Impact Resistance – What the Hail Is Happening?

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April 11th 2016 Wylie, TX Hail Storm

Hail can be very destructive!

How can we manage the risk?
April 11th 2016 Wylie, TX Hail Storm
Before We Start...

The information in this presentation is for general informational purposes only and does not constitute a warranty with respect to any product described.
Reported hailstorm events are rising -

National hail claims estimates vary, but all are high:

• $850 Million – 2009
• $924 Million – 2010
• FM Global estimates total claims >$1 Billion/yr (crops, property)
Technology Transition

TPO now >1.5 billion sq.ft. / year

- TPO
- Asphalt
- EPDM
- PVC
Looking Ahead

Slowly declining asphaltic market results in 50% TPO market by 2020
Implications for Impact Resistance...

• Hail frequency and damage are increasing
• Commercial roofing stock is being dominated by single ply
• TPO is increasingly the membrane of choice...
  – Thermoplastic, weldable, no plasticizers
  – Cost
  – Performance
TPO Heat Aging - Time Before Failure Begins

(>1.5% wt. loss or cracking)

Some TPOs are going to be around for a long time!!
IMPACT TESTING AND HAIL RESISTANCE

• Hail is very difficult to predict
  • Shape?
  • Speed?
  • Direction?

• We fire ice balls at test decks to rank performance
  • Cannot predict hail resistance!
  • Can only give general guidance!
Takeaways -

- Hail is not uniform
- Hail is hard to predict
- Let’s use impact testing to rank products

Learning -

Impact resistance of TPO is becoming more important!
**IMPACT RESISTANCE TEST METHODS – UL2218**

- **UL2218**
- Steel ball – dropped
- Damage to shingle?

**Pros**
- Safe, reproducible
- Can replicate hail’s kinetic energy

**Cons**
- Steel is non-elastic, non-deformable
- Mass to size ratio (steel is denser than ice!)
IMPACT RESISTANCE TEST METHODS – FM 4473

- Freezer ice ball - fired
- Damage to rigid roofing materials
- Work on-going with single-ply

Pros
- Can replicate hail’s kinetic energy
- Density “closer” to hail
- Possibly elastic / deformable

Cons
- Ice balls are different to hail stones!
- Experimentally difficult
This study used:

- Freezer ice-balls
- Ice-ball launcher, using compressed air
- 1’ x 1’ deck
- Class 4 testing – 2” diameter ice-balls at ~78 mph (23.75 – 26.13 ft.lb, 115 ft/s)
- Consecutive ice-balls, max. distance of 0.5 inches between impact.
MATERIALS USED

• Membrane – TPO
• Comparison by thickness – 45, 60, and 80 mil
• Polyester Fleece Weights – 3.5, 5.5, and 8 oz.
• Substrates – 1/4” 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
  3. Two-part low rise urethane foam, (4 inches on center and rolled for full coverage)
RATING MEMBRANE DAMAGE

Rating Criteria

<table>
<thead>
<tr>
<th>Rating</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>Pass</td>
</tr>
<tr>
<td>4</td>
<td>Hairline Crack in cap</td>
</tr>
<tr>
<td>3</td>
<td>Crack in cap</td>
</tr>
<tr>
<td>2</td>
<td>Puncture through cap with scrim showing</td>
</tr>
<tr>
<td>1</td>
<td>Puncture through entire membrane</td>
</tr>
</tbody>
</table>
Key learnings –
• “Pass” in field of membrane (but, large dimples!)
• Impact over fastener always results in a “Fail”

<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></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></td>
<td>2.5</td>
</tr>
<tr>
<td>45 mil MA</td>
<td>½” HD coverboard</td>
<td>1.0</td>
</tr>
<tr>
<td>45 mil MA</td>
<td>¼” Gypsum</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Work with fastener designs did not identify a solution.
Takeaways -

Impact over fasteners always punctures the membrane

The best systems are fully adhered
  Membrane and coverboard
  or
  Membrane and top layer of polyiso

Learning -
No fasteners directly under the membrane!
However -

Impact on membrane is only part of the equation

Let's look at...

**IMPACT EFFECT ON SUBSTRATE**
ICE BALL IMPACT – EFFECT ON SUBSTRATE

Cracked facer on polyiso – core crushed to ½”

Cracked underside of gypsum board (over polyiso)

Cross-section of HD polyiso board (facer undamaged) (over polyiso)

All loose laid TPO

• Polyiso foam – paper facer damaged/crushing of the foam.
• Gypsum board – brittle failure/ damage to both the top and the underside. Core shattered / powder.
# 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>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coverboard</th>
<th>1/2 in. HD Polyiso</th>
<th>1/4 in. Gypsum</th>
<th>1/2 in. HD</th>
<th>1/4 in. Gypsum</th>
<th>1/2 in. HD Polyiso</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>Self Adhered</th>
<th>SBA</th>
<th>SBA</th>
<th>SBA</th>
<th>WBA</th>
<th>LRF</th>
<th>WBA</th>
<th>WBA</th>
<th>WBA</th>
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<tbody>
<tr>
<td>Membrane</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Coverboard</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Polyiso</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Coverboard (Internal)</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

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

Thicker membrane is better

Fleeceback better than smooth

HD polyiso cover board better than gypsum

Learnings -

No fasteners directly under the membrane!
Use fleeceback, fully adhered over...
Adhered HD polyiso cover board
This was ice-ball testing;
the relationship to hail damage is unknown.
What about aged membrane?

Hail rarely affects new roofs!

Let’s age the membrane and repeat the key systems
Aged TPO Study Used One System...

*2x = two hits, 3x = three hits,
Testing Sequence...

Two approaches:
- Membrane was aged; system was built; iceball impact testing
- Iceball impact on fresh membrane; membrane was aged; system was built; iceball impact testing
# TPO Aged Prior to Iceball Impact

<table>
<thead>
<tr>
<th>Days at 275 F</th>
<th>Equivalent Age (yrs)</th>
<th>60 mil Smooth with SBA</th>
<th>60 mil Fleecceback with WBA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Standard</td>
<td>Long Life</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P</td>
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<td>P</td>
<td>P*</td>
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<td></td>
<td></td>
<td>P</td>
<td>P</td>
</tr>
</tbody>
</table>

* Passed with 2 impacts, failed with 3rd impact

Key observations:
- The membranes do really well!
- Fleecceback long life membrane provides best impact resistance

TPO cracked during aging
TPO Iceball Impact / Aged / Iceball Impact

Key observations:
- On balance, smooth membrane not as “robust” as fleeceback.
- In both studies, standard fleeceback has issues >20 years equivalent.
Takeaways -

TPO does well, even when aged!

Membrane designed for long life does best

Learnings -

No fasteners directly under the membrane!
Use fleeceback, fully adhered over...
Adhered HD polyiso cover board
Use TPO designed for long life and demanding situations
OVERALL CONCLUSIONS...

1. The relationship between iceball impact resistance and hail resistance is not known!

2. TPO fails on iceball impact above fasteners - always.

3. Fully adhered systems do not fail at the membrane (i.e no cracking etc)

4. HD polyiso coverboard performs better than gypsum

5. Aged TPO performs well

6. Best results were FA fleeceback long life TPO over adhered HD polyiso.
Thank You!

Questions?