Understanding the puncture resistance of TPO membranes

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SINGLE-PLY MEMBRANES AND PUNCTURE

• ‘Puncture-Resistance’ - critical property.
• Sharp objects/fast-moving blunt objects.
• Aim to compare different roofing systems for their puncture resistance.
• Different factors (reinforcement, thickness, substrate, adhesive, etc.) investigated.
• Study divided into different categories based on speed.
• Speeds *lower than 20 in/min* were classified as *low-speed puncture* or penetration-type puncture.
• Speeds *higher than 20 in/min* were classified as *high-speed puncture* or impact-type puncture.
TEST METHODS – LOW SPEED PUNCTURE

- **ASTM D4833**
- Speed: 12 in/min
- Results were recorded as the force required to puncture the membrane, i.e. the maximum load.
TEST METHODS – HIGH SPEED IMPACT

- Modified ASTM D4226
- Impactor had a Phillips #2 screwdriver head.
- All the values reported are for complete puncture.
- Membrane configurations - Supported and unsupported.
- Ladder method for measurement of maximum energy.
• Hail – Different shapes, sizes and surface roughness. ~$1 billion in losses to property and crops in 2014*.
• FM 4473 – Currently used for residential roofing applications but modified to test commercial roofing.
• 1’ x 1’ deck
• Class 4 testing – 2” diameter ice balls at 23.75 – 26.13 ft.lb (~115 ft/s)
• 2 consecutive ice balls, max. distance of 0.5 inches between impact.

*http://www.iii.org/fact-statistic/hail
MATERIALS USED

• Comparision by Manufacturer – 60 mil membranes by all four US manufacturers.
• Comparision by thickness – 45 mil, 60 mil and 80 mil
• Polyester Fleece Weights – 3.5 oz., 5.5 oz. and 8 oz.
• Substrates – ½” gypsum board, 2” polyiso insulation, ½” HD polyiso coverboard
• Adhesives for fully adhered systems
  1. Water based adhesive, GAF’s WB 181 TPO Bonding Adhesive
  2. Solvent based adhesive, GAF’s SBA 1121 TPO Bonding Adhesive,
  3. Two-part low rise urethane foam adhesives, GAF’s LRF M and LRF O (4 inches on center for full coverage)
• Increase in thickness $\rightarrow$ increase in penetration resistance.
• Coverboards provide added protection against penetration by objects.
• Gypsum board significantly increases penetration resistance.
Membrane thickness improves drop impact resistance by almost 80% from 45 mil to 80 mil membrane.

Gypsum offers a significant improvement (100%) over unsupported membrane.
ICE BALL IMPACT – IMPACT EFFECT ON MEMBRANE

<table>
<thead>
<tr>
<th>Membrane</th>
<th>Substrate</th>
<th>Average Rating over Fastener</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 mil FA</td>
<td>2” polyiso</td>
<td>5 (no fastener)</td>
</tr>
<tr>
<td>60 mil MA</td>
<td>2” polyiso</td>
<td>1.0</td>
</tr>
<tr>
<td>80 mil MA</td>
<td>½” coverboard</td>
<td>2.5</td>
</tr>
<tr>
<td>45 mil MA</td>
<td>¼” Gypsum</td>
<td>1.0</td>
</tr>
<tr>
<td>45 mil MA</td>
<td>¼” Gypsum</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- TPO installations in high hail areas ➔ fully adhered methods of attachment
ICE BALL IMPACT — IMPACT EFFECT ON SUBSTRATE

- Integrity of the substrate important.
- Polyiso foam – paper facer damaged/crushing of the foam.
- Gypsum board – brittle failure/ damage to both the top and the underside.
**Impact Effect on Substrate**

<table>
<thead>
<tr>
<th>Membrane</th>
<th>Smooth TPO</th>
<th>Fleeceback TPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness mil</td>
<td>45 60 80 60</td>
<td>60 +3.5 oz fleece</td>
</tr>
<tr>
<td>Coverboard</td>
<td>1/2 in. HD Polyiso</td>
<td>1/4 in. Gypsum</td>
</tr>
<tr>
<td>Adhesive</td>
<td>Self Adhered SBA SBA SBA WBA LRF-M LRF-O WBA WBA WBA</td>
<td>WBA WBA WBA</td>
</tr>
<tr>
<td>Membrane</td>
<td>3 5 5 5 5 5 5 5 5</td>
<td>5 5 5 5</td>
</tr>
<tr>
<td>Coverboard</td>
<td>3 3 5 1 5 5 5 1 5</td>
<td>5 5 1 5</td>
</tr>
<tr>
<td>Polyiso</td>
<td>3 3 5 1 5 5 5 1 5</td>
<td>5 5 1 5</td>
</tr>
<tr>
<td>Coverboard (Internal)</td>
<td>1 1 3 1 3 5 5 3 1</td>
<td>5 5 5</td>
</tr>
</tbody>
</table>

1 – poor/cracking ; 3 – borderline ; 5 – no damage

- Thicker membrane – better performance.
- Fleece – lower damage. Heavier weight fleece → more protection.
- Low rise foam – Added protection.
1. Single ply membrane puncture resistance $\rightarrow$ function of thickness and reinforcement.

2. Cover boards always improve puncture resistance.

3. For hail resistance –
   - fully adhered systems preferred.
   - HD coverboard performs better than gypsum and polyiso.
   - Fleece and foam adhesive reinforce the system.