Hail – Understanding Impact Resistance

Each year, hail causes about 1.6 billion dollars' worth of damage to residential roofs in the United States. Hailstorms are most concentrated in the southern and central plains states, but have been observed almost everywhere that thunderstorms take place. Hailstorms can potentially cause damage to any exposed object, especially when hailstone diameters exceed one inch. The level of hail damage depends on the size, density, falling velocity and distribution of the hailstones, as well as the climate and the building structure.

Roofs are very susceptible to damage. Hailstones can cause more damage to low slope roofs than to high slope roofs, because the most damage occurs at a 90-degree angle impact. Therefore, a steep slope (6:12 and greater) will improve the impact resistance of a roof. In general, hailstone damage can be categorized into two types:

- Aesthetic damage
- Functional damage

Aesthetic damage is simply damage that has an adverse effect on the appearance but does not affect the performance of the roof. Functional damage results in diminished water-shedding ability and a reduction in the expected service life of the roof.

UL 2218 – Steel Ball Drop

The most effective way to reduce hail damage is to use impact resistant roof materials – like stone coated steel. In 1996, the Institute of Business and Home Safety (IBHS) and the Underwriters Laboratory (UL) developed the **UL 2218** classification, a national standard for roof impact resistance by rating materials Class 1 through Class 4, based on their resistance to the steel ball drop simulation test. A Class 4 rating is the toughest. The test evaluates the effect of impact from a steel ball at locations on the roof assembly selected to be most vulnerable – including the edges, corners, unsupported sections and joints. Here is the Rating Class summary:

- **Rating 1** Sample did not crack when hit twice in the same spot – 1.25 inch diameter steel ball
- **Rating 2** Sample did not crack when hit twice in the same spot – 1.50 inch diameter steel ball
- **Rating 3** Sample did not crack when hit twice in the same spot – 1.75 inch diameter steel ball
- **Rating 4** Sample did not crack when hit twice in the same spot – 2.00 inch diameter steel ball

The UL 2218 **"Standard for Impact Resistance of Prepared Roof Covering Materials"** Class 4 Impact Rating test simulates the damaging impact of a 2" size hail stone. The test drops a 2" steel ball onto the roof shingle/panel twice in the same spot and the shingle/panel cannot exhibit any signs of fracture – in DECRA's case, our panel can ***"show no evidence of tearing, fracturing, cracking, splitting, rupture, crazing or other evidence of opening"***. If the steel panel incurs an indent or impact site granule loss, this is considered aesthetic and not a functional damage warranty claim.

Steel Ball Drop Height and Kinetic Energy

Class	Steel Ball Diameter Inches	Distance Feet	Kinetic Energy ft.lbf
1	1-1/4	12	3.53
2	1-1/2	15	7.35
3	1-3/4	17	13.56
4	2	20	23.71

Why Is Impact Resistance Important?

Impact resistance is important because it's a measure of resistance to hail (and other debris). Generally speaking, you can't label something as "hail proof" but those products that have been classified as Class 4 have met the strongest level of resistance that UL has deemed appropriate. So purchasing roofing materials that are Class 4 rated means you will have a smaller likelihood of damage after a hail event or a storm where debris has made contact with your roof. Further, replacing a roof isn't the only expense when it fails in a hail storm – if a leak occurs, additional damage is likely to the building interior.

NBS Series 23 – Ice Sphere Air Cannon

Another test method involves propelling an ice sphere at a roofing target. The NBS Series 23 (Ice Sphere Method) is based on the work of a noted scientist Sidney Greenfeld. Using ice spheres, Greenfeld researched the hail resistance of various roofing materials. He utilized the **terminal velocities** and impact kinetic energies from earlier industry research which are primary values used today. NBS is the National Bureau of Standards, now known as the National Institute of Standards and Technology (NIST).

The NBS Series 23 test method is considered since laboratory cast ice spheres closely correlate with actual hailstones. The diameters of ice spheres tested are: 1", 1.5", 2", 2.5" and 3". The ice spheres are propelled from a compressed air-fired "hail gun" at velocities listed by the NBS Series 23 and impact selected targets on the roof sample. A gauge measures the hail gun compressed air pressure and a ballistics timer measures the spheres' velocities.

Ice balls are formed in silicone molds. Water mass is weighed for each mold diameter size, and then frozen at 10 degrees F. A known mass and velocity of each ice ball size allows for an accurate determination of the kinetic energy.

In actual hailstorms, smaller sized hail is most common to occur, and the frequency of hail generally decreases with increasing hailstone size. As hailstones fall to earth, they achieve a velocity approximating the terminal

velocity. Hailstone terminal velocity is the speed at which hail is falling when it strikes the ground. A hailstone of 0.4 inches diameter falls at a rate of 20 mph, while a hailstone of 3.1 inches diameter falls at a rate of 110 mph. Hailstone velocity is dependent on:

- Hailstone size
- Friction with air it is falling through
- Wind motion it is falling through
- Collisions with rain drops or other hailstones
- Melting as the stones fall through a warmer atmosphere

As hailstones are not perfect spheres, it is difficult to calculate their speed accurately.

NBS 23: Hail Velocity and Impact Energy Chart

Hail – Inches Diameter	Terminal Velocity	Approximate Impact Energy – ft lbs
1”	50 mph	<1
1.25”	56 mph	4
1.5”	61 mph	8
1.75”	66 mph	14
2”	72 mph	22
2.5”	80 mph	53
3”	88 mph	120
4”*	125 mph*	546*

*** Yes – you read that correct: A 4” diameter hailstone descends from the sky reaching 125 miles per hour, and strikes the ground with 546 foot-pounds of direct force!**

A hailstone terminal velocity increases with hailstone size, thus the impact energy (and the damage potential) of hailstones increases significantly with increased hail size. As an example, the impact energy of a 2” diameter hailstone – falling at terminal velocity – is more than 20x that of a hailstone measuring 1” in diameter.

DECRA Hail Lab Testing

All DECRA roof panel styles – **Shingle XD, Shake XD, Villa Tile, Shake, Tile, and Shingle Plus** – meet the **Class 4** impact resistance requirements of **UL 2218**. We re-tested UL 2218 for up to date compliance records in 2019: **QAI Laboratories, Rancho Cucamonga, CA; Evaluation Report No. RJ7006-EEV, dated May 31, 2019**.

In 1994, DECRA conducted **NBS Series 23** “Hail Resistance of Roofing Materials” testing with ice ball compressed air gun: **Terralab Engineers international, Salt Lake City, UT; Analysis No. 16481, dated January 25, 1994**

Per the cover narrative to Terralab's analysis report:

> ***"The above identified DECRA products withstood hailstones up to 3 inches in diameter without damage. The products also withstood without damage by impact from 4 inch hailstones. The 4 inch hailstones are not part of the NBS Series 23 and were shot for client information purposes only."***

Summary

DECRA's roofing systems have excelled through some of the harshest weather conditions around the world for over 60 years. DECRA Roof Systems are covered by a Lifetime Limited Warranty (50 Years Warranty for commercial buildings), and includes separate warranty coverage clauses for both wind uplift AND hail penetration (UL 2218 Class 4 Impact Resistant). DECRA's hailstone warranty coverage sets no limit as to the hailstone size – a testament to our industry-setting quality standards back by the strength and integrity of DECRA Roofing Systems, Inc.

Hail Trivia

Heaviest Hailstone: 2.25 lbs; Gopalganj District, Bangladesh – April 14, 1986

- Look Out Below: This hailstorm in Gopalganj District, Bangladesh killed 92 people, with hailstones weighing in at up to 2 pounds each!

Largest Diameter Officially Measured: 7.9 inches diameter, 18.6 inches circumference; Vivian, South Dakota – July 23, 2010

Largest Circumference Officially Measured: 18.74 inches circumference, 7.0 inches diameter; Aurora, Nebraska – June 22, 2003

- The National Severe Storms Laboratory deems this the largest hailstone recorded in the U.S. – about the size of a soccer ball!

Hail and Farewell: In 1360, A hailstorm outside Paris, France killed hundreds of invading English soldiers. King Edward III soon gave up his conquest of France.