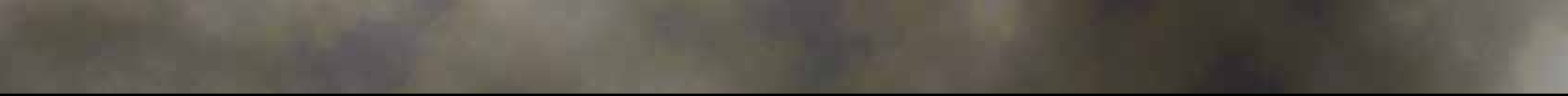

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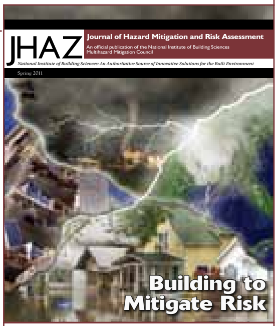


On the cover: Tornados, earthquakes, hurricanes and floods—these threats put millions of Americans at risk each year. The Multihazard Mitigation Council (MMC) is working to reduce the total costs associated with these disasters and other related hazards to buildings by fostering and promoting consistent and improved multihazard risk mitigation strategies, guidelines, practices and related efforts.

Green Building Practices for Residential Construction and Natural Hazard Resistance: **How Are They Linked?**

By Philip Line, PE; Omar Kapur, EIT, LEED Green Associate; and Samantha Passman, EIT

BUILDING GREEN HAS BECOME more common as the nation focuses on achieving energy savings and other environmental goals. As such, green building practices are increasingly being incorporated into residential building design and construction. As green building continues to gain popularity in the residential market, home designers, builders and code officials will increasingly be faced with making decisions concerning how to apply green building practices while not compromising other performance goals, including resistance to natural hazards.

For some house components and in some areas especially susceptible to natural hazard events (for example, coastal regions where hurricane winds are likely), decision makers will need to balance the benefits of green practices and the associated green building rating system points with practices that can improve house performance in a disaster event but do not garner points. Designers will also need to determine whether a green practice under consideration warrants a re-evaluation of the home's structural design or detailing to ensure that natural hazard resistance is maintained.

This paper provides only a cursory overview of the relationship between green building practices and natural hazard resistance. A more detailed discussion is presented in a new publication by the Federal Emergency Management Agency (FEMA), entitled *Natural Hazards and Sustainability for Residential Building*, FEMA P-798 **(FIGURE 1)**.

GREEN BUILDING RATING SYSTEMS FOR RESIDENTIAL CONSTRUCTION

Several nationally recognized green building rating systems used in the United States apply to residential construction. The two most recognized systems are the *National Green Building Standard* (ICC 700), which is circulated jointly by the National Association of Home Builders (NAHB, 2008a and b) and the International Code Council (ICC) **(FIGURE 2)**, and the *Leadership in Energy and Environmental Design (LEED) for Homes* rating system, which is circulated by the U.S. Green Building Council (USGBC, September 2010) **(FIGURE 3)**. A variety of local and regional residential green building programs are also in use today (described by Bowyer, 2010). These rating systems are often used voluntarily and are not incorporated as reference standards in the model codes, such as the *International Residential Code* (IRC) or the *International Building Code* (IBC).[1]

This article focuses primarily on green building practices, as described

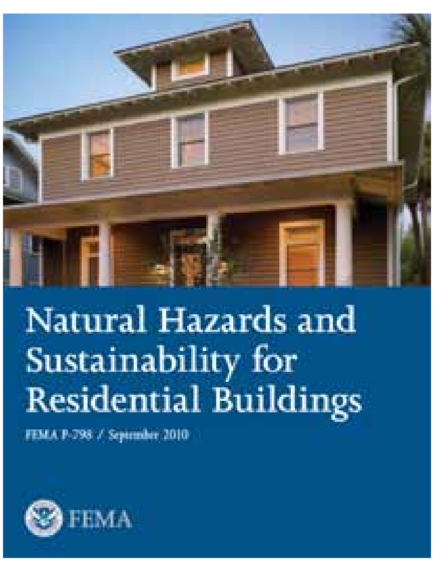


Figure 1. Natural Hazards and Sustainability for Residential Construction, FEMA P-798.

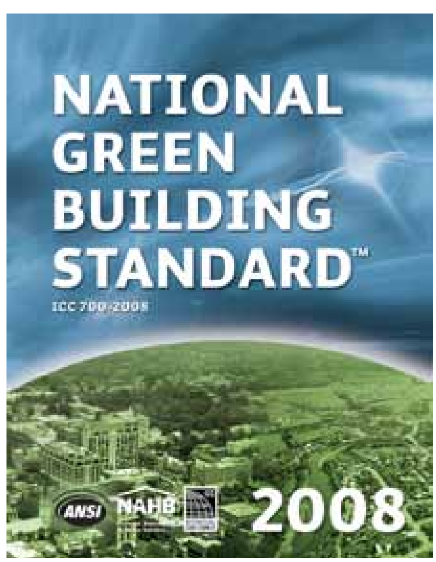


Figure 2. The National Green Building Standard (ICC 700).

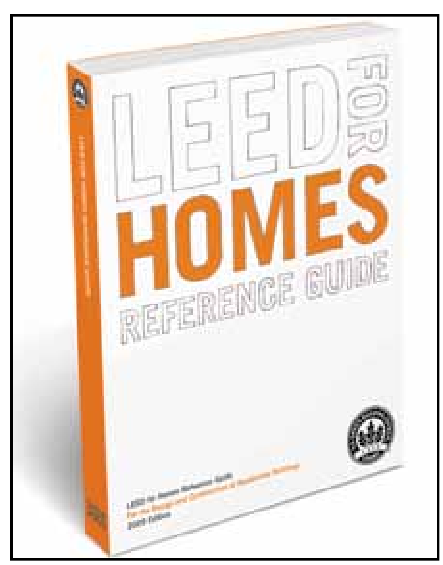


Figure 3. Leadership in Energy and Environmental Design (LEED) for Homes rating system, Version 3.

in ICC 700. Its use here is not intended to indicate a preference for ICC 700 relative to either LEED for Homes or any other green building rating system.

Green building categories

Green rating systems commonly group specific practices into broad categories, as shown in FIGURE 4, for both ICC 700 and LEED for Homes.

For example, the "Resource Efficiency" category in ICC 700 includes specific practices, such as using framing techniques that optimize material use and installing roof overhangs or awnings that protect the building from the effects of precipitation and solar radiation. Other green rating system categories include a similarly-detailed list of specific practices.

Green building performance levels

As noted earlier, a number of rating points are generally assigned to each specific green building practice. For example, under ICC 700, a specific number of points qualifies a building design as achieving a bronze, silver, gold or emerald performance-level, where emerald represents the highest level. LEED for Homes uses a similar points-based approach. Implicit in the rating system approach is that the final as-built construction will provide natural hazards resistance commensurate with other applicable laws, codes and ordinances that regulate building construction.

The benefits of hazard resistance are not explicitly identified by the green rating systems in their current form but may be taken into account indirectly in some categories. For example, ICC 700 gives credit for performing a life-cycle analysis (LCA) of a building design. By implementing LCA concepts, designers can demonstrate avoided damages—specifically, avoided materials loss that would otherwise be required for repair or reconstruction—and show measurable environmental benefits for a stronger home.

GREEN BUILDING PRACTICES AND HAZARD RESISTANCE: WHAT'S MISSING?

While many common green building practices have minimal interaction with structural performance, others may require reevaluation of the building's structural design or detailing to retain its integrity during natural hazard events. The proper implementation of a new green building practice for residential construction can be particularly challenging because designer participation is often limited and prescriptive design methods are prevalent. Many considerations involved in ensuring successful implementation of new building practices are not specifically covered by the requirements of the IRC.

The following are some of the questions to ask before implementing a green building practice or, for that matter, any new building practice:

- Are any *design changes* required to maintain compliance with codes related to hazard mitigation specific to the region or to other aspects of structural performance and durability?
- Are there any special *building detailing* issues that must be addressed?
- Will any special *installation and maintenance* instructions need to be developed and communicated in the field?

Examples of green building practices not specifically addressed by the prescriptive requirements of the IRC include large roof overhangs for solar shading, attachment of rooftop solar photo-voltaic panels and attachment of exterior siding products over exterior insulation on exterior walls.

EXAMPLES OF SPECIAL CONSIDERATIONS TO MAINTAIN HAZARD RESISTANCE

TABLE 1 is found on pages 14 and 15. It is derived from FEMA P-798 and describes the interaction between green

FOOTNOTE

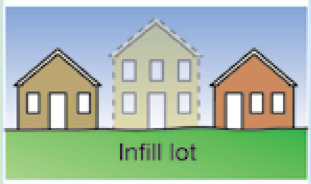
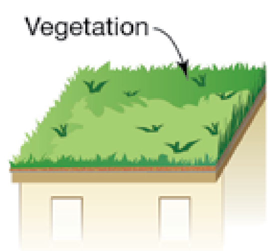
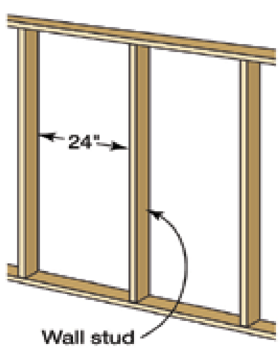
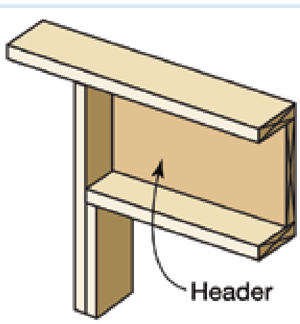
1. ICC 700 was referenced in Version 1.0 of the *International Green Construction Code* (IgCC) but was dropped from Version 2.0. The IgCC is currently under development, with publication targeted for March 2012.

ICC-700 AND LEED FOR HOMES CATEGORIES

ICC-700 Categories	Corresponding LEED for Homes Categories
Lot Design, Preparation, and Development	• Innovation and Design Process • Location and Linkages • Sustainable Sites
Water Efficiency	Water Efficiency
Energy Efficiency	Energy and Atmosphere
Resource Efficiency	Materials and Resources
Indoor Environmental Quality	Indoor Environmental Quality
Operation, Maintenance, and Building Owner Education	Awareness and Education

Figure 4. ICC 700 and LEED for Homes green building categories (FEMA 2010).

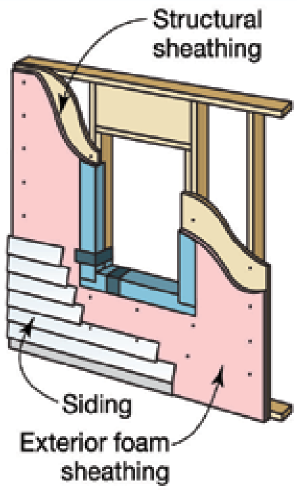
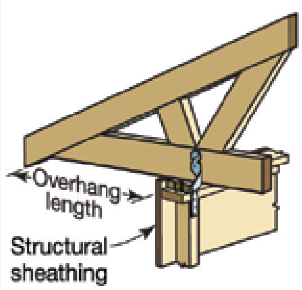
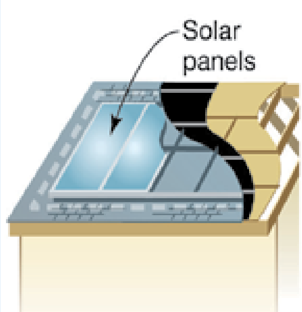
Table 1. Green Building Practice Natural Hazard Sensitivity Matrix

ICC-700 Section	Description of Green Building Practice	Graphical Depiction	Natural Hazards: Seismic	Flood	Wind	Wildfire	Explanation of Relationship
Lot Design, Preparation, and Development							
501.1 (1)	**Lot:** An infill lot—vacant or underutilized land with pre-existing utilities—is selected.		NA	⚠	NA	⚠	This credit incentivizes building on vacant or unutilized land that has at least some existing utilities on the property. **Flood:** Infill development within flood hazard areas increases flood risks. Check items such as foundation type, elevation, and materials for compliance with flood-resistant construction practices. **Wildfire:** Maintain perimeter protections against wildfires.
Lot Design, Preparation, and Development							
503.4 (4)	**Stormwater management:** A roof that is partially or completely covered with vegetation (a green roof) is installed on the building.		⚠	NA	⚠	⚠	Additional dead load, potential debris, and durability factors create additional considerations for green roofs. For dead load considerations, the structure should be evaluated for its ability to resist the added roof weight. The roof waterproofing system should be evaluated for its ability to resist leaks, root penetration, and moisture related problems. **Seismic:** Evaluate structure's ability to resist increased seismic forces from increased roof weight. **Wind:** Evaluate system's ability to minimize potential for the roof surface to become windborne debris. **Wildfire:** Vegetation on a building can increase the building's risk from wildfires.
Resource Efficiency (material usage, advanced framing techniques)							
601.2	**Increased framing spacing:** Increase wood or steel stud spacing to reduce material usage and increase insulation. May include increased spacing of floor and roof framing.		⚠	NA	⚠	NA	Using 24-inch stud spacing (as opposed to 16-inch stud spacing) results in each stud carrying a greater load, reduction in number of studs for connections, and increased spans for sheathing and other finish materials. **Seismic and Wind:** Check the design capacity of the studs, stud attachment to plates, fastener schedule, sheathing thickness, and load path for out-of-plane wind and seismic loads. Increasing stud spacing may affect the performance of certain exterior finishes under out-of-plane wind loads. More fasteners or thicker finish materials may be required.
	Right-sized header: Design wood or steel framing for single member header optimally sized for loads.		⚠	NA	⚠	NA	A single member header (as opposed to the traditional two-member header) has reduced ability to transfer gravity loads and out-of-plane wind loads if not properly designed and interconnected. Check the design of the header for loads from the framing above. **Seismic and Wind:** Check connection of header to framing for connections to transfer out-of-plane wind or seismic loads.

NOTE:

⚠ indicates relationship between the green building practice and the given natural hazard that should be considered.

"NA" indicates little or no significant relationship between the green building practice and the given natural hazard.

ICC-700 Section	Description of Green Building Practice	Graphical Depiction	Natural Hazards: Seismic	Flood	Wind	Wildfire	Explanation of Relationship
Energy Efficiency							
703.1	**Building envelope:** Increase exterior insulation on exterior walls; often accomplished by use of foam sheathing.		⚠	NA	⚠	⚠	Designing for increased insulation can change the structural and fire properties of the wall. **Seismic and Wind:** Check for adequate structural strength and connections to resist in-plane and out-of-plane forces as applicable. Check flashing/installation details to address potential for water intrusion. **Wildfire:** Check siding and sheathing used on exterior walls to ensure that they have been approved for use in wildfire-prone areas.
704.3.1.1 (7)	**Solar space heating and cooling:** Overhangs, adjustable canopies, awnings, or other coverings to provide shading over glazing.		⚠	NA	⚠	⚠	Extended overhangs require an adequate load path and proper connections. Check headers and other framing members supporting the roof for adequate size for the increased loads due to the roof itself as well as snow load. **Seismic:** Check for adequate attachment of the roof diaphragm to the wall below, as well as the seismic load path for increased forces due to the weight of the roof and potentially increased snow loads. **Wind:** Check roof uplift connections, soffit details, shear transfer, and sizing of roof framing for added loads. **Wildfire:** Check requirements for protection of soffit vents, fire rating of soffit sheathing and coverings, and other requirements for protecting the underside of the overhang from blown embers.
704.3.3	**Additional renewable energy options:** Roof-mounted solar photovoltaic panels (not applicable to building-integrated photovoltaic systems).		⚠	NA	⚠	⚠	Adding a rooftop solar panel system can add dead loads and create durability issues. Check the framing for adequacy to support the added weight of these systems and determine if the potential for water intrusion at the connections is addressed. The designer should also: **Seismic and Wind:** Check framing and connections for ability to maintain load path and resist applied forces. **Wildfire:** Check that the flame spread rating of the solar panel system meets applicable code requirements.

NOTE:

⚠ indicates relationship between the green building practice and the given natural hazard that should be considered.

"NA" indicates little or no significant relationship between the green building practice and the given natural hazard.

Source: FEMA P-798, Natural Hazards and Sustainability for Residential Buildings, 2010.

building practices and the need for natural hazard resistance for several ICC 700 categories. In addition, it illustrates potential effects and is intended to encourage further thought and consideration of improved design, detailing and installation techniques.

Lot design, preparation and development

Beneficial interactions: Green building practices that minimize slope disturbance, soil disturbance and erosion can also significantly improve the resistance of a neighborhood to some natural hazards (such as earthquakes, some types of flooding and wildfires). Further, development of stormwater management plans, hydrologic analyses, soil studies and other such actions that garner points under ICC 700 can also guide the designer to solutions that increase a building's resistance to natural hazards.

Special considerations: Site selection decisions, made in order to qualify for green rating system points, should also take into account the dominant natural hazards in a region. For example, the decision to build on an infill site should include consideration of floodplain and stormwater management issues.

Energy efficiency

Beneficial interactions: Green building practices that improve energy-efficiency by using thermal mass can also increase resistance to certain natural hazards. For example, the use of properly detailed concrete or masonry walls can improve resistance to windborne debris in high-wind events.

Special considerations: Increasing thermal mass also increases the loads imparted on a building in an earthquake. The use of heavier walls requires increased bracing to withstand the higher earthquake loads. Additionally, energy-efficiency practices that reduce the number of framing connections or their effectiveness (due to increased framing spacing [see the example under Resource Efficiency] or wider spaces between structural framing and sheathing or siding) require special attention to detailing. For example, thick exterior insulating sheathing in a high-wind region may require non-standard attachment and flashing to maintain resistance to wind suction and wind-driven rain intrusion into wall cavities.

Resource efficiency

Beneficial interactions: The green building practices that optimize building framing (as per ICC 700, Section 601.2) can have a significant effect on structural performance. When this design accounts for the dominant natural hazards in a given region, optimization can improve structural robustness. For example, optimization in a high-wind region often includes reinforcing highly-stressed connections.

Special considerations: The Commentary to Section 601.2 of ICC 700 (NAHB 2008b) encourages advanced wood framing techniques that use less material in the building while complying with applicable structural requirements. In some cases, the optimization of framing creates additional challenges for designers to maintain load paths and other aspects of structural capacity.

Unless these techniques are carefully implemented, some parts of the structure may be compromised. For example, increasing framing spacing from 16 inches (40 cm) on center (o.c.) to 24 inches (60 cm) o.c. earns credits in the ICC 700 rating system but provides fewer points of connectivity within walls and between the walls and the roof. If the optimized framing system is used, proper installation of each connection is more important than it would be in the more redundant 16 inches (40 cm) o.c. situation, simply because there are fewer connections.

Operation, maintenance and building owner education

Beneficial interactions: ICC 700 provides credit for communicating important building operation and maintenance information to the homeowner. This information can help the homeowner to maintain critical areas in the exterior building envelope, thus minimizing long-term water intrusion and associated building degradation. Well-maintained buildings are better equipped to resist wind and seismic hazards.

ADDED BENEFITS OF MAINTAINING NATURAL HAZARD RESISTANCE

FEMA P-798 defines sustainable building design as "building design that addresses fundamental sustainability principles by optimizing the use of land, materials, energy and water for human occupancy and ecosystem health while considering the ability of the building to resist natural hazards."

Buildings that incorporate green building practices and provide needed resistance to natural hazards have distinct advantages and offer considerable sustainability benefits, even though these benefits are difficult to quantify. For example, every home that survives a hurricane:

- Provides post-disaster shelter for the home's occupants;
- Minimizes windborne debris to downwind homes;
- Removes the need for one additional temporary housing structure; and
- Provides post-disaster sustainability benefits (less material sent to landfill and less new material needed for reconstruction).

If a home has self-sufficiency attributes (also known as "passive survivability"), it can shelter occupants after a disaster without relying on outside infrastructure. Consider, for example, the use of solar power for on-site electric power generation. Numerous design and detailing considerations are needed for such a system to function after a disaster, including coordination with the local utility, actively planning for what power generation is achievable and matching that to the more important electrical loads. These all may be of value to the homeowner. Sizing the system to supply critical loads will also help a homeowner respond to natural hazard events (for example, ice storms, hurricanes or floods), all of which can interrupt utility power for extended periods.

BALANCING GREEN BUILDING PRACTICES AND INCREASED RESISTANCE TO NATURAL HAZARDS

The desire of a homeowner, builder or designer to achieve improved environmental performance creates a preference for building practices recognized by green rating systems. In some cases, this may create the need to decide between practices that increase efficiency and garner green rating system points or use of practices that increase resistance to natural hazards without garnering green rating system points.

> The proper implementation of a new green building practice for residential construction can be particularly challenging because designer participation is often limited and prescriptive design methods are prevalent.

Consider, for example, the use of advanced framing options that earn points for resource efficiency versus framing options that increase resistance to wind hazards. Use of the green building practice that will garner points toward a higher green-performance-level rating often will be preferred. However, benefits associated with increased resistance to natural hazards may not be fully understood because they are often difficult to quantify and specific guidance concerning their consideration is not presented by today's green rating systems.

QUANTIFYING BENEFITS OF NATURAL HAZARD RESISTANCE IN THE GREEN RATING SYSTEMS: THE CHALLENGE FOR DESIGNERS

As noted earlier in this article, by implementing LCA concepts, designers can demonstrate avoided damages and show measurable environmental benefits for a stronger home. Conducting such an analysis requires designer involvement, considerable information about the materials of construction and specialized calculation tools.

FEMA P-798 provides one example of how such an analysis can be used to identify avoided environmental impacts associated with two failure scenarios: the partial failure of a house (for example, the loss of a roof) and complete structural failure (for example, the loss of the entire home). Both are determined and compared to the environmental costs of improving the initial construction to avoid such losses.

For the example building, the analysis shows that the environmental benefits associated with avoiding either failure scenario far outweigh the negligible environmental cost of actions taken to strengthen the building. Although avoided environmental impact analysis is not specifically defined in green rating systems, it is one tool that can be used to show that the relative environmental benefits associated with avoiding premature failure can far outweigh the environmental cost of actions taken to strengthen the building to avoid such failures.

CONCLUSION

Some green practices for residential construction provide improved environmental performance without any effect on structural performance. By comparison, others may require a reevaluation of the entire design in order to retain the home's integrity and building functions in natural hazard events. As home designers, builders and code officials make decisions about how to implement new green building practices in compliance with requirements of applicable building codes, they must consider how the new practices affect resistance to natural hazards.

This message is particularly useful in residential construction that relies heavily on prescriptive design and construction requirements that may not specifically address the most current building practices.

Building practices that provide increased resistance to natural hazards can have significant and measurable green benefits without being recognized as a green building practice and without accruing points in common green rating systems. While life-cycle analysis provides opportunities to demonstrate the green benefits of hazard-resistant buildings, the complexity associated with demonstrating benefits is a potential barrier to its use for this purpose. ■

The information presented in this article is largely derived from FEMA P-798, Sustainability and Natural Hazard Resistance for Residential Construction, which provides a more detailed explanation of green rating systems in the broader context of sustainability. Visit www.fema.gov/library/viewRecord.do?fromSearch=fromsearch&id=4347 to download or order FEMA P-798.

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