A Multi-Faceted Approach to Tackling Hail Losses

ICLR Friday Forum
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Lead Research Engineer & Director of Hail Research
“Where building safety research leads to real-world solutions.”
Accomplishing the Mission

1. Conduct building science
2. Identify mitigation solutions for all aspects of building chain
3. Improve public policy
4. Develop voluntary standards and guidance
5. Communicate research findings
Insurance Operational Implications

- Lower loss exceedance curve
- Better understand vulnerability; how to reduce it (underwriting)
- More accurately assess interaction between weather and built environment (pricing)
- Improve catastrophe models
- Provide new tools for claims adjustment
- Focus on priorities ("getting the roof right")
Topics for Today

• IBHS Research Center
• Hailstorm Risks—How to Study This with Goal to Reduce Losses?
• Hailstone Characteristics Field Project
  – Measurements
  – Radar Detection
• Asphalt Shingle Impact Resistance Testing
• Full-Scale Laboratory Testing
• Aging
• Roofing and Collaboration
IBHS Research Center
Laboratory Building for Small Tests
Large Test Chamber

- 145 ft W x 145 ft L x 70 ft H test chamber
- 60 ft W x 30 ft H wind inlet
- 105 fans, each with 350 hp motors
- Enough power for 9,000 homes
- Flow volume = 20 X GREATER THAN Niagara Falls
- High-definition cameras & TV lighting
Gain a better understanding of:

- Risks through field work and environmental analysis
- Realistic impact on buildings through damage surveys; claims analysis
- Existing test methods; true applicability to actual performance
- Cosmetic vs. functional damage through full-scale testing
- Repair methodologies through full-scale testing after aging
- Effects of long-term aging on various materials
- Materials comparisons
Hailstorm Risks

- Severe hail (≥ 1 inch diameter) most commonly occurs in thunderstorms
- Largest hailstones occur in supercell thunderstorms with strong updrafts; tornadoes can also be present
- Risk extends across the US; east of Rocky Mountains
- More than 75% of US cities experience at least one hailstorm a year
- On average, annual hail losses are nearly $1 billion
Hailstorm Risks
Multidisciplinary Approach

Meteorological
- Radar-based hail detection
- Computer forecast models

Engineering
- Product testing & rating - Laboratory
- Fragility curves & hazard modeling

HAIL OBSERVATIONS
- Economics cost vs. event frequency
- Understanding & mitigating the hail HAZARD

Economics
- Cost vs. event frequency

Understanding & mitigating the hail HAZARD
IBHS Hail Research: Pushing the Boundaries of Building Science

• Full-scale hailstorm simulation; three sizes of hailstones
• Small roof and component panel impact testing
• Field work to validate laboratory findings; improve hail forecasting and detection
Hailstone Characteristics Field Project
Hailstone Characteristics Field Project

Mission: Safely collect measurements of the physical properties of hail

Turkey, TX
Hailstone Characteristics Field Project

- Develop relationships between hailstone characteristics and environmental/radar data
- Understand spatial and temporal variability in hailfall
Hailstone Characteristics Field Project

Photograph → Measure/Weigh → Crush Test

- Photograph of hailstones
- Measure/Weigh instrument
- Crush test equipment

Graphs showing hailstone size distribution and solid ice sphere data.
Hailstone Characteristics Field Project

- 2012-2014
- 33 parent thunderstorms
- 2500+ hailstones cataloged
- Multiple dimensions, mass, compressive strength test
Hailstone Characteristics Field Project
## Hailstone Characteristics Field Project

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storms</td>
<td>9 storms</td>
<td>12 storms</td>
<td>11 storms</td>
</tr>
<tr>
<td>Days</td>
<td>7 days</td>
<td>7 days</td>
<td>7 days</td>
</tr>
<tr>
<td>Size</td>
<td>0.16 in. – 3.05 in.</td>
<td>0.04 in. – 4.21 in.</td>
<td>0.05 in. – 2.66 in.</td>
</tr>
<tr>
<td>Stress</td>
<td>9 psi - 620 psi</td>
<td>1 psi - 1097 psi</td>
<td>0 psi - 2958 psi</td>
</tr>
</tbody>
</table>
Hail Hazard: Shapes

Shape classes:
- Conical: 0.1
- Spheroid: 0.84
- Irregular: 0.06

Images of different hail shapes.
Hail Hazard: Shapes
Hail Hazard: Density

Field observations

Ice sphere density = 0.2 g cm⁻³
Mass = 0.532 D^{2.406}
Ice sphere density = 0.9 g cm⁻³
Hail: Field vs. Lab

Density
• Artificial hailstones—varies from 0.45-1.1 g/cm³
• Natural hailstones—varies from 0.1-0.9 g/cm³ (historical studies)

Compressive Stress
• Artificial hailstones—varies from 3-308 psi
• Natural hailstones — 1-8000 psi (limited field dataset)
Hail: Field vs. Lab

Standardized tests
• UL 2218 - Steel ball
• FM 4473 - Ice ball
“worst case impact”

Field observations
• Lab ice sphere will have higher mass than typical natural hailstone of same maximum diameter

Oblate spheroids (e.g. “hamburger bun-ish”), depart from perfect spheres with size
Hail: Field vs. Lab
When we shoot a 2 in. stone, it’s really like a typical 2.65 in. hailstone.

UL 2218 & FM 4473 kinetic energy all based on spheres.

### Hail: Field vs. Lab

<table>
<thead>
<tr>
<th>Pure ice sphere diameter (in)</th>
<th>Typical natural hail diameter of the same mass (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.65</td>
</tr>
<tr>
<td>0.75</td>
<td>0.68</td>
</tr>
<tr>
<td>1.00</td>
<td>1.18</td>
</tr>
<tr>
<td>1.25</td>
<td>1.56</td>
</tr>
<tr>
<td>1.50</td>
<td>1.90</td>
</tr>
<tr>
<td>1.75</td>
<td>2.21</td>
</tr>
<tr>
<td>2.00</td>
<td>2.65</td>
</tr>
<tr>
<td>2.50</td>
<td>3.40</td>
</tr>
<tr>
<td>3.00</td>
<td>4.30</td>
</tr>
<tr>
<td>3.50</td>
<td>5.05</td>
</tr>
<tr>
<td>4.00</td>
<td>5.90</td>
</tr>
</tbody>
</table>
Hail: Loss Reduction

• Predict which hailstorms are damaging
• Accurately delineate hail swath using improved radar data
• Reduce “neighboritis” and claims at fringe of swath
Hail: Radar Detection

- National Weather Service Network of Doppler Radars
- WSR-88D
- First deployed 1988 (NEXRAD)
- Operate continuously
- Data are free
- All NWS radar upgraded to “dual-pol” (2013)
- Collaboration with Dr. Matt Kumjian (Penn State)
- Develop and improve dual-pol hail detection
- No “operational” hail size or concentration algorithm using dual pol information
- Only classification: “HAIL/HEAVY RAIN”
- Field observations for validation and tuning
Hail: Conventional Radar Detection
Hail: Conventional Radar Detection
Hail: Emerging Radar Detection

Data courtesy of Matt Kumjian (Penn State)
Hail: Emerging Radar Detection

Conventional radar reflectivity

Dual pol derived swath - contribution of hail to backscattered energy at lowest radar scan

Data courtesy of Matt Kumjian (Penn State)
Hail: Future Forecasting

- Numerical model simulation
- 6 different wind profiles
- Can “turn the knobs” on the environment
- Shaded colors represent hail concentration
- Next step: simulations of field events

Dennis and Kumjian 2014 (Penn State)
Hail Impact Disdrometer Probes

- Rapidly deployable
- Detect hail impacts
- Group into sizes
- Impact energy
- RUGGED!!!

GOAL: Deployable research network (20 or more)
GOAL: Use on fixed observing stations (2015 pilot study)
Hail Impact Disdrometer Probe Example

Punkin Center, CO; 5 June 2014

- Large volume of small hail
  - 10-20 impacts per minute

Single piezo-electric sensor

Three piezo-electric sensors
Asphalt Shingle Impact Resistance: What We Need to Know

HYPOTHETICAL LAB TEST: SHINGLE “XYZ”

At what point does the shingle lose its water shedding ability?

What does the relationship actually look like?

How do the effects of aging play a role?
Asphalt Shingle Impact Resistance Testing

Systematic approach to compare:
1. Different classes of materials
   a) 3-tab vs. architectural shingles
   b) standard vs. IR vs. premium
   c) Traditional IR vs. polymer modified IR
2. Standard test methods: UL 2218 / FM 4473
3. Altered test methods: different density and/or hardness of stones
4. Aging and climate effects

Goal = Develop statistically based damage curves for size, density, and hardness of hailstones
UL 2218 Shingle Impact Test Method

• Official method for rating shingle impact resistance
• 3’ x 3’ panels constructed with shingles installed by manufacturer’s guidelines
• Conditioned for 16 hours @ 135-140 °F
• Steel balls dropped from height necessary to achieve same kinetic energy as similarly-sized hailstone
  – Class 1 ball = 1.25”
  – Class 2 ball = 1.50”
  – Class 3 ball = 1.75”
  – Class 4 ball = 2.00”
UL 2218 Shingle Impact Test Method

- Two impacts at each of six locations on 3’ x 3’ test panel
- Resultant impact marks inspected under microscope
- Any evidence of opening—tearing, cracking, fracturing, or rupturing—visible on the back of the shingle is considered test failure
UL 2218 Shingle Impact Test Method
Asphalt Shingle Impact Test Observations

- Common impact marks
  - Crushed granules—visible on all panels, not seen in real-world
  - Dents—most severe at midspan 2 x 4 brace
  - Flattening of shingles—particularly at edges, joints, corners
Asphalt Shingle Impact Test Observations

• Common performance criteria failures
  – Cracks—through 3-tab and single-ply ply portion of architectural shingles; both plies of double-ply
  – Tears—at edge of 3-tab and single-ply portion of architectural shingles; both plies of double-ply
  – Unclear if one damage mode is more detrimental
Asphalt Shingle Impact Resistance Testing

UL 2218 Impact Location Passing Rates: 3-tab vs. Architectural Shingles

<table>
<thead>
<tr>
<th>Shingle Type</th>
<th>Class 1 Impacts</th>
<th>Class 2 Impacts</th>
<th>Class 3 Impacts</th>
<th>Class 4 Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-tab</td>
<td>43%</td>
<td>23%</td>
<td>27%</td>
<td>23%</td>
</tr>
<tr>
<td>architectural</td>
<td>55%</td>
<td>42%</td>
<td>33%</td>
<td>32%</td>
</tr>
</tbody>
</table>
Asphalt Shingle Impact Resistance Testing

UL 2218 Impact Location Passing Rates:
3-tab vs. IR 3-tab Shingles

- Class 1 impacts: 43% for 3-tab, 67% for IR 3-tab
- Class 2 impacts: 23% for 3-tab, 75% for IR 3-tab
- Class 3 impacts: 27% for 3-tab, 58% for IR 3-tab
- Class 4 impacts: 23% for 3-tab, 58% for IR 3-tab
Asphalt Shingle Impact Resistance Testing

UL 2218 Impact Location Passing Rates: Architectural, IR Architectural and Premium Architectural Shingles

<table>
<thead>
<tr>
<th>Shingle Type</th>
<th>Class 1 Impacts</th>
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<th>Class 3 Impacts</th>
<th>Class 4 Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural</td>
<td>55%</td>
<td>42%</td>
<td>33%</td>
<td>32%</td>
</tr>
<tr>
<td>IR Architectural</td>
<td>77%</td>
<td>71%</td>
<td>60%</td>
<td>41%</td>
</tr>
<tr>
<td>Premium Architectural</td>
<td>60%</td>
<td>43%</td>
<td>38%</td>
<td>35%</td>
</tr>
</tbody>
</table>
Asphalt Shingle Impact Resistance Testing

UL 2218 Impact Location Passing Rates: Polymer Modified IR vs. Traditional IR Shingles
Asphalt Shingle Impact Resistance Testing—Next Steps

• Panel variability—increase sample size for select products
• Subjective rating variability—include damage ratings from 4 or 5 independent raters for select products
• Ice testing
  – Limited sample of pure ice (FM 4473)
  – IBHS hailstones replicating natural hail
• Layers/substrates—approved for 2015
Full-Scale Impact Testing

- 12 hail cannons on upper catwalk
  - Computer-controlled firing system
  - Fully-controllable shooting speeds
  - Fully-controllable shooting frequencies
Full-Scale Impact Testing

- 3 sizes (1 in., 1.5 in., 2 in.)
- Adaptable for different sizes
- Structural vs. Aesthetic Damage
- Repair vs. Replace Methodologies
Full-Scale Impact Testing
Full-Scale Impact Testing
Full-Scale Impact Testing

Future Research (after automatic hailstone production)

Test New & Aged Specimens

Repair & Replace Methodologies

Age

Test Against Water Intrusion

Test Against Water Intrusion

Provide Guidance on Best Practices
Effects of Aging

- Older Roofs
- Higher Claim Frequencies
- Higher Claim Severities

©Insurance Institute for Business & Home Safety
Impact of Aging on Insurance Industry

Aging and Durability

- Climate
- In-service length
- Directionality of sun exposure
- Material type
- Material color
- Roof pitch

- Underwriting
- Duration of Incentives
- Risk Modeling
- Claims Processing
Roof Aging Farms
Roof Aging Farms: Climates
Roof Aging Farms

• Naturally age small roof specimens for wind and hail testing up to 20 years
• Test at five-year increments (baseline = new)
• Multiple test panels for each age; north and south facing
Roof Aging Farms

- 50 in. x 66 in. panels
  - 2 north-facing
  - 2 south-facing

- 36 in. x 36 in. panels
  - 1 north-facing
  - 1 south-facing
Roof Aging Farms: Areas of Focus

- 6/12 roof slope
- In-Service Length
  - Control (baseline)
  - 5-year
  - 10-year
  - 15-year
  - 20-year

- Similar colors
- Materials
  - 3-tab asphalt
  - Architectural asphalt
  - Traditional IR
  - Polymer Modified
Roof Aging Farms: Construction

- Both roof slopes instrumented with thermocouples
- Adjacent weather station
Roof Aging Farms: Data

Temperature (C)

Total Solar Rad (mJ)

Specimen 2013 F-20
TC 10-18, 27-34 South Face

Wx Station Ambient 2m T

Wx Station
N-Phase
S-Phase
Protection from the Top: Focus on the Roof

RESEARCH

CODE PROPOSALS

COMMUNICATIONS

OUTREACH & TRAINING

Roofing the Right Way

RE-ROOFING THE RIGHT WAY FOR SHINGLE ROOFS IN HURRICANE-PRONE AREAS

When it's time to replace your roof due to weather-related damage or simply age, follow the advice in this guide to improve the long-term performance of your new roof. When you're ready to get started, find a qualified roofing contractor. Proper installation directly impacts a roof's long-term performance. Now's the time to check the contractor's references and their insurance coverage (or "Professional Liability Insurance") and to talk to the contractor about your expectations.

NINE STEPS TO REPAIRING YOUR ROOF THE RIGHT WAY

1. Remove the old roof shingles. Remove the damaged shingles and nails at each location where the new shingles are to be installed. The nails are usually recessed into the roof deck; sawing off the wood fibers a little longer than the shingle thickness will help the nails protrude above the surface of the new shingles.

2. REPAIR DAMAGED ROOF DECKS. Any damaged areas should be cut out and repaired before installing the new shingles. Use a new wood patch of the same thickness and species as the existing roof deck. The patch should be at least 12 inches larger than the damage in all directions. Apply the patch with roofing cement and allow to dry before applying the new shingles.
Roofing Industry
Questions?

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