Comparison of Metal and Non-Metal Retrofit Systems

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ABSTRACT

Multiple options are available to a building owner when considering a new or reroof over a metal roofing system, including coatings, single-ply systems, and metal panels. Each option has its advantages and disadvantages. Due to observed problems with retrofit of metal roofing system projects, such as altered drainage, uplift resistance, and changes in fire classification, MBMA initiated a project that summarized advantages and disadvantages of metal and non-metal retrofit systems, with the goal of producing a factual, objective resource that can be used to educate others about retrofit systems. By educating building owners, specifiers, contractors, and building officials, problems in retrofit systems will hopefully be reduced. This paper reviews the results of the project.

BACKGROUND

The Metal Building Manufacturers Association (MBMA) initiated a project to summarize advantages and disadvantages of metal and non-metal retrofit roofing systems, with the goal of producing a factual, objective resource that can be used to educate others about retrofit systems. The project was the winning submittal in 2014 of our annual Associate Member MBMA Innovation Award. The objective of this program is to stimulate innovative project ideas from our Associate Members that will grow the metal building market share over conventional construction. The submittal identified problems with non-metal retrofits on metal roof systems (Figures 1 and 2). It was hoped the resulting resource would reduce problems. This paper discusses the retrofit considerations that are more fully covered in a white paper, *Comparison of Retrofit Systems Over Existing Metal Roofs*,[1] that is available via free download at mbma.com/media/MetalRoofRetrofits.pdf.

The type of metal roof that is the focus of this paper is what is commonly referred to as "structural" metal roofing. According to the Section 1504.3.2 of the 2015 International Building Code[2] (IBC), structural metal roofing is described as "where the metal roof panels functions as the roof deck and roof covering and it provides both weather protection and support for loads . . ." The structural panels are normally characterized by significant rib dimensions and are supported on framing members spaced at intervals up to 5 feet apart. These roofs are typically used in metal building system applications and common in commercial applications, such as agriculture, education, manufacturing, offices, recreational facilities, retail stores and shopping centers, and warehouses. The other type of metal roof, nonstructural, requires a structural deck or substrate to support the new roof and loads, and are common in residential construction. Residential is not a common use for metal building systems.

There are two different types of structural metal roof systems, through-fastened roof system and standing seam roof systems. Through-fastened roof systems is more typically in older metal buildings, while standing seam roof systems are more common in more recent construction. According to the 2012 MBMA Metal Building Systems Manual (2012)[3]:

A through-fastened roof system is one in which the roof panels are attached directly to the roof substructure

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with fasteners which penetrate through the roof sheets and into the substructure.

A standing seam roof system is one in which the longitudinal (side) joints between the roof panels are arranged in a vertical position above the roof line. The roof panel system is secured to the roof substructure by means of concealed hold down clips attached with screws to the substructure, except that through fasteners may be used at limited locations where simple lap joints occur, such as at ends of panels and at roof penetrations.

The differences in these metal roof systems need to be considered in a retrofit application.

NEW ROOF OPTIONS

The good performance and long service life of metal roof systems are well documented[4, 5]. However, there are reasons to evaluate an existing roof system:

- End of service life
- Building rehabilitation
- Experience performance problems and excessive maintenance, such as leaks, ineffective repairs, and poor aesthetics

To address these conditions, there are options available beyond in-kind replacement, such as metal retrofits, single-ply retrofits, and coatings. Replacement has a couple of advantages over retrofit:

- If extensive deterioration of the roof panels, underlying structure (secondary and primary framing), and insulation systems, etc. exists, the deteriorated sections can be removed and replaced.
- When strengthening is required by the applicable building code, there is better access to the existing structure.
- While retrofit has the following advantages over replacement:
- The original roof can remain in place to protect the building interior during the installation of the new roof thus allowing for building operations to continue.
- Retrofit takes full advantage of the existing insulation with the option of easily adding more insulation over an existing roof.
- Safer work surface than open framing for the workers installing the new roof.
- Reduces demolition waste and the need for a large laydown area for temporary storage of roofing materials.
- A through-fastened metal roof system diaphragm remains providing structural stability to the structure.
- Exceptions for building code required strengthening when a lightweight system retrofit is used.
- Many of these factors can add up to a reduced cost for retrofit versus replacement.

Two lightweight options available for an existing metal roof retrofit are metal and single-ply systems. Coatings and fluid applied roofing systems can also be utilized, but those are not specifically addressed in this paper because they are generally considered short-term solutions. In additions, many of the same issues relating to a single-ply retrofits are applicable to roof coatings, such as the integrity of the existing metal roof panels and meeting current code requirements.

Figures 3 and 4 shows a typical metal over metal installation with new insulation provided between the metal surfaces. This is one of two options for a metal retrofit that incorporates new supports. In this option, the existing deck is not required structurally in the final configuration, but needed during construction and supports any new additional insulation. The other option is directly fastening the new roof panel to the existing roof panels. In this option, the existing deck is relied upon structurally (Figure 5).

Figure 6 shows a single-ply system over an existing metal roof. Many single-ply membrane roofs rely on the

existing metal roof to function as a structural deck for support and attachment of the roof system, including board insulation, as well as to support live, snow, and wind loads, and for providing stability to the roof framing members.

The best option for a new roof on a building depends on a variety of factors, including the condition of the existing roof system, the condition of the support structure, occupancy of the building during the roofing work, expected service life, and the differences between the building codes at the time of original design and construction and the current building code. For a metal roof retrofit, there are important issues that need to be considered to achieve proper longevity and performance of the new roof, some that are unique to the type of retrofit, metal or single-ply. Many of these factors will be discussed in this paper.

BUILDING CODE REQUIREMENTS

Retrofits of existing metal roof systems can be governed by the IBC and/or the International Existing Building Code (IEBC)[6], depending on what the governing municipality has adopted. Note that in the IBC and IEBC, the term "recover" is used instead of "retrofit." Check with the local building official (authority having jurisdiction) to determine which code is applicable. In both the IBC and IEBC, reroofing, including retrofits, requires a permit, according to Section 105.2.

International Building Code (IBC)

The information on reroofing is limited. The requirements for existing building, once found in Chapter 34, are not present in the 2015 IBC; they have been moved to the IEBC. The requirements that remain on reroofing, including retrofits, are found in Section 1511. Section 1511.3.1 specifically addresses metal roof retrofits: "Complete and separate roofing systems, such as standing-seam metal roof panel systems, that are designed to transmit the roof loads directly to the building's structural system and that do not rely on existing roofs and roof coverings for support, shall not require the removal of existing roof coverings."

International Existing Building Code (IEBC)

In jurisdictions that adopt the 2015 IEBC, there are more provisions that apply to reroofing and the existing structure. The IEBC has three compliance methods, Prescriptive, Work Area, and Performance, which have different provisions. However, the Work Area method provides exceptions that are advantageous to lightweight retrofit systems, so its requirements will be discussed in the paper. In addition, Chapter 7 contains a section on conformance (701.2), which expresses a major objective of this method, "An existing building or portion thereof shall not be altered such that the building becomes less safe than its existing. condition."Regarding the other two methods, as noted in the Preface of the 2015 IEBC, that the other two options originated in the former Chapter 34 of the IBC, 2012 and earlier editions.

The IEBC Work Area Method, which is covered in Chapters 5 to 13, provides two applicable exceptions. Starting in Chapter 5, the classification of work is determined. Section 503 provides the scope of Level 1 alterations, which includes ". . . the covering of existing materials." This section states, "Level 1 *alterations* shall comply with the provisions of Chapter 7."

Section 706 Reroofing is similar to Section 1511 of the 2015 IBC. Section 707 applies when a reroofing permit is required and states the following in Section 707.2, "Where addition or replacement of roofing or replacement of equipment results in additional dead loads, structural components supporting such reroofing or equipment shall comply with the gravity load requirements of the *International Building Code*."

This provision has three exceptions, two of which are applicable to metal and single-ply retrofits:

1. Structural elements where the additional dead load from the roofing or equipment does not increase the force in the element by more than 5 percent.

3. Addition of a second layer of roof covering weighing 3 pounds per square foot or less over an existing, single layer of roof covering.

Most metal and single-ply retrofit systems meet Exception 3, and possibly Exception 1, even when additional insulation is included.

DESIGN CONSIDERATIONS

Existing Support Structure

For any retrofit option, the existing support structure must be evaluated with regard to load path, strength, serviceability, and its condition. This evaluation would include a review of the code requirements that may require strengthening or stiffening of the existing support structure, as discussed in the previous section.

The evaluation begins with the recognition that a structural metal roof system on an existing metal building (Figure 7) is different from a conventional steel framed building. A metal building is typically constructed with the following features:

- Cold-formed steel secondary framing members, not cambered
- 24 gauge or thinner structural roof panels
- Standing seam or through-fastened roof panels
- Roof level lateral stability system - steel panel diaphragm, bracing, or both

A conventional structural steel framed building typically is constructed with the following features:

- Steel joists or hot-rolled members that may be cambered
- 22 gauge or thicker steel roof deck
- Roof level lateral stability system - steel deck diaphragm

The essential differences affecting the a retrofit design is that conventional structural steel framed buildings are typically built to support a roofing system to provide weather protection, while a metal building with a structural metal roof does not. The resulting differences affect the design and installation of the retrofit.

Secondary Framing Allowable Deflection Considerations

The deflection of the secondary framing is a design consideration, for both code compliance and performance of the retrofit roofing system. The 2015 International Building Code (IBC) Table 1604.3, Footnote “a” stipulates an L/150 live load deflection limit for secondary roof structural members that support only "formed metal sheeted roofing," which is obviously structural metal roofing. Otherwise, the deflection limit when supporting a non-metal sheeted roof such as a single-ply membrane roof is L/180. The IBC deflection limits under snow loading and wind loading are identical for these two retrofit systems. These difference in deflection limits could require stiffening of the secondary structural members for code compliance when a single-ply membrane roof retrofit is used.

Existing Metal Roof Properties Considerations

The difference in allowable deflection limits for the metal deck is even greater than for the secondary framing. As discussed previously, structural metal roofing is not the same as structural steel decking and it is not designed to perform the same function. According to the IBC, "structural metal roofing is where the metal roof panels functions as the roof deck, providing support for loads, and as a roof covering, providing weather protection." The Steel Deck

Institute (SDI) defines roof deck as" steel deck panels used in a structural manner as a base for construction and supporting the roof insulation and membrane."

The Steel Deck Institute's ANSI/SDI RD-2017 Standard for Steel Roof Deck has a total load deflection limit for roof deck of L/120, whereas IBC Table 1604.3, Footnote "a" stipulates a total load deflection limit of L/60 for structural metal roofing. The IBC deflection limit is twice the SDI limit. For a 5 foot secondary framing spacing, the allowable deflection is 1 inch for structural metal roofing and 0.5 inch for roof deck.

Single-ply membrane roof manufacturers have minimum requirements for roof deck properties, such as minimum thickness, minimum fastener pullout capacity, or both. A common minimum thickness is 22 gauge. For fastener pullout capacity, minimum values are specified and fastener pullout tests are required.

Water Ponding / Drainage

The 2015 IBC Table 1604.3 states in Footnote "e", "The above deflections do not ensure against ponding. Roofs that do not have sufficient slope or camber to assure adequate drainage shall be investigated for ponding." Metal buildings with structural metal roofing on a metal building system have characteristics that effectively address ponding between purlins even if the slope does not appear to be sufficient and with roof panels that have an allowable L/60 deflection limit. Ribbed metal roof panels control rainwater flow and do not allow lateral water movement to purlin mid-span locations where water ponding could progress into a significant problem.

A smooth-surfaced single-ply membrane roof system, on the other hand, does not control lateral water migration. In addition, a mechanically-attached single-ply membrane that billows or flutters during wind events may cause an unbalanced load due to water displacement. Hence, changing from a ribbed panel to a smooth-surfaced single-ply membrane roof can cause unbalanced loads to occur. In addition to lateral water flow, unbalanced loads and water accumulation may occur due to a modified drainage system. A characteristic of metal building secondary framing that affects ponding and drainage is the secondary framing is typically continuous and not cambered. In addition, the metal building secondary framing may have been designed for a uniform load. There are documented failures (Figures 8 and 9) because of this issue.[7]

Retrofit Roof Fastening

The retrofit roof attachment or fastening depends on several factors, including the capacity of the new roof system, the existing metal roof structure (roof panel thickness and secondary framing thickness and spacing), and the design wind loads. Drag loads, discussed in the next sections, may also affect the fastening. Design wind loads vary due to building height, geographic location, enclosed vs. partially enclosed, parapet height, and other factors. Roofs have greater wind pressures in corner and edge zones. For steeper slope roofs, there are additional areas of greater wind pressures along the ridge, as well as greater drag forces. However, current code requirements, if applicable, may be substantially different, such as ASCE 7-16[8]. Greater wind pressures and other forces will typically require more fasteners, fasteners with greater diameter, or both to adequately attach the retrofit system to the underlying structure.

When fastening a retrofit roof system to a structural metal roofing system on a metal building, attaching directly to the underlying existing purlins is best. This approach provides a direct load path, and does not rely on the exiting steel roof panels. The condition of the roof panels may be compromised due to damage or deterioration, or its condition is unknown. Fastening directly to the purlins may be required by the manufacturer as a result of the pullout testing or by FM Global requirements.

For an FM Global insured project or a project that is required to meet FM Global recommendations, the minimum requirements in FM Global Data Sheet 1-31[9] may apply. The scope of Data Sheet 1-31, Panel Roof Systems (DS 1-31) includes loss prevention recommendations for wind resistance, installation, and maintenance of standing seam metal roofs (SSR) and lap seam metal roofs, and information on "re-covers over existing metal roof systems."

DS 1-31 includes several sections on fastening for retrofits existing metal roof systems, including the following:

- Section 2.2.4 Re-Cover of Existing Metal Roof Systems
- Section 3.1.3 Re-Cover of Metal Roof Systems
- Section 3.1.4 Roof Areas Needing Increased Fastening
- Appendix C, Section C.3 Re-Cover of Metal Roof Systems

Section 2.2.4 begins with the following in Section 2.2.4.1: "Analyze the structure to ensure it can support the additional weight of the new roof without reducing the gravity load capacities below acceptable limits. It is not recommended that the wind or gravity load path from a new roof system go through the existing roof panels. The wind and gravity load path from a new roof system should go directly into the existing secondary structural framing (purlins, joists) that supports the existing roof."

The remaining sections provide additional guidance on fastening retrofits on metal roofs, including fastener density and spacing, and the factors affecting it, such as panel thickness and secondary framing spacing.

Drag Loads

Drag loads act on the roof parallel to the roof plane, which have the effect of pulling the roofing system down the slope of the roof.[10] Because it is a component of the gravity load, the load is higher as the slope increases. The loads is also higher when there is more gravity loads on the roof, such as accumulation of ice and snow.

In the original metal building, drag loads are resisted in an existing metal roof system by mechanical anchorage of the metal roofing panels to the underlying structure. The anchorage can be achieved in a variety of ways, which may depend on the roof type. For example, anchorage of a through-fastened roof is achieved by screws installed throughout the roof panels. For a standing seam roof, the anchorage may be limited at the ridge to allow for thermal movement. Another anchorage option for a standing seam roof may be "fixed clips." The supporting secondary framing anchorage can also be achieved in a variety of ways, such as bracing continuous across a ridge and purlin anti-roll-clips.

When a metal roof retrofit is installed with secondary members placed over and anchored to the existing metal roof system, the secondary members provide the resistance to the drag forces. Existing secondary roof members can be restrained to resist increased drag loads with bracing or flexural members installed. Without supports, the drag loads are resisted by screw fasteners connecting the roof panels through direct shear.

In the case of a single-ply retrofit the loads are resisted by the lateral loading on long fasteners from the top of the insulating system to the existing purlins. The greater the insulation depth, the greater the bending of the fasteners. The fasteners are acting as cantilevers, relying on their flexural strength and its "fixed" connection to the underlying structure, which may be a 26 gauge (0.0179 in.) thick steel deck.

Fire Rating

Adding a new roof to a building, which may include supplemental insulation to improve its energy efficiency, may affect its fire rating. As a result, the current insurance coverage on the building may also be affected. A roof system consisting of metal panels directly supported on steel framing are typically rated as a Class A roof assembly, according to IBC Section 1505.2, Exception 2. Single-ply systems may or may not have a similar rating. The IBC defines Class roof assemblies as ". . . those that are effective against severe fire test exposure."

For a metal retrofit, there is no significant change in the fire rating from the original metal building roof system provided the appropriate insulation used, i.e. unfaced fiberglass. Therefore the Exception 2 of IBC Section 1505. 2 applies and it remains a Class A roof assembly.

For a single-ply retrofits, which typically incorporate board insulation, the fire rating needs to be evaluated, reviewing all components of the system including the insulation and the membrane. Even The impact is even though the original roof was a Class A roof assembly, the new roofing system has own rating. And therefore, IBC Section 1505.2, Exception 2 does not apply.

SUMMARY AND RECOMMENDATIONS

Retrofits on existing metal roofs have several potential benefits. A building owner/ property manager, with their roofing consultant, design professional, or contractor, should evaluate retrofit roof solutions for their project to determine the best choice. There are several design considerations related to the decision to choose a metal over metal, or a single-ply membrane roof, especially when installing the retrofit on a metal building. The following recommendations are provided to assist with this decision.

Recommendations for All Retrofit Systems

Engage a licensed professional engineer practicing structural engineering, with knowledge of metal buildings, to evaluate the following:

- Existing roof and structural system to ensure it is adequate to support its original design loads and able to support the anticipated loads imposed by the retrofit roof system.
- Retrofit roof system fastening in the field, perimeter, and corner zones to ensure code compliance.
- Necessary resistance to anticipated drag loads on retrofit roof system and existing structure

The retrofit designer should verify the fire classification of the existing roof system and the retrofit roof system according to the building code, and for any change, how it affects the insurance coverage for the building.

Consult with the local building official, a licensed professional engineer practicing structural engineering, and retrofit roofing manufacturer to confirm that the existing building's metal roof is adequate to perform as a structural deck for the new roofing system.

Recommendations Only Applicable to Single-Ply Retrofits

For a single-ply retrofits over a metal roof, it is also recommended to engage a licensed professional engineer practicing structural engineering, with knowledge of metal buildings, to evaluate the unbalanced loads and potential water accumulation on a single-ply retrofit with respect to structural capacity and drainage provisions.

ACKNOWLEGEMENTS

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[2] "International Building Code," ICC, 2015.
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[8] "Winds of Change," Metal Construction News, pp. 14-17, June 2017.
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[10] "Metal Roofing Systems Design Manual," Metal Building Manufacturers Association, Cleveland, OH. 2012.

Figure 1 - Example of Non-metal Retrofit on a Metal Roof System (courtesy od Dale Nelson).

Figure 2 - Example of Non-metal Retrofit on a Metal Roof System (courtesy of Dale Nelson).

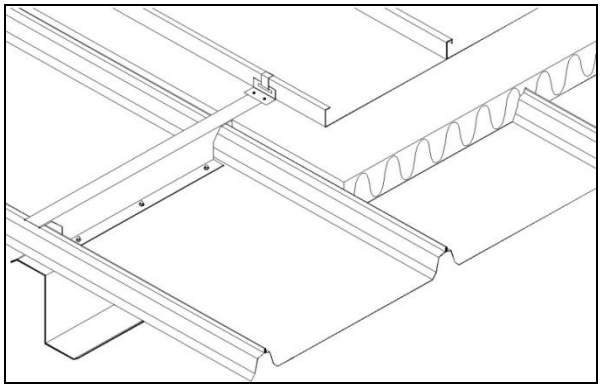

Figure 3: Metal Retrofit over Existing Metal Roof with Supports (courtesy of Brian Gardiner).

Figure 4: Metal Retrofit over Existing Metal Roof with Supports (courtesy of Rodger Russ).

Figure 5: Metal Retrofit over Existing Metal Roof without Supports (courtesy of MBCI).

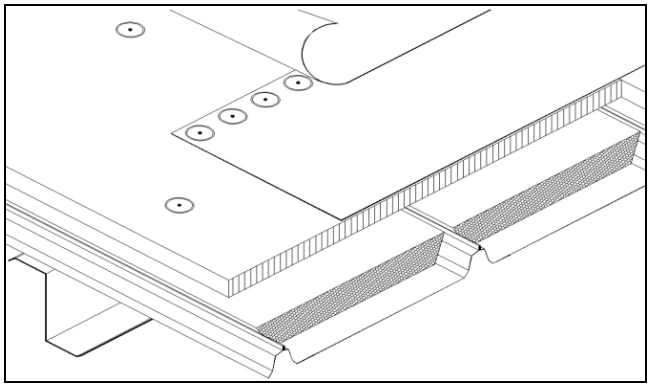

Figure 6: Single Ply Retrofit over Existing Metal Roof (courtesy of Brian Gardiner).

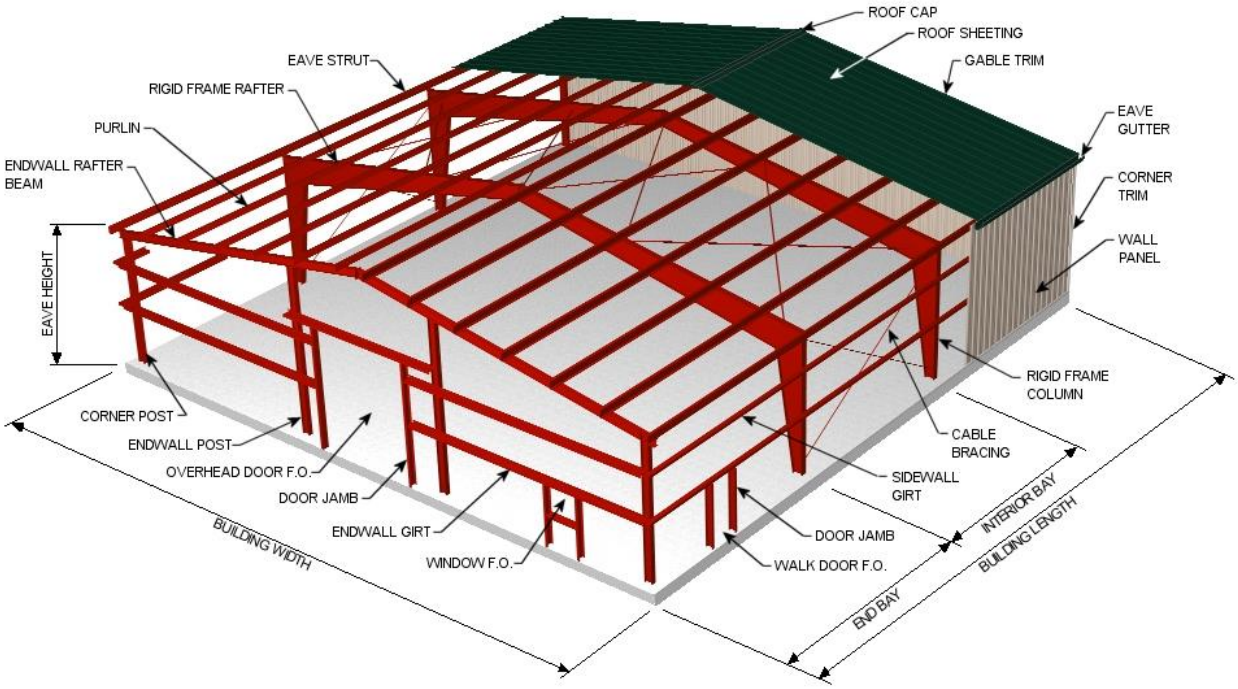

Figure 7: Typical Metal Building Construction.

Figure 8: Retrofit Roof Structure Failure, Exterior View (courtesy of Terry Wolfe).

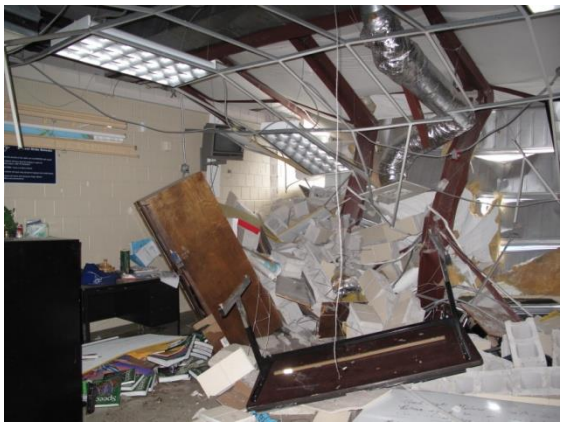

Figure 9: Retrofit Roof Structure Failure, Interior View (courtesy of Terry Wolfe).