Best Practices in Building Resilience

Annotated Bibliography

April 2, 2015
The Infrastructure Standards and Measuring Resilience Committee, in collaboration with the TISP Regional Infrastructure Disaster Resilience Task Force, have prepared this annotated bibliography to be a resource for design professionals to integrate resilience concepts into building design.

The Department of Homeland Security has defined resilience as the ability to resist, absorb, recover from or successfully adapt to adversity or a change in conditions.1 Resilience formally entered the national dialog when President Barak Obama issued Presidential Policy Directive 8, in 2011 which identified resilience as a way to contain the effect of natural and man-made disasters.

Historically, the Federal Emergency Management Agency has dominated the federal response to disasters, with a special focus on operational preparation and response functions. Today resilience encompasses a wide range of disciplines including economics, urban planning, public policy, risk management, sustainability, healthcare, and sociology. To date there has been scholarly research in narrow disciplines. Planners have explored the impact of recovery time on the overall resilience of a community2. Social scientists have focused on the affect of community engagement and human behavior due to disasters. Economists have developed concepts to estimate the total losses associated with disasters3. There also has been research to define a framework in which to develop overall resilience of communities4 5.

Buildings have the potential to provide a critical part of resilience by providing shelter for the public until a reasonable degree of normalcy has returned. It also promotes more rapid return of services by lessening the impact of a disaster and providing a space where vulnerable populations can be sheltered and emergency workers can plan and activities be out of the elements. In these way limiting physical damages facilitating rapid response and recovery. Arguably, resilient buildings are a precursor for all other post-disaster recovery functions.

Most literature related to the response of buildings to extreme events, has focused on defining the forces acting on buildings for defined scenarios and acceptable damage levels. This information is typically derived from risk-based models calibrated with society’s tolerance of loss for a given hazard. Although this approach may have been valid in the past, our infrastructure today is subject to factors which were not issues previously, such as deterioration due to deferred maintenance, unpredictable weather due to

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2 The Resilient City, San Francisco Planning and Urban Research (SPUR), 2009, [http://www.spur.org/initiative/resilient-city](http://www.spur.org/initiative/resilient-city)


climate change, and increased service loads due to population growth. In addition, given the rapidity of the changes that are anticipated throughout this century, there is little confidence that the specific loads considered today will be relevant as the building ages.

This document is intended to be a precursor to other documents addressing resilience mitigation for new and existing buildings. The intended users of this document include architects, engineers, construction professionals, owners, planners, investors, insurers and elected officials. Ultimately it is hoped that TISP will develop a series of guidelines addressing various critical infrastructure sectors which have non-building structures such as transportation, water and power.

The focus here is on the direct contribution of physical building systems to resilience or mitigation. It may be applied to most building types but is most appropriate for commercial buildings typical in a community where resilience may not be major design driver. Contribution of the people systems such as the emergency operations and social issues associated with disruptive events are addressed in terms of how building systems are able to facilitate the rapid evacuation, response, and recovery. Similarly, ramifications associated with factors outside the building such as supply chain disruptions, and utility service disruptions are addressed in general terms. Wherever possible, references are provided for those issues which are not addressed in detail.

This annotated bibliography is organized by chapters 1-7 organized by disaster type followed by 7 appendices addressing issues that are not unique to a single hazard.

Chapters

1. Flood
2. Earthquake
3. Hurricane
4. Tornado
5. Ice Storm/Blizzard
6. Drought/Heat
7. Wildfire
8. Terrorism

Appendices

A. Resilience (General)
B. Cascading Hazards
C. Hazard Loss Management
D. Further Reading
E. Funding Sources
Section 1. Flood

In this chapter the term *flood* is used to describe traditional water body overflow flood, lahars, water-driven landslides, landslide, and hurricane surge. FEMA ([www.fema.gov](http://www.fema.gov)) provides many documents on their website. Only a few of the most relevant ones are mentioned below.

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**Flood Resistance of the Building Envelope**


**Author:** Christopher P. Jones, PE
Summary: Jones develops the summary method quoted below with examples and figures of the various design considerations necessary in his evaluation of a flood resistant structural design.

“Achieving a flood-resistant building depends upon several things:
1. Identifying the source, nature and severity of flood hazards affecting potential building sites
2. Selecting a building site where flood hazards are eliminated or minimized
3. Determining any flood-related regulatory requirements, for example:
4. Determining design flood characteristics anticipated at the selected site, both now and over the life of the building
5. Planning, designing and constructing the building to minimize any potential flood damages by:

Fragility Analysis Methodology for Performance-Based Analysis of Wood-Framed Buildings for Flood

Link: http://ascelibrary.org/doi/abs/10.1061/%28ASCE%...

Author: John W. van de Lindt and Mason Taggart

Summary: The paper establishes fragility curves relating wood-framed building damage state to flood water duration. An RMS means value was placed upon various wood-framed building systems and analysis was completed for the damage state when in contact with flood waters based upon Aglan et al. (2004) provided failure or non-failure of various building materials after a three day duration flood event, testing conducted by APA – The engineered wood association, and the national institute of standards and technology for six day wetting of plywood products.


Link: http://ecodes.biz/ecodes_support/free_resources/14FloridaDraft/Building/PDFs/Appendix...

Author: State of Florida

Summary: The appendix states the appendix G objective is “to protect human life, minimize the expenditure of public money for flood control projects, minimize the need for rescue and relief efforts associate with flooding, minimize prolonged business interruption, minimize damage to public facilities and utilities, help maintain a stable tax base by providing for the sound use and development of flood-prone areas, contribute to improved construction techniques in the flood plain and ensure that potential owners and occupants are notified that property is within flood hazard areas.”

Hurricane – Flood Protection: Port Arthur and vicinity, Texas

Link: http://www.wbdg.org/ccb/VALUE/swg9304.pdf

Author: US Army Engineer District, Kansas City – Value Engineering Team – Team Leader: Kenneth R. Niemann
Summary: Embankment evaluation and design for the vicinity of Port Arthur, Texas for an improvement of approximately 10,000 feet of hurricane-surge protective levees due to settlement. The settlement of the levee system created a condition below the desired level-of-protection for surge, and the settlement zone was near the Chevron Oil Refinery Sabine Road Tank Farm. Five plans are given and evaluated to solve the settlement issue resulting in an earth fill and sheet pile floodwall system maintaining an elevation of +16.5 feet.

ASCE 24-05: Flood Resistant Design and Construction
Author: American Society of Civil Engineers
Summary: The document provides best practices and provisions to aid in the design and construction of flood resistant buildings. The document discusses basic requirements for flood hazard areas: non-coastal, high risk flood hazard, and coastal flood hazard. Materials, dry and wet flood proofing, utilities, and building access are all discussed within the document.

Flood Risk Management: Call for a National Strategy
Author: American Society of Civil Engineers, Robert Traver
Summary: The document addresses the flood issues referencing Katrina and similar inundation related hazards that have resulted in large financial losses for the United States as a whole. The document identifies specific actions that can and should be implemented in the short term to reduce the inundation exposure and vulnerability to flood.

Highlights of ASCE 24 Flood Resistant Design and Construction
Link: [https://www.fema.gov/media-library/assets/documents/14983](https://www.fema.gov/media-library/assets/documents/14983)
Author: Federal Emergency Management Agency
Summary: Link provides free, highly condensed versions of ASCE 24 (both the 2005 and 2014 versions). For the 2014 version, provides a summary of the changes from the 2005 version.

Flood Resistant Provisions of the 2015 International Codes (2014)
Link: [https://www.fema.gov/media-library/assets/documents/100537](https://www.fema.gov/media-library/assets/documents/100537)
Author: Federal Emergency Management Agency
Summary: Link provides flood resistant provisions, prepared by FEMA, of the 2015 International Codes (IBC and IRC). Also included, as a separate document on this web page is a summary of changes from
the 2012 I-Codes. The 2015 edition of the I-Codes contains provisions that are consistent with the minimum flood-resistant design and construction requirements of the NFIP for buildings and structures.

**Flood Resistant Design CodeMaster (2011)**


**Author:** Federal Emergency Management Agency

**Summary:** Laminated 8 page summary of design considerations for building in accordance with the flood requirements of the 2009 and 2012 International Building Code (IBC) and other codes and standards.


**Link:** [https://www.fema.gov/media-library/assets/documents/3293](https://www.fema.gov/media-library/assets/documents/3293)

**Author:** Federal Emergency Management Agency

**Summary:** This 2-volume publication that provides a comprehensive approach to protecting residences vulnerable to flooding. Volume I provides information about hazard identification, siting decisions, regulatory requirements, economic implications, and risk management. Volume II contains in-depth descriptions of design, construction, and maintenance practices that increase the durability of residential buildings in the harsh coastal environment and reduce economic losses associated with coastal natural disasters.

**Flood Resistant Design CodeMaster (2011)**


**Author:** Federal Emergency Management Agency

**Summary:** Laminated 8 page summary of design considerations for building in accordance with the flood requirements of the 2009 and 2012 International Building Code (IBC) and other codes and standards.

**FEMA P-646: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis**

**Link:** [http://www.fema.gov/media-library-data/20130726-1641-20490-9063/femap646.pdf](http://www.fema.gov/media-library-data/20130726-1641-20490-9063/femap646.pdf)

**Author:** FEMA
**Summary:** The document outlines the provisions for designing a building for tsunami load to act as a vertical evacuation location for tsunami hazard. Guidance is given on determining the tsunami hazard (including: depth and velocity on a site-specific basis), a list of alternatives for vertical evacuation from tsunamis, determining tsunami and earthquake loads and structural design criteria to handle these loads, and other structural design concepts and considerations of note.

**Behavior of a One-Sixth Scale Wood-Framed Residential Structure under Wave Loading**

**Link:** http://woodscience.oregonstate.edu/sites/...

**Author:** Jebediah S. Wilson, Rakesh Gupta, John W. van de Lindt, Milo Clauson, and Rachel Garcia

**Summary:** The article lists the objectives of the research as: “1) to measure forces exerted on a 1/6th scale, two-story, wood-framed residential structure when subjected to waves; 2) to evaluate qualitatively the structural response to different loading conditions; and 3) to compare the effects of different structural configurations on the structural response.”

**Design for Flooding: Architecture, Landscape, and Urban Design for Resilience to Climate Change**

**Link:** http://www.amazon.com/Design-Flooding-Architecture-Landscape-Resilience/dp/0470475641

**Author:** Donald Watson & Michele Adams

**Summary:** Comprehensive book which describes the changing hazard for coasts as well as inland. Solutions for buildings, sites and communities are also given. Chapter 9 provides practice solutions for the architect and engineer. There is also a chapter on flood walls and gates.
Section 2. Earthquake

This chapter includes references related to earthquake and the hazards that commonly follow earthquakes such as tsunami, landslide, and liquefaction.


Seismic Safety of the Building Envelope


Author: Chris Arnold, FAIA, RIBA

Summary: The section discusses the exterior cladding, glazing, and roofing performance for a seismic event. No below grade seismic considerations are given. IBC cladding and glazing code provisions are reproduced along with commentary, and seismic cladding and glazing research is reviewed.


**Author:** Building Seismic Safety Council

**Summary:** Guide outlines best practices for residential construction for seismic consideration and focuses on wood frame houses due to the gap in seismic code development for small low story structures. The document argues that the large number of wood frame residential structures yields a high possibility of large loss even for minimal damages due to seismic activity. The guide specifically addresses above-code techniques to improve seismic structural performance, and uses a typical model home in examples to illustrate the guidance concepts.

Primer for Design Professionals Communicating with Owners and Managers of New Buildings on Earthquake Risk: FEMA 389 – Jan 2004


**Author:** Department of Homeland Security: Federal Emergency Management Agency

**Summary:** Section 2.8 gives a case study example for implementing a risk management program. Figure 3-15 is a site evaluation checklist for site planning evaluation. Figure 4-3 gives a graphical interpretation of the varying differences between collapse prevention (code minimum) and fully operational structural performance within Section 4.3’s Building Performance Levels subsection.

The Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami


**Author:** 2012-2013 Oregon Seismic Safety Policy Advisory Commission

**Summary:** The document determines the likely impacts of a probable Cascadia earthquake and subsequent tsunami including an estimate for required time to restore functions, definition of acceptable timeframes to restore functions after a future quake to meet the desired resilient design performance, and recommendations to alter current practices and policies over the next 50 years to reach a specified resilient target.

SPUR Report: Safe Enough to Stay


**Author:** 2012-2013 Oregon Seismic Safety Policy Advisory Commission
Summary: This document provides a strategy for achieving community resilience for the seismic hazard. It provides guidance regarding the recovery time required for various critical building types to minimize the recovery time for the community as a whole.

Quantifying and Communicating Uncertainty in Seismic Risk Assessment

Link: http://www.ripid.ethz.ch/PPT/Ellingwood_ppt.pdf
Author: Bruce R. Ellingwood and Kursat Kinali
Summary: The paper discusses how uncertainties propagate throughout seismic risk assessment of steel framed buildings, and focuses on the issues of low-to-moderate seismic risk areas of the central and eastern United States.

FEMA 397 - Incremental Seismic rehabilitation of Office Buildings

Link: http://www.ripid.ethz.ch/PPT/Ellingwood_ppt.pdf
Author: Bruce R. Ellingwood and Kursat Kinali
Summary: The paper discusses how uncertainties propagate throughout seismic risk assessment of steel framed buildings, and focuses on the issues of low-to-moderate seismic risk areas of the central and eastern United States.

Designing for Earthquakes: A Manual for Architects

Link: http://www.ripid.ethz.ch/PPT/Ellingwood_ppt.pdf
Author: Bruce R. Ellingwood and Kursat Kinali
Summary: The paper discusses how uncertainties propagate throughout seismic risk assessment of steel framed buildings, and focuses on the issues of low-to-moderate seismic risk areas of the central and eastern United States.
Section 3. Hurricane

In this section, only the effect of wind is considered. For water related impacts such as storm surge or tsunamis, refer to Section 1. If a single document is related to both hazards, it may be listed in both sections.


Author: FEMA (total hurricane land fall from 1851 – 2012)

Wind Safety of the Building Envelope


Author: Tom Smith, AIA

Summary: This paper focuses upon office building issues, but the concepts presented can easily be translated onto the residential structure. The author defines wind zones of note in the US; describes the dynamics of wind loading on a structure; gives examples of wind damage to office buildings; discusses
priorities, costs, and benefits of wind design; gives step by step instructions for evaluating wind load, risk reduction through site planning, and typical building design process; applications are given for: structural systems, exterior doors, non-load bearing walls, wall coverings, soffits, underside of elevated floors, roof systems, windows and skylights, and mechanical equipment.


Link: http://ecodes.biz/ecodes_support/free_resources/14FloridaDraft/Building/14FL_Building_Draft.html

Author: State of Florida

Summary: The code follows the current IBC standard, but makes changes consistent with the special hazard conditions associated with Florida. Due to Florida’s increased threat of hurricane, special provisions above those listed in the IBC are presented.

Hurricane and Tornado-Resistant Concrete Houses

Link: http://tornadoproofhouses.com/intro.php

Author: Kenneth A Luttrell and Joseph C. E. Warnes

Summary: The website consists of an introduction to the hazard types associate with high wind: hurricane and tornado, addresses the IRC code for wind, discusses disaster-resistant shells with links to companies providing prefab. building elements, walls, roofs, connections, energy conservation considerations, indoor environment systems, electrical and mechanical, design considerations, custom versus production houses, and concludes with summary and references.

Hurricane Damage Prediction Model for Residential Structures

Link: http://fire.nist.gov/bfrlpubs/build04/PDF/b04048.pdf

Author: Jean-Paul Pinelli, Emil Simiu, Kurt Gurley, Chelakara Subramanian, Liang Zhang, Anne Cope, James J. Filliben, and Shahid Hamid

Summary: The article develops a practical probabilistic model to estimate expected annual damage induced by hurricane winds to residential structures. The modes of damage are defined and the inter-relation between the damage states is illustrated. Monte Carlo simulations were used to define the damage states as functions of wind speed. The model employs a component-based approach.
Section 4. Tornado

Tornado Risk Map


Investigations and Recommendations based on the May 22, 2011 Joplin, Missouri Tornado


Author: Joplin Tornado Committee, Structural Engineers Association of Kansas and Missouri
**Summary:** The report is the summary of the observed performance of wood structures, pre-engineered metal structures, structural steel buildings, concrete framed buildings, hard wall structures, and roof deck diaphragms for the Joplin, Missouri tornado. The report includes primary gathering facilities such as churches and office structures, retail store structures, and a high importance factor structure, the local hospital. Examples of damage for the building types, facility equipment layout improvement suggestions, and material specific recommendations above code minimum, along with a summary of the recommendations are provided in the report.

**Wind Safety of the Building Envelope**

**Link:** [http://www.wbdg.org/resources/env_wind.php](http://www.wbdg.org/resources/env_wind.php)

**Author:** Tom Smith, AIA

**Summary:** The paper focuses upon office building issues, but the concepts presented can easily be translated onto the residential structure. The author defines wind zones of note in the US; describes the dynamics of wind loading on a structure; gives examples of wind damage to office buildings; discusses priorities, costs, and benefits of wind design; gives step by step instructions for evaluating wind load, risk reduction through site planning, and typical building design process; applications are given for: structural systems, exterior doors, non-load bearing walls, wall coverings, soffits, underside of elevated floors, roof systems, windows and skylights, and mechanical equipment.

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**Tornado Risks and Hazards in the Southeastern United States**


**Author:** FEMA DR-1679-RA1 (February 2007)

**Summary:** The FEMA document describes in detail tornado mitigating design practices for buildings, including alternative mitigation measures for structures like manufactured homes. Wind Shelter design and construction codes, standards, and guidance is given as a comparison table to direct the document user to established code standards concerning different wind hazards.
FEMA P-320 Taking Shelter from the Storm: Building a Safe Room for your Home or Small Business (2014)

Link: https://www.fema.gov/media-library/assets/documents/2009?id=1536

Author: Federal Emergency Management Agency

FEMA P-361 Design and Construction Guidance for Community Safe Rooms


Author: Federal Emergency Management Agency

Residential Tornado Safe Room Doors Fact Sheet

Link: https://www.fema.gov/media-library/assets/documents/99139

Author: Federal Emergency Management Agency

Summary: Residential safe rooms are becoming more popular as families seek protection from violent tornadoes. Like any other room, safe rooms must be accessed through an opening or door. When careful selection and installation of the safe room door assembly is overlooked, the safe room door opening can leave occupants at great risk of injury or death during tornado

Public Law 108-146


Author: 108th Congress

Summary: The law is an act “to amend the Housing and Community Development Act of 1974 to authorize communities to use community development block grant funds for construction of tornado-safe shelters in manufactured home parks.” The act is a short legal document for the distribution of funds to specific communities for the development of tornado shelters, but is of note for the concept of tornado shelters build for communities living in shelters with specifically high tornado loading risk.

Dual-Objective-Based Tornado Design Philosophy

Link: http://woodscience.oregonstate.edu/sites/...

Author: John W. van De Lindt, Shiling Pei, Thango Dao, Andrew Graettinger, David O. Prevatt, Rakesh Gupta, and William Coulbourne

Summary: The paper utilizes the Haan et al. (2010) tornado generator experiments completed at Iowa State University as a means of developing a two pronged approach to tornado design criteria namely: to develop damage control for low wind speeds and life safety for high winds speeds. The small-scale tornado generator experiments yielded transverse wind pressures 1.8-3.2 times those of straight line wind pressures and cladding pressures to be seen between 1.4 and 2.4 times those of straight line wind
pressures of the same velocity. The paper utilizes a case study from the Tuscaloosa, AL tornado, develops a figure to describe the goal, illustrates damage states with real life photos from the case study, and lists a set of design recommendations.

**Technical Investigation of the May 22, 2011 Tornado in Joplin, Missouri**


**Author:** Mark L. Levitan, David P. Jorgensen, Erica D. Kuligowski, Franklin T. Lombardo, Long T. Phan

**Summary:** The paper is the Final Report issued by NIST for the Joplin, MO tornado. The report describes the methodology NIST used to develop the paper’s conclusions: document, photograph, video, and building plan collection; wind field computer model development; performance analysis by building type for life-safety and functionality; survivor interviews and development of an evidence-based explanation of the public response decisions; and analyzed the factors affecting life-safety outcomes. The report then lists recommendations to improve tornado hazard characterization and measurement, methods for tornado resistant design of buildings, enhanced guidance for sheltering, and improved emergency communication.
Section 5. Ice Storm/Blizzard

Frequency of Winter Storm Events By County: 1996-2013

Reference: [http://www.community.fema.gov/inovery/sites/site1030/assets/maps/winter-storm.jpg](http://www.community.fema.gov/inovery/sites/site1030/assets/maps/winter-storm.jpg)

Considerations for Building Design in Cold Climates


Author: Mike Carter, C.E.T. and Roman Stangl, C.E.T.

Summary: The resource webpage discusses the considerations of winter weather/winter precipitation and the associated hazard consequences. Building geometry, exterior envelope, roof, and egress situation is discussed for the risk of falling snow and ice. Energy efficiency concerns, design trends, materials choices including vegetative roof covering, and new technologies are addressed as issues becoming important to the design for snow and ice build-up loading and falling hazards.

FEMA P-957: Snow Load Safety Guide

**Author:** Department of Homeland Security

**Summary:** The report discusses the ASCE 7 descriptions of snow load determination, and also addresses the issues of: unbalanced snow load, snow fall rate, ambient temperature, rain-on-snow, and snow melt between storms. Building shape/characteristic is discussed including: roof geometry and material, wind exposure, and insulation. Additional chapters are provided concerning the monitoring of the structure for snow related damage which can be mitigated (such as roof snow removal during abnormally deep snow events) and reduction measures to influence the risk of snow hazard.

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**A Framework for Performance-Based Design and Assessment of Buildings Subjected to Extreme Snow Loads**

**Link:** [http://bechtel.colorado.edu/~liel/publications_files/...](http://bechtel.colorado.edu/~liel/publications_files/...)

**Author:** A. B. Liel, K. A. Jackson, and J. M. Geis

**Summary:** The paper provides an analysis approach for evaluating extreme snow loads while incorporating uncertainty. The method utilizes historic weather data for ground snow loads and adjusts the value considering location, frequency, and intensity, and then uses a probabilistic approach to account for uncertainty in exposure, building thermal conditions, roof material and slop, wind speed and direction, temperature, and moisture. The framework allows for the inclusion of snowstorm into a multi-hazard design context.
Section 6. Drought/Heat

Passive survivability is an architectural term that refers to designs that are able to be inhabited without power or water for an extended period of time. These concepts are used for a range of climates but are particularly useful in dry, hot climates. It refers to approaches which naturally provide insulation, air circulation, light, and rainwater harvesting. These concepts are closely aligned with the concepts of vernacular architecture, living buildings, net zero and sustainable design. These concepts are critical for successful shelter-in-place post-disaster. Some links are given below.

Link: https://www2.buildinggreen.com/article/passive-survivability-new-design-criterion-buildings#DefiningPassiveSurvivability

Resilient Design Institute
Link: http://www.resilientdesign.org

Making House Resilient to Power Outages
Link: http://www.greenbuildingadvisor.com/category/site-wide-tags/passive-survivability

Passive Survivability Builds in Disaster Preparedness
Link: http://realtytimes.com/consumeradvice/homeownersadvice1/item/9125-20060105_passivesurvive

Sustainable Design: Green Building Design and Delivery.
Link: http://www.amazon.com/Sustainable-Construction-Building-Design-Delivery/dp/0470904453

Sustainability of the Building Envelope
Link: http://www.wbdg.org/resources/env_sustainability.php
Section 7. Wildfire

Wild fire is a major issue in the western U.S. and is linked to drought. Wildfires can spread quickly and decimate entire communities. Fortunately, there are ways to limit the hazard by keep trees and foliage away from buildings. There are also plants which are not as prone to catching fire.


How to Build Fire-Proof Homes


Author: Matthew Power
Summary: Summary article with brief introduction on the number of homes lost to wildfire, discusses the value of site planning to incorporate fire breaks into site layout and possibilities for fire-resistant fences, discusses a list of beneficial design elements, and finishes with a discussion of perimeter fire defenses.

Fire Protection
Link: http://www.wbdg.org/design/fire_protection.php
Author: The WBDG Secure/Safe Committee
Summary: The article at large specifies the inclusion of fire protection engineering consulting throughout all aspects of the building design, and Performance-Based Engineering Design methodology is expressly recommended for fire aspects. Brief recommendations are given for: the design team, design standards and criteria, site, building construction, egress, fire detection and notification systems, fire suppression, emergency power/lighting/exit signage, and special fire protection requirements. pavement are listed.

Link: http://www.wbdg.org/ccb/VA/VAFIRE/dmfpfire.pdf
Author: Department of Veterans Affairs – Office of Construction and Facilities Management
Summary: The design manual addresses Building Features including: interior finish, site considerations, insulation, roof covering and deck assemblies, roof access, fire and smoke barriers, protection of openings, and door locking requirements. Special protection areas such as: high cost equipment rooms, storage, and laboratories are also addressed.

Defensible Space and Fire-Resistant Building Materials Save Home from Wildfire
Link: https://www.llis.dhs.gov/content/defensible-space-and-fire-resistant-building-materials-save-home-wildfire
Author: Department of Homeland Security
Summary: The website briefly discusses a case study of a home near San Diego, CA that avoided wildfire damage through appropriate site planning. Of note, are the example photographs to the right hand side of the text which illustrate the fire breaks and selective plant usage in preventing fire spread.

Determining Design Fires for Design-level and Extreme Events
Link: http://fire.nist.gov/bfrlpubs/fire06/PDF/f06014.pdf
Author: Richard W. Bukowski, P.E., FSFPE
Summary: The paper illustrates a method for determining design fires which informs the Bukowski 2001 paper (listed below) Fire as a Building Design Load.

Fire as a Building Design Load
Link: http://fire.nist.gov/bfrlpubs/fire01/PDF/f01106.pdf
Author: Richard W. Bukowski, P.E., FSFPE
Summary: The paper proposes a method of adapting “standard” design fires to loadings consistent with other design loads typical to structural engineering which can be factored.

Framework for Addressing the National Wildland Urban Interface Fire Problem - Determining Fire and Ember Exposure Zones using a WUI Hazard Scale
Author: Alexander Maranghides and William Mell
Summary: The paper develops a method for establishing Wildland Urban Interface hazard zoning. The zoning is defined by the wind conditions typical to the area, the wildland fuel available, and the topography. The method allows for ember and fire exposure to developed and subsequently considered in the building design such as building density, vegetation control, land use, and urban growth boundary.

Fire Protection Engineering
Link: http://www.wbdg.org/design/dd_fireprotecteng.php
Author: Morgan Hurley, P.E., SFPE
Summary: The article is an in-depth look at what fire protection engineering does and how it affects the “whole building” design. Specific reference to performance-based engineering design is given with reference to the established SFPE performance-based engineering guide book. Emerging issues in fire protection engineering and relevant codes and standards are given.

Disaster Resiliency and NFPA Codes and Standards
Link: http://www.nfpa.org/research/fire-protection-research-foundation/current-projects/...
Author: National Fire Protection Association (NFPA)
Summary: The proposed document will incorporate all of the NFPA codes and standards that are applicable to resiliency. The document will be a technical reference listing the NFPA provisions in a single location as they relate to the full spectrum of preparedness from mitigation to emergency planning and response.
Load Combination Requirements for Fire-resistant Structural Design

Link: http://jfe.sagepub.com/content/15/1/43.abstract

Author: B. R. Ellingwood

Summary: The article discusses the vulnerability of current fire protection for building structural systems due to the reliance on component qualification testing in regard to a “standard” fire. The paper calls for a development in fire load consideration from the prescriptive approach currently employed to a performance-based approach. The paper yields a probabilistic basis for fire load combinations to facilitate fire-resistant structural design incorporating uncertainty principles.

DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01)

**Link:** [http://www.wbdg.org/ccb/DOD/UFC/ufc_4_010_01.pdf](http://www.wbdg.org/ccb/DOD/UFC/ufc_4_010_01.pdf)

**Author:** Department of Defense

**Summary:** The document presents the processes to develop building design criteria which are necessary to protect a structure and the occupants through security and antiterrorism consideration. The document exists as a guide for DoD facilities design and for identifying the cost implications of applying those design criteria. The overall goal of the criteria is to reduce the likelihood of mass casualties within
buildings or portions of buildings controlled by the DoD in the event of terrorist attack. Site planning, structural element response, and MEP equipment considerations are discussed and issued as a set of criteria a building must meet to maintain reduced terrorist activity risk.

DoD Security Engineering Facilities Planning Manual (UFC 4-020-01)


Author:  Department of Defense

Summary: The criteria supports the UFC 4-010-01 as a means of identifying the costs for providing the applicable levels of protection and risk management process for evaluating those costs and the protection options. The goal is to provide guidance to develop appropriate, effective, unobtrusive, and economical protective designs to a level appropriate for project programming and to provide commanders with the information to allocate resources.

Design of Buildings to Resist Progressive Collapse (UFC 4-023-03)

Link:  [http://www.wbdg.org/ccb/DOD/UFC/ufc_4_023_03.pdf](http://www.wbdg.org/ccb/DOD/UFC/ufc_4_023_03.pdf)

Author:  Department of Defense

Summary: The guide provides the design requirements to minimize the potential progressive structural collapse of buildings experiencing localized structural damage from low probability events. Based upon the occupancy category defined within the document for new and existing construction progressive collapse resistance must be analyzed via the tie force method, alternate path method, or enhanced local resistance. The steps for these analysis types are given within the document as a means of providing a guide for progressive collapse consideration.

Alternate Path Analysis and Design Guidelines for Progressive Collapse Resistance


Author:  General Services Administration

Summary: The document was written as a guild to limit the potential for progressive collapse of federal buildings of the United States Government. The GSA Progressive Collapse Guidelines utilizes the alternate path analysis procedures listed in the UFC 4-023-03, Design of Buildings to Resist Progressive Collapse and ASCE-41, Seismic Rehabilitation of Existing Buildings. The guide uses a threat-dependant approach to reduce the likelihood of a disproportionate collapse with regard to the magnitude of the initiating event.

Single Degree of Freedom Structural Response Limits for Antiterrorism Design (PDC-TR 06-08)

Link:  [https://pdc.usace.army.mil/library/tr/06-08/](https://pdc.usace.army.mil/library/tr/06-08/)

Author:  United State Army Corps of Engineers: Protective Design Center
Summary: The document identifies the response limits for blast design from available test reports, technical expert consultation, and existing criteria. The document provides an overview of the DoD building levels of protection and the relationship between component damage and building Level of Protection, discusses the relationship between component damage and structural response, provides specific response limits for common structural components, and illustrates the selection of appropriate limits.

Blast Resistant Design Methodology for Window Systems Designed Statically and Dynamically (PDC-TR 10-02)

Link: https://pdc.usace.army.mil/library/tr/10-02/

Author: United State Army Corps of Engineers: Protective Design Center

Summary: The technical report builds upon the UFC 4-010-01 minimum levels of protection baseline for windows and window supporting elements. The report gives window performance criteria, gives a comparison between the DoD Levels of Protection, the GSA, DoS, and ASTM F 1642 standard, and quantifies the values for rotation and ductility for window supporting systems.

Air Force Manual 32-1084


Author: Department of the Air Force

Summary: Pages 142-143 discusses geomagnetic storm detection and possible disruption types; of note is the possibility of power grid shut down.


Link: http://www.wbdg.org/ccb/FEDMIL/std188_125_1.pdf

Author: Department of Defense

Summary: The military standard discusses the design requirements to mitigate the effects of a High-Altitude Electromagnetic Pulse threat including details for: HEMP shields, water/wastewater delivery through shields, HVAC through shields, etc.

The Greening of Security

Link: http://securitymanagement.com/print/4271

Author: Security Management (professional organization)

Summary: The article published in July 2008 discusses common problems confronted in projects with both sustainability and security objectives. The included discussions highlight the common occurrence
where these two disciplines butt heads with respect to various site and building design aspects and provides specific examples of integrated design solutions that balance the needs of each.

**Related Articles:** "Balancing Security/Safety and Sustainability Objectives"

**Engineering Security: Protective Design for High Risk Buildings**


**Author:** New York City Police Department

**Summary:** The document outlines New York City's response to the city's terrorist attacks covering the topics inherent to anti-terrorism structural design. Threat Risk, Progressive collapse, blast, chemical/biological/radioactive/nuclear, to name but a few, are topics addressed within the document. The code incorporates design considerations from FEMA 426, 452, 426, and 430.

**The Site Security Design Guide**

**Link:** [http://www.gsa.gov/graphics/pbs/GSA_Cover_Intro_8-8-07.pdf](http://www.gsa.gov/graphics/pbs/GSA_Cover_Intro_8-8-07.pdf)

**Author:** New York City Police Department

**Summary:** This document focuses on attractive ways to design sites to keep vehicles from approaching a building. It was developed for federal buildings but are useful for any building in an urban area.
Appendix A. Resilience (General)

This appendix includes documents that discuss what resilience is and how to integrate resilience into design independent of a defined hazard.

Natural Hazards and Security

Link: http://www.wbdg.org/design/resist_hazards.php
Author: WBDG Secure/Safe Committee
Summary: The authors present an introduction to the impacts and risk-reduction concepts to provide mitigation of loss due to a range of hazards. Brief recommendations are given for: Earthquake, Hurricane/Typhoons/Tornadoes, Flooding, Rainfall/Wind-Driven Rain, Differential Settlement, Landslides/Mudslides, Wild Land Fire/Urban Interface, Tsunami, and Areas of Refuge. The paper continues with discussion of Hazard Mitigation, Sustainability, and Climate Change before listing relevant codes and standards and other resources including organizations and associations and publications by hazard type.

Hazard Mitigation, Planning, and Disaster Resiliency: Challenges and Strategic Choices for the 21st Century

Link: http://www.ie.unc.edu/cscd/pdf/Berke_Smith_chapter_Fra_editor.pdf
Author: Philip Berke and Gavin Smith
Summary: The paper discusses the major benefits of land use planning applied to hazard mitigation, addresses why communities fail to utilize effective planning strategies, and presents five sets of choices to help guide communities toward disaster resilient design.

Building It Right the First Time

Link: http://www.spur.org/sites/default/files/publications_pdfspdf/SPUR_Building_It_Right
Author: Joe Maffei
Summary: The report has a matrix on page 4/18 which illustrates time duration after hazard that can be extrapolated to an all-hazard (multi-hazard) form. The matrix yields expected deadlines for return to residential housing, medial provider office, school operation, workplace operation, and neighborhood retail services giving a framework of goals hazard recovery should attempt to meet.


Link: https://www.disastersafety.org/fortified/fortified-for-safer-living-standards-guide/
Author: Institute for Business & Home Security (IBHS)
Summary: The standard specifies construction, design, and landscaping guidelines to increase a new home's resistance to natural, catastrophe-level perils most likely to occur in the area where the structure is located. Discussed load criteria and design objectives strive to adapt conventional building code requirements to provide an elevated level of performance for critical hazard scenarios. Specific prescriptive design recommendations are provided to represent both baseline "Mandatory" requirements and those that are supplemental recommendations. IBHS reviews and certifies buildings that are designed and constructed pursuant to Fortified standards. The certification can be used by property owners in applying for incentivized property insurance programs.

Disaster Resilience: A Guide to the Literature

Link: http://www.nist.gov/customcf/get_pdf.cfm?pub_id=906887

Author: Gilbert, S. W. (NIST)

Summary: Gilbert combines a large selection of the research regarding resilience and hazard risk literature. The background portion of the Introduction section has a particularly nice phrase to characterize resilience and hazard mitigation from a building perspective as well as respond to the argument that resiliency is a community (and therefore, people) centered problem. Gilbert writes, “While the overall goal is to improve resilience at the community scale, buildings play a critical role in assuring community resilience. Thus, measuring the resilience of buildings provides a foundation for the more complex problem of measuring the resilience of communities.”
Appendix B. Cascading Hazards

This section focuses on references that focus on the potential for one hazard initiating a one or more secondary hazards which can compound the losses in a disaster.

Challenges of Analyzing Multi-Hazard Risk: A Review

Link: http://link.springer.com/article/10.1007/s11069-012-0294-2#page-1
Author: Kappes, M. S., Keiler, M., and von Elverfeldt, K.
Summary: The paper discusses the challenges which are presented when transitioning from a single-hazard to multiple-hazards. A guideline is presented to establish a criteria to determine the significance of all hazards at a national level.

Review of Methods to Assess, Design for, and Mitigate Multiple Hazards

Link: http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29CF.1943-5509.0000279
Author: Li, Y., Ahuja, A., and Padgett, J.
Summary: Abstract: “Large parts of the world are subjected to one or more natural hazards, such as earthquakes, tsunamis, landslides, tropical storms (hurricanes, cyclones, and typhoons), coastal inundation, and flooding; although, many regions are also susceptible to artificial hazards. In recent decades, rapid population growth and economic development in hazard-prone areas have greatly increased the potential of multiple hazards to cause damage and destruction of buildings, bridges, power plants, and other infrastructure; thus, grave danger is posed to the community and economic and societal activities are disrupted. Although an individual hazard is significant in many parts of the United States, in certain areas more than one hazard may pose a threat to the constructed environment. In such areas, structural design and construction practices should address multiple hazards in an integrated manner to achieve structural performance that is consistent with owner expectations and general societal objectives.

Cascading Disaster Models in Postburn Flash Flood

Author: May, F.
Summary: The author focuses upon the cascading hazards of post wildfire and subsequent flash flooding. The introduction is of note because the idea and concept of cascading hazards is well established. The author utilizes falling domino chains as a means of delivering cascading hazards conceptually. FEMA, DHS, as well as regional cascading hazard documents are referenced with specific quotes to necessitate further definition and understanding of the cascading hazards process and modeling.
Preliminary Proposal for Performance-Based Structural Engineering for Fire Following Earthquake


Author: Barbosa, A. R., Neves, L. C., and Ribeiro, F.

Summary: The paper lays the “ground work” to develop an assessment of earthquake and fire following earthquake. Discussion involves probabilistic hazards analysis, probabilistic hazards demand analysis, probabilistic damage analysis, and subsequent probabilistic loss analysis for both seismic and fire hazards occurring in a cascading fashion.
Appendix C. Hazard Loss Management

Mitigating Disaster Losses through Insurance

**Link:** [http://link.springer.com/article/10.1007/BF00055792#page-1](http://link.springer.com/article/10.1007/BF00055792#page-1)

**Author:** Kunreuther, H.

**Summary:** “Losses from natural disasters have increased in recent years due to growth of population in hazard-prone areas and inadequate enforcement of building codes. This article first examines why homeowners have not voluntarily adopted cost-effective protective measures and have limited interest in purchasing insurance. It then proposes a disaster-management program which utilizes insurance coupled with well-enforced building codes to reduce future damage. Banks and financial institutions play a key role in this program by requiring inspections of homes as a condition for a mortgage. New forms of reinsurance coverage against catastrophic losses from natural disasters are necessary to protect insurers against potential insolvency from the next mega-disaster.”

Business interruption losses from natural hazards: conceptual and methodological issues in the case of the Northridge earthquake


**Author:** Rose, A. and Lim, D.

**Summary:** “This paper present several refinements in a hazard loss estimation methodology and applies it to measuring business interruption losses from utility lifeline disruptions following the Northridge Earthquake. The analysis indicates that losses are highly sensitive to business resiliency. The results are then compared with survey-based estimates in an attempt at model validation.”

Extreme Losses from Natural Disasters - Earthquakes, Tropical Cyclones and Extratropical Cyclones

**Link:** [http://www.air-worldwide.com/_public/NewsData/000208/Extreme_Losses.pdf](http://www.air-worldwide.com/_public/NewsData/000208/Extreme_Losses.pdf)

**Author:** Guin, J. and Saxena, V.

**Summary:** “While the debate over whether catastrophe events are actually occurring with greater frequency remains inconclusive, there is a consensus of opinion that the trend toward increasing economic losses is largely due to two reasons: (1) population density is increasing worldwide and densely populated large cities continue to grow in areas of high hazard; (2) at the same time population density is increasing, standards of living have increased, resulting in huge increases in the concentration of property values. Regions that were formerly shunned because of their high hazard potential are now heavily populated.” The paper continues the discussion giving quantities for economic losses and insured losses, and lists specific hazard case studies along with the proposed methodology to quantify the loss.


Author: Committee on Assessing the Costs of Natural Disasters, National Research Council

Summary: An example of the costs of a natural disaster Hurricane Andrew was used with a break down distribution of where the losses were present and who absorbed the cost. The book is comprehensive with chapters covering loss estimation, direct losses of natural disasters, indirect losses of natural disasters, and recommendation to improve our position with regard to mitigating those losses.

Roundtable on Standards for Disaster Resilience for Buildings and Infrastructure Systems (September 26, 2011)


Author: Chris D. Poland

Summary: The white paper lays out the comprehensive recovery planning initiative from the City and County of San Francisco to set resilience achieving goals during recover. A list of time to operation after a disaster table is provided with target goals for operation of specific essential services.
Appendix D. For Further Reading

This section provides more advanced technical references which provide methods for quantifying uncertainty, risk, reliability and cost effectiveness. Though not as practical for the design who needs solutions in a hurry, it provides insight into the advanced approaches available used by specialty firms and researchers.

Uncertainty in Structural Engineering


Author: William M. Bulleit

Summary: The paper discusses the concepts of uncertainty from a structural engineering perspective. The differences between aleatory and epistemic uncertainties are given and the sources are given: time, statistical limits, model limits, randomness, and human error. The limitations are discussed in relation to allowable stress design and LRFD.

Risk-Informed Condition Assessment of Civil Infrastructure: State of Practice and Research Issues

Link: [http://www.tandfonline.com/doi/abs/10.1080/15732470412331289341#.U3pRRygv8tM](http://www.tandfonline.com/doi/abs/10.1080/15732470412331289341#.U3pRRygv8tM)

Author: Bruce R. Ellingwood

Summary: The paper discusses the issues at hand with our aging infrastructure. The introduction and conclusion especially give good language and basis for and introduction of the proposed TISP document for the issues surrounding existing infrastructure towards reduced structural capacity in response to extreme events due to aging. The body of the article introduces the topics of probability analysis as a means of determining, with uncertainty, risk of exposure and failure of our current infrastructure.

Structural Reliability and Risk Assessment and Their Relevance to Performance-Based Engineering


Author: Bruce R. Ellingwood

Summary: The paper makes the argument for the performance-based engineering approach to design and the necessary steps needed to fully flesh out a coherent and useful set of performance goals. It summarizes some of the advances performance-based approaches have made “The safety level inherent in any code, embedded in the various safety factors chosen by the code developers, represents a value judgment on acceptable risk based on past experience.
Cost Effectiveness of Risk Mitigation Strategies for Protection of Buildings against Terrorist Attack

Link: http://politicalscience.osu.edu/faculty/jmueller/STEWJPCF.PDF

Author: Mark G. Stewart

Summary: The paper examines the cost effectiveness of risk mitigation for terrorist activities. The cost analysis was performed through calculating the cost of protective measures, attack probability, reduction in risk due to protective measures, and failure consequences. The paper concludes with comparison between hurricane and seismic hazards.
Appendix E. Hazard Mitigation Funding

The federal government provides funding to those interested in reducing the impact of hazards within their communities. Some of the opportunities are listed below.

**Hazard Mitigation Grant Program**

**Link:** [http://www.fema.gov/hazard-mitigation-grant-program](http://www.fema.gov/hazard-mitigation-grant-program)

**Author:** FEMA

**Summary:** The website gives a description of a grand program offered by FEMA to state and local governments to implement long-term hazard mitigation measures after a major disaster declaration. Updates to the program are also posted and available on this website.

**Pre-Disaster Mitigation Grant Program**

**Link:** [http://www.fema.gov/pre-disaster-mitigation-grant-program](http://www.fema.gov/pre-disaster-mitigation-grant-program)

**Author:** FEMA

**Summary:** The website discusses the program funds available for hazard mitigation planning and projects. States, territories, commonwealths, and Indian Tribal Governments are eligible applicants, while eligible subapplicants include: state agencies, Indian Tribal Governments, and local governments/communities. Updates to the program are also posted and available on this website.

**Flood Mitigation Assistance Program**

**Link:** [http://www.fema.gov/flood-mitigation-assistance-program](http://www.fema.gov/flood-mitigation-assistance-program)

**Author:** FEMA

**Summary:** The website discusses the program funds available for flood hazard planning and projects. States, territories, commonwealths, and Indian Tribal Governments are eligible applicants, while eligible subapplicants include: state agencies, Indian Tribal Governments, and local governments/communities. Updates to the program are also posted and available on this website.

**National Disaster Resilience Competition**

**Link:** [http://www.whitehouse.gov/the-press-office/2014/06/14/fact...](http://www.whitehouse.gov/the-press-office/2014/06/14/fact...)

**Author:** The White House

**Summary:** The fact sheet describes the resilience competition making available $1 billion to communities which have experienced natural disasters to aid in rebuilding and increasing resilience toward future disasters.