STEEL FRAMING INDUSTRY ASSOCIATION

October 2018

COLD-FORMED STEEL AND RESILIENCE

SUMMARY

The term "resilience" and its importance to the built environment has resulted in many discussions on how this term relates to systems, society, and the individual. Resilience even extends to our need to establish a preparedness protocol for natural and man-made disasters. From academia to Federal, state, and local governments, these discussions have the potential to change our thinking on sustainability and building design. This paper explores the concept of resiliency and relates it to a better understanding of the inherent properties of cold-formed steel framing that make it a resilient material.

WHAT IS RESILIENCE?

Many different definitions of resilience have been published, with sources that range from universities to government agencies. Consequently, "resilience" means many things to many people. The Merriam-Webster online dictionary contains several definitions but the one that seems to best apply to buildings is:

> *Resilience - an ability to recover from or adjust easily to misfortune or change.*

At the Federal level in the United States, resilience is part of a larger program introduced in the National Preparedness Goal under FEMA, an agency under The Department of Homeland Security (DHS). First developed in 2011 and updated to a 2nd edition in in 2015, the National Preparedness Goal discusses how resilience fits into their overall plan as follows:

"A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk."

The 2nd edition of the National Preparedness Goal (available here) further states that these risks include

The Attributes of Resilience

"High Performance Based Design for the Building Enclosure" establishes what are termed "Attributes," defined as "high-level properties that define a building in terms of the performance the building is to deliver." These attributes are listed as

1. **Safety:** the ability of a structure to withstand natural hazards, including fire, flood, seismic, and wind. The goal is for the building to continue to operate after such an event.
2. **Security:** the ability of a building to resist a man-made event. These events include ballistics and blast resistance.
3. **Energy Conservation:** pertains to the energy efficiency of the structure, and such attributes as air tightness, thermal transfer, and the use of renewable energy. The goal is to reduce the amount of fossil fuel consumption in the operation of the structure.
4. **Environment:** the overall environmental footprint of the building as well as acoustic performance of the exterior envelope.
5. **Durability:** the building enclosure's ability to withstand the effects of water penetration and water vapor migration while performing without a degradation in function for a specified period of time.

Source: National Institute of Building Sciences (NIBS) *"High Performance Based Design for the Building Enclosure – A Resilience Application Project Report"*

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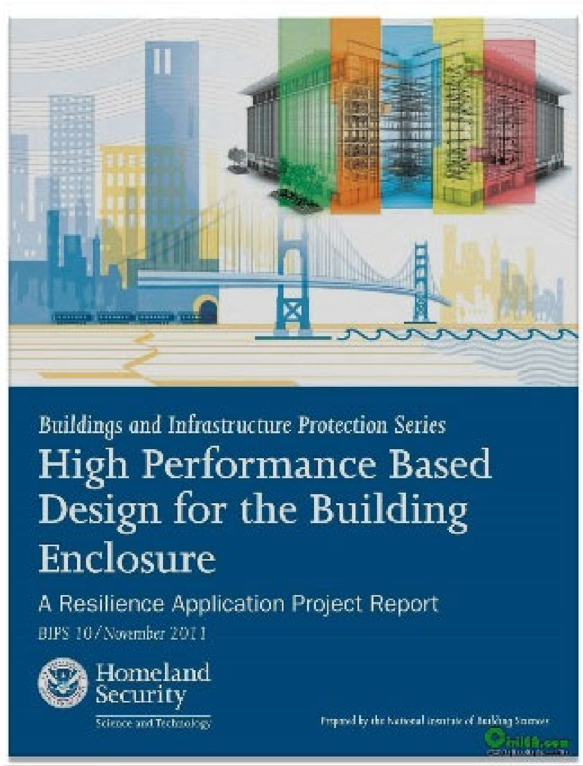
natural hazards (e.g., hurricanes), accidental hazards, and manmade threats (e.g., acts of terrorism).

After the initial establishment of the National Preparedness Goal, DHS published a joint document in 2011 with the National Institute of Building Sciences (NIBS) "*High Performance Based Design for the Building Enclosure – A Resilience Application Project Report" (available here and hereafter referred to as the DHS/NIBS report).* This report provides specific



guidelines to follow for the design of resilience in exterior envelopes. It states resilience is "a function of Robustness, Resourcefulness and Recovery, and is a product of quality of function loss and the time to recover." The report defines various levels of performance versus a specific threshold for declaring a building to be resilient.

There is a suggestion in these definitions that "resilience" isn't limited to the ability of a building to provide for life-safety and just barely surviving a major event, but also extends to the ability of a building to continue operating as designed. A reasonable approach to that dimension of resilience recognizes that there are other conditions in the built environment other than extreme events that can negatively impact the ability of a building to operate as originally intended. The durability of a building is something that is impacted over long-term use, not just a specific event down the road that needs to be addressed. For example, decay or termite damage, moisture from condensation or hidden plumbing leaks, or inadequate fire protection can degrade or destroy a building's useful life and make it less able to hold up to catastrophic events.

Given that durability and thus resilience of buildings is threatened by everyday conditions as well as events that are sudden and catastrophic, it makes sense from a sustainability perspective that we construct buildings to last and remain in service for as long as their expected economic life. Further, buildings should be adaptable to avoid functional obsolescence to achieve or possibly even extend their economic life.

The DHS/NIBS document establishes the five resiliency "Attributes" shown in the text box on page 1 above. These attributes are defined as "high-level properties that define a building in terms of the performance the building is to deliver." These five attributes correspond directly to the level of resilience of a building in addressing natural hazards. man-made hazards, and the environmental conditions of a building location.

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RESILIENCE ATTRIBUTES AND COLD-FORMED STEEL

Given that improvement to one or more of the five attributes in the DHS/NIBS document establishes a more-resilient structure, then the same attributes are useful to benchmark a building material. Cold-formed steel framing exhibits inherent resilience as a material that contributes to the improvement in building performance relative to each of the attributes.

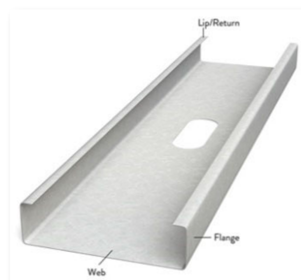
Attribute 1: SAFETY and Cold-Formed Steel.

Cold-formed steel offers material characteristics and performance attributes that enable a building to safely withstand the demands identified in the DHS/NIBS document, and then continue to operate after a major event.

Ductility. Regardless of material, an important consideration in structural design is the lateral load resistance of exterior walls, or how well the wall will resist high wind and seismic forces. Structures are designed to absorb energy produced by ground movement and wind by "flexing" or "deflecting" in varying degrees, depending upon the construction materials, design of the structure, quality of construction, level of engineering, and the applicable building code requirements. Cold-formed steel is an optimal material for this purpose because it is ductile; making it more forgiving than other more brittle materials in earthquakes and high-wind conditions. Cold-formed steel also has inherent strength in uplift and gravity loading.

Material stability: Steel behaves in a highly predictable manner when subjected to the structural loads and movements imposed by high wind and seismic events. This is because steel is an inherently stable, manufactured material with consistent chemical and mechanical properties. Once a steel stud has been formed, it will remain straight with virtually no change to the thickness, width or other dimensions, and maintain its strength and stiffness. Likewise, steel fasteners used to join steel framing members retain their strength and reliability over time.

Strength-to-Weight Ratio: A key characteristic of resilient building materials is the strength-to-weight ratio. This relatively easy way to compare the merits of several different materials is determined by dividing the maximum imposed load by the weight of the material. Of all the most commonly-used construction materials, steel has the highest strength-to-weight ratio. When cold-formed steel sheet is formed into a C-shape like a stud, the bends increase the strength of the steel sheet dramatically, providing a strength-to-weight ratio that is up to seven times greater than that of dimensional lumber.



Courtesy: ClarkDietrich Building Systems

Noncombustible: Steel-framing is inherently noncombustible and does not burn nor contribute to the spread or intensity of a fire. Steel is permissible in every type of construction in the International Building Code and all other major modern codes. Unlike wood framing products, steel framing doesn't require gypsum or other coverings to be in place to prevent its ignition. With cold-formed steel you get noncombustible construction from the start, even during the construction phase when sprinklers and coverings are not yet in place.

Connection Strength: Steel framing is constructed with screws or other fasteners that provide a mechanical locking connection where the load is carried in shear. This is in direct contrast to wood, where connection strength is often limited – not by the strength of the fastener, but by the resistance of the wood in bearing or withdrawal[1]. The fact that steel is dimensionally stable and attached with fasteners that are mechanically locked-in to the framing members, means its strength as designed is what you get throughout its life.

The inherent characteristics above are building blocks that enable cold-formed steel to provide the needed resilience when subjected to the following hazards identified in the DHS/NIBS document as important for a resilient building.

FIRE. A resilient and sustainable building is the one that is not destroyed or heavily damaged by fire. Noncombustible materials as the structural system are recognized as one of the most important factors in preventing the start and spread of fires in buildings.

Building codes recognize cold-formed steel as "noncombustible" and therefore make it eligible for use in Type I buildings where the fire-resistance standards are the most stringent. In addition, steel can be used as the primary framing material in all other Types of Construction, so you never have to worry about its acceptance under building codes. This is because cold-formed steel does not burn and will not contribute to the spread or intensity of a fire. In addition to its noncombustible properties, cold-formed steel is regularly used to limit the spread of fire in buildings in cases where the building contents or finishes are the source of ignition and spread. "Fire walls" or fire-resistant rated assemblies, are code-mandated assemblies that help limit or slow the spread of flames in a building, and cold-formed steel frame assemblies have ratings up to four hours when subjected to tests conforming to ASTM E119 (Standard Test Methods for Fire Tests of Building Construction). Fire-rated cold-formed steel assemblies are available for both load-bearing and non-loadbearing conditions. A directory of fire-rated assemblies can be found by clicking here.

Cold-formed steel has also proven it can withstand the severity of fire exposure in tests that follow the rigorous protocols of NFPA 285, "Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components."

Noncombustible cold-formed steel construction also make sense from a cost savings standpoint, as insurers traditionally offer lower builders risk and general liability premiums compared to wood. Click here to access an white paper titled "Insurance savings with Cold-Formed Steel."

Noncombustible materials are especially important during construction when buildings with exposed combustible materials are at their greatest risk due to fires. Over the past several years, dozens of fires in mid-rise buildings constructed with wood have occurred during construction, leading to loss of the buildings themselves and damage to adjacent buildings, destruction of infrastructure, and excessive costs to the community.

In one fire alone in Los Angeles in 2014, at least four nearby buildings were damaged to the tune of $80 million, a major commuting road was shut during peak hours, and damage to infrastructure was estimated at over $1.5 million.

According to a report by assistant adjunct professor Urvashi Kaul at Columbia University, in Los Angeles County alone, fires in mid-rise residential buildings with combustible frames could have a negative impact of $22.6B over 15 years, including $17.14B in

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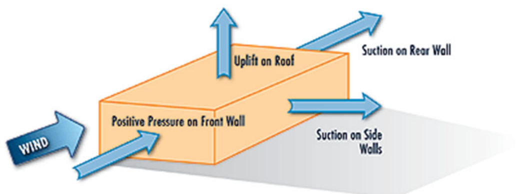
direct losses from property damage. The full report is available here.

HIGH WINDS. A variety of windstorm types occur in different areas of the United States., and can include hurricanes, tornadoes, straight-line winds, thunderstorms and downbursts. The one thing they all have in common is the combination of uplift, and positive and negative pressures that the building must resist.



Courtesy: National Institute of Building Sciences

Topography and building orientation are critical considerations for a resilient building, but the performance of a building during a high wind event starts with strong design. The American Iron and Steel Institute (AISI) has established a set of ANSI-accredited design standards for cold-formed steel applicable to all buildings, as well as a prescriptive method for one- and two-family dwellings that addresses wind speeds up to 180 miles per hour.

The Steel Framing Industry Association (SFIA) publishes design tables to assist designers in selecting the proper size stud or joist for a given structural condition. The *"Technical Guide for Cold-Formed Steel Framing Products"* (available from SFIA by clicking here) contains tables that cover exterior walls that must have the capacity to resist wind loads. The tables cover curtain wall applications as well as applications where the exterior wall is a load-bearing wall. The data therein provides guidance on designing walls to resist up to 40 psf pressures or approximately 125 mph winds. Cold-formed steel framing has the capacity for much higher wind loads, but it is suggested to contact the cold-formed steel framing manufacturer for specific technical assistance.

Courtesy: National Hurricane Center

Resilient structural systems are also helped by the selection of the structural systems and framing material. For example, the inherent ductility of cold-formed steel is a benefit in minimizing damage due to building movements during extreme wind events. As mentioned previously, screw fasteners used in cold-formed steel construction tend to provide better connections and more secure continuous load paths than typical nailing patterns.

Most buildings are not made uninhabitable due to wind damage itself, but because the roof cover and sheathing is lost or compromised, and subsequent water damage occurs. Securing the roofing and selecting cladding that can resist the expected wind in an area is important, as is a durable water-resistant membrane under the cladding. However, if the sheathing does not stay intact, the other measures can be easily compromised. This is where a product like cold-formed steel framing can increase the resilience of the envelope due the use of screws that provide superior resistance to pull-out forces on the sheathing.

SEISMIC FORCES. Earthquakes are one of the most destructive forces in nature. In recorded history, single seismic events have altered the course of major rivers, erased significant areas of land from the map and devastated structures within a considerable distance of the earthquake's epicenter.

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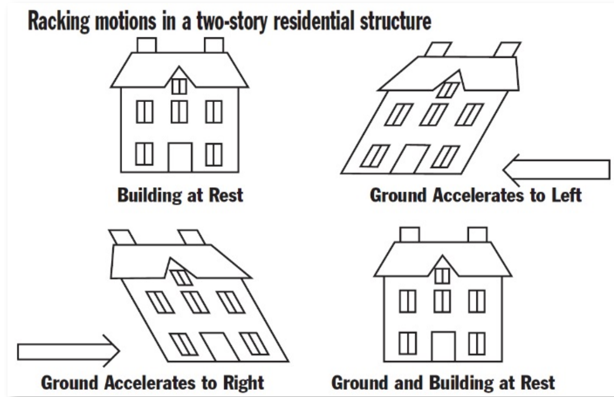
A resilient building is designed to absorb energy produced by ground movement by "flexing" or "deflecting" in varying degrees, depending upon the construction materials, design of the structure, quality of construction, level of engineering, and the applicable building code requirements. Cold-formed steel is the ideal material for buildings design to withstand seismic forces because of its high ductility and light weight.

Steel is considered a ductile material because of its ability to bend or stretch without breaking when a force is applied. As the load is reduced, the energy is dissipated without permanent deformation or

Courtesy: CFS NEES, Johns Hopkins University

damage to the steel. On the other hand, brittle materials like concrete or masonry units will fracture and fail at their ultimate loads.

In the summer of 2013, full scale shake table tests, sponsored by the steel industry were run at the State University of New York in Buffalo[2]. A shake table is a platform that is used to simulate ground motion such as an earthquake. The results of these tests exceeded expectations. Project leader of the program was Dr. Benjamin Schafer, professor and chair of the Department of Civil Engineering at Johns Hopkins University, who has stated "we've shown that cold-formed steel structures hold up extremely well under earthquake conditions and that it is possible to design cold-formed steel structures even more efficiently."



Courtesy: Santa Clara University

Subsequent tests in 2016 of a six story CFS building conducted at the University of California San Diego further confirmed the findings from the 2013 tests, showing that the test building suffered only minimal damage during the service level earthquake tests[3].

The weight of a building will be heavily influenced by the structural system, and cold-formed steel is one of the lightest framing materials used in construction today. Structural damage is typically caused by "inertia," or the reluctance of upper stories to begin moving as the ground shifts, and then conversely, to stop moving once the structure has moved. Lighter structures have less weight available to be subjected to the stresses of inertia.

FLOODS. In their fact sheet called <u>*Cleaning Flooded Buildings*</u> (*available here*) FEMA has recognized these three "key issues" related to mitigating the ravages of a flood:

1. Flood duration
2. High velocity flow
3. Flood-borne debris and degradation of building materials.

In all three instances, the selection of material is critical.

When materials are underwater for any length of time, many are not salvageable after the waters recede, and make the building inhabitable. Thus, the first line of defense is to keep susceptible materials above the local flood elevation. In cases where flood waters submerge a building, materials that are not susceptible to water damage are good solutions. Steel is an excellent material for framing, although one should also consider insulation, sheathing and finishes that are resistant to moisture damage.

Another advantage of cold-formed steel framing is in velocity zones where break-away construction is necessary to relieve pressure on a structure. In this case, cold-formed steel is very effective option. Designers should be cognizant of non-structural items that may defeat the breakaway characteristics if not attached properly including items such as wiring and plumbing, water heaters, and even outside HVAC units that should be secured independent of the breakaway component.

Courtesy: FEMA

Steel is also resistant to the formation of mold (see later discussion) after floods when buildings or parts of them are submerged for extended periods of time.

Attribute 2: SECURITY and Cold-Formed Steel

Blast resistance and ballistics are the two major metrics for security. Cold-formed steel is used as a framing component in systems that perform well in both categories.

Blast Resistance. Federal agencies, as well as many other building owners, have significant desire to protect their personnel and operations from potential terrorist acts. Mitigation strategies include maximizing standoff distance, preventing building collapse, and minimizing hazardous flying debris.

Recent research demonstrate that steel stud walls can be utilized to resist blast threats using conventional construction methods that add little cost to traditional designs[4].

Ballistics. The definition of security relative to "ballistics" can be a man-made event, such as a bomb or bullet, or a missile could also be a roof tile or a 2x4 wood stud turned into a projectile by a hurricane or other high wind event.

Steel studs and steel sheathing products have been proven to provide a high level of resistance to penetration from large, blunt objects. Although bullet penetration is more difficult to resist because the force is concentrated on a very small are, proprietary solutions have been developed using cold-formed steel to help spread the load over a larger area.

Attribute 3: ENERGY CONSERVATION and Cold-Formed Steel

The use of cold-formed steel can play an integral role in developing resilient exterior wall systems that meet the stringent requirements of the International Energy Conservation Code (IECC). On a prescriptive basis the IECC mandates the use of continuous insulation to fully sheath what are considered opaque walls in most climate zones. Further, there are requirements for air/water barriers that are continuous from below grade, up the exterior walls, and to the roof membrane.

The CFS industry has conducted thermal testing on assemblies as far back as in the early 1990s. These test results, and those from others, have been used to develop methods for determining the thermal performance of cold-formed steel assemblies, and have been accepted into the IECC and ASHRAE 90.1 ("Energy Requirements for Buildings Except Low-Rise Residential Buildings"). Thus, a steel framed building can meet even the most stringent of the major energy codes and standards in an economical manner.

All major interior and exterior finish systems used in today's buildings are compatible with steel framing, and it also allows for the installation of cavity and/or exterior continuous insulation. Steel framing has been

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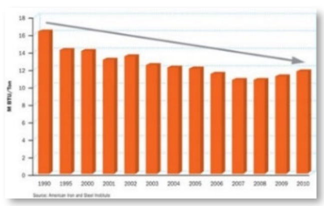
used in projects meeting LEED© and other green building programs that place a heavy emphasis on energy efficiency.

Perhaps as important as a building's performance after construction is the energy that goes into making a product. Because it can be infinitely recycled and due to other efficiency improvements over the years, the US steel industry has reduced energy intensity by 32% per ton of steel since 1990. No other major building structural system can match that level of energy savings.



Courtesy: American Iron and Steel Institute

Attribute 4: THE ENVIRONMENT and Cold-Formed Steel

This attribute for resilience explores a material's impact on the environment and sustainability, an area where the steel industry can point to clear benefits and achievements.

Recycling. The Steel Recycling Institute (SRI) reports that steel is recycled more than paper, plastic, glass, copper, lead and aluminum combined. All steel products, including steel framing, contain recycled steel. Steel framing contains a minimum of 25% recycled steel and is 100% recyclable at end of life. Using recycled steel takes the pressure off renewable resources: about six scrapped cars are needed to build a typical 2,000-square foot home with steel framing.

Reuse and adaptability. In contrast to many other building materials, steel is routinely collected in aggregate quantities from construction and demolition sites and recycled into new steel products. It can be recycled repeatedly into new products without a loss in quality. Cold-formed steel is also adaptable to reconfigure buildings and has been proven to enable re-use of whole buildings that might otherwise be demolished.

Buildings can't always be constructed for permanency. Changes in tenants and financial/economic conditions often lead to building uses that are not consistent with the original design. To avoid the extreme case of demolition and rebuilding, designers should consider methods and materials that facilitate changes in the future, and that allow for sustainable uses of materials that are not reused.

Heavy mass construction is not usually conducive to modifications. Cold-formed steel partitions, on the other hand, can easily be removed, reused, and/or recycled during building modifications. Light weight, fire-resistance, and flexibility are advantages other materials can't match for this purpose. Unlike wood, noncombustible materials such as steel do not pose increased risk of ignition when exposed during alterations to a building.

Adding stories of cold-formed steel over existing buildings has been a successful way to reuse buildings that would otherwise have to be demolished to build a larger structure to meet changing needs. The light weight of cold-formed steel can often allow additional stories without the need to drastically modify the structure and foundation below.

Energy and Emissions. As mentioned earlier, since 1990, the US steel industry has reduced energy intensity by 32%. The industry has achieved a reduction in CO_2 emissions of 37% per ton of steel over the same time frame. Globally, the World Steel Association states that world-wide, the steel industry has reduced energy consumption since the 1970's in the manufacture of steel by 50%. This also directly relates to a reduction in greenhouse gas emissions.

A Sound Environment. In terms of acoustics, the use of cold-formed steel framing is instrumental in achieving acoustical privacy. Acoustical privacy from one room to the next is a function of the Sound Transmission Classification (STC) of the separating assembly. This assembly can either be a wall or a floor-ceiling assembly. STC is a single number rating system that gives a comparative look at how well an assembly impedes sound energy as it moves through the assembly. Essentially the higher the STC is, the greater the acoustical privacy.

The 2015 International Building Code requires a minimum STC of 50 to separate sleeping areas and dwelling units from adjacent spaces. Cold-formed steel framed assemblies readily attain STC's in the mid-60s.

Attribute 5: DURABILITY and Cold-Formed Steel

Long life, or durability, is a primary attribute necessary for all building materials and a key component of resilience. Durability is especially important for structural materials and finishes in areas where moisture from atmospheric conditions or inadvertent exposures occur. Even though all materials need to be protected through effective claddings and barriers, it is reasonable to assume some breakdown of those protections will occur. Plumbing or roof leaks are not uncommon. Similarly, a breakdown in the building envelope creates opportunities for pests like termites and carpenter ants to attack a structure. Consequently, choosing materials that won't sustain significant damage from moisture or pests is essential.

Corrosion resistance. Cold-formed steel has a resistant coating that effectively protects steel from corrosion. This coating must meet the requirements of ASTM A1003 *"Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members."* The recognized test standard for measuring corrosion resistance is ASTM B117 *"Standard Practice for Operating Salt Spray (Fog) Apparatus."* Compliance to these standards is assured through the Steel Framing Industry Association Code Compliance Program (click here for more details). This is a mandated program that requires participation of all SFIA manufacturer members.

With the proper coating and construction techniques, the protective barrier over cold-formed steel will last hundreds of years beyond the typical building's life. Unlike other structural materials, steel can be ordered with extra heavy zinc or similar coatings for even more durability in harsh environments. New types of metallic coatings have also been recently introduced, referred to as EQ (equivalent) coatings, and are used to supplement the layer of zinc to achieve higher corrosion resistance performance.

Termites. According to the U.S. Department of Agriculture, termites cause an estimated five billion dollars of damage each year in the United States[5]. Termites represent a significant threat to the long-term resilience of a building throughout most of the United States and particularly in warmer climates.

Courtesy: University of Florida

Cold-formed steel is one of the few materials that can resist termites in nearly any climate or building type. Even though it seems like termite damage would be a long-term issue, when a hurricane or other high winds strike, it pays to have a building that performs as designed, versus one that may be weakened by termite damage.

The Formosan termite poses a unique threat to buildings across the southeast and gulf coast regions in the United States, as well as in Hawaii and other tropical locations. Unlike the more traditional subterranean termite that attacks from the ground up, the Formosan termite can establish colonies even on the roof due to its ability to attack aerially. In these areas, using cold-formed steel framing for the entire structure will increase the building's resilience.

Mold. Preventing exposure to susceptible materials during a flood or even under normal conditions in some areas is critical to preventing mold, mildew, and structural deterioration.

Although the safest approach may be to elevate a building above the flood elevation, that is not always practical or even possible in some areas. An alternative approach is to not use susceptible materials in flood-prone areas in the first place.

Courtesy: Houselogic

Cold-formed steel is inherently a good choice for any framing where it may get wet during a flood. Unlike wood framing, cold-formed steel is inorganic and won't provide a source for mold and mildew. Steel will not absorb water like wood. In effect, steel framing will aid in drying out the space faster.

When floods and leaks do occur, organic materials represent the perfect materials for mold growth. Non-organic materials such as steel don't support mold growth. It will not function as a food source for mold.

Further, steel is dimensionally stable in a moist environment. It will not warp. Walls and floors remain plumb once the building dries out.

Endnotes:

[1] *ASCE Manuals and Reports on Engineering Practice No. 84, Mechanical Connections in Wood Structures, American Society of Civil Engineering)*

[2] http://www.ce.jhu.edu/cfsnees/

[3] Earthquake and Fire Performance of a Mid-Rise Cold-Formed Steel Framed building – Test Program and Test Results: Rapid Release Report by Xiang Wang, et.al. Department of Structural Engineering, University of California, San Diego, December 2016

[4] http://ascelibrary.org/doi/abs/10.1061/(ASCE)ST.1943-541X.0000760

[5] https://www.srs.fs.usda.gov/compass/2012/11/15/forest-service-termiticide-testing-program/

SFIA
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The Steel Framing Industry Association is dedicated to expanding the market for cold-formed steel in construction through programs and initiatives that Promote the use of cold formed steel framing as a sustainable and cost-effective solution, Advocate the development and acceptance of favorable code provisions, Educate members with reliable data and other critical information that is essential to effective business planning, and Create a positive environment for Innovation.

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