The Effects of Hail on Metal Roofing Systems

Jim D. Koontz, RRC, PE, and Troy L. White, PE

Jim D. Koontz & Associates, Inc.

3120 North Grimes, Hobbs, NM 88240

Phone: 575-392-7676 • Fax: 575-392-7602 • E-mail: jim@jdkoontz.com and troy@jdkoontz.com

Abstract

The purpose of this study is to evaluate the effects of hail size on metal roofing and its ability to shed water over an extended period of time. Substantial indentation at side laps, end laps, or at the juncture with concealed clips can result in conditions that may affect water-shedding capabilities. Commonly used metal roof panels will be impacted by variably sized ice spheres at multiple locations across the panel per National Bureau of Standards 23. Panels will then be visually inspected and subjected to laboratory testing to determine effects on water-shedding capability and coating resilience and performance.

Speakers

Jim D. Koontz, RRC, PE – Jim D. Koontz & Associates, Inc.

Jim Koontz, president of Jim D. Koontz & Associates, Inc., is a graduate of Tulane University with a bachelor of science degree in engineering and a master's in business administration. Koontz has been involved in the roofing industry since 1960 and began testing roofing material in 1976. He has experience as a roofer, estimator, consultant, lecturer, researcher, and expert witness. Koontz was first published in 1984 and has numerous articles relating to roofing material/product research to his credit.

Troy L. White, PE – Jim D. Koontz & Associates, Inc.

Troy White received a master's degree in civil engineering from Texas Tech University in Lubbock in 2002 and became a registered professional engineer in Texas and New Mexico in 2005 and 2008, respectively. He has worked as a construction observer, designer, and project manager in civil and architectural firms since March 2000. White recently became an associate with Jim D. Koontz & Associates, Inc. and currently serves as a construction observer, field investigator, and research associate within the firm. His experience ranges from industrial and public works infrastructure to roofing systems design, construction observation, and damage and failure analysis.

The Effects of Hail on Metal Roofing Systems

ABSTRACT

The purpose of this study is to evaluate the effect of hail on metal roofing. Metal roofing systems utilized on both steep- and low-sloped roofs constitute a major market share of the roofing industry. The function of metal roofs obviously can vary from a simple water-shedding capacity that protects the building, to wind resistance, fire resistance, aesthetics, and potentially some hail resistance.

Within a substantial area of the United States, hail occurrence is common (refer to the hail map[1] in *Figure 1*). Dependent upon geographical location, metal roofs are often impacted by hail, resulting in permanent indentations. Significant insurance claims are filed as a result of these indentations, with disputes arising as to whether the indentations constitute actual physical loss or damage. Substantial time and expense are expended to resolve these claims. The extent to which these indentations affect the functional attributes of the metal roof system—including water-shedding capacity, wind resistance, aesthetic value, material longevity, and corrosion resistance—is a common issue in these claims debates.

In exceptionally rare cases, metal roofs impacted with very large hail may split at the site of impact. Substantial indentations at side laps, end laps, or at the juncture with concealed clips can result in conditions that may affect water-shedding capabilities of a metal roof. Minor indentations may have little to no effect on roof performance over an extended period of time. Aesthetics of hail indentations to metals roofs also come into consideration when assessing reported damage.

To evaluate the effect of hail impact on various metal roofing systems, two methods of impacting metal roofs were utilized. Both ice and steel spheres were used to impact selected metal roofing systems. A pneumatic launcher was used to fire ice spheres at metal roofs. The ice spheres were propelled at velocities listed by the National Bureau of Standards (NBS) Building Science Series No. 23.[2] The metal roofing systems were also impacted with steel spheres by methods listed by Underwriters Laboratories (UL)[3] and by procedures listed in the marketing literature published by the metal roofing manufacturers.

Some metal samples indented during naturally occurring hail events were also examined and impacted. Comparisons were made of naturally occurring hail indentations and indentations that were a result of laboratory testing. Observations were made of differences between impacting a metal roof with steel spheres or with ice.

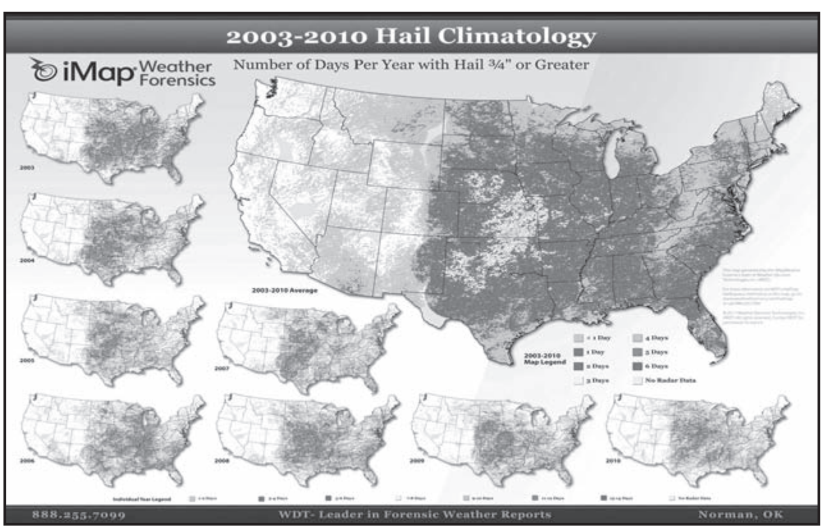

Figure 1 – Hail climatology map.

INTRODUCTION

Mankind has used various types of metal roofing for thousands of years. Historically, the first metals used included both lead and copper. In some cases, the roofs had a service life of over a century. The temple in Jerusalem was reportedly covered with a copper roof in 970 BC.[4] In more recent years, corrugated metal and various types of configurations of metal roofing have been utilized. Copper, although still widely used in some applications, has been more commonly replaced with coated-steel metals. The coating over the steel is to provide enhanced corrosion resistance. Today, metal roofs are commonly coated with galvanized zinc, aluminized steel, aluminum-zinc coatings, and a variety of polymer coatings and films.

Two basic configurations of metal roofing are widely used today: metal roofing mechanically attached with exposed fasteners, and variations of standing-seam metal roofing secured with concealed clips. Metal roofing can be installed on slopes as low as ¼ in. per ft.

MANUFACTURERS' MARKETING LITERATURE

In 1998, the Texas Department of Insurance (TDI)[5] instituted a program in which homeowners would receive discount insurance rates if their residences were covered with hail-resistant roofing. The reduction in insurance rates does not apply to commercial structures.

The methodology used by TDI to determine hail resistance consists of impacting roofing products according to UL test procedure 2218. The UL 2218, Class 4 test requires dropping a 2-in.-diameter steel sphere from a height of 20 ft. The resultant impact energy is equivalent to the impact from a 2-in. hailstone falling at terminal velocity. The UL test requires two impacts at the same location. After impact, visual damage observation is to be made with 5x magnification. The acceptance criteria,

FM 4471

Rating	Height of Drop	Diameter of Steel Sphere	Impact Energy
Class 1 – Severe hail	17 feet 9.5 inches	1.75 inches	14 ft-lbf.
Class 1- Moderate hail	5 feet	2.0 inches	8 ft-lbf.

Table 1 – FM 4471.

according to UL 2218, are as follows:

> The report requires measurements of the depth of depression and a determination of any tearing, fracturing, cracking, splitting, rupture, crazing, or other evidence of damage to the roofing system. A pass/fail determination is then made.

Numerous metal roofing manufacturers have submitted their products for testing and are marketing their products for compliance with UL 2218. The TDI[6] website lists 28 roofing manufacturers that represent their metal roofing products as passing UL 2218, Class 4.

Metal roofing manufacturers may also market their roofing systems as being in compliance with Factory Mutual (FM) 4471.[7] Under FM 4471, two steel-sphere impact tests are utilized (see *Table 1*). The impact energy of the resultant FM Severe Hail rating is less than the UL 2218, Class 4 impact energy (4 ft-lbf. [foot-pound force] versus 23.71 ft-lbf). The FM Moderate Hail rating is slightly higher than the UL Class 2: 8 ft-lbf. versus 7.35 ft-lbf.

Roof systems that pass the tests are rated either Moderate Hail- or Severe Hail-resistant. FM also allows the use of ice sphere testing according to FM 4473.[8]

> Class 1 panel roofs shall be able to withstand the effects of hail. Panels shall show no evidence of puncture or chipping, peeling, blistering, cracking, or crazing of the coating when examined under 10x magnification.

Some metal manufacturers warrant that their products will be hail-resistant. These manufacturers define hail damage as penetration completely through the panel or cracks/splits of the panel's steel substrate around the point of impact. Other metal manufacturers may list a resistance to hail up to hailstones less than 2.5 inches in diameter. The claimed hail resistance of some of these roofing systems is obviously a part of the manufacturer's marketing features.

BUILDING CODES

Per the International Building Code (IBC)[9] Section 1502, "roof covering" is defined as "the covering applied to the roof deck for weather resistance, fire classification, or appearance."

Under Section 1504, paragraph 1504.7, roof coverings installed on low-slope roofs (roof slope <2:12) shall resist impact damage based on the results of test procedures developed by The American Society for Testing and Materials[10] (ASTM) D3746 and the Canadian General Standards Board[11] (CGSB) 37-GP-52M.

ASTM D3746 and CGSB 37-GP-52M involve impacting a roof system with a steel dart dropped from a prescribed height. The ASTM laboratory procedures were originally developed for testing built-up roofing. The Canadian test was developed for both bituminous roofing and single-ply roofing. The testing has been utilized for all types of roofing. It is not entirely clear that this part of the IBC would be applicable to metal roofing.

The impact energy described in ASTM D3746 and UL 2218, Class 4, are very similar. ASTM D3746 uses a 2-in.-diameter, 5-lb. dart dropped from 4 ft., 5 in. that generates impact energy of 22 ft-lbf. The UL 2218 Class 4 uses a 2-in. steel sphere dropped from 20 and develops impact energy of 23.71 ft-lbf.

FIELD STUDIES OF HAIL EVENTS

Data derived from real-world hail events are somewhat limited. The Roofing Industry Committee on Weather Issues (RICOWI)[12] has conducted two Hail Investigation Programs (HIP) following hail events. The first HIP investigation was in April 2004 in Oklahoma City, Oklahoma (OKC). Jim D. Koontz & Associates, Inc. (JKA) participated in the OKC investigation conducted by RICOWI.

Six metal roofs were examined. The metal roofs were impacted by hail reported to be 1 to 2.5 inch in diameter. Dents were also observed on roofs impacted with hail 1.5 inches or larger.

> On these roofs, the hail-caused dents were found to be a cosmetic issue, with no functional damage to the paint or the metal plating. On exposed fastener systems, there were no instances found of fasteners loosened by hailstone impacts. Panel joints had not been distorted sufficiently to affect the water-shedding ability of the panels.

A second RICOWI HIP program was conducted in May 2011 in Dallas, Texas. Sixteen metal roofs were examined during this investigation. Hail 1 to 4 inches in diameter was reported during this hail event. Nine of the 16 roofs did not exhibit dents in the metal systems. No fractures, spalling, or punctures occurred on the metal panels. There was also no evidence of leakage within any of metal roofs.

LABORATORY TESTING

Ten metal roofing targets made of corrugated, standing-seam, and R-panel roofing of different gauges were constructed for test purposes. Each of the metal roofing systems was assembled over a 5-ft.-wide purlin system similar to structural supports commonly used in the construction industry.

Steel Sphere Testing		Ice Sphere Testing	
1.5-in.-diameter UL Class 2	2-in.-diameter UL Class 4	1.5-in.-diameter NBS 23	2-in.-diameter NBS 23
KE	KE	KE	KE
7.35 ft-lbf	23.71 ft-lbf	7.35 ft-lbf*	23.71 ft-lbf*

*Impact energy +10%

Table 2 – Steel and ice sphere testing results.

Figure 2 – Steel sphere.

Panel ID	Gauge	Configuration	Panel Type
A	26	R-panel 36 in.	Steel prefinished
B	24	Corrugated 36 in.	Galvanized
C	24	Standing seam 16 in.	Steel prefinished
D	24	Standing seam 18 in.	Steel prefinished
E	26	R-panel 36 in.	Galvalume
F	26	R-panel 36 in.	Steel prefinished
G	25	Standing seam 16 in.	Steel prefinished
H	32	Corrugated 22 in.	Galvanized
I	24	R-panel 36 in.	Galvalume
J	24	Standing seam 24 in.	Galvanized

Table 3 – Metal roof targets.

The ten targets of metal roofing were impacted using both 1.5- to 2-in.-diameter steel spheres and 1.5- to 2-in.-diameter ice spheres (refer to *Table 2*). The ice spheres had a density of .91 g/cm^3. The steel sphere testing was per UL 2218 Class 2 and Class 4 test standards. The steel sphere impact testing involves dropping a steel sphere from a prescribed height to generate a given kinetic energy (*Figure 2*). Since a steel sphere of an exact weight is dropped from the same height each time, the specific kinetic energy produced is very reproducible. The UL procedure calls for impacting the same location twice. For the purposes of this study, only one impact was performed in order to have a comparison to a single ice sphere impact.

The ice sphere testing was per NBS No. 23 standards. The ice sphere impact method propels an ice sphere with the use of a pneumatic launcher, as seen in *Figure 3*. The weight of each ice sphere is initially recorded. As the ice spheres are propelled at the target, their speed is recorded with a ballistic timing device. The kinetic-impact energy of each ice sphere is then calculated. The kinetic energy of the ice spheres may vary by a +10% kinetic energy value. The metal roof targets are listed in *Table 3*.

Depending on the type of metal roof target, impact locations included flat locations, tall rib, and short rib. If a metal roofing manufacturer represents that its roofing passes the UL and FM tests, then an impact at any location within the metal roofing is acceptable. Following impacts, the indentation diameters and depth of indentations were measured for each type of impacting steel or ice or sphere (refer to *Figures 4* and *5*). The surface of each sample target was examined for cracking or damage to the coating.

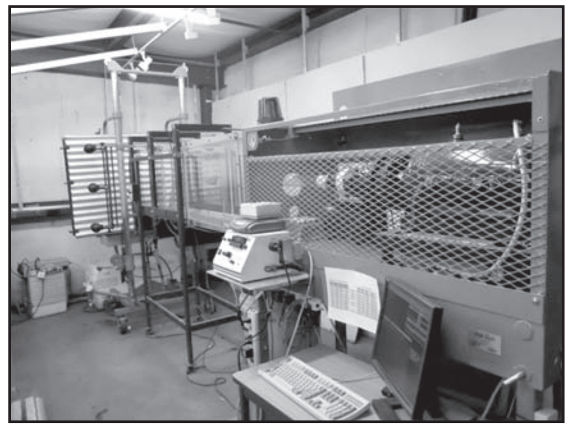

Figure 3 – Pneumatic launcher and target.

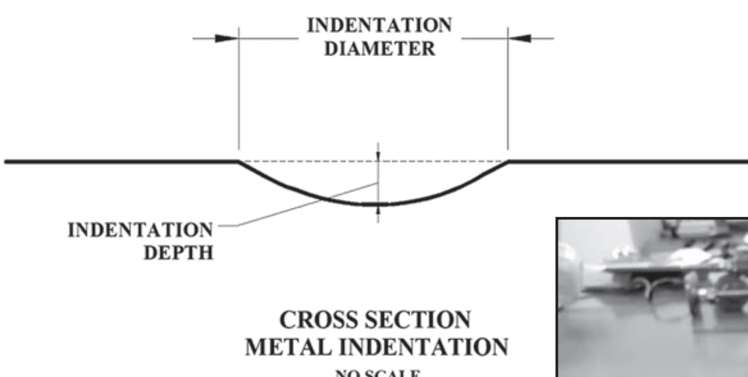

Figure 4 – Cross section metal indentation.

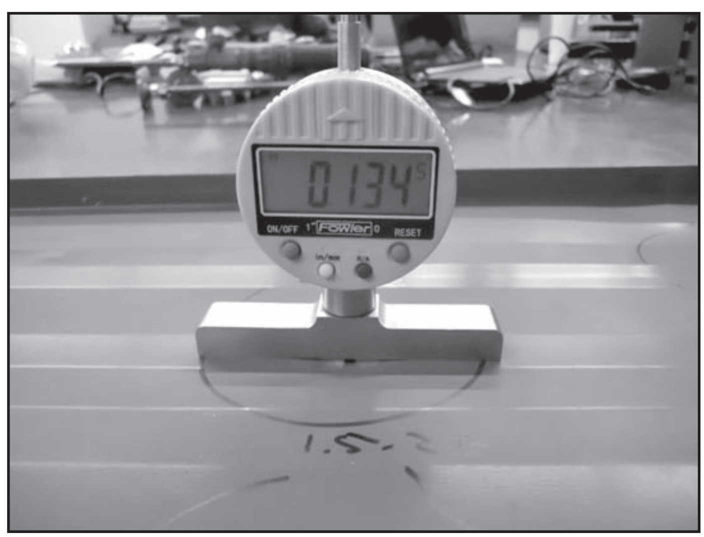

Figure 5 – Indentation measurement with micrometer.

A typical ice sphere impact is depicted in *Figure 6*. The resulting data from the steel and ice sphere impacts is recorded in Attachment 1.

There is a correlation between indentation depth and dent diameter. The indentation obviously varies depending upon gauge, type of metal roof, and diameter of impacting sphere. Refer to *Figures 7* through *10*. The higher the impact energy (i.e., the greater the diameter of hail or steel sphere), the wider and deeper the indentation.

LABORATORY OBSERVATIONS

- With the exception of a 32-gauge corrugated metal penetration, splitting of the metal did not occur with any of the metal roofing tested per the UL and NBS impact procedures.
- Indentations resulted in all metal roofing tested when impacted by either ice or steel spheres.
- The depth and width of dents varied, depending upon impact location, gauge, and type of metal. For the most part, the characteristics of the dents, diameter, and depth are generally random. There are some differences between steel and ice sphere impacts; however, it does appear that with high-density ice spheres, the degree of indentation is slightly higher than that observed with steel spheres.

Figure 6 – Typical ice sphere impact.

- The random results of indentation, diameter, and depth in two metal roofs with the same gauge is mostly like due to variation in yield strength in kilopound force per square inch (ksi = 1,000 psi). Most roofing metals range from 33 ksi to 80 ksi. Prior research[13] has documented that higher-yield strengths result in metal roofs less vulnerable to indentation from hail impacts.
- The steel sphere impact testing did damage the coatings of some metal roofing panels. Ice sphere impact testing did not damage the coatings of the metal tested.

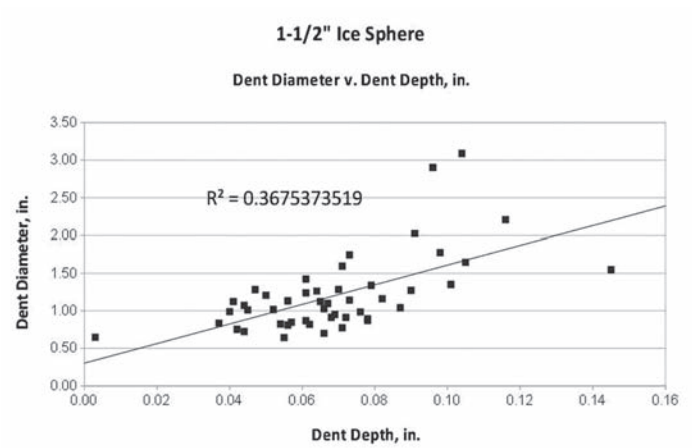

Figure 7 – 1½-in. ice sphere.

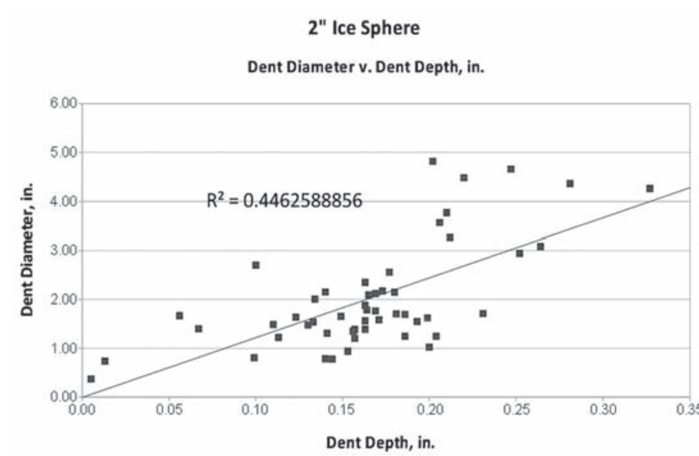

Figure 8 – 2-in. ice sphere.

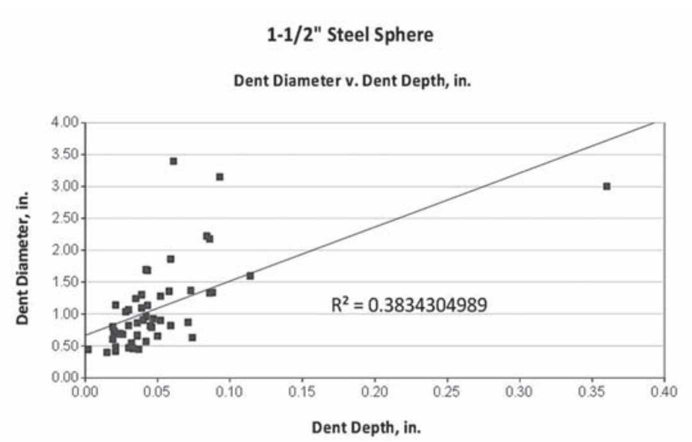

Figure 9 – 1½-in. steel sphere.

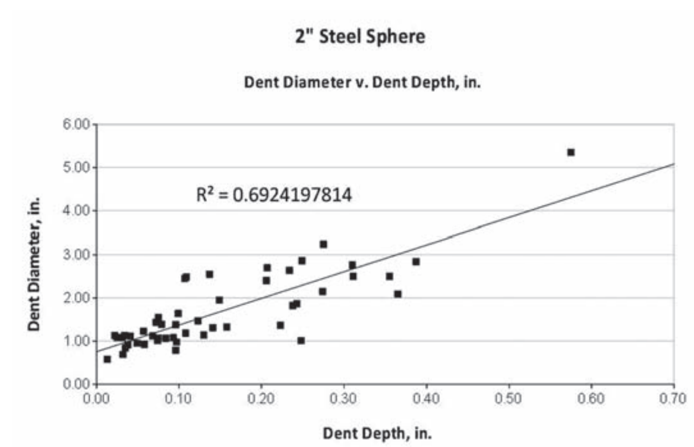

Figure 10 – 2-in steel sphere.

Figure 11 – 24-gauge metal roof installed in 1980.

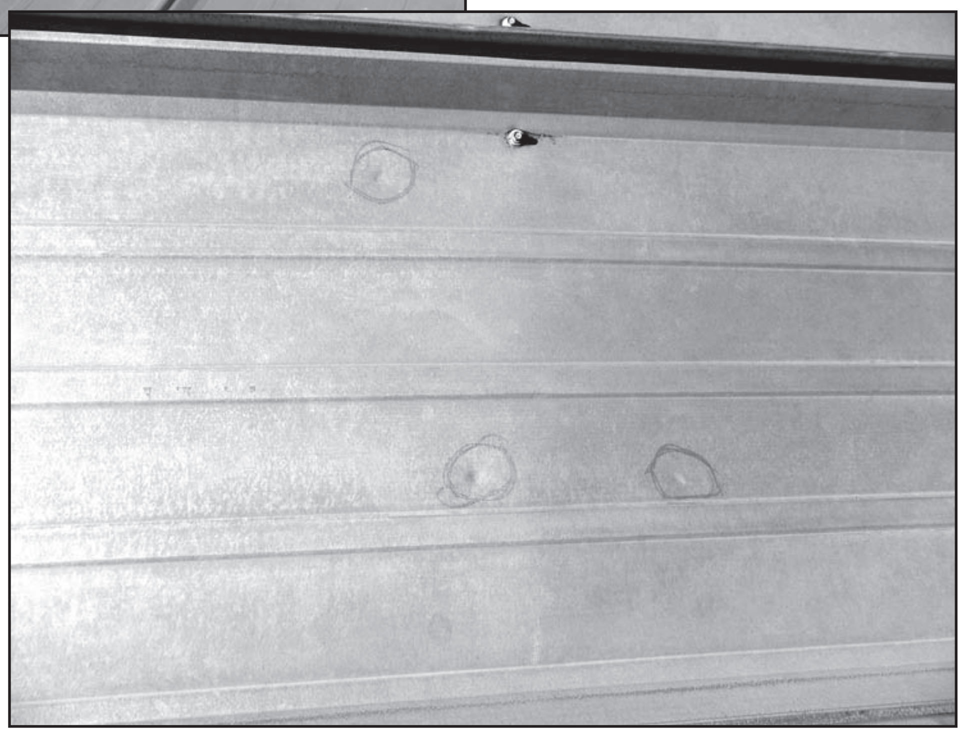

Figure 12 – Minor dents have not resulted in any apparent deterioration.

LONG-TERM EXPERIENCE

Over the last 50 years, the staff of Jim D. Koontz & Associates, Inc. has examined thousands of metal roofs impacted by hail. This has included all types of metal roofs commonly used in the roofing industry.

For purposes of this study, five typical metal roofs impacted by numerous hail events of varying size of hail are reviewed:

Roof 1: Hobbs, New Mexico

The 24-gauge metal roof of standing seam, two foot on center, was installed in 1980 (see *Figures 11* and *12*). Multiple hail events have occurred at this location. Minor dents observed have not resulted in any apparent deterioration or loss of functional or aesthetic value.

Roof 2: Hobbs, New Mexico

The 24-gauge, R-panel metal roof was installed on an office area and warehouse in 1980. These metal roofs have been exposed to multiple hail events over 30 years. Minor dents in the metal roofs have not resulted in any premature failure, corrosion, or loss of functional or aesthetic value.

Roof 3: Dora, New Mexico

The corrugated metal Quonset hut building has been in place for approximately 40 years. Although subject to numerous hail events over the years resulting in numerous indentations, premature failure from corrosion did not occur. The roof was replaced following a 2.5-in. hail that distorted side and end laps, resulting in leakage during wind-driven rain events.

Roof 4: Plainview, Texas

Multiple R-panel and corrugated metal roofs installed in the 1950s and 1960s at a warehouse location were examined. The various buildings have been subjected to numerous hail events of various magnitudes over the last 60 years. Some surface corrosion was observed at various locations not related to hail impacts. Corrosion or deterioration of the metal roofs at hail impact points was not observed at any location.

Roof 5: Lovington, New Mexico

Metal roofs consisting of both R-panels and corrugated metal have been subjected to numerous hail events over the last 40 years. Minor dents in the metal roofs have not resulted in corrosion, deterioration, or premature failure.

During this 50-year time period, several observations on metal roofs have been made by Jim D. Koontz & Associates:

- Fewer than ten metal roofs have actually been punctured or split by hail impact. Obviously, very large hail is required to actually puncture or split a metal roof.
- Long-term corrosion or deterioration of metal roofs at the points of impact has not occurred. Minor impacts or dents have no effect on the long-term performance of metal roofing systems.
- Hail impact dents have to be of significant size for side laps or end laps to be distorted to the point that leakage will occur during wind-driven rain events. Standing seams have to be impacted to the point that some distortion occurs from thermal expansion and contraction at concealed clips.

Opinions

- The impact test procedures for both FM and UL should be better defined for metal roofing. Criteria for precise points of impacts, measurements of dents, and visual examination should be clarified.
- Pass/fail criteria should be better defined by FM, UL, and by metal roofing manufacturers.
- Metal roofing manufacturers should provide consumers with test data documenting FM and UL compliance.
- The use of steel spheres for impacting metal roofing may result in surface coating damage not consistent with impacts from ice spheres with the same kinetic energy.
- Consumers, contractors, and designers rely upon information that roofing products comply with building code requirements for performance criteria such as wind and fire. Building code officials should consider additional requirements to ensure all roofing products—including metal panel roofing systems—will perform in reasonably expected hail events.
- Naturally occurring hail dents in metal roofing that are smaller than dents created by test standards listed in manufacturer marketing literature should not be considered damage, as the dents have no long-term effect on the performance of the metal roofing.
- Aesthetic concerns may be a consideration for steep-sloped metal roofing when hail dents are visible from the ground. Aesthetics should not be a consideration for low-sloped commercial roofs.
- Additional research in this area should be performed.

REFERENCES

1. *Weather Forensics*, Weather Decision Technologies, 2003-10 Hail Climatology.
2. Sidney H. Greenfield, "Hail Resistance of Roofing Products," U.S. Department of Commerce, National Bureau of Standards, Build Science Series 23, Washington, DC, August 1969.
3. Underwriters Laboratory, 2218, "Impact Resistance of Prepared Roof Covering Materials," May 31, 1996.
4. C.W. Griffin and R.L. Fricklas, *Manual of Low-Slope Roof Systems*, 2006.
5. Texas Department of Insurance, Austin, TX, 1998.
6. Texas Department of Insurance website, www.tdi.texas.gov, "Qualified Metal Products."
7. Factory Mutual Approvals, Class Number 4471, Approval Standard for Class 1 Panel Roofs, March 2010.
8. Factory Mutual Approvals, Class Number 4473, *Specification Test Standard for Impact Resistance Testing of Rigid Roofing Materials by Impacting With Freezer Ice Balls*, July 2005.
9. International Building Code, 2009.
10. American Society for Testing and Materials, D3746, *Standard Test Method for Impact Resistance of Bituminous Roofing Systems*, 1985.
11. Canadian General Standards Board, 37-GP-52M, August 1984.
12. Roofing Industry Committee on Weather Issues, April 21, 2004, 2011.
13. United States Steel Corporation, Technical Bulletin 2012.17.

Laboratory Testing Data

Panel ID	Panel Thickness, in (US Standard Gauge)	Panel Type	Impact Location, Description	1-1/2" Ice Hail Ball		2" Ice Hail Ball		Visual Observations		1-1/2" Steel Sphere		2" Steel Sphere		Visual Observations	
				Indentation Diameter, in	Indentation Depth, in	Indentation Diameter, in	Indentation Depth, in	Damaged Coating, Pass / Fail	Cracked Metal, Pass / Fail	Indentation Diameter, in	Indentation Depth, in	Indentation Diameter, in	Indentation Depth, in	Damaged Coating, Pass / Fail	Cracked Metal, Pass / Fail
A	0.020 (26)	Steel Prefinished R-Panel 36" Coverage	1. Flat Location	0.81	0.06	0.79	0.14	Pass	Pass	0.40	0.02	1.08	0.03	Fail	Pass
				1.24	0.06	0.78	0.14			0.61	0.02	0.95	0.05		
			2. Tall Rib	1.65	0.11	4.82	0.20	Pass	Pass	1.70	0.04	1.87	0.24	Fail	Pass
				1.12	0.04	4.48	0.22			1.14	0.04	2.70	0.21		
			3. Short Rib	1.60	0.07	1.79	0.16	Pass	Pass	0.96	0.04	0.84	0.04	Fail	Pass
				1.75	0.07	1.40	0.07			0.74	0.02	2.55	0.14		
B	0.025 (24)	Steel Galvanized Corrugated 36" Coverage	1. Ridge	0.82	0.06	1.77	0.17	Pass	Pass	0.87	0.07	1.83	0.24	Pass	Pass
				1.35	0.10	1.64	0.12			0.67	0.04	1.07	0.08		
			2. Flute	0.87	0.06	1.48	0.13	Pass	Pass	0.69	0.02	1.47	0.12	Fail	Pass
				0.84	0.04	1.62	0.20			0.45	0.04	1.39	0.08		
C	0.024 (24)	Steel Prefinished Standing Seam 16" Coverage	1. Flat Location	1.27	0.09	1.39	0.16	Pass	Pass	0.86	0.04	0.93	0.06	Fail	Pass
				0.95	0.07	1.31	0.14			0.81	0.05	1.01	0.25		
			2. Rib	0.85	0.06	1.56	0.16	Pass	Pass	0.82	0.06	0.58	0.01	Fail	Pass
				1.03	0.07	1.58	0.17			0.55	0.03	1.38	0.10		
			3. Seam	1.21	0.05	2.35	0.16	Pass	Pass	0.70	0.02	1.33	0.16	Fail	Pass
D	0.024 (24)	Steel Prefinished Standing Seam 18" Coverage	1. Rib	1.12	0.07	2.15	0.14	Pass	Pass	1.28	0.05	1.55	0.08	Fail	Pass
				1.10	0.07	2.01	0.13			1.24	0.04	2.41	0.21		
			2. Flute	0.99	0.04	1.49	0.11	Pass	Pass	0.70	0.02	1.13	0.03	Fail	Pass
				1.28	0.05	1.22	0.11			0.80	0.02	1.23	0.06		
			3. Seam	0.65	0.00	0.74	0.01	Pass	Pass	1.14	0.02	1.13	0.02	Fail	Pass
E	0.020 (26)	Steel Galvalume R-Panel 36" Coverage	1. Flat Location	0.73	0.04	1.35	0.16	Pass	Pass	0.66	0.04	1.12	0.04	Pass	Pass
				0.70	0.07	1.21	0.16			0.68	0.03	1.12	0.07		
			2. Tall Rib	1.77	0.10	4.66	0.25	Pass	Pass	1.86	0.06	2.87	0.25	Pass	Pass
				2.90	0.10	3.77	0.21			1.68	0.04	2.15	0.27		
			3. Short Rib	0.75	0.04	2.56	0.18	Pass	Pass	0.91	0.04	1.31	0.14	Pass	Pass
				1.42	0.06	2.09	0.17			0.82	0.03	1.08	0.03		
F	0.019 (26)	Steel Prefinished R-Panel 36" Coverage	1. Seam	2.21	0.12	3.26	0.21	Pass	Pass	3.40	0.06	2.49	0.11	Fail	Pass
				2.02	0.09	3.57	0.21			3.15	0.09	2.46	0.11		
			2. Inside of Seam	---	---	0.81	0.10	Pass	Pass	0.66	0.05	1.01	0.07	Fail	Pass
			3. Outside of Seam	---	---	1.55	0.19	Pass	Pass	1.09	0.04	1.08	0.09	Fail	Pass
			4. Flat Location Double Impacts	1.55	0.15	1.71	0.23	Pass	Pass	1.36	0.06	0.79	0.10	Fail	Pass
G	0.022 (25)	Steel Prefinished Standing Seam 16" Coverage	1. Ridge	1.16	0.08	1.71	0.18	Pass	Pass	1.30	0.04	2.64	0.23	Fail	Pass
				1.28	0.07	1.69	0.19			1.07	0.03	3.25	0.28		
			2. Flute	1.02	0.05	2.12	0.17	Pass	Pass	1.04	0.03	1.37	0.22	Fail	Pass
				1.26	0.06	1.54	0.13			0.63	0.07	1.95	0.15		
H	0.0105 (32)	Steel Galvanized Corrugated 22" Coverage	1. Ridge	0.87	0.08	1.66	0.15	Pass	Pass	1.37	0.07	5.35	0.58	Pass	Pass
				0.83	0.05	2.70	0.10			0.45	0.00	---	---		
			2. Flute	0.78	0.07	2.18	0.17	Fail Split	Fail Split	0.49	0.02	2.84	0.39	Pass	Pass
				0.91	0.07	1.02	0.20			3.00	0.36	---	---		
I	0.024 (24)	Steel Galvalume R-Panel 36" Coverage	1. Flat Location	1.14	0.07	1.25	0.20	Pass	Pass	0.93	0.05	1.19	0.11	Fail	Pass
				1.34	0.08	1.25	0.19			0.90	0.05	1.14	0.13		
			2. Tall Rib	3.09	0.10	4.37	0.28	Pass	Pass	2.22	0.08	2.09	0.37	Fail	Pass
				0.92	0.07	4.26	0.33			2.18	0.09	2.50	0.31		
			3. Short Rib	0.99	0.08	2.95	0.25	Pass	Pass	1.60	0.11	2.50	0.36	Fail	Pass
				0.64	0.06	3.08	0.26			1.33	0.09	2.76	0.31		
J	0.024 (24)	Steel Prefinished Standing Seam 24" Coverage Butler Type	1. Flat Location	0.88	0.08	0.94	0.15	Pass	Pass	0.46	0.03	1.07	0.08	Fail	Pass
				1.01	0.05	1.38	0.16			0.57	0.04	0.92	0.04		
			2. Short Rib	1.07	0.04	1.88	0.16	Pass	Pass	0.79	0.05	1.64	0.10	Fail	Pass
				1.04	0.09	2.15	0.18			1.34	0.09	0.98	0.10		
			3. Seam	0.89	0.08	1.67	0.06	Pass	Pass	0.47	0.03	0.69	0.03	Fail	Pass
				1.13	0.06	0.37	0.01			0.42	0.02	1.44	0.07		