



# 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.

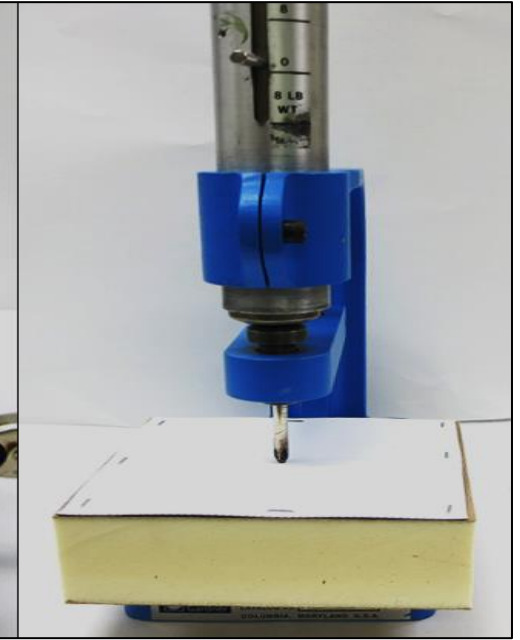
# GAF® DIFFERENT TYPES OF IMPACT

- 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.



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

# GAF 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.

# GAF TEST METHODS – ICE BALL IMPACT

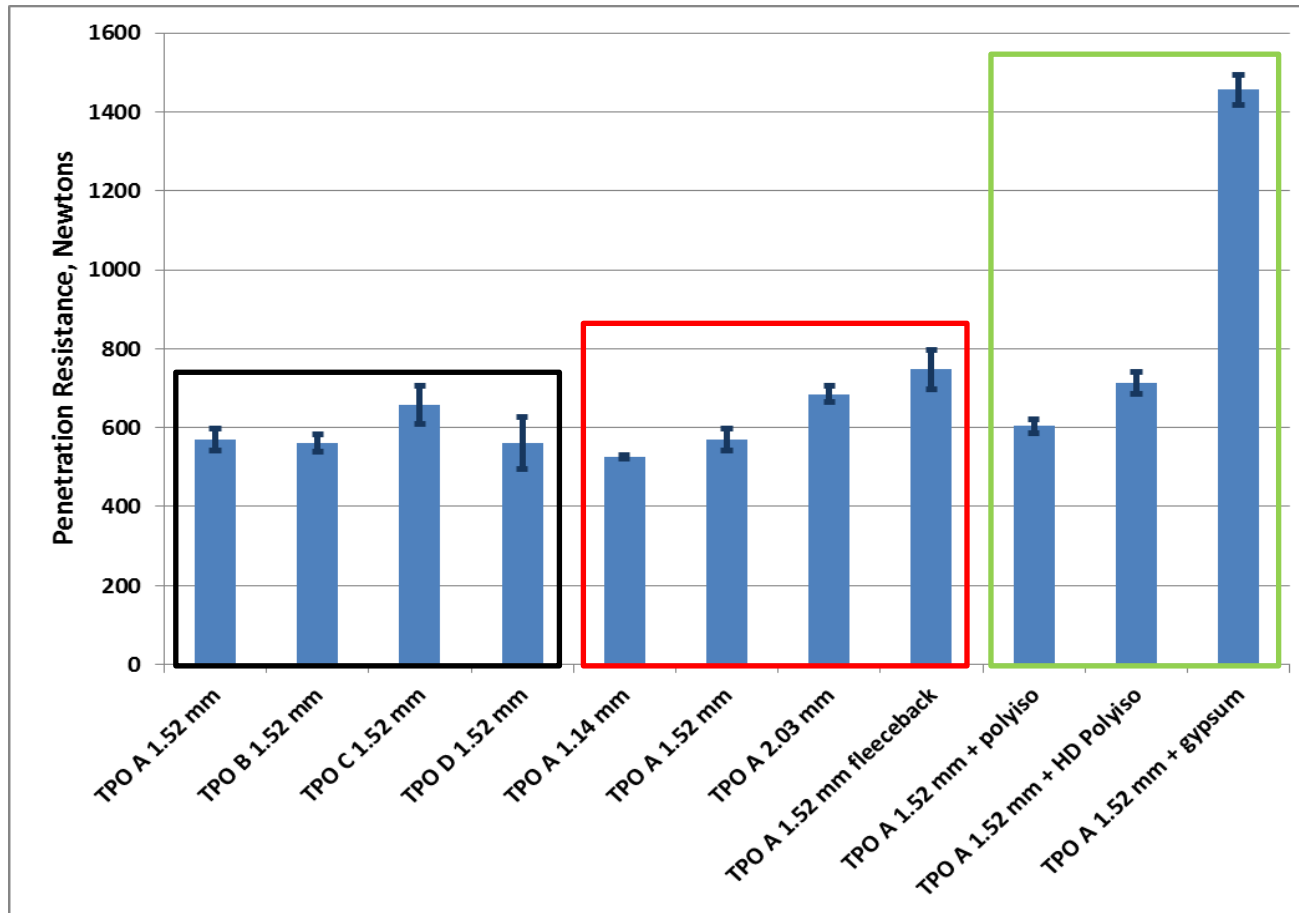
- Hail – Different shapes, sizes and surface roughness. ~\$1 billion in losses to property and crops in 2014\*.
- FM 4473 – Currently used for residential roofing applications but modified to test commercial roofing.
- 1' x 1' deck
- Class 4 testing – 2" diameter ice balls at 23.75 – 26.13 ft.lb (~115 ft/s)
- 2 consecutive ice balls , max. distance of 0.5 inches between impact.

\*<http://www.iii.org/fact-statistic/hail>



# **GAF** MATERIALS USED

- **Comparison by Manufacturer** – 60 mil membranes by all four US manufacturers.
- **Comparison 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)

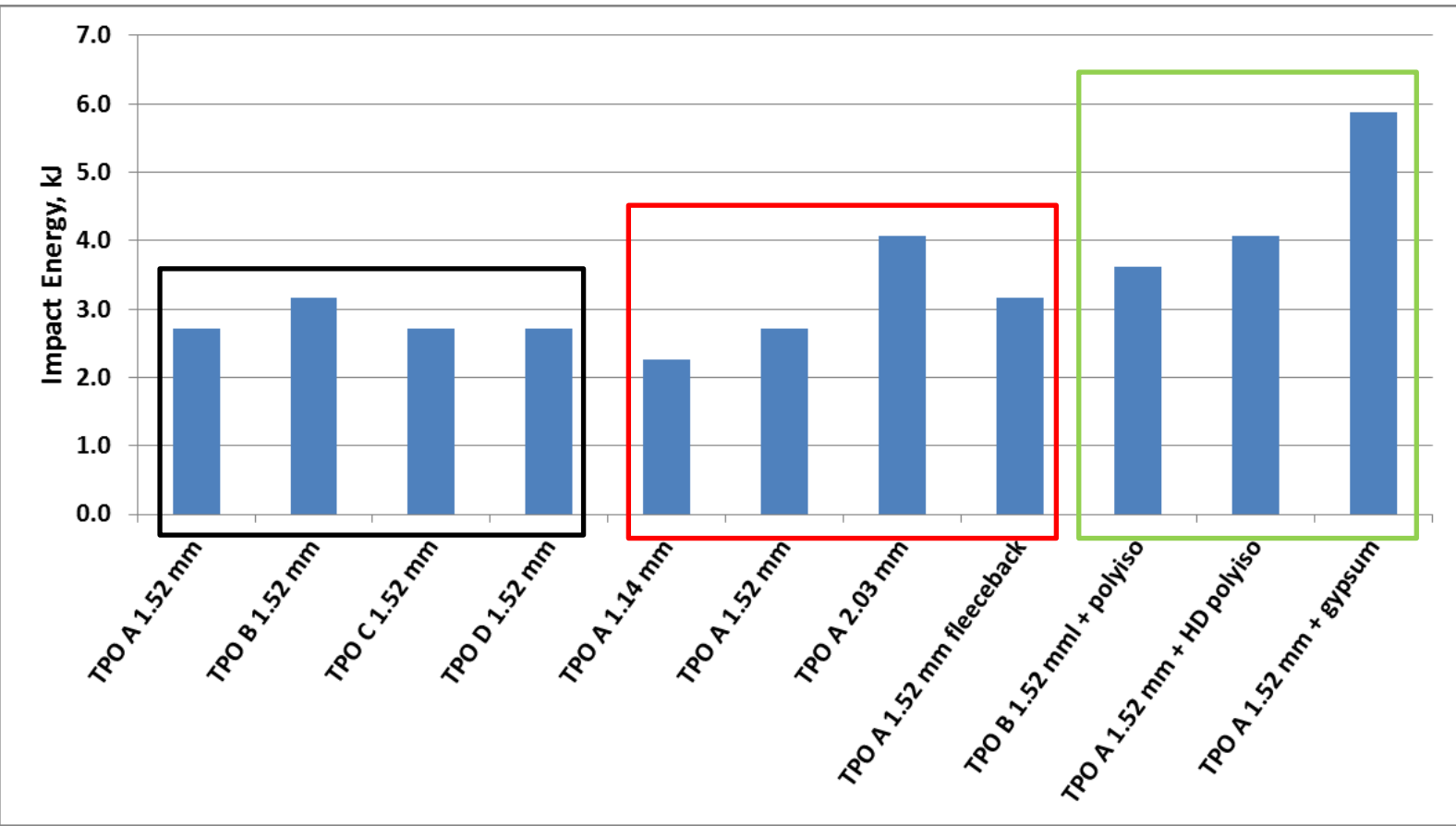


- Increase in thickness → increase in penetration resistance.
- Coverboards provide added protection against penetration by objects.
- Gypsum board significantly increases penetration resistance.



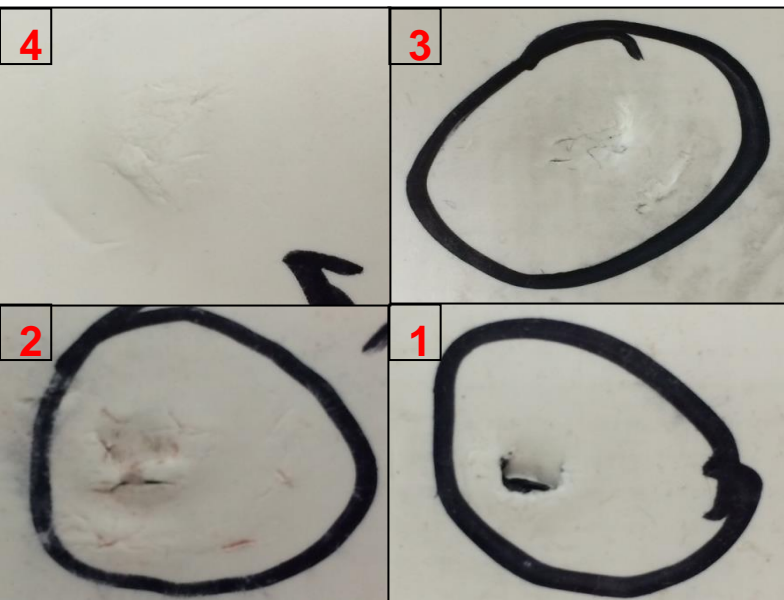


# HIGH SPEED IMPACT – RESULTS AND DISCUSSION



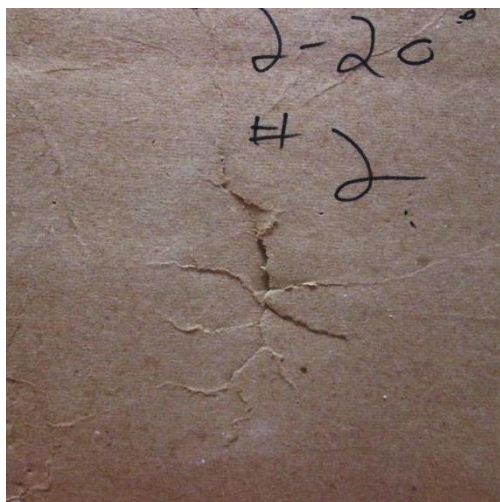
- Membrane thickness improves drop impact resistance by almost 80% from 45 mil to 80 mil membrane.
- Gypsum offers a significant improvement (100%) over unsupported membrane.

# GAF ICE BALL IMPACT – IMPACT EFFECT ON MEMBRANE



Membrane	Substrate	Average Rating over Fastener
45 mil FA	2" polyiso	5 (no fastener)
60 mil MA		1.0
80 mil MA		2.5
45 mil MA	½" coverboard	1.0
45 mil MA	¼" Gypsum	1.5

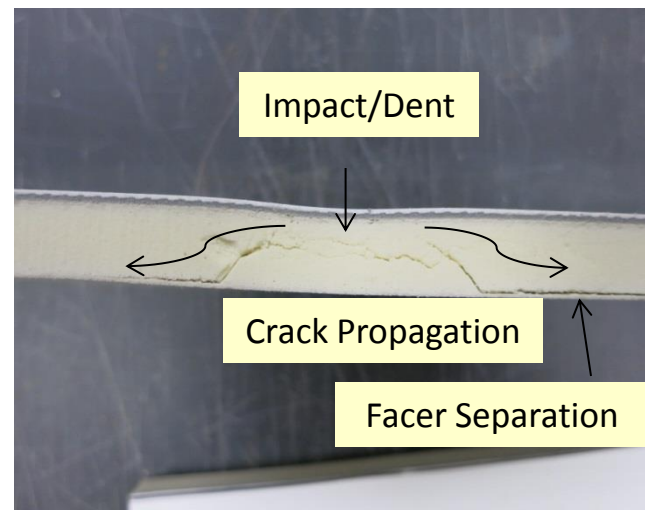
- TPO installations in high hail areas → fully adhered methods of attachment



**Cracked facer on a polyiso**



**Cracked underside on a gypsum board**



**Cross-section of a HD polyiso board after impact**

- 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.
- HD polyiso board –best performance.

# IMPACT EFFECT ON SUBSTRATE

Membrane	Smooth TPO				Fleeceback TPO							
Thickness mil	45	60	80	60	60 +3.5 oz .fleece				60+5.5 oz Fleece	60 +8 oz. fleece	80 + 3.5 oz. fleece	
Coverboard	1/2 in. HD Polyiso			1/4 in. Gypsum	1/2 in. HD			1/2 in. HD	1/4 in. Gypsum	1/2 in. HD Polyiso		
Adhesive	Self Adhered	SBA	SBA	SBA	WBA	LRF -M	LRF -O	WBA	WBA	WBA	WBA	WBA
Membrane	3	5	5	5	5	5	5	5	5	5	5	5
Coverboard	3	3	5	1	5	5	5	5	1	5	5	5
Polyiso	3	3	5	1	5	5	5	5	1	5	5	5
Coverboard (Internal)	1	1	3	1	3	5	5	3	1	5	5	5

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.

# GAF<sup>®</sup> CONCLUSIONS

1. Single ply membrane puncture resistance → 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.