. Days to cracking was monitored concurrent with weight loss; cracks were checked for using 7x magnification.
2. Lamination strength was checked using ASTM D 1876 (T-Peel).
3. Thickness of sheet overall was checked using ASTM D751.
4. Thickness of coating over scrim followed the ASTM D7635 method.



5. Accelerated Weathering – samples were exposed to fluorescent UV light (QUV) per ASTM G154, using UVA 340 lamps with a 700 minute light cycle followed by 20 minute water spray. Exposure was 30,240 kJ/(m²·nm).
6. Samples were also weighed and heat aged after QUV testing per Item 1 above.

SPECIFIC TEST PROTOCOL USED

1. Heat Aging & Inspection for Cracking

Sampling

Five 2 x 6 inch specimens were taken from each roll. Specimens were cut at equidistant intervals over the full roll width, including one specimen taken from each edge.

Preparation and Initial Inspection

Specimens were cleaned with water, and excess edge fibers removed. Specimens were then weighed and inspected under 7x magnification using an Olympus SZX16 zoom stereomicroscope and high intensity LED illuminated, objective mounted ringlight, providing homogeneous, shadow-free illumination. The microscope had an integrated Olympus UC50 (C-mounted) digital imaging camera system capable of providing real-time image viewing, high resolution image acquisition, and interactive image measurement and analysis via Olympus image analysis software.

Heat Aging

Heat aging was conducted using a 14.1ft³ capacity SalvisLab Thermocenter TC400 laboratory oven with an internal back-panel dual-fan air circulation system, microprocessor PID controller, and computer interface for temperature / time data acquisition and monitoring. Specimens were placed within the laboratory oven so that none were directly in line with either of the two internal air-circulating oven fans.

Specimens were hung vertically using metal clips and protective release paper. Additionally, specimens were isolated from contact with other specimens, oven racks, and any interior oven surfaces.

Specimen Inspection Protocol

Specimens were removed from the laboratory oven and allowed to condition at laboratory conditions for a period of 30 minutes prior to the inspection procedure detailed below.

Specimens were weighed to an accuracy of 0.001g using an Ohaus Explorer 220 gram capacity balance with draft shield housing, remote terminal display, and computer interface for data acquisition. All weights were recorded digitally.



Immediately following weighing, specimens were inspected visually. Visual inspection was conducted with each specimen wrapped around a rotatable, sliding, 3-inch diameter mandrel directly beneath the microscope objective. The moveable mandrel apparatus allowed inspection of the entire specimen under high intensity illumination, directly beneath the microscope objective. All specimens were inspected at 7x magnification. The inspection procedure included digital photography of any visible surface cracking.

During inspections, specimens were out of the oven for 2 to 7 hours, depending on the overall specimen load at the time of assessment. Upon return, the oven would re-stabilize at 275°F within approximately 20 minutes.

Initially, specimens were subject to 1-month interval inspections. After 8 weeks of inspections, specimens were subject to 1-week interval inspections until project termination. Heat aging oven time ran from February 25, 14 to January 28, 2015

2. Thickness

Specimen Thickness - Overall

Six 2 x 2 inch specimens were taken from each roll. Specimens were cut at equidistant intervals over the full roll width, including one specimen from each edge.

Each specimen was measured using an Ames Thickness device with a 0.375-inch diameter measurement foot, according to ASTM D6878, Section 7.2 Thickness, Sheet Overall. The measuring foot was centered within each specimen.

One measurement was taken from each specimen, for a total of six measurements per roll.

Thickness Over Scrim Measurement

Six 2 x 2 inch specimens were taken from each roll (the same specimens used for overall thickness). Specimens were cut at equidistant intervals over the full roll width, including one from each edge. Each specimen was tested following procedures noted below and in ASTM D6878, Section 7.3 Thickness of Coating over Scrim.

The specimens were knife cut parallel to the cross-machine direction, then mounted in a vice-type holding device, with custom 1/2-inch aluminum gripping blocks to ensure trueness along the specimen measurement plane. All measurements were taken over scrim threads running in the machine direction, excluding any tie yarn threads which may have been present at the examination point. Measurement was performed at 40x magnification using an Olympus SZX16 stereomicroscope and Olympus digital measurement software. Three measurements were taken on representative fibers nearest the coating surface for each specimen.



Thickness Profile Measurement

A series of 24-inch long sections (2-inches wide) were cut for thickness profile measurement. The sections were taken spanning the entire width of the membrane roll. An Ames thickness device with 0.375-inch diameter measurement foot was used to take contiguous readings across the entire width of the roll.

3. Peel Testing

Weld Construction

One roll from each manufacturer was randomly chosen for peel evaluation after heat welding. All membrane was cleaned prior to the welding process, and all welds were made using an automatic heat welder. Welding was performed in the laboratory. Laboratory conditions were maintained at $73.4 \pm 3.6^\circ\text{F}$ & $50 \pm 5\%$ RH.

Welder temperature and speed was evaluated for each membrane. Temperature settings ranged from 850°F to 1148°F ; speed settings ranged from 7 ft/min to 13 ft/min.

Testing

All specimens were conditioned and tested @ $73.4 \pm 3.6^\circ\text{F}$ & $50 \pm 5\%$ RH according to ASTM D1876 - 08 Standard Test Method for Peel Resistance of Adhesives (T-Peel Test). Specimens were tested at a machine crosshead speed of 10 inches/minute (rate of separation of 5 inches/minute).

Initial peak load and overall strike-through peel strength data were collected and reported.

4. QUV Testing

One roll from each manufacturer was randomly chosen for accelerated weathering. Five specimens, measuring 2 x 6 inches, were sampled from the chosen rolls. Specimens were cut at equidistant intervals over the full roll width, including one specimen taken from each edge. All specimens were weighed immediately after sampling, prior to QUV exposure.

The specimens were forwarded to Q-Lab, Homestead, Florida, for accelerated weathering exposure using fluorescent UV light. The protocol followed ASTM G154-12a - *Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials*, modified to achieve a total exposure of 30,240 kJ/m² at 340 nm. Each cycle consisted of 700 minutes of light at 155 W/m² using UVA-340 lamps at 80°C, followed by 20 minutes of light and water spray.



After 5420 hours of exposure, the specimens were returned to SRI. Upon receipt, the specimens were weighed and visually inspected. The specimens were then integrated into the heat aging oven, at 275°F, with the remaining heat aging specimens. The QUV exposed specimens were then subject to the established 7-day interval inspection process. QUV exposure time ran from February 11, 2014 to October 28, 2014 followed by up to 84 days of heat aging for some of the samples.

Data File Appendices

The data files are electronically attached due to their size. The appendices contain the data file listed by test or work activity.

- A. ASTM D6878 Thickness - Overall & Thickness of Coating over Scrim.
- B. Roll Thickness Profile
- C. ASTM D903 - Peel Resistance
- D. Heat Aging – Weight Change
 - Observations
 - Photographs
- E. QUV & Heat Aging – Weight Change
 - Observations
 - Photographs

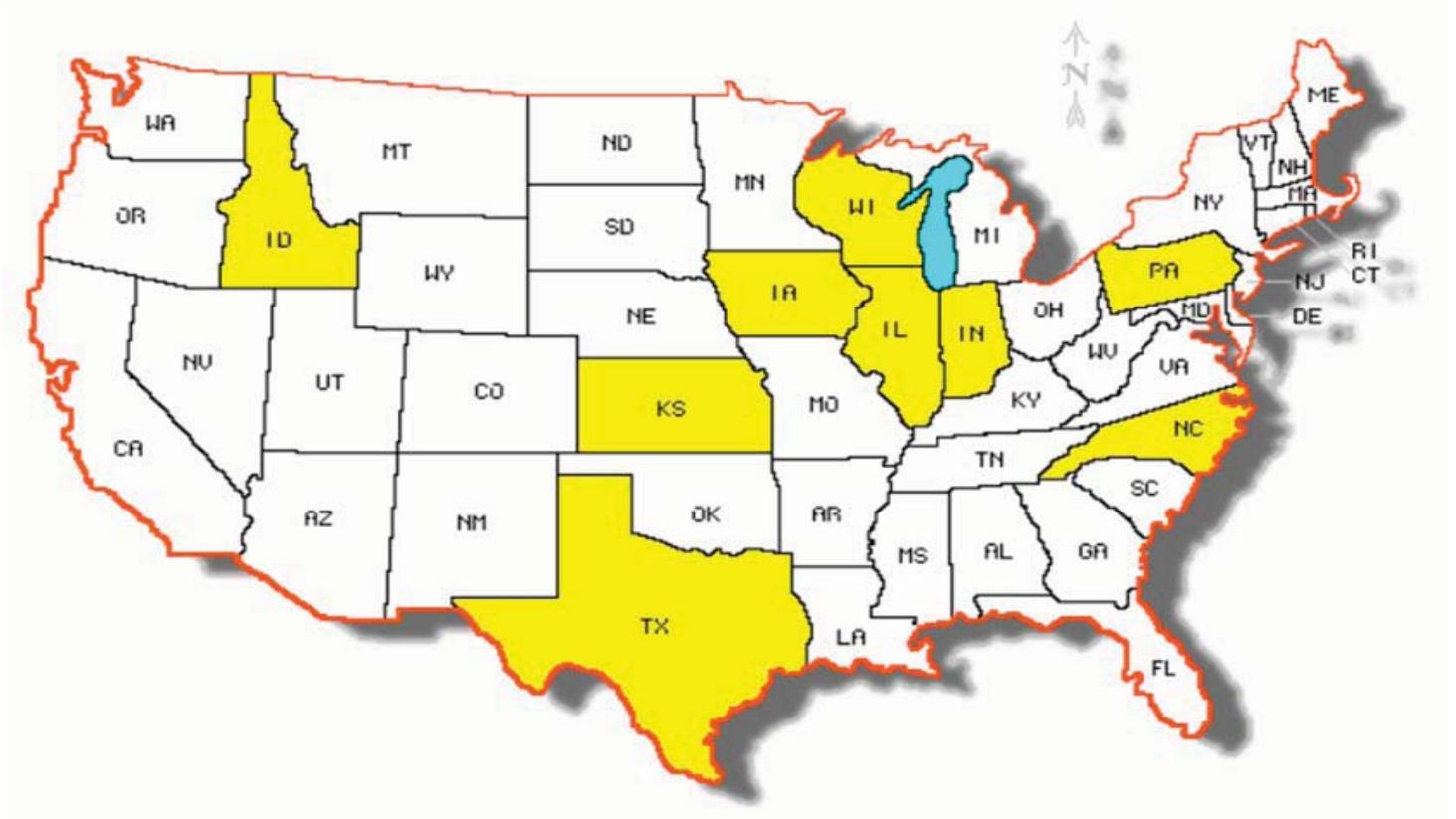
Reporting Key

The 2013 – 2014 TPO Test Program used codes on all test specimens. The SRI report key is listed below.

<u>Product Number</u>	<u>Manufacturer</u>
1	Johns Manville TPO 60 mil
2	GAF EverGuard Extreme TPO 50 mil
3	GAF EverGuard Extreme TPO 60 mil
4	Firestone UltraPly TPO 60 mil
5	GAF EverGuard TPO 60 mil
6	Carlisle Sure-Weld TPO 60 mil



TPO Roll Sample Source Areas



Month TPO Roll Manufactured Jan 2013 to Jan 2014

