

COLD-FORMED STEEL AND RESILIENCE

SUMMARY

Over the last few years there has been an emerging awareness of the term “resilience” and its importance to the built environment. This 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 to natural disasters. From the halls of academia to the corridors of congress, these discussions have led to changes in our thinking on sustainability and building design. This paper will explore the concept of resiliency and relate it to a better understanding of the inherent properties of cold-formed steel framing that make it a resilient material.

WHAT IS RESILIENCE?

In the last ten years there have been many published definitions of resiliency, 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.

Even the U.S. Congress has attempted to define resilience in a bill proposed during the 113th Congressional session. Proposed Bill HR 2241 includes a more detailed definition specific to buildings:

“...buildings are designed and constructed to: (1) resist hazards brought on by a major disaster; (2) continue to provide their primary functions after a major disaster; (3) reduce the magnitude or duration of a disruptive event; and (4) have the absorptive capacity, adaptive capacity, and recoverability to withstand a potentially disruptive event.”

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 Attributes of Resilience

The US Government report “*High Performance Based Design for the Building Enclosure*” establishes what are termed “Attributes”, which are 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 (sometimes defined through Life Cycle Analysis, or other calculator tools), as well as acoustic performance of the exterior envelope.
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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. Given that resilience of the overwhelming majority of buildings is threatened more by events other than those that are sudden and catastrophic, it makes sense from a sustainability perspective that we construct buildings to last and remain in service as long as their expected economic life. Further, buildings should be adaptable in order to avoid functional obsolescence in order to achieve or possibly even extend their economic life.



U.S. FEDERAL AGENCIES' VIEW ON RESILIENCE

The work of several Federal agencies helps translate the theoretical aspects of resilience into a practical application. Active agencies include the Federal Emergency Management Agency (FEMA), the Department of Homeland Security (DHS), and the National Institute of Building Sciences (NIBS). FEMA has established what is termed a MAT or Mitigation Assessment Team Program. The goal is to increase the damage resistance of future building stock by forensic investigation of buildings impacted by natural and man-made disasters. From Hurricane Sandy to the Oklahoma bombings, FEMA experts have investigated structures and ultimately made recommendations for code changes intended to enhance building resilience.

The Department of Homeland Security provides the President of the United States with advice on security through the National Infrastructure Advisory Council, NIAC. In 2009 NIAC published a report entitled "*Critical Infrastructure Resilience Final Report and Recommendations*". One of the fundamental recommendations was to "examine what steps government and industry should take to best

integrate resilience and protection into a comprehensive risk-management strategy."

The most comprehensive definition was developed in 2011 by the DHS in partnership with NIBS. Their document, "*High Performance Based Design for the Building Enclosure – A Resilience Application Project Report*" provides specific guidelines to follow in the design of resilience in exterior envelopes. It states resilience as "a function of Robustness, Resourcefulness and Recovery is a product of quality of function loss and the time to recover."

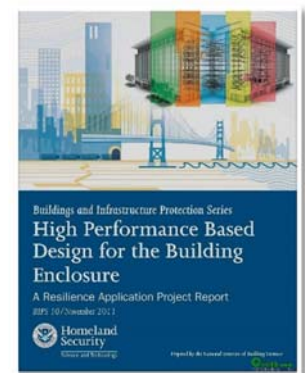
The intent of the performance based design is to be assimilated into a potential Owners Project Requirements (OPR). The OPR is then to be used as roadmap for drafting the Basis of Design, BOD, for a future structure. It offers a practical approach to establishing cold-formed steel as a resilient building material.

RESILIENCE ATTRIBUTES

"*High Performance Based Design for the Building Enclosure*" establishes what are termed "Attributes", which are defined as "high-level properties that define a building in terms of the performance the building is to deliver." These attributes are defined on page one of this document, and include:

1. Safety
2. Security
3. Energy Conservation
4. Environment
5. Durability

These attributes are basic requirements for meeting the three types of conditions (Demands) placed or exerted on a building. The report groups these Demands in three categories: Natural hazards. Man-made hazards, and the environmental conditions of the building location. The resilience of a building corresponds directly to how well the five Attributes enable the building to meet the three Demands.



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COLD-FORMED STEEL AND RESILIENCE

Accepting the premise that the above five attributes establish a resilient structure, then by extension, the same attributes could also benchmark a building material. Following the direction provided by DHS and NIBS, cold-formed steel framing can be seen as definitely having inherent resilience.

SAFETY and Cold-formed Steel

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

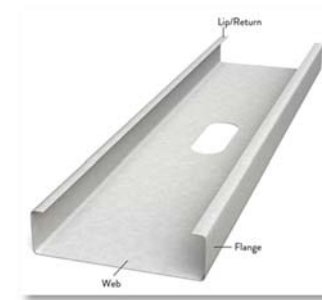
Lateral Load Resistance: Regardless of material, an important consideration in structural design is the lateral load resistance of exterior walls, or how well the wall will resist high wind and seismic forces. Structures are designed to absorb energy produced by ground movement and wind by "flexing" 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, and has inherent strength in uplift and gravity loading.



Consistent Performance: 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, as well as strength and stiffness. Likewise, 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



Courtesy: ClarkDietrich Building Systems

of several different materials is determined by dividing the maximum imposed load by the weight of the material. Of all 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 act as stiffeners and 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.

Non-Combustible: Steel-framed structures are inherently non-combustible, and do not burn nor contribute to the spread or intensity of a fire.

Connection Strength: Because the material and geometric properties of a steel-framing member are stable, the overall strength of the structure will depend upon the quality of connections between the studs. Steel framing typically uses screws that provide



a mechanical locking connection where the load is carried in shear. This is in direct contrast to wood, where

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connection strength is often limited – not by the strength of the fastener, but by the resistance of the wood in bearing or withdrawal.¹

These characteristics (above) enable cold-formed steel to provide the needed resilience when subjected to the following hazards identified in the DHS/NIBS definition of Safety.

Fire. A resilient and sustainable building is the one that is not destroyed or heavily damaged by fire. Therefore, non-combustible materials – especially as the structural system – can help achieve a resilient building.



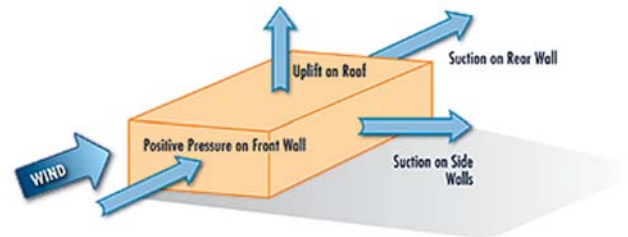
The building codes recognize cold-formed steel as “non-combustible” and therefore make it eligible for use in Type I buildings where the fire-resistance standards are the most stringent. This is because cold-formed steel does not burn and will not contribute to the spread or intensity of a fire.

“Fire walls” are code-mandated assemblies that help limit or slow the spread of flames in a building, and cold-formed steel frame assemblies have been proven to be fire proof in up to four hours when subjected to tests conforming to ASTM E119 (Standard Test Methods for Fire Tests of Building Construction). These fire-rated assemblies are available for both load-bearing and non-loadbearing conditions.

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.

Non-combustible cold-formed steel construction also make sense from a cost saving standpoint, as insurers traditionally offer lower builders risk and general liability premiums compared to wood.

High Wind. A variety of windstorm types occur in different areas of the U.S., 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 all 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, with 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, has published design tables to assist engineers and architects in selecting the proper size stud or joist for a given structural condition.



and architects in selecting the proper size stud or joist for a given structural condition. This document entitled “Technical Guide for Cold-Formed Steel Framing Products” contains tables that cover exterior walls that must have the capacity to resist wind loads. The tables cover what are called

curtain wall applications as well as applications

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

where the exterior wall is also a load-bearing wall. The data therein provides guidance on designing walls to resist up to 40 psf wind loads or approximately 125 mph winds. Cold-formed steel framing has the capacity for 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. In addition, 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 covering and sheathing is lost and the subsequent water damage. 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 do not matter. This is where a product like cold-formed steel framing can increase the resilience of the envelope due to the use of screws that better resist pull-out forces on the sheathing.

Seismic. 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.

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 for two key reasons: high ductility and light weight.

Steel is considered a ductile material because it has the 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 damage to the steel. On the other hand, brittle materials like concrete or masonry units will fracture and fail at their ultimate loads.

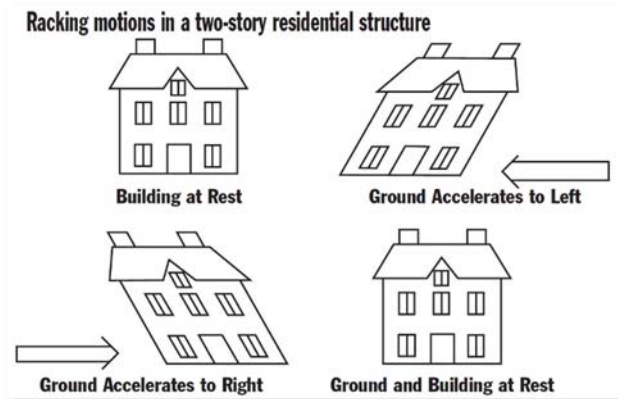


Courtesy: CFS_NEES, Johns Hopkins University

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 Buffalo². 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 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

² <http://www.ce.jhu.edu/cfsnees/>

earthquake conditions and that it is possible to design cold-formed steel structures even more efficiently."



Courtesy: Santa Clara University

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. In a seismic event, the effect on a structure is similar to what players experience in the game "crack the whip." Lighter structures have less weight available to be subjected to the stresses of inertia.

Flood. FEMA has recognized three "key issues" related to mitigating the ravages of a flood, including:

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

This is documented in their fact sheet called Cleaning Flooded Buildings. 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 and concrete are two good moisture-resistant choices 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



Courtesy: FEMA

HVAC units that should be secured independent of the breakaway component. Steel is also resistant to the formation of mold, a major concern after floods.

SECURITY and Cold-formed Steel

DHS and NIBS look at blast resistance and ballistics as metrics for security. Cold-formed steel framing has been shown 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.³

³ [http://ascelibrary.org/doi/abs/10.1061/\(ASCE\)ST.1943-541X.0000760](http://ascelibrary.org/doi/abs/10.1061/(ASCE)ST.1943-541X.0000760)

Ballistics. The DHS and NIBS definition of Security connects “ballistics” with a man-made event, such as a bomb or bullet, but the 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. Bullet penetration is more difficult to resist because the force is concentrated on a very small area. Proprietary solutions have been developed using cold-formed steel to help spread the load over a larger area.



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 2012 International Energy Conservation Code, IECC. On a prescriptive basis this code mandates the use of continuous insulation to fully sheath what are considered opaque walls. Further, there are requirements for air/water barriers that are continuous from below grade, up the exterior walls, and unto the roof membrane.

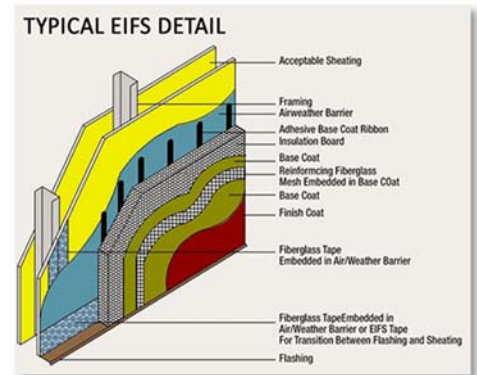
Four exterior wall systems that use cold-formed steel are currently available that meet these IECC requirements. The main difference in the four is the final exterior finish.

Cement Plaster. This system has a nominal 1 inch thick cement plaster finish on metal lath. The cement plaster/lath is installed over the continuous insulation, air/water barrier, and gypsum sheathing. The cold-formed steel framing is the structural component to which all of the above is mechanically attached. The IECC may require insulation in the stud cavity, and the interior is finished with a layer of gypsum panels. Details for this were originally developed by the Technical Services Information Bureau. They published a document entitled The Energy Code and

Plaster Assemblies, which can be found at www.tsib.org.

Brick Veneer. A consortium of building product manufacturers partnered and came up with brick veneer over cold-formed steel framing system that meets the requirements of the IECC. The concept called Cavity Complete™ is to provide a single source of information related to this system. The partners include those that manufacture insulation, sealants, waterproofing, fasteners, and brick anchoring systems. Information for this system can be found at www.cavitycomplete.com

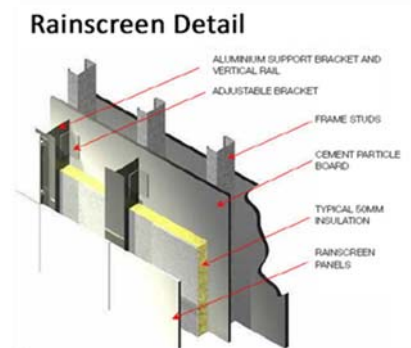
Exterior Insulation Finish System, EIFS. This system is based on having continuous insulation, typically over gypsum sheathing on cold-formed steel framing.



Courtesy: West Coast Drywall

Expanded polystyrene attached to gypsum sheathing is mechanically attached to cold-formed steel framing. Over the foam insulation is troweled a cementitious basecoat and elastomeric coating. Information for this system can be found at www.eima.com.

Rain Screen. This system starts with a finish material such as an aluminum composite panel, ACM, or a high pressure laminate panel, HPL, or even terra cotta



Courtesy: Manor Craft

attached to a steel furring system. This metal furring, which is typically cold-formed steel, is attached through continuous insulation back to cold-formed

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steel framing. Information on these systems can be found with the manufacturer of the individual panels.

All of the above systems utilize cold-formed steel framing for its structural capacity, and all meet the requirements of the IECC. This certainly proves that cold-formed steel framing can be used integrally with other components to provide a high performance exterior envelope.

Cold-formed Steel and the ENVIRONMENT

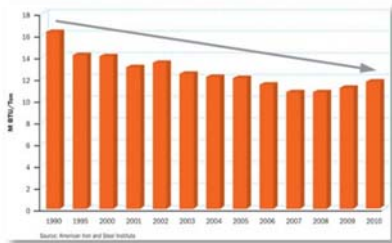
This attribute for resilience explores a material's impact on the environment and sustainability, an area where the steel industry can point to clear benefits and achievements.

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 on average 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-squarefoot home with steel framing. Finally, 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.



Energy and Emissions. Since 1990, the US steel industry has reduced energy intensity by 32% and CO₂



Courtesy: American Iron and Steel Institute

by 37% per ton of steel. 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 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. A threshold of quality is an STC of 50. The 2012 International Residential Code, IRC, in Section AK102.1 requires a STC of 45. The 2012 International Building Code, IBC, in Section 1207.2 requires a STC of 50.

Cold-formed steel framed assemblies readily attain that performance. There are assemblies that have been tested and achieved STC's in the mid-60's.

DURABILITY and Cold-formed steel

Long life is a primary attribute necessary for all building materials and a key component of resilience, but is especially important for structural materials and finishes in areas where moisture from atmospheric conditions or inadvertent exposure to moisture occurs. 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 also unplanned but do occur. Similarly, a breakdown in the building envelope creates opportunities for pest like termites and carpenter ants to attack a structure. Consequently, choosing materials that won't sustain significant damage from moisture or pests is an 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

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Compliance Program. This is a mandated program that all SFIA members must meet.

With the proper coating and construction techniques, the protective barrier over cold-formed steel will last nearly 700 years before the level of corrosion resistance deteriorates, even under extreme conditions such as near aggressive salt-laden waters. Unlike other structural materials, steel can be ordered with extra heavy zinc or similar coatings for even more durability. New types of metallic coatings have also been recently introduced, referred to as EQ (equivalent) coatings, and used to supplement the layer of zinc to achieve higher corrosion resistance performance.

Another critical characteristic for building materials in moisture mitigation is water retainage. Some materials absorb water in a flood situation and exacerbate the situation. It is important after a flood that the space is dried out as quickly as possible. The EPA has stated there is a window of 24-48 hours to effectively reduce the potential for mold propagation. That time window can be severely taxed if the building materials in the space absorb and hold moisture. Steel does not retain water.

Termites. Approximately five billion dollars of damage occur each year due to termite infestations in the United States and represent a significant threat to the long-term resilience of a building throughout most of the US and particularly in warmer climates. 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



Courtesy: University of Florida

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. When it is a reasonable approach, extra protection can be added by using another foot or two of "freeboard" above the flood elevation.

An alternative approach is to not use susceptible materials in flood-prone areas in the first place. 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



Courtesy: Houselogic

and won't provide a source for mold and mildew. Even in extreme coastal environments, the long term life of cold-formed steel framing used in accordance with AISI design standards and U.S. building codes has been shown to be hundreds of years, or well beyond the expected life of a building.

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The use of cold-formed steel framing can mitigate two of those concerns. Since steel will not absorb water like, it will not retain dampness in the space. In effect, steel framing will aid in drying out the space faster for it won't serve as a moisture reservoir.

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.

Steel is inorganic. 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 and level in a wet environment.

Building use and tenant changes – Although this seems somewhat different than the other resilience-related issues in this document, the strong relationship between sustainability and resilience requires that society consider how buildings may be used in the future. 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. In order 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. Its light weight, fire-resistance, and flexibility are benefits few other materials can match for this purpose. Unlike wood, non-combustible materials such as steel do not pose increased fire risks when exposed during alterations to a building.

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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