Feature

Impact Resistance of Roof Coverings

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HAIL DAMAGE TO roof coverings has become a significant, multibillion-dollar issue in the US and other parts of the world. According to CAPE Analytics, annual losses from hailstorms in the US have surged from approximately $1 billion per year in the 1990s to between $8 billion and $15 billion in 2021. Roofs, in particular, are cited as "the most exposed and vulnerable part of any structure during hailstorms."[1,2]

This increase in damage costs is largely due to the growing frequency and severity of hail events, as well as "urban sprawl"—the expansion of populated areas vulnerable to hailstorms. Just as hurricanes and other extreme weather events have intensified due to changing climate patterns, hail too has become more frequent and severe. Severe hail is now a reasonably foreseeable weather event in many regions of the US, underscoring the need for proactive preparation and mitigation strategies.

One of the most effective approaches to mitigate hail damage is requiring hail-resistant roofing systems in regions prone to hailstorms. According to FM, "Hailstorms are a widespread hazard affecting many areas of the world that can severely damage building roofs … providing hail-resistant exterior building components and equipment can greatly reduce this hazard."[3]

This article provides a historical perspective of changes in roof construction that have influenced the hail resistance of roof coverings. It further examines the current codes and standards related to hail resistance and the shifts in the geographical regions impacted by damaging hailstorms, and it proposes a rational approach to implement reasonable impact-resistant requirements into building codes.

IMPACT RESISTANCE IN THE *INTERNATIONAL BUILDING CODE*

The International Code Council published the first version of the *International Building Code* (IBC) in 2000.[4] This first edition of the IBC recognized the need for impact (hail) resistance and contained Section 1504.6, Impact Resistance. The 2000 edition of the IBC dictated that standard low-slope roof coverings should resist impact damage based on the standards discussed below:

- ASTM D3746, *Standard Test Method for Impact Resistance of Bituminous Roofing Systems*, is a hail resistance standard specifically for built-up roofs. The test method involves impacting a bituminous roofing sample with a steel missile calibrated to simulate the impact energy of a 2 in. (50 mm) hailstone generated approximately 22 ft-lb (30 J) of impact energy. The standard provides a damage rating scale ranging from 0 for no damage, 2 for dents only, and 4 for any cracks or splits. The standard does not establish acceptance criteria per se.[5]
- The 1986/1992 editions of FM 4470 Approval Standard, *Class 1 Roof Covers,* included hail resistance tests in Appendix F, Susceptibility to Hail Damage Test Standard for Class 1 Roof Covers.[6,7] These tests utilize steel balls dropped from a height calibrated to simulate impact from *moderate hail*, defined as 1.5 in. (38 mm) hail (~8 ft-lb [11 J] impact energy), and from *severe hail*, defined as 1.75 in. (44 mm hail) (~14 ft-lb [19 J] impact energy). The protocol's pass-fail acceptance criterion states that the roof covering shall show no signs of "cracking or splitting under 10x magnification" and that field seams (if present) shall show no signs of "cracking, splitting, separation, or rupture when examined under 10x magnification."[6,7] NOTE: The April 2022 version of FM 4470 is titled *Examination Standard for Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR) and Liquid Applied Roof Assemblies for Use in Class 1 and Noncombustible Roof Deck Construction.*[8]
- ASTM D4272, *Standard Test Method for Total Energy Impact of Plastic Films by Dart Drop*, is not a roofing standard. It is a test method for testing plastic films like polyethylene and polypropylene. It is an impact resistance standard, but it is not applicable to roofing.[9] (This standard should not have been included and creates ambiguity within the standard.)
- CGSB 37-GP-52M, *Roofing and Waterproofing Membrane, Sheet Applied, Elastomeric,*[10] is a standard created by the Canadian General Standards Board that applies to sheet-applied elastomeric membranes, which has since been withdrawn. Among other properties, this standard includes a test for mechanically caused impact damage. The "Dynamic Impact 6.8 N (Puncturing) Test" involves dropping a 2.24 lb (6.8 N) weight onto an impactor rod measuring slightly less than 0.5 in. 1.6 J in diameter to generate approximately 1.18 ft-lb (13 mm) of impact energy. This test primarily addresses resistance to mechanical damage and is not correlated to the impact energy from hail impact.

IMPACT RESISTANCE IN THE *INTERNATIONAL RESIDENTIAL CODE*

The 2006 edition of the *International Residential Code* (IRC) added Section R903.5.[11] The IRC standard not only provided a hail resistance benchmark but also offered a map to guide its implementation. This made it a more practical and user-friendly standard compared to the one included in the IBC. The map shown in **Fig. 1** is derived from Figure 903.5, Hail Exposure Map, from the 2006 IRC,[11] and it illustrates the regions where the impact resistance standard was applicable.

However, the roof impact resistance standard was removed from the IRC in the 2009 edition. To date, an impact resistance standard has not been reinstated in the IRC.

CHANGES IN THE IBC IMPACT RESISTANCE STANDARD

In the 2006 edition of the IBC, Section 1504.7, Impact Resistance, was revised such that a general reference to FM 4470 was removed and replaced with a specific reference to the "Resistance to Foot Traffic" test standard in Section 5.5 of FM 4470 (1986/1992 version of 4470).[12]

"**1504.7 Impact resistance**. Roof coverings installed on low-slope roofs (roof slope < 2:12) in accordance with Section 1507 shall resist impact damage based on the results of tests conducted in accordance

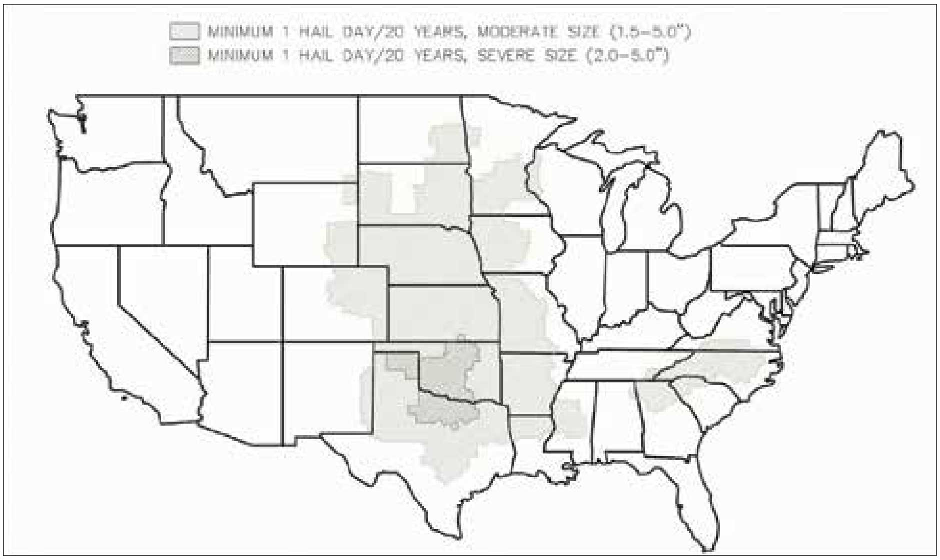

Figure 1. *Map shown is derived from Figure 903.5, Hail Exposure Map, from the 2006 International Residential Code.*[11]

with ASTM D3746, ASTM D4272, CGSB37-GP-52M or the "Resistance to Foot Traffic" test in Section 5.5 of FM 4470."[12]

The **"**Resistance to Foot Traffic" test in Section 5.5 of FM 4470 (1986/92) is unrelated to hail impact resistance, making its inclusion in IBC Section 1504.7 confusing. The criteria for passing this test state that there should be no "tearing or cracking of the protective coating causing exposure of the plastic, glass fibers, foam or other compressible core material." This language implies that this test is generally applicable to cover boards and insulation, rather than the roof covering itself. The test essentially simulates a 200-lb (890 N) worker stepping on a rock or other object resting on the roof surface. Consequently, the modification of this reference standard in the 2006 IBC shifted the focus from a general impact (including hail) resistance standard to a specific test assessing a roof covering's ability to withstand foot traffic.

"5.5 Resistance to Foot Traffic

5.5.1 Requirements

The ability of the roof cover-insulation to resist foot traffic shall be verified.

5.5.2 Test/Verification

1) A 3 in. (76 mm) square steel plate with rounded corners shall be centered on the centerline of a 2 in. (305 mm) square horizontal panel and positioned along the butt edge and side joint of the insulation boards.
2) A 200 lb (890 N) load shall be imposed on the plate. The superimposed load shall be reduced to zero and the sample cover reloaded a minimum of four additional times, with penetration and residual reading taken each time without removing the plate. The specimen shall be inspected after the test and the condition of the cover noted at the steel plate interface.
3) Tear or cracking of the protective coating causing exposure of the plastic, glass fibers, foam or other compressible core material shall be unacceptable."[6]

The previous, broader reference to FM 4470, which encompassed various impact resistance tests, including those for hail, was narrowed in this version of the IBC, leaving the section without practical applicability for its stated purpose. Rather than addressing hail or similar impact scenarios, the revised 2006 IBC standard stipulated that a roof covering should meet one of four unrelated criteria, and "Resistance to Foot Traffic" is among them. This removed the specificity required to evaluate roofing materials for hail resistance and essentially rendered this section of the IBC ineffective as an impact resistance guideline. The omission of a direct hail resistance requirement reduced clarity and usability in regions where hail is a significant concern.

In 2018,Section 1504.7 of the IBC was amended to remove the reference to CGSB 37-GP-52M, while retaining the "Resistance to Foot Traffic Test" from Section 5.5 of FM 4470.[13] It is important to note that the current edition of FM 4470 contains a hail resistance requirement in Section 4.4, Hail Damage Resistance, though the IBC did not reference this section.

PERTINENT IMPACT RESISTANCE STANDARDS

Noticeably absent from Section 1504.6, Impact Resistance, in the 2000 IBC was the UL 2218 standard. UL 2218 was an active standard in 2000 that was commonly used and widely referenced by roofing manufacturers to establish hail resistance of roof coverings. **Table 1** is a representative table developed from Table 5.1, Drop Height and Kinetic Energy, from UL 2218.[14]

The Underwriters Laboratories (UL) test standard employs falling steel balls to simulate the impact energy of hailstones, similar to FM 4470 for moderate hail and severe hail ratings. FM very severe hail ratings use ice balls. The UL protocol includes a pass-fail acceptance criterion that there shall "show no tearing, fracturing, cracking, splitting, rupture, crazing or other evidence of opening through any prepared roof covering layer" when examined under 5x magnification. Roofing manufacturers commonly list their products as meeting UL Class 1 through 4, depending on their tested resistance.

As previously discussed, the FM 4470 standard provides a hail resistance test, making it a suitable standard for impact resistance. Additionally, FM has another widely used impact testing standard: ANSI/FM 4473, *American National Standard for Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls*.[15] Like UL 2218, this standard includes four classifications based on the simulated impact energy of hailstones. The key difference is that ANSI/FM 4473 uses ice balls instead of steel balls to simulate hail impact more realistically. **Table 2** reproduces FM's chart depicting the hail classifications and simulated impact kinetic energy range.

Testing with ice balls provides a better correlation to real-world conditions, as ice balls more closely mimic the physical properties of hailstones, including their density, texture, and

TABLE 1.
This shows a representative table developed from Table 5.1, Drop Height and Kinetic Energy, of UL 2218.[14]

Class	Steel ball diameter, in. (mm)	Distance, ft (m)	Kinetic Energy, ft-lb (J)
1	1.25 (31.8)	12 (3.66)	3.53 (4.79)
2	1.50 (38.1)	15 (4.57)	7.35 (9.97)
3	1.75 (44.5)	17 (5.18)	13.56 (18.38)
4	2.00 (50.8)	20 (6.09)	23.71 (32.15)

TABLE 2.
This table reproduces FM's chart depicting the hail classifications and simulated impact kinetic energy range

Class	Nominal ice ball diameter, in. (mm)	Kinetic Energy	
		Target, ft-lb (J)	+10% ft-lb (J)
1	1.25 (31.8)	3.72 (5.0)	4.09 (5.5)
2	1.50 (38.1)	7.77 (10.4)	8.55 (11.6)
3	1.75 (44.5)	14.00 (19.0)	15.40 (20.9)
4	2.00 (50.8)	23.75 (32.2)	26.13 (35.5)

deformation upon impact. Ice balls distribute impact energy in a way that better replicates the energy transfer from natural hailstones. Steel balls, while consistent in size and mass, have a much higher density than hailstones and do not meaningfully deform or shatter upon impact, delivering a concentrated, more localized force. These properties can exaggerate damage in certain roofing materials, such as tile and slate.

HAIL-PRONE REGIONS

There are well-known hail-prone regions in the US, often referred to as the "hail belt." The size and location of these areas have shifted over time due to changing climate patterns. Historically, the hail belt was generally considered to be a regional issue, which was representative of the map included in the 2006 IRC (**Fig. 1**). FM publishes FM Property Loss Prevention Data Sheets (DS) to provide guidelines to minimize the potential for property damage. *FM Property Loss Prevention Data Sheet 1-34: Hail Damage* (FM DS 1-34) is the FM data sheet that deals with hail damage. FM DS 1-34 includes maps that are based on National Weather Service and property loss data that represent the areas of the country that are subject to damaging hail. These maps have changed over time. **Figure 2** shows the approximate areas of the US where severe hail and moderate hail could be expected in 2009. As previously stated, FM historically defined *moderate hail* as 1.5 in. (38 mm) hail and *severe hail* as 1.75 in. (44 mm) hail.

In 2014, FM DS 1-34 revised the hail hazard map to include an area of very severe hail that generally represented the historical hail belt shown in Fig. 1. **Figure 3** shows the approximate areas at risk for very severe hail, severe hail, and moderate hail in 2014.

In conjunction with changes to the maps in 2009 and 2014, there were also changes to the hail resistance rating required for each of the very severe, severe, and moderate hail exposure risks that correspond to the map in Fig. 2 and 3, respectively.

The 2009 classifications were similar to the classifications in UL 2218 and are the testing standard classifications most roofing manufacturers use to test the hail resistance of their roofing systems.

In 2018, FM once again revised the Hailstone Hazards Map, enlarging the area where very severe and severe hail can be expected, as shown in **Fig. 4**.

In 2022, FM DS 1-34 revised their map showing the areas where hail with diameters greater than or equal to 3 in. (76 mm) and greater than 4 in. (102 mm) fell based on National Weather Service data between 2009 and 2021. The FM map shown in **Fig. 5** generally correlates to the maps produced by the National Oceanic and Atmospheric Administration (NOAA) that are shown in **Fig. 6**.[16] The important difference is that FM assigns hail-resistant classifications to their maps. The FM hail-resistant classifications are based on industry standard testing protocols that roofing manufacturers and others rely on.

HAIL RESISTANCE OF ROOFS

Hail is a normally occurring weather event in most of the US. The size and frequency of hail depend on the geographical region of the country, as the hail maps discussed previously show. Numerous hailstorms can be expected to occur over the life of any given building in most areas of the US.

The size of the hail and the impact energy of the hail are critical in the evaluation of hail damage on roofs. Impact energy is a measure of the potential for hail to damage a roof covering. The higher the impact energy, the more likely the hailstone will damage a roof. The weight and impact energy of a hailstone both increase exponentially with the increase in the diameter of the hailstone. For example, 2 in. (51 mm) hail has almost 17 times the impact energy of 1 in. (25 mm) hail, and 0.5 in. (13 mm) hail only has 6% of the impact energy of 1 in. hail. **Table 3** shows the impact energy of falling hail based on National Bureau of Standards (NBS) data.[17]

Roofs should be able to resist reasonably foreseeable weather events, and hail is a reasonably foreseeable weather event. There have been a number of studies related to the hail resistance of commonly used roofing products, and most manufacturers publish hail resistance ratings of their various systems typically based on UL 2218 or FM 4473 Class 1 through 4 hail resistance ratings or FM 4470 moderate hail, severe hail, or very severe hail.

Based on our research, the first comprehensive hail resistance tests of commonly used roofing

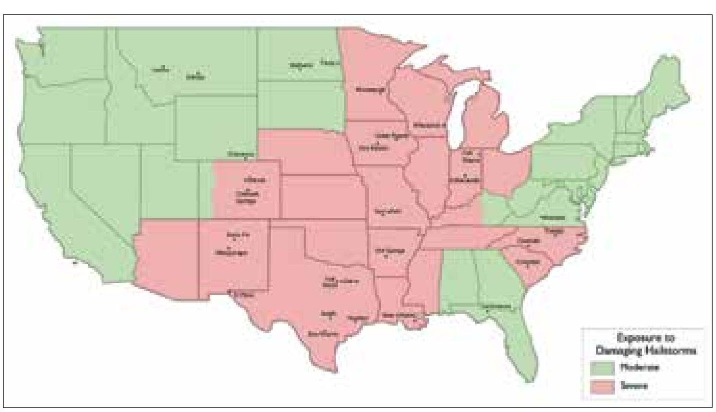

Figure 2. *A map showing the approximate areas of the US where severe hail and moderate hail could be expected in 2009.*

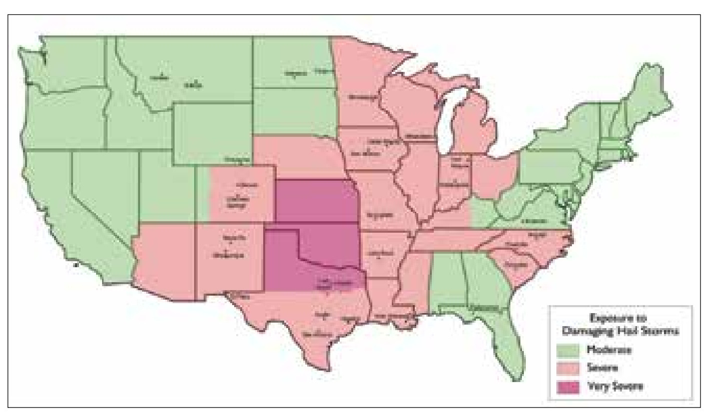

Figure 3. *A map showing the approximate areas of the US at risk for very severe hail, severe hail, and moderate hail in 2014.*

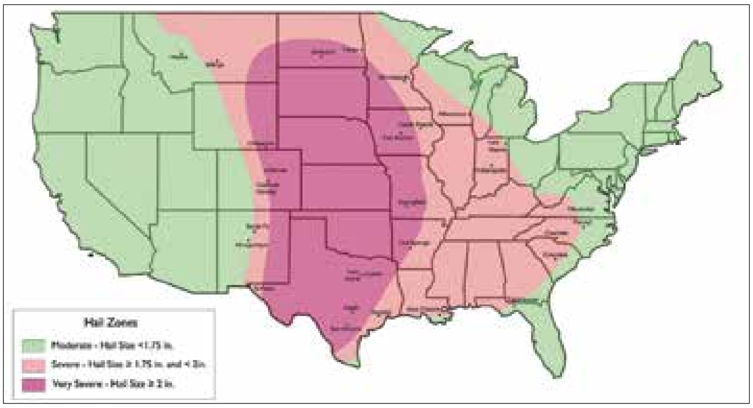

Figure 4. *In 2018, FM revised their Hailstone Hazards Map, enlarging the area where very severe and severe hail can be expected.*

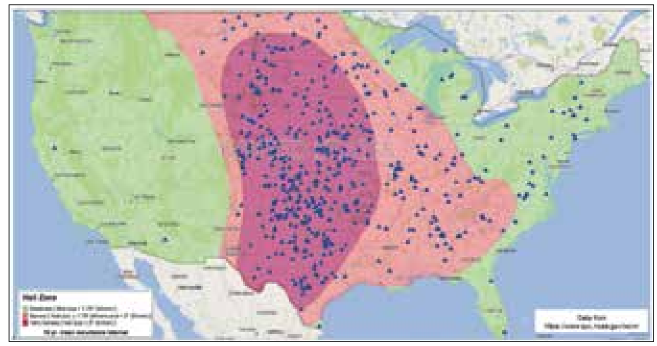

Figure 5. *In 2022, FM DS 1-34 revised the map showing the areas where hail with diameters greater than or equal to 3 in. (76 mm) and greater than 4 in. (102 mm) fell based on National Weather Service data between 2009 and 2021.*

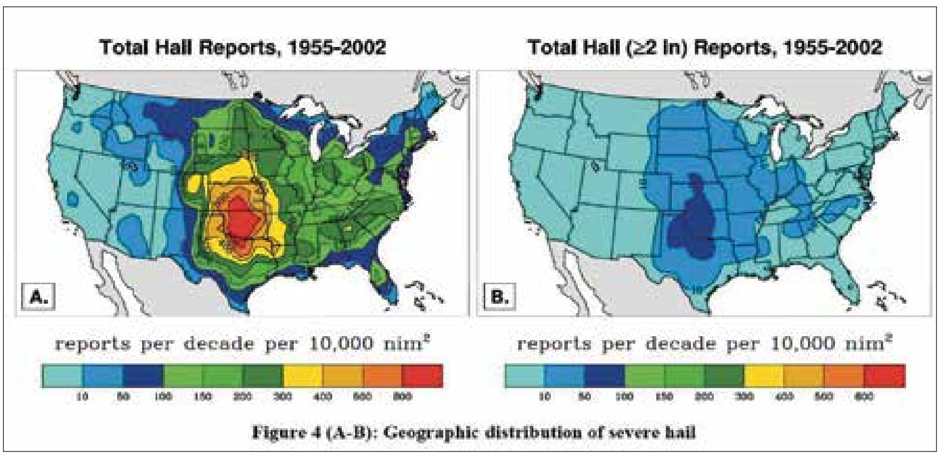

Figure 6. *The maps produced by the National Oceanic and Atmospheric Administration (NOAA),[16] which generally correlate to the FM map shown in Fig. 5.*

TABLE 3.
Data developed in Building Science Series 23: Hail Resistance of Roofing Products *(NBS study) in 1969*[17]

Size in. (mm)	Weight lb (kg)	Free Fall Velocity mph (kmh)	Impact Energy ft-lb (J)
1.00 (25.40)	0.017 (0.008)	49.8 (80.2)	1.43 (1.93)
1.25 (31.75)	0.034 (0.015)	55.9 (90.0)	3.53 (4.79)
1.50 (38.10)	0.058 (0.026)	61.4 (98.8)	7.35 (9.97)
1.75 (44.45)	0.093 (0.042)	66.2 (106.5)	13.56 (18.38)
2.00 (50.80)	0.138 (0.062)	71.6 (115.2)	23.71 (32.15)
2.25 (57.15)	0.197 (0.089)	75.7 (121.8)	37.73 (51.16)
2.50 (63.50)	0.270 (0.122)	79.8 (128.4)	57.48 (77.93)
3.00 (76.20)	0.467 (0.212)	88.6 (142.6)	122.66 (166.30)
3.50 (88.90)	0.742 (0.336)	97.5 (156.9)	235.67 (319.53)
4.00 (101.60)	1.108 (0.502)	105.7 (170.1)	413.31 (560.37)

products and systems were performed by the NBS, and the results were published in *Building Science Series 23: Hail Resistance of Roofing Products* (NBS study) in 1969.[17] This study developed the data for Table 3 and included a map similar to the maps in FM DS 1-34. The NBS study tested a variety of built-up roofs and asphalt shingles as well as commonly used non-bituminous roofs, including asbestos cement shingles, slate shingles, cedar shingles, red clay tiles, and terne-coated standing-seam metal roofs. The NBS study tested roofs over various substrates and concluded that roofs installed on firm substrates were more hail resistant. The hail resistance of the various tested systems varied, but both the aggregate-surfaced built-up and metal roofs were the most hail resistant roofs and were not damaged by hailstones up to 2.5 in. (64 mm).[17] The general criteria for failure was fracturing of the roof covering, and the thresholds of failure were the smallest hail size producing these failures.

At the time of the NBS study, almost 100% of the low-slope roof systems were built-up roofs.[18] That changed dramatically when oil embargoes in the 1970s caused asphalt prices to soar, opening the door for ethylene propylene diene terpolymer (EPDM), polyvinyl chloride (PVC), and other low-slope roofing options. Today, single-ply roofing makes up more than 80% of the low-slope roofing, and thermoplastic polyolefin (TPO) is the most commonly used.[19] The hail resistance of these systems varies tremendously depending on many variables. Haag Engineering has performed hail impact resistance studies of commonly used roofing systems today. **Figure 7** shows the thresholds of damage for common roofs adapted from Haag's "Hail Damage Thresholds: What Do They Really Mean?"[20] The threshold of damage is the smallest hail size to create a failure, and failure is generally defined as a fracture in the roof covering.

Most roofing manufacturers publish the hail resistance of their various roofing systems. All commonly used roofing systems have some hail resistance and can be classified as Class 1, 2, 3, or 4 or mild hail, severe hair, or very severe hail. Using the data in Fig. 7, built-up roofs (smooth or aggregate surfaced), EPDM (smooth or ballast surfaced), metal panels, and some modified and thermoplastic roofs meet Class 4 hail resistance.

Unlike the NBS study, Haag does not include testing related to substrates in this study. As NBS recognized, the firmness of the substrate is an extremely important factor in the hail resistance

Roofing System	Threshold of Damage
Built-up roofs (smooth)	2 inches
Aggregate surfaced built-up roofs	2.5 inches
Modified bitumen membranes	1.5 to 2 inches
EPDM membranes (smooth)	2 inches
Ballasted EPDM membranes	2.5 inches
Galvanized steel panels	2.5 inches
Thermoplastic membranes	1 to 2 inches

Figure 7. *This figure shows the thresholds of damage for common roofs adapted from Haag's "Hail Damage Thresholds: What Do They Really Mean?"*[20]

of roofing systems. The introduction of firm cover boards has made a tremendous difference in the hail resistance of roofs. **Figure 8** is an illustration of what happens when large hail impacts a roof with a soft substrate. The soft substrate crushes or deforms, so the roof membrane is subjected to tensile forces on the bottom of the roof membrane and compressive forces on the top of the roof membrane. If these forces are large enough, a fracture can develop in the roof.

The introduction of a firm cover board can significantly improve the hail and puncture resistance of a roof system. In response to the increasing frequency of hail and increasing size of hail being reported, FM introduced a very severe hail (VSH) rating, which is defined as resistant to 2.5 in. (64 mm) hail with an impact energy of 53 ft-lb (72 J). The key to meeting these higher ratings is the firm cover boards. It should be noted, however, that of the 33,000 VSH rated roofs in the RoofNav database, over 4400 do not require a coverboard. More and more roofing systems are being tested for the very severe hail rating.

On one project in 2023, Rooftech inspected 38 buildings in Austin, Texas, that had been impacted by hail ranging in size from 1.75 in. (44 mm) to more than 3 in. (76 mm) in diameter. Many of the roofs were thermoplastic, typically TPO, single-ply roof membranes over dense cover boards that met FM's criteria for severe and very severe hail ratings. Most of the roofs with hail 2 in. (51 mm) or larger were damaged and had been installed over a soft substrate. None of the roofs installed over dense cover boards were damaged by hail, even from hail in the 3 in. range. The use of hail-resistant roofs over dense cover boards saved millions of dollars. **Figure 9** shows a map of the estimated maximum hail size occurring in Austin on September 24, 2023. The map is based on a proprietary evaluation of the meteorological data. The 38 locations inspected are shown on the map.

Figure 10 shows spatter marks consistent with 2.5 in. to 3 in. (64 to 76 mm) hail on the TPO roof membrane. Note that there are no indentations in the roof at the impact, as the TPO was supported by a dense, impact-resistant cover board.

Figure 11 shows some of the collateral damage. The solar panels were literally destroyed, and the fractures in the panels were in the 2.5 in. (64 mm) to 3 in. (76 mm) range. The conclusion was that the installation of hail-resistant roof systems prevents hail damage from the vast majority of hail events.

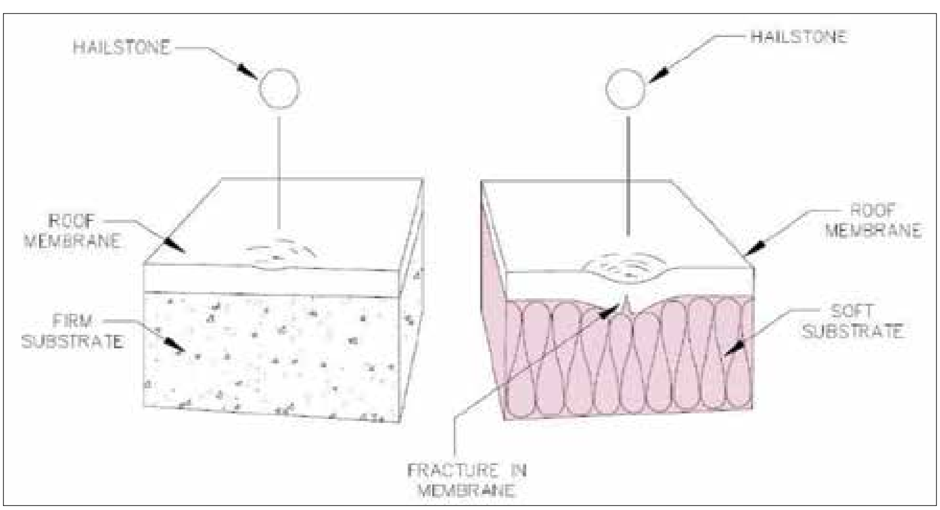

Figure 8. *An illustration of what happens when large hail impacts a roof with a soft substrate.*

A RATIONAL APPROACH FOR IMPACT RESISTANCE STANDARDS

Hail damage to roofs in the US has become one of the biggest problems in the roofing industry, literally costing billions of dollars a year in roof damage. It is critical that our codes and standards address this problem, particularly in light of the increasing frequency and intensity of thunderstorms and hail occurrences. The data and standards are already in place. We know where large hail can be expected to occur, and the maps in FM DS 1-34 represent reasonably current data that are consistent with NOAA's maps of hail activity.[16] We know what hail resistance is required to resist reasonably foreseeable hail events. Manufacturers and others have been testing roof systems for hail resistance going back at least to 1969. Most manufacturers already publish the hail resistance of their roofing products and systems, and many, if not most, of these systems meet reasonable hail standards.

What is needed is a rational approach to address this multi-billion-dollar-a-year roofing problem. The best approach is to amend the Impact Resistance section in the IBC so that the standards reflect the current industry standard hail impact testing standards and provide a map identifying areas where appropriately rated hail resistant roofs are required. Below is a simple revision to the code that addresses all these issues.

1504.7 Impact resistance. Roof coverings installed on low-slope roofs in accordance with Section 1507 shall resist impact damage based on the results of tests conducted in accordance with the Hail Damage Resistance test of FM 4470 or UL 2281. Hail resistance exposure shall be determined by **Fig. 12**, which is derived from the map in FM DS 1-34.

Figure 9. *This map shows the estimated maximum hail size occurring in Austin on September 24, 2023. The map is based on a proprietary evaluation of the meteorological data. The 38 locations inspected are shown on the map.*

Figure 10. *Spatter marks consistent with 2.5 in. (64 mm) to 3 in. (76 mm) hail on the thermoplastic polyolefin roof membrane.*

Figure 11. *The solar panels were destroyed by hail, and the fractures in the panels were in the 2.5 in. (64 mm) to 3 in. (76 mm) range.*

Figure 12. *This map shows hail resistance exposure.*

1504.7 Impact resistance. Roof coverings installed on low-slope roofs in accordance with Section 1507 shall resist impact damage based on the results of tests conducted in accordance with the Hail Damage Resistance test of FM 4470, 4473, or UL 2281. Hail resistance exposure shall be determined by Fig. 16, the Hail Zone map included in FM DS 1-34 2023 and as defined in Sections 1504.7.1, 1504.7.2, and 15047.3.

1504.7.1 Moderate Hail Exposure. One or more hail days with hail diameters < 1.5-inch (38-mm) over a 15 year mean recurrence interval. Roof covering shall meet ANSI FM 4473 or UL 2218 Class 2 hail resistance.

1504.7.2 Severe Hail Exposure. One or more hail days with hail diameters < 1.75-inch (44 mm) over a 15 year mean recurrence interval. Roof covering shall meet ANSI FM 4473 or UL 2218 Class 3 hail resistance.

1504.7.3 Very Severe Hail Exposure. One or more hail days with hail diameters < 2.0-inch (51 mm) over a 15 year mean recurrence interval. Roof covering shall meet ANSI FM 4473 or UL 2218 Class 4 hail resistance.

Note: NOAA's National Centers for Environmental Information Storm Events Database ("https://www.ncdc.noaa.gov/stormevents/" Storm Events Database | National Centers for Environmental Information) provides data related to the size of hail reported by county that is searchable over a selected day, month, and year range. The database can easily be searched for the size of hail occurring over the past 15-year interval.

This rational approach to hail impact resistance has the potential for saving billions of dollars in roofing damage and reducing the waste associated with removing and replacing roofs and insulation. It makes no sense to install a roof over a soft substrate in an area where severe hail is likely to fall. In every case, the roofs installed over soft substrates that Rooftech inspected in Austin failed, while the roofs installed over dense substrates resisted severe and very severe hail. The solution to this problem is relatively simple, and our rational approach should be adopted by the IBC.

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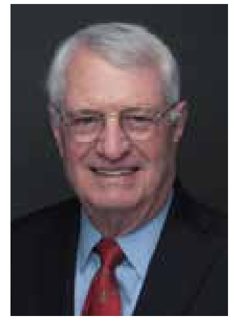

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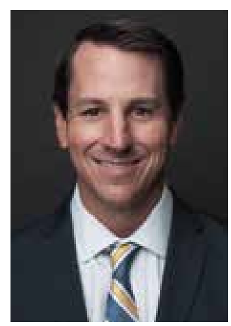

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