Protecting Lives and Property: Making Green Buildings "Functionally Resilient"

The enhanced functional resilience of a building's structure should be the first consideration of a green building.

Functional resilience—A building's capacity to provide viable operations through extended service life, adaptive re-use and the challenges of natural and man-made disasters.

In addition to satisfying minimum life safety provisions, truly sustainable buildings must also:

- ✓ Be sufficiently robust and durable to minimize the amount of energy and resources required for routine maintenance, repair, and replacement
- ✓ Provide enhanced safety and security for improved occupant comfort and productivity
- ✓ Have lengthy design service lives
- ✓ Enhance the operational continuity of the community in which they are built
- ✓ Be adaptable for future use and re-purposing to minimize long-term environmental impacts involved with replacement, removal, disposal, and reconstruction
- ✓ Be resistant to natural and man-made disasters to minimize energy expended and resources needed for emergency response, relief, and recovery
- ✓ Resist damage of building materials and contents to avoid excessive disposal in landfill

Functional Resilience – What and Why?

The need for increased functional resilience in building design and construction has long been recognized by many entities and identified in many publications and programs. One of the most noteworthy programs is the FORTIFIED® program developed and implemented by the Institute for Business and Home Safety (IBHS), a national association representing the insurance and re-insurance industries. The FORTIFIED program focuses on the need for more durable and more disaster-resistance construction.

However, functional resilience is much more than disaster resistance. The increased robustness, longevity, and durability, combined with improved disaster resistance result in less energy and resources required for repair, removal, disposal, and replacement of building materials and contents due to routine maintenance and operations, as well as disasters. Functionally resilient buildings create safe, secure, comfortable, and productive environments in which to live and work.

Source: Federal Emergency Management Agency

Flooding not only damages, but typically contaminates building materials and contents rendering them unusable and requiring incineration or disposal in landfills.

Community-Wide Operational Continuity

The impact of enhanced functional resilience is not limited to buildings. More functionally resilient buildings can significantly enhance the sustainability of communities. Continuous business operations and residential occupancy provide the economic benefits of a more consistent tax base and generally support continuity of the community's vitality. Further community economic, societal, and environmental benefits result from reductions in resources that would need to be reallocated for emergency response, disaster relief, and disaster recovery.

The Missing Link

To date most sustainability or green voluntary certification programs, codes, and standards have focused primarily on energy, material, and water conservation; indoor environmental quality; and site selection and development. Each of these is an important aspect of sustainable building design and construction. However, the assumption that the basic building will be functionally resilient is not inherent in these programs. Often minimum requirements in many building codes are focused on life safety and do not provide the protection of buildings and their contents necessary for truly sustainable buildings. Unfortunately, this is consistent with our disposable-mentality and often results in buildings that satisfy the absolute minimum project requirements at the least possible initial cost. Even today, many jurisdictions do not have a building code or the building code may not be applicable to all building occupancies.

Source: Federal Emergency Management Agency, photographed by Greg Henshall

Conflagrations from building fires jeopardize communities. For example a dormitory under construction at Virginia Commonwealth University (not depicted here) burnt to the ground and spread fire to 28 surrounding buildings.

Championing Functional Resilience

There are many resources and references highlighting the need for enhanced functional resilience. The following seven references capture the most significant aspects:

1. A study of FEMA-awarded grants[1] indicates "**a dollar spent on disaster mitigation saves society an average of $4.**" The analysis included some strategies other than enhanced disaster resistance of buildings. However, more disaster-resistant buildings enhance life safety; reduce costs and environmental impacts associated with repair, removal, disposal, and replacement; and reduce the time and resources required for community recovery.
2. "When Hurricane Katrina made landfall on August 29, 2005, it caused an estimated $41.1 billion in insured losses across six states, and took an incalculable economic and social toll on many communities. Five years later, the recovery continues and some residents in the most severely affected states of Alabama, Louisiana, and Mississippi are still struggling. **There is no question that no one wants a repeat performance of this devastating event that left at least 1,300 people dead. Yet, the steps taken to improve the quality of the building stock, whether through rebuilding or new construction, call into question the commitment of some key stakeholders to ensuring that past mistakes are not repeated.**"[2] This report indicates that there is a need to implement provisions to make buildings more disaster-resistant.
3. **The average annual direct property loss due to natural disasters in the United States exceeds $35,000,000,000.**[3] This does not include indirect costs associated with loss of residences, business closures, and resources expended for emergency response and management. These direct property losses also do not reflect the environmental impact due to reconstruction. Functional resilience will help alleviate the environmental impact and minimize both direct and indirect losses from natural disasters.
4. "Climate changes are underway in the United States and are projected to grow. Climate-related changes are already observed in the United States and its coastal waters. These include **increases in heavy downpours, rising temperature and sea level, rapidly retreating glaciers, thawing permafrost, lengthening growing seasons, lengthening ice-free seasons in the ocean and on lakes and rivers, earlier snowmelt, and alterations in river flows. These changes are projected to grow.**"[4] The report further identifies that "Threats to human health will increase. Health impacts of climate change are related to heat stress, waterborne diseases, poor air quality, extreme weather events, and diseases transmitted by insects

Source: U.S. Geological Survey, Department of the Interior
It is not just in California. Some of the largest wild fires occurred in the Southeast and South Central United States and as far north as Maine.

Source: Federal Emergency Management Agency.
Damage from earthquakes and other disasters can render buildings inhabitable. Further fires after disasters may have even larger impacts.

Source: United States Geological Survey Photograph by Martin Klimek, Marin Independent Journal.
Fires following disasters, where power, water, or emergency response access are unavailable or limited, can jeopardize entire communities.

[1] ***Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*** National Institute of Building Sciences Multi-Hazard Mitigation Council - 2005

[2] ***Five Years Later – Are we better prepared?*** Institute for Business and Home Safety – 2010.

[3] ***National Weather Service Office of Climate, Water and Weather Services*** National Oceanic and Atmospheric Administration (NOAA) – 2010. Data source is the NOAA website [www.weather.gov/os/hazstats.html]

[4] ***Global Climate Change Impacts in the United States*** U.S. Global Change Research Program (USGCRP) – 2009. The USGCRP includes the departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, State and Transportation; National Aeronautic and Space Administration; Environmental Protection Agency; USA International Development; National Science Foundation; and Smithsonian Institution.

and rodents. Robust public health infrastructure can reduce the potential for negative impacts." Key messages in the report on societal impacts include:

- "City residents and city infrastructure have unique vulnerabilities to climate change."
- "Climate change affects communities through changes in climate-sensitive resources that occur both locally and at great distances."
- "Insurance is one of the industries particularly vulnerable to increasing extreme weather events such as severe storms, but it can also help society manage the risks."

Sustainable building design and construction cannot be about protecting the natural environment without consideration of the projected growth in severe weather. Minimum codes primarily based on past natural events are not appropriate for truly sustainable buildings. Buildings expected to reduce negative environmental impact over the long-term must be protected from these extreme changes in the natural environment. The provisions for improved property protections are necessary to reduce the amount of energy and resources associated with repair, removal, disposal, and replacement due to routine maintenance and damage from disasters. Further such provisions reduce the time and resources required for community disaster recovery.

5. A study by the Brookings Institution[5] projects that "**by 2030 we will have demolished and replaced 82 billion square feet of our current building stock, or nearly one-third of our existing buildings, largely because the vast majority of them weren't designed and built to last any longer.**" Durability, as a component of functional resilience, can reduce these losses.
6. During panel discussions, a representative of the National Conference of State Historic Preservation Officers noted that **more robust buildings erected prior to 1950 tend to be more adaptable for reuse and renovation.**[6] Prior to the mid-1950s, most local jurisdictions developed their own building code requirements that uniquely addressed the community's needs, issues, and concerns—generally resulting in more durable and robust construction.
7. "The risks posed by natural hazards to the built environment demonstrate the need for disaster preparedness to **assure that buildings and infrastructure are made more resilient and respond better when disaster strikes.**"[7] Supporting statements include that in the first three and one-half months of 2010 there were 31 natural disasters declared in the U.S. and insured catastrophic losses in the 2000s total $138 billion, a 56 percent increase when compared to the amount in the 1990s. One of the recommendations is:"Encourage the design community toward greater focus on resilience."

Without power or water supplies after disasters, individuals resort to open fires for light, heating, cooking and purifying water. Such open fires are often not properly contained furthering the potential for even greater disasters.

While typical building codes and standards are based on previous weather events and disasters, the National Weather Service is advising that due to global warming we should expect more extreme and severe weather.

Source: Federal Emergency Management Agency, taken by Andrea Booher of FEMA.

Impact of disasters is often beyond the damaged buildings. During this flood FEMA provided much needed financial assistance and ensured that fresh water, food, shelter and communications were available. After this flood a total of 534 counties in nine states were declared for federal disaster aid and 168,340 people registered for federal assistance.

[5] ***Sustainable Stewardship - Historic preservation plays an essential role in fighting climate change***, Traditional Building, National Trust for Historic Preservation – 2008. Article by Richard Moe.

[6] ***Opportunities for Integrating Disaster Mitigation and Energy Retrofit Programs*** Senate Environment and Public Works Committee Room, Dirksen Senate Office Building, Washington, D.C. - 2010

[7] ***Designing for Disaster: Partnering to Mitigate the Impact of Natural Disasters*** - Insights Drawn from the National Building Museum's Industry Council for the Built Environment, May 12, 2010 - Executive Summary

The total environmental impact of insulation, high efficiency equipment, components, and appliances, low-flow plumbing fixtures, and other building materials and contents are relatively insignificant when rendered irreparable or contaminated and must be disposed of in landfills after disasters. The US Army Corps of Engineers estimated that **after Hurricane Katrina nearly 1.2 billion cubic feet of building materials and contents ended up in landfills. This is equivalent to a band of refrigerators placed end to end twice around the equator of the Earth.**

Design of buildings should appropriately consider long-term community development plans to help assure buildings can be re-used or re-purposed.

DESIGN FOR FUNCTIONAL RESILIENCE

BASIS FOR THE CRITERIA

Functional resilience as presented here is modeled after the concepts of the Whole Building Design Guide developed jointly by the National Institute of Building Sciences and the Sustainable Building Industries Council. For building design and construction the Whole Building Design Guide addresses:

Accessible	Historic Preservation
Aesthetics	Productive
Cost-effective	Secure / Safe
Functional / Operational	Sustainable

The minimum requirements are set to be consistent with the design and construction requirements identified in the Institute for Business and Home Safety FORTIFIED® programs. The design and construction strategies presented are material-neutral. There are a few exceptions, similar to the requirements in current building codes, such as limiting construction below flood elevation to treated wood, concrete, or masonry.


Source: U.S. Department of Energy
Robust, disaster resistant, buildings with long lives and low maintenance minimize the contribution of the built environment to landfills.

ENVIRONMENTAL BENEFITS

There are many benefits related to the enhanced functional resilience of buildings. In addition to long-term environmental benefits, other benefits are better buildings for occupant safety, comfort, and productivity; property protection – both building and building contents; economic benefits for the building occupants, owners, and the community; and societal benefits related to operational continuity for the community. The significant direct environmental benefits include reduced demand for resources and less energy expenditures required for:

1. Repair, removal, disposal and replacement of building elements due to normal operations and maintenance;
2. Building demolition and replacement resulting from increased adaptability for re-use and even re-purposing;
3. Repair, removal, disposal and replacement of building elements and building contents when disasters occur; and
4. Emergency response, relief and recovery when disasters occur.

Source: Federal Emergency Management Agency, taken by Michael Rieger of FEMA.
During and after disasters, huge amounts of energy and resources are expended for emergency response, disaster relief, and community recovery.

USE OF THE RECOMMENDATIONS

These recommendations are intended to provide enhancements to basic minimum building code requirements. They are offered to help designers lessen the environmental footprint of the building core and shell. As previously mentioned the recommendations are modeled after the concepts of the *Whole Building Design Guide* and are consistent with the criteria of the FORTIFIED® programs. Thus, for the design and construction of green or sustainable buildings, they are presented as enhancements to minimum building code and are intended for buildings with design service lives of 50 to 60 years. The American Society for Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings* provides for a design service life of 50 years. The design service life in draft ASTM International standards and International Code Council *International Green Construction Code Public Version 2.0* is 60 years. Naturally, further enhancements than those provided here may be appropriate to achieve the functional resilience commensurate with longer design service lives for buildings.

Overview of Prerequisites for Green Buildings

SERVICE LIFE
Design Service Life – Minimum design service life of 50 years.
STRUCTURAL COMPONENTS
Fire Damage Resistance – Maintain fire resistance ratings of not less than one-hour.
Flood Damage Resistance – Comply with ASCE 24; do not consider levees and flood walls as flood protection; and apply Coastal V Zone construction criteria for Coastal A Zones.
Seismic Damage Resistance – Increase seismic loads by 20% where the 0.2 second spectral response acceleration parameter is equal to or greater than 0.4g.
Snow Load Damage Resistance – Increase design snow loads by 20%.
Storm Shelters – require storm shelters designed and constructed in accordance with ICC 500.
Wind Damage Resistance – Increase basic design wind speed by 20 mph and use attachments methods in accordance with UL and FM Global standards.
FIRE PROTECTION COMPONENTS
Automatic Sprinkler Systems – Use sprinklers systems in all occupancies except low hazard manufacturing and storage facilities and do not use NFPA 13R automatic sprinkler systems.
Internal Fire Barriers – Maintain minimum 2-hr fire separations and provide draftstopping and fire stopping in concealed spaces.
Storage and Collection Areas – Provide enhanced fire protection of areas intended for collection and storage of separated recyclables.
INTERIOR COMPONENTS
Acoustical Comfort – Require STC ratings of at least 50 for opaque walls and at least 30 for fenestrations and require IIC ratings of at least 50 for floor ceiling assemblies.
Moisture Protection – Protect materials susceptible to moisture damage during construction and provide smooth hard non-absorbent surfaces when water is likely to be present during building operations.
EXTERIOR COMPONENTS
Exterior Fire Damage Resistance – Limit size of openings and the use of combustible materials on exterior walls in close proximity to adjacent structures.
Wildfire Damage Resistance – Satisfy the requirements of the *International Wildland-Urban Interface Code*.
Wind Damage Resistance – Limit the use of exterior cladding materials susceptible to wind damage to locations outside hurricane and tornado prone areas.
Hail Damage Resistance - Limit the use of exterior cladding materials susceptible to hail damage to locations outside moderate or severe hail exposure regions.
Rodent Proofing – Satisfy the requirements of Appendix F Rodent proofing of the *International Building Code.*
Radon Entry Resistance – Satisfy the minimum requirements of EPA *Guide to Radon Prevention in the Design and Construction of Schools and Other Large Buildings* or Appendix F, Radon Control Methods, of the *International Residential Code*.

SCOPE OF RECOMMENDATIONS

Robust, functionally resilient buildings are frequently reused and even re-purposed when downtowns are renovated.

Enhanced functional resilience lends to reusing or even re-purposing rather than disposal due to premature collapse.

There are many programs, codes, and standards addressing the design and construction of green, high-performance or sustainable buildings. To date, the scopes of these documents are limited to energy, water and materials resource conservation and management; indoor environmental quality; and site selection and development. The recommendations presented here are intended to be combined with those important aspects of design to further reduce the long-term environmental footprint of new buildings. Detailed criteria that combine functional resilience with the other key aspects related to the design and construction of green buildings are presented as a compilation of modifications to the International Code Council International Building Code on the Portland Cement Association website as *High-Performance Building Requirements for Sustainability (HPBRS)*. The HPBRS: (1) are written in mandatory language to facilitate compliance and enforcement; (2) presented as modifications to the International Building Code for easy adoption; (3) avoid complexities and potential misinterpretations associated with multiple compliance alternatives; (4) limit the provisions for traditionally accepted sustainability features [i.e. energy, water, and material conservation and management; indoor environmental quality; and site development] to those within the purview of the typical building code department; (5) combine criteria for functional resilience with those for the traditionally accepted sustainability features. The result is a uniquely comprehensive package for the design and construction of green buildings. The HPBRS provide for functional resilience and are intended to be used with and compliment other sustainable, green, or high-performance building programs.

The majority of the recommendations apply to building core and shell and address building components and systems that can be difficult or cost prohibitive to upgrade or strengthen once the building is occupied. While each of the criteria discussed may satisfy multiple aspects of enhanced functional resilience, they are presented in these main categories:

- **Service Life** - Design service life criteria addressing durability, longevity, re-use, and adaptability.
- **Structural Components** - Enhanced structural load resistance addressing fire, flooding, frost, snow loads, wind loads, seismic loads, and storm shelters in high wind areas.
- **Fire Protection Components** - Enhanced protection related to internal structure fires addressing automatic sprinkler systems, fire containment, and potentially hazardous conditions created where recyclables are collected and stored.
- **Interior Components** – Increased acoustical comfort and reduction of damage where moisture may be present.
- **Exterior Components** - Enhanced protection related to exterior finishes and systems used to clad the building – addressing wind, impact, fire, rodent infestation, and radon entry resistance.

The following recommendations for enhanced functional resilience are presented for consideration in the design and construction of buildings where the minimum requirements of the local building code or the *International Building Code*, whichever is more stringent, are satisfied.

Discussion on intent is provided with specific design and construction recommendations. Resources are cited in the end notes to this document.

SERVICE LIFE

DESIGN SERVICE LIFE

Intent – High-performance building designs should address building longevity with low operation and maintenance costs throughout the life of the building. A design service life plan helps the designer and owner to evaluate the long-term performance of the building and ensures the choice of materials and building systems minimize long-term costs for repair, maintenance, and replacement. Earlier discussions identify that the more robust buildings designed and constructed prior to the 1950s are often more adapatable for reuse and renovation. This observation is reinforced by a Brookings Institution study which suggests recently constructed buildings tend to be more disposable and are being replaced rather than renovated or reused.

Design and Construction [C, I, M] – The design service life of a building should be no less than 50 years. The general recommendations are that the design service life of some components may be less than that of the building. The design service life of structural components, concealed materials, and materials and assemblies where replacement is deemed impractical or cost prohibitive should have a design service life equal to that of the building. The minimum design service life for materials and assemblies identified as major is 40 years. Roofing materials and systems are recommended to have a design service life of not less than 20 years. Mechanical, plumbing, and electrical equipment and systems are typically recommended to have a design service life of not less than 25 years, and typically hardscape components should have a design service life of at least 30 years. Further enhancements for functional resilience than those presented here may be appropriate where the design service lives of buildings exceed 50 years.

Source: City of Atlanta

Image courtesy of the Ellis Hotel, Atlanta, GA: www.ellishotel.com.

The Winecoff Hotel in Atlanta Georgia was constructed in 1913 and completely gutted by fire in 1946. It reopened as another hotel in 1951 and subsequently was used as housing for elderly. After being left vacant for 20 years it reopened as the luxury Ellis Hotel in 2007.

Image courtesy of Multifamily Investor: www.multifamilyinvestor.com.

Several buildings adjacent to the collaping World Trade Center Towers were damaged by falling debris and uncontrolled fires, and either collapsed or needed to be demolished. The office building commonly referred to as 90 West, built in 1907 was damaged by debris and sustained uncontrolled fires for five days. It reopened as an apartment building in 2005.

STRUCTURAL COMPONENTS

FIRE DAMAGE RESISTANCE

Intent - To increase the overall robustness of buildings and reduce environmental impacts related to fire, smoke, suppression operations, and emergency response.

Fire Losses in the United States During 2009 by the National Fire Protection Association, August 2010 shows that property loss due to structure fires in buildings other than one- and two-family dwellings was approximately $4.5 billion. Increased fire resistance of building elements reduces the amount of damage to the building and its contents. This enhances sustainability by minimizing building materials required to restore the building and reducing the amount of materials entering landfills. Additional benefits are enhanced life safety, potentially less demand on community resources, especially for emergency response, and facilities that are more readily adaptable for re-use.

There are many examples of where noncombustible fire resistive construction as defined by the building code has provided exceptional performance in fire events, allowing buildings to be re-used and often re-purposed. Two such examples are the Winecoff/Ellis Hotel in Atlanta and 90 West Street in New York City.

Design and Construction [G, M] - Buildings should be designed so that all structural load-bearing elements (i.e. walls, columns, beams, girders, floors and roofs) have a fire resistance rating of not less than 1-hour, and as the building size increases in height or area the fire resistance of the structural components need to increase accordingly. These enhanced fire resistance features should be implemented in the building design independent of other fire protection design features such as automatic sprinklers. The fire resistance rating of structural elements should not be reduced or building height or area increased simply because sprinklers are present.

FLOOD DAMAGE RESISTANCE

Intent - To minimize the amount of building materials and contents that become contaminated or otherwise irreparably damaged by flood water Further, flood-resistant construction is less likely to generate debris and contaminants that pollute the downstream environment.

Design and Construction [A, B, M] - The design and construction of buildings in flood hazard areas, including flood hazard areas subject to high velocity wave action, should be designed and constructed in accordance with ASCE 7[A] and ASCE 24[B] and the following criteria:

Where required by ASCE 24[B] to be built above the base elevations, floors and their lowest horizontal supporting members should not be less than the higher of:

- Design flood elevation
- Base flood elevation plus 3 feet (1 m)
- Advisory base flood elevation plus 3 feet (1 m) or
- 500-year flood if known

Additionally, levees and flood walls designed as protective works should not be considered as providing flood protection.

Robustness of foundations can also be enhanced by following the design parameters located in Coastal V Zones and applying them to foundations built in the adjacent Coastal A Zones. Increasing the robustness of foundations in Coastal A Zones reduces the likelihood that the buildings and contents will be subject water damage.

Source: Federal Emergency Management Agency, taken by David Fine of FEMA

Severe storms and floods damage and destroy homes and businesses.

Source: Federal Emergency Management Agency, taken by Michael Rieger of FEMA

The levee in the foreground though topped with sandbags still breeched.

Source: Federal Emergency Management Agency, photograph taken by Liz Roll.

Flood damage isn't limited to the building, but debris carried by flood waters damage other buildings and the environment.

EARTHQUAKE DAMAGE RESISTANCE

Intent - To reduce the amount of damage when earthquakes occur. Increasing the stringency of the design criteria of high-performance buildings for earthquakes enhances a buildings ability to respond to a ground motion event. This results in more durable buildings which reduces damage to the building and its contents from seismic events.

Design and Construction [A,G,M] - Buildings in high seismic risk areas should be designed by a registered design professional. The seismic load applied to the building design, determined in accordance with IBC[G], should be increased by at least a factor of 1.2 when located where the 0.2 second spectral response acceleration parameter is equal to or greater than 0.4g. In addition, for high seismic risk buildings a site specific geotechnical report complying with the provisions of ASCE 7[A] should be provided.

This recommendation is consistent with the criteria of the Institute for Business and Home Safety FORTIFIED® program.

Source: Federal Emergency Management Agency
Earthquake damage to personal property.

Source: Federal Emergency Management Agency
A magnitude 6.7 earthquake caused 72 deaths and destroyed or damaged 114,000 residential and commercial buildings. The direct cost of damage alone was estimated by FEMA to be 25 billion dollars.

SNOW LOAD DAMAGE RESISTANCE

Intent - To reduce building damage from excessive snow loads. The National Weather Service reports that U.S. property damage due to winter storms and ice exceeded $1.5 billion in 2009. Increasing the stringency of the design criteria for snow hazards results in more robust buildings with less risk of damage. Enhanced sustainability is achieved by minimizing the amount of both replacement materials required to restore the building and damaged materials entering landfills

Design and Construction [A, G, M] - The ground snowloads used for sustainable buildings should be equal to no less than 1.2 times the ground snowloads determined in accordance with ASCE 7[A] or the *International Building Code*.

Source – Institute for Business and Home Safety
In many instances roof collapse due to snow loads not only results in damage to roof and building contents below but may also remove lateral support, allowing walls to collapse.

STORM SHELTERS

Intent - To require storm shelters for enhanced life safety of building occupants. Minimizing injuries and related health costs preserves the human component of the community and permits more rapid recovery after disasters. These shelters are havens for protecting people from injury or death due to structural collapse and impact from windborne debris.

Design and Construction [A, G, H, M] - Storm shelters complying with the requirements of ICC 500[H] should be provided for occupants of all sustainable buildings in hurricane-prone and tornado-prone areas where the shelter design wind speed is 160 mph or more. When combined hurricane and tornado shelters are needed the more stringent requirements of ICC 500[H] should be used.

Source: Oklahoma Department of Emergency Management
Storm shelters and safe rooms really work.

WIND DAMAGE RESISTANCE

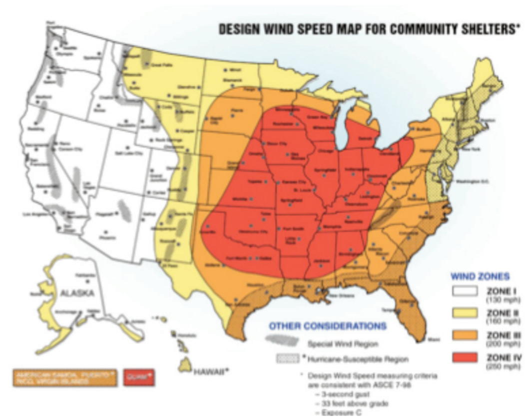
Intent - To assure enhanced life safety and to minimize property damage due to wind loads. The last significant hurricane season in the United States was in 2005. The American Society of Civil Engineers reported in *Normalized Hurricane Damage in the United States, 1900 – 2005*, National Hazard Review, ASCE 2008, that property damage from hurricanes was $81 billion in 2005. Increasing the stringency of the design criteria of buildings from wind hazards results in more robust buildings. The sustainability benefit from reduced damage includes less landfill building waste and fewer resources needed for replacement and repair.

Design and Construction [A, G, M] - Wind loads should be determined in accordance with ASCE 7[A] or the IBC[G]. The design wind pressure, p, and design wind force, F, determined in accordance with ASCE 7[A] or IBC[G], should be based on a design wind speed equal to the basic wind speed (or locally adopted basic wind speed in special wind zones, if higher) plus 20-mph. Determine component and cladding loads for the design wind speed defined, assuming terrain Exposure C, regardless of the actual local exposure. Assume wind can come from any horizontal direction and wind pressures to act normal to the surface considered.

Besides the design for overall structural resistance to wind loads, additional attention is needed for specific elements associated with the exterior building envelope, such as the roof and wall coverings. Roof coverings and their attachment should be subjected to rigorous tests for resistance to the effects of wind following the protocols of nationally recognized programs such Underwriters Laboratory or FM Global. Where roof coverings depend on structural sheathing for support, give extra attention to the stiffness of the panels and the connections to framing. Vinyl siding, exterior insulation finishing systems, and other lightweight exterior wall covering materials should not be used as exterior coverings in hurricane and tornado prone regions.

Source: Federal Emergency Management Agency, photograph taken by Tim Burkitt of FEMA.

FEMA advises that the storm shelter at this high school will provide near absolute protection for more than 2,000 people in the event of a hurricane or tornado.



Design Wind Speed Map for Community Shelters

Source: Federal Emergency Management Agency, photograph taken by Lara Shane of FEMA.

Homes and businesses that are not designed and constructed to provide an appropriate level of functional resilience are at greater risk in high wind exposures.

Source: Federal Emergency Management Agency, photograph taken by Greg Henshall of FEMA

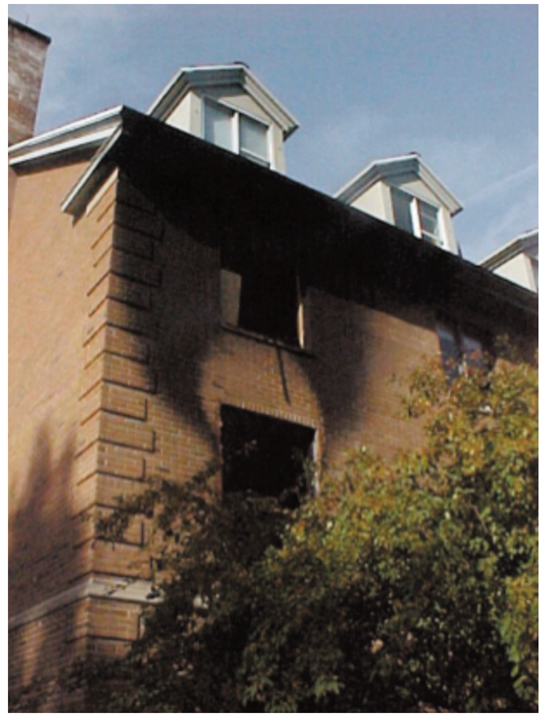
The center of a town twelve days after it was hit by an tornado with 200 mph winds. FEMA reported that debris removal was moving at a record pace, but reconstruction would likely take years. Such devastation places a large strain on the community and the environment.

FIRE PROTECTION COMPONENTS

AUTOMATIC SPRINKLER SYSTEMS

Intent - To reduce damage due to fire, smoke, and suppression operations and enhance life safety. A buiding's robustness is enhanced by requiring sprinkler protection. Sprinkler protection and other fire safety systems combined with established fire compartments can reduce damage to the building and its contents from a fire event. Appropriate levels of combined containment with automatic fire sprinkler systems minimize damage from fire, smoke, steam, and water used for suppression and control, Further, the combination reduces the amount of toxic smoke that may be generated by some building materials and building contents when fires occur.

Design and Construction G, L, M – All buildings, except low fire-risk manufacturing and storage facilities, should be protected with automatic sprinkler systems conforming to the NFPA 13L. The presence of sprinkler protection reduces the risk of damage to the building from a fire event. This risk is further reduced when the sprinkler protection is provided in all spaces of the building including concealed spaces such as open-truss floor assemblies and attics constructed of combustible materials. Because National Fire Protection Association *Standard for the Installation of Sprinkler Systems in Residential Occupancies Up To and Including Four Stories in Height* (NFPA 13R). sprinkler systems do not provide sprinkler protection in these concealed spaces, they should not be used. This enhanced sprinkler protection and compartmentation in residential occupancies will tend to minimize the portion of the building and time for which the building cannot be inhabited.



Source: Northeast Fire Safety Construction Advisory Council
Fire containment achieved with compartmentation minimizes damage due to fire, smoke, and water used for suppression.

Standpipe and fire alarm system features should not be reduced or modified based on the presence of automatic sprinkler protection. These additional fire protection systems in conjunction with sprinkler protection add to the robustness of the building.

INTERNAL FIRE BARRIERS

Intent - To reduce damage from fire, smoke, suppression, and control operations and generallyincrease the robustness and durability of the building.

Design and Construction G, M - Fire walls are used to create separate building areas for large buildings. They should be constructed entirely of noncombustible materials; have fire resistance ratings of at least 2-hours; and be constructed in accordance with the IBCG.

Source: Northeast Fire Safety Construction Advisory Council
Fire resistant non-combustible materials contain fires minimizing fire and smoke damage. This damage resistance allows portions of the buildings to simply be cleaned, painted and reoccupied rather than completely re-constructed.

To further reduce the risk of fire spread within buildings, provide internal fire barriers (walls, shafts around floor openings and horizontal floor systems) to establish multiple fire area compartments and restrict the spread of fire between floors of multi-story buildings. Fire barrier assemblies should be constructed in accordance with the IBCG, have fire resistance ratings of at least 1-hour, and not have the fire resistance rating reduced due to the presence of sprinkler protection.

Robustness is also enhanced through compartmentation using fire barriers to separate dwelling and sleeping units as well as separate these spaces from adjacent non-residential areas in residential occupancies (i.e. hotels, motels, and apartments). These fire barriers should have fire resistances established by the IBCG for creating separate fire areas. A compartmentation requirement replacing fire partitions with fire barriers and reduces the risk of fire spread. Such containment also reduces damage due to smoke and suppression operations.

Finally, designs should provide draftstopping and fire stopping in concealed combustible spaces irrespective of the presence of sprinkler protection. Fires within these concealed spaces can spread quickly and cause damage to larger portions of the building without adequate measures in place.

STORAGE AND COLLECTION AREAS

Intent - To assure adequate life safety and property protection in areas where large amounts of separated combustible materials are collected and stored. Separated combustible materials pose a much greater life safety and property protection risks than blended waste. The increased risk and danger to occupants and the potential for damage to structures when fires occur has not been addressed in the development of model building codes. To rectify this potential threat to occupants, the structure, and its contents, special criteria should be satisfied when providing collection or storage areas for separated combustibles in or adjacent to buildings. Collection and storage areas for recyclables should be designed and constructed in a manner that does not increase the fire risk exposure for occupants.

Source: www.stuytownluxliving.com
No matter how idyllic recycling areas can be envisioned, they tend to become trash rooms.

Design and Construction [G, L, M] - Areas intended for the storage and collection of recyclables should be designed and constructed to minimize the potential for jeopardizing life safety and to assure a minimum level of property protection as they pose a larger hazard than traditional storage and collection areas within and around buildings.

Interior collection and storage areas should be appropriately separated from the other parts of the building and equipped with automatic fire sprinkler systems.

Walls, floors, and ceilings of interior collection or storage areas provided for recyclable materials should be completely separated from other parts of the building by non¬combustible construction having a fire resistance rating of not less than 2-hours and constructed as fire walls or smoke partitions in accordance with the IBC[G].

Interior collection and storage areas should also be equipped with automatic fire-extinguishing systems in accordance with NFPA 13[L]. An alternative to the separation requirements may be to require fire suppression systems other than water for these potentially high intensity fires. However, the use of such systems may not be consistent with the general principles of sustainability because of the negative environmental impacts.

Exterior walls of buildings within 30 feet (measured horizontally and vertically) to exterior collection or storage areas provided for recyclable materials should have a fire resistance rating of not less than 2-hours.

Further consideration should be paid to requiring smooth hard surfaces in these areas and give attention to assure these areas are adequately rodent proof. Both are especially important for areas accepting liquid containers intended to be"empty."

INTERIOR COMPONENTS

ACOUSTICAL COMFORT

Intent – Enhancement of occupant comfort and productivity by limiting the distractions and disruptions due to sound transmitted through building elements. Increases in sound transmission reductions are particularly important for assembly, business, educational, institutional, mercantile, and residential occupancies. Noise control should be addressed with provisions for external air-borne sound, internal air-borne sound, and structure-borne sound. Generally, requirements for enhanced resistance to sound transmission will result in more robust and durable buildings.

Source: U.S. Department of Transportation, Federal Highway Administration
Increased population density results in more noise.

Improved sound attenuation in buildings increases occupant comfort and work productivity. Urban areas with high population densities tend to have smaller carbon footprints per capita than less dense areas. An urban planning concept known as compact development capitalizes on this by aligning higher population-density areas with mixed use commercial zoning and mass transit routes to reduce the reliance on personal automobiles. Enhanced noise control is a necessity for healthy, safe, comfortable, and productive interior environments in these more densely populated and trafficked areas. Provisions need to be integrated into the building design to reduce the audibility of not just for current but also for future noises from increased population density and proximity to transportation routes.

Design and Construction [C, D, G, M] – In addition to satisfying the more stringent requirements of the local building code or IBC[G] all exterior opaque wall and roof/ceiling assemblies should have a composite sound transmission classification (STC) rating of not less than 50 (45 where field tested). All fenestration that is a part of the exterior wall or roof ceiling assembly should have a STC rating of not less than 30 (25 where field tested).

For interior walls, partitions, and floor/ceiling assemblies special consideration should be given to these elements used in educational, institutional, and residential occupancies. For residential and institutional occupancies, the elements separating units and spearing units for from all other interior spaces should have a STC rating of at least 50 (45 where field tested). In educational occupancies, classrooms should be separated from adjacent classrooms and other interior spaces with elements having a STC rating of at least 50 (45 where field tested). Further, the interior elements separating restrooms and showers from other spaces should have a sound transmission classification rating of at least 53 (48 where field tested) and music rooms, mechanical rooms, cafeterias, gymnasiums, and indoor swimming pools should have an STC rating of at least 60 (55 where field tested).

Floor ceiling assemblies between rooms or units and between rooms or units and public or service areas in assembly, business, educational, institutional, mercantile, and residential occupancies should have impact insulation classification rating of not less than 50 (45 is field tested) when tested in accordance with ASTM E492[D].

MOISTURE PROTECTION

Intent – Exposure of building materials during construction and during building operation to excess or unnecessary moisture can damage the materials or increase the rate of deterioration. Further, moisture present in organic materials can support the growth of mold and mildew. For high-performance buildings, provisions to minimize these negative effects of moisture not just for the building materials themselves but also as related occupant health and additional resources and energy required for cleaning, treatments, repair, and replacement are crucial.

This is accomplished with features such as durable, non-absorbent floor and wall finishes, providing extra protection to piping subject to freezing and protecting building materials on construction sites from exposure to high moisture prior to incorporation into the structure. This results in more robust building with reduced risk of damage to the building and its contents from moisture. Several of these modifications will also help minimize the potential for the growth of mold and mildew which reduces the risk to occupant health problems and requires fewer resources to remove, dry, and clean affected building components.

Design and Construction $^{C, G, M}$ – During construction, any materials susceptible to damage from moisture exposure should be protected for excess or unnecessary moisture exposure during storage, handling and installation. Any organic materials with visible organic growth should not be installed on or in the building.

In addition to the more stringent requirements of the local code or the IBC^{G}, for the use of smooth, hard, non-absorbent, surrounding surfaces, the requirements for high performance should be augmented. The surface of floors and wall base material, extending upward on the at least 6 inches, should be smooth, hard, and nonabsorbent in all toilet, bathing and shower rooms; kitchens; laundries; and spa areas. Smooth, hard, non-absorbent surfaces might also be considered to reduce maintenance and repair in highly trafficked areas such as corridors, especially those in educational facilities.

Source: Federal Emergency Management Agency - contributed by John Martyny

Organic building materials provide a food source for mold and mildew in building.

Source: Federal Emergency Management Agency, photograph taken by Dave Gatley of FEMA.

Moisture damage is not just related to flooding. Here, an inspector is seen evaluating water damage when a roof was compromised by wind and rain.

Source: Federal Emergency Management Agency - contributed by Terry Brannen

Hard, smooth, nonabsorbent surfaces in areas prone to water exposure can prevent damage to adjacent areas and hidden components.

EXTERIOR COMPONENTS

EXTERIOR FIRE DAMAGE RESISTANCE

Intent - To reduce building damage from fire events. Enhanced property protection is a crucial component of green construction and thus requirements for enhanced performance of exterior walls and roofs above the minimum requirements in the IBC[G] are necessary. This recommendation results in the use of more robust exterior walls and limits openings located in close proximity to other buildings.

Source: Brick Institute of America Region 9.
Siding on a building nearly 100 feet away from a burning building needs to be replaced.

Also strengthening roof coverings to resist the affect of fire reduces the amount of damage to the building and its contents. *Fire Losses in the United States During 2009* by the National Fire Protection Association, August 2010 shows that property loss due to structure fires in buildings other than one and two family dwellings was approximately $4.5 billion.

Design and Construction [G, M, N] - Buildings should be designed so the exterior of buildings are less susceptible to damage when exposed to fire.

Source: Federal Emergency Management Agency
Topography, vegetative fuels and drought contribute to the potential for devastating wildfires.

Use exterior wall coverings of vinyl siding and exterior insulation and finish systems conforming to the requirements of the IBC[G] as an exterior finish only where the separation distance to other buildings or to property lines is at least 30 feet.

In addition, any combustible exterior wall coverings should not be installed on exterior walls of buildings with a separation distance of 5 feet or less to other buildings or to property lines.

Further, space openings in exteriors such that sufficient solid wall occurs between openings to limit spread of fire on the exterior of the building. Reducing or eliminating this solid wall area due to sprinkler protection within the building should not be allowed.

Roof coverings that are unclassified in regard to spread of fire should not be used. Roof systems are classified in accordance with UL Standard 790[N] as A, B, or C, with A providing the best resistance to fire spread. For roofs located in hot dry climates where exposure from wildfires is more prevalent the roof classification should be a minimum of Class A. (Also see Wildfire Damage Resistance)

Damage to siding and sheathing as a result of high winds.

WILDFIRE DAMAGE RESISTANCE

Intent - To reduce building damage due to wildland fires. According to the National Weather Service the property damage from wildland fires was 110 million in 2009. To reduce the likelihood of damage, this proposal requires sites for buildings to be reviewed to see if they may contribute to wildfires. If found, the building design should incorporate features that enhance the robustness of the building, thereby reducing the risk of fire damage and production of toxic emissions.

Design and Construction [K, M] - The construction, alteration, movement, repair, maintenance, and use of any building, structure, or premises within the wildland interface areas should follow the provisions of the IWUIC[K]. The design and construction of exterior walls should be based on the fire hazard severity value determined for the site.

WIND DAMAGE RESISTANCE

Intent - To minimize property damage during high wind events. Enhanced property protection is a crucial component of green construction

Source – Institute for Business & Home Safety
Wind damage to lightweight exterior wall covering.

and thus requirements for enhanced performance of exterior walls above the minimum requirements in the IBC[G] are necessary. Property damage from wind was reported to be almost $2 billion in 2009 according to the National Weather Service. The use of exterior wall coverings most susceptible to wind damage should be limited to non-hurricane prone regions.

Design and Construction [G, M] - Vinyl siding conforming to the requirements of the IBC[G] and exterior insulation and finish systems conforming to the requirements of the IBC[G] should only be selected as the exterior finish of buildings located outside hurricane-prone and tornado-prone regions as defined in the IBC[G].

HAIL DAMAGE RESISTANCE

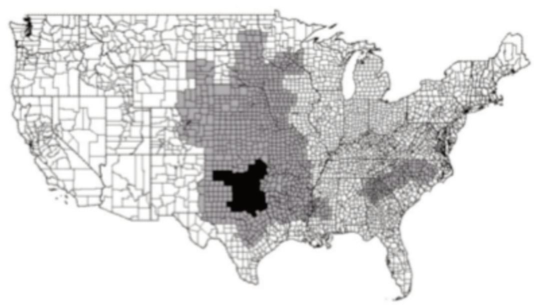
Intent - To minimize property damage during hailstorms. Requirements for enhanced performance of exterior walls above the minimum requirements in the IBC[G] are necessary. Property damage from hail was reported to be approximately $1.3 billion in 2009 according to the National Weather Service. This proposal requires exterior wall coverings most susceptible to damage from hail be tested, classified, and labeled in accordance with UL 2218[O] or FM 4473[F] to be more robust and limited in hail exposure areas.

Design and Construction [F, G, M, O] – Use vinyl siding conforming to the requirements of the IBC[G] and exterior insulation and finish systems (EIFS) conforming to the minimum requirements of the IBC[G] only as an exterior finish of buildings located outside moderate and severe hail exposure regions.

Roof coverings and exterior wall coverings of vinyl siding and EIFS intended for use in regions where hail exposure is Moderate or Severe should be labeled accordingly. Labeling should be determined based on testing and classification in accordance with UL 2218[O] or FM 4473[F].

Source: Federal Emergency Management Agency, photograph taken by Mark Wolfe of FEMA

Roofs damaged by high winds are evident everywhere blue tarps appear.



Hail Exposure Map

Dark Areas Indicate Severe and Moderate Exposures.

Source National Oceanic and Atmospheric Administration, National Weather Service

Siding needs to be removed, disposed and replaced due to hail damage.

Source: Michael E. Clark & Associates, Inset from Institute for Business and Home Safety.

Roof shingles need to be removed, disposed and replaced due to hail damage.

RODENT PROOFING

Intent - Assuring adequate provisions for rodent infestation resistance reduces the potential for damage and to use pesticides over the life of the building. The use of pesticides may have a negative impact on occupant comfort and health. Adequate rodent proofing will minimize the amount of energy and resources required during the life of the building if means other than pesticides are required to eliminate infestations.

The amount of energy and resources required for repair and replacement when rodent infestations occur can be significant. In addition, the use of pesticides and other measures to eradicate infestations can have a negative impact on human health and comfort. To provide for increased safety to occupants and minimize the negative impact on the built environment from rodents, requires that buildings be designed and constructed in a manner that at least satisfies the minimum requirements of the Appendix F of the IBC[G]. Currently, the use of Appendix F is optional and, thus it is not required in many jurisdictions. A green building should not be readily susceptible to rodent infestations and following these criteria should be a mandatory prerequisite for green buildings.

Source – Image provided with permission from Alternative Building Services: www.alternativebuildingservices.com.

Building elements need to be repaired due to rodent damage. Undetected damage can compromise the integrity of the building thermal envelope and moisture protection.

Design and Construction [G, M] - Buildings should be provided with rodent proofing in accordance with Appendix F of the IBC[G] or the Code of local jurisdiction, whichever is more stringent.

Extermination and pest control require energy and resources. In addition to the inconvenience, extermination techniques could create unfavorable conditions for pesticide sensitive individuals, and be major disruptions in productivity and business operations.

RADON ENTRY RESISTANCE

Intent - Assuring adequate indoor environmental quality by requiring radon mitigation systems for buildings in high radon potential areas. While radon mitigation is not a mandatory requirement for many building codes provisions to minimize the exposure of occupants of green buildings to radon is an important part of providing an appropriate minimum level on indoor environmental quality.

Design and Construction [E, J, M] - Buildings in high radon potential locations as indicated in the respective Environmental Protection Agency document or the IRC[J] should be designed in accordance with:

1. Chapter 2 of EPA 625-R-92-016[E];
2. Appendix F of the IRC[J];

Resources

[A] American Society of Civil Engineers ASCE 7 - *Minimum Design Loads for Buildings and Other Structures*

[B] American Society of Civil Engineers ASCE 24 - *Flood Resistant Design and Construction*

[C] American Society of Heating Refrigerating and Air-Conditioning Engineers ASHRAE 189.1 - *Standard for the Design of High-Performance Green Buildings, Except Low-Rise Residential Buildings.*

[D] ASTM International ASTM E492 - *Standard Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine*

[E] Environmental Protection Agency *Radon Prevention in the Design and Construction of Schools and Other Large Buildings* EPA 625-R-92-016

[F] Factory Mutual Global Research FM 4473 - Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls

[G] International Code Council *International Building Code*

[H] International Code Council/National Storm Shelter Association ICC 500 - *Standard on the Design and Construction of Storm Shelters*

[I] International Code Council IGCC - *International Green Construction Code Public Review Version 2.0*

[J] International Code Council IRC – *International Residential Code*

[K] International Code Council IWUIC - *International Wildland-Urban Interface Code*

[L] National Fire Protection Association NFPA-13 *Standard for the Installation of Sprinkler Systems*

[M] Portland Cement Association HPBRS - *High-performance Building Requirements for Sustainability*

[N] Underwriters Laboratory UL-790 - *Standard Test Methods for Fire Tests of Roof Coverings*

[O] Underwriters Laboratory UL-2218 - *Impact Resistance of Prepared Roof Covering Materials*

Portland Cement Association
5420 Old Orchard Road
Skokie, Illinois 60077-1083
847.966.6200 Fax 847.966.9781
www.cement.org

To view or download High-Performance Building Requirements for Sustainability visit:
www.cement.org/codes/hpbrs.asp