Hurricane Katrina was one of the strongest and most destructive storms to impact the coast of the United States in a century. Faced with the biggest catastrophic disaster in its history, the Federal Emergency Management Agency (FEMA) had to evolve and manage to deliver its programs on unprecedented levels. The experience has and continues to shape the new FEMA: a FEMA that is more dynamic and innovative than ever before; a FEMA that is increasingly recognized as the world’s preeminent emergency management and preparedness agency.

With a focus on mitigation and hazard-resistant construction, this article highlights some of the ways FEMA has advanced the cause of disaster-resistant communities and multihazard building sciences.
FEMA’s History of Mitigating the Effects of Natural Disasters

When FEMA’s Mitigation Directorate was established on November 29, 1993, mitigation became the cornerstone of emergency management for the first time in the history of federal disaster assistance. The Mitigation Directorate’s partners include a broad spectrum of stakeholders in federal, state, tribal and local governments as well as the private sector. Partners also include professional associations and nongovernmental groups involved in public policy and administration, insurance, higher education, the building sciences and urban planning.

The mission of FEMA’s Mitigation Directorate is to create safer communities by reducing loss of life and property, enable individuals to recover more rapidly from floods and other disasters, and lessen the financial impact of disasters on the nation.

Mitigation focuses on breaking the cycle of disaster damage, rebuilding and repeated damage. Some examples of mitigation efforts to create safer communities and reduce loss of life and property include:

- enforcing stringent building codes, flood-proofing requirements, seismic design standards, and wind-bracing requirements for new construction or repairing existing buildings;
- adopting zoning ordinances that steer development away from areas subject to flooding, storm surge or coastal erosion;
- retrofitting public buildings to withstand hurricane-strength winds or significant seismic forces;
- acquiring repetitive loss properties in Special Flood Hazard Areas (SFHA);
- elevating properties to reduce the risk posed by flooding;
- strengthening or better protecting utility systems from wind and water; and
- developing and implementing high-wind (tornado and hurricane) residential and community safe room projects.

Initial Post-Katrina Efforts to Improve Hazard-Resistant Construction

FEMA’s efforts toward reducing the impacts of natural disasters began long before Hurricanes Katrina and Rita, the catastrophic impacts of those storms brought new focus to the importance of developing a new hazard mitigation paradigm.

FEMA has long recognized the importance of building codes in the design and construction of hazard-resistant buildings and actively participates in the development of the International Codes by, for example, proposing and promoting the inclusion of flood-resistant provisions. As a result, since their inception the I-Codes have been consistent with the design requirements of the National Flood Insurance Program (NFIP). To further illustrate this consistency the ICC guidebook, Reducing Flood Losses through the International Codes, was developed in partnership with FEMA.

FEMA has also worked with the American Society of Civil Engineers (ASCE) and Structural Engineering Institute (SEI) to improve the flood design requirements of ASCE 07, Minimum Design Loads for Buildings and Other Structures, and to develop ASCE 24, Flood Resistant Design and Construction. The agency supported proposed changes in the 2005 edition of ASCE 24 to enhance freeboard, establishing minimum elevation requirements above the Base Flood Elevation (BFE) in SFHAs, and to establish design and construction requirements for Coastal A zones (areas exposed to 1.5- to 3-foot breaking waves during base flood conditions). The changes were not only made in ASCE 24 but also incorporated by reference into the 2006 International Building Code (IBC). Also, an approved change proposed by FEMA in 2007 to the International Residential Code (IRC) now permits the use of ASCE 24 for residential buildings located in Coastal High Hazard Areas.

Pre-Katrina Efforts to Improve Hazard-Resistant Construction

Although FEMA’s efforts toward reducing the impacts of natural disasters began long before Hurricanes Katrina and Rita, the catastrophic impacts of those storms brought...
critical facilities such as fire stations, hospitals and schools to identify common issues. A separate MAT was charged with focusing on long-term flood impacts, including environmental issues related to the loss of containment of hazardous and toxic materials resulting from the flooding in the New Orleans area following Hurricane Katrina.

The MAT published two important documents that presented damage assessment observations and recommendations for future designs: *Summary Report on Building Performance: Hurricane Katrina 2005* (FEMA 548, April 2006) and *Hurricane Katrina in the Gulf Coast: Mitigation Assessment Team Report, Building Performance Observations, Recommendations and Technical Guidance* (FEMA 549, July 2006). In addition, the team published a manual, *Recommended Residential Construction for the Gulf Coast, Building on Strong and Safe Foundations* (FEMA 550, July 2006), that provides guidance in designing and building safer homes in the Gulf Coast. All three documents are available from the FEMA website at www.fema.gov/rebuild/mat/mat_reprts.shtm.

**Hurricane Katrina Flood Recovery Maps**

Recognizing the tremendous flood impacts from Katrina and an improved understanding of flood risk along the Gulf Coast, FEMA quickly responded by producing state-of-the-art Flood Recovery Maps with Advisory Base Flood Elevations. The best available scientific methods were used to produce these maps in an accelerated timeframe to guide the reconstruction effort. The better, more accurate maps (some existing maps were more than twenty years old) leveraged GIS technology and digital aerial photos to depict advisory base flood elevations; flood zone boundaries; the extent of Katrina inundation; and, for the first time, the area associated with the Coastal A zone hazard. Most communities adopted these maps in some form and they were used as minimum requirements in the FEMA grant programs, Public Assistance and Hazard Mitigation Assistance, made available following Katrina.

In recognition of years of field evidence and laboratory testing showing that breaking waves of 1.5 to 3 feet cause damage and destruction to conventional walls of buildings typically located in A zones adjacent to V zones in coastal areas, FEMA hopes to establish procedures in the near future to show the Coastal A hazard as an information layer on all-new coastal flood map studies. (Note that the IBC and ASCE 24 require buildings located in Coastal A zones to have elevation and flood-resistant requirements similar to those required for buildings in V zones.)

**Hurricane Katrina Recovery Advisories**

During the preparation of FEMA 549, it was recognized that technical recommendations to address building damages and vulnerabilities commonly encountered along the Gulf Coast needed to be disseminated as rapidly as possible. Thus in November 2005, seven months before FEMA 549 was published, a series of *FEMA Hurricane Katrina Recovery Advisories* was published. The advisories, which can be found on the FEMA website at www.fema.gov/library/viewRecord.do?id=2633, provide updated technical guidance for the design, construction and restoration of buildings in areas of coastal flooding and high winds as a method of reducing damages from future events. Technical guidance is provided on the following topics:

- “The ABCs of Returning to Flooded Buildings,”
- “Initial Restoration for Flooded Buildings,”
- “Reconstruction Using Hurricane Katrina Surge Inundation and Advisory Base Flood Elevation Maps,”
- “Design and Construction Considerations in Coastal A Zones,”
- “Designing for Flood Elevations above the Base Flood Elevation,”
- “Attachment of Brick Veneer in High-Wind Regions,”
- “Attachment of Rooftop Equipment in High-Wind Regions,” and

Typical interior damage to buildings in Louisiana from Hurricane Katrina. (Source: FEMA 549, Appendix E.)
• “Rooftop Attachment of Lightning Protection Systems in High-Wind Regions.”

**Long-Term Post-Katrina Hazard Mitigation Efforts**

Since issuing the initial technical guidance, FEMA has continued its effort to develop and implement recommendations leading to less vulnerable buildings. Important long-term post-Katrina mitigation efforts include continued outreach to regulatory and technical organizations to enhance implementation of hazard-resistant building codes and development of technical guidance documents directed toward achieving more hazard-resistant construction.

**Hazard-Resistant Building Codes**

In December 2005, with the encouragement of the FEMA MAT and other groups, Louisiana enacted legislation adopting the 2003 IBC as the basis for its *State Building Code* (the state updated to the 2006 edition of the IBC in January 2007). State officials in Mississippi were also encouraged by the MAT to adopt newer codes, and in July 2006 the Mississippi Building Codes Council adopted the 2003 IBC for all state buildings and as the standard for use by counties and cities. Although the action did not require local governments to adopt the codes for all buildings, Mississippi does require the five coastal counties of Hancock, Harrison, Jackson, Pearl River and Stone to enforce the flood and wind provisions. In addition, the Alabama Building Commission acted recently to adopt the 2006 IBC for state buildings, schools, hotels/motels and motion picture theaters, while many of Alabama’s coastal communities enforce the 2003 editions of the IBC and IRC.

**Outreach and Training**

FEMA has presented many training classes in the Gulf Coast on the use of best practices for coastal construction and flood retrofitting. Attended by hundreds of engineers, architects, building officials, floodplain managers and builders, discussions include the benefits observed in past storm events of the use of strong hazard-resistant building codes.

**Strong and Safe Foundations**

Soon after Katrina, it became evident that the 100-year floodplain was expanding; BFEs were going up; and thousands of rebuilt homes must now be at elevations beyond the previous experience of designers, contractors and communities, and thousands more rebuilt homes will be subject to flood-resistant design requirements for the first time. Complicating the situation, many Gulf Coast areas previously had older codes, inadequate enforcement or no codes at all, and once states and communities began adopting newer codes FEMA started receiving requests from designers, builders and code officials for help understanding the new wind and flood design requirements.

In response, FEMA 550, *Recommended Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations*, was developed to help reduce the tremendous engineering burden created by the need to rebuild thousands of destroyed homes and provide communities with reliable, prescriptive, pre-engineered foundation solutions complete with cost estimates, plans and guidance for selecting the most appropriate design. The publication includes a review of foundation failure lessons learned from Hurricanes Katrina and Rita as well as other storms, and identifies and provides design guidance for several types of appropriate coastal foundation types.

FEMA 550 has been well received by the coastal residential design and construction industry, being referred to in an article by the Editor of *Coastal Contractor Online* as “a new standard for practical engineering guidelines, making it a must-have document for any coastal building professional” (www.coastalcontractor.net/cgi-bin/article.pl?id=113). It has been widely disseminated throughout the Gulf Coast region and is referenced in the upcoming ICC 600, *Standard for Residential Construction in High Wind Regions*, and a one-day training course on design of
foundations using FEMA 550 is under development by the agency for delivery this fall.

**Safe Rooms and Community Shelters**

It is particularly critical for areas that serve as safe rooms during hurricanes to be constructed of appropriate materials and for those materials to be properly connected. Based on design enhancements identified by the Hurricane Katrina MAT, FEMA has nearly completed the process of updating two key publications on the design and construction of safe rooms: FEMA 320, *Taking Shelter from the Storm: Building a Safe Room inside Your House*, and FEMA 361, *Design and Construction Guidance for Community Shelters*.

FEMA 320 has been revised to ensure that the prescriptive safe room designs included meet or exceed the requirements for residential and small community shelters set forth in the new ICC/National Storm Shelter Association (NSSA) 500, *Standard on the Design and Construction of Storm Shelters*. Similarly, the updated FEMA 361 provides best practices guidance based on the design requirements of ICC/NSSA 500 and addresses emergency management considerations such as evacuations, operations and maintenance plans, and evaluation of existing buildings.

**Critical Facility Safety**

The FEMA MAT report for Hurricane Katrina, as well as previous FEMA MAT reports for Hurricanes Charley and Ivan, reported extensive flood and wind damage to facilities whose performance significantly impacts a community’s ability to respond to and recover from a disaster. To address this issue, FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*, has been developed. The guide provides wind and flood resistance best practices for facilities such as hospitals, fire and police stations, emergency operations centers, and schools as well as extensive information on the impact of storm surges to the Gulf area and recommendations for improving building performance. It is also accompanied by a two-day training course.

**National Flood Insurance Program Bulletins**

The findings of the Hurricane Katrina MAT pertaining to the effects of long-term flood inundation have been used to update an important publication related to the NFIP: FEMA Technical Bulletin 2, *Flood-Resistant Materials Requirements*.

Technical Bulletin 2 has been revised to incorporate new building materials not in use when the original bulletin was written and to consider the effects of environmental contaminants transported by floodwaters that may be absorbed into porous and semiporous building materials. The latter was prompted by findings of the Katrina MAT indicating that research is needed to identify appropriate testing protocols and potential remediation strategies to remove flood-borne contaminants such as gasoline, diesel fuel and other refined petroleum products; industrial acids and solvents released from damaged or unsealed containers; medical wastes and other biological contaminants; and untreated waste from flooded wastewater treatment plants.


**Mitigation Reconstruction Pilot Program**

In the wake of the unprecedented damage caused by Hurricane Katrina to homes in the Gulf Coast region, FEMA has developed a pilot program to fund a new approach to residential structure mitigation.

A typical mitigation strategy for residential structures is to elevate them above the Design Flood Elevations. For some situations, an alternative pilot program mitigation strategy known as Mitigation Reconstruction may be applicable. Mitigation Reconstruction consists of demolishing the existing remnants or foundation of a residential building and constructing an improved, elevated structure to at least the BFE or the Advisory Base Flood Elevation. The new structure must be designed and con-
structed to meet all applicable requirements of the current hazard-resistant building codes (generally expected to be the IRC).

Evaluation of NFIP Building Standards
Although not directly linked to FEMA’s Hurricane Katrina work, a related study examined NFIP building standards and examined the benefits and costs of incorporating freeboard in new home construction. The report, available at [www.fema.gov/business/nfip/nfipeval.shtm](http://www.fema.gov/business/nfip/nfipeval.shtm), concluded that due to damages avoided and flood insurance premium reductions, the benefits of adding freeboard exceed the added construction costs over a wide range of coastal flood conditions.

Other Programs
FEMA’s Hazard Mitigation Grant Program has provided direct assistance to states and local governments impacted by Katrina for the purpose of adopting building codes, establishing building departments and training building officials.

In addition, to improve upon its Temporary Housing Program, FEMA’s Alternative Housing Pilot Program has awarded $400 million in grants to Louisiana, Mississippi, Texas and Alabama to develop and pilot cost-effective, code-compliant alternative housing solutions that can be used to provide temporary, transitional and long-term housing options to disaster victims.

FEMA also continues to provide training opportunities to homeowners and builders interested in constructing less vulnerable structures. The core training is offered through the Homebuilder’s Guide to Coastal Construction course—based on FEMA 499, which incorporates lessons learned from various coastal storm events including Hurricane Katrina. To date, more than 35,000 copies of FEMA 499 have been distributed.

Challenges
Despite advances in hazard-resistant construction and building codes, future catastrophic disasters like Katrina will continue to strain and overwhelm local building departments as they attempt to deal with potentially thousands of damaged and destroyed buildings and the huge responsibility of managing a major reconstruction effort. Better approaches need to be developed to address the surge hiring of professionals and assistance to building departments needed so communities are able to fulfill their responsibilities in protecting their citizens and helping them rebuild safer and stronger.

Summary
Since Hurricanes Katrina and Rita struck the Gulf Coast region in 2005, FEMA has been proactive in working to ensure a more disaster-resistant built environment. This includes carrying out the key elements of the newly released FEMA Strategic Plan:

- promoting the development of national, consensus-based building codes and standards, and encouraging their adoption by governmental entities;
- providing technical assistance and public education on building techniques to reduce the potential for future loss of life and property; and
- ensuring the integration of sound building designs, construction standards and up-to-date risk information into the recovery process to mitigate against future disaster losses.

The FEMA Strategic Plan can be found online at [www.fema.gov/about/strategicplanfy08.shtm](http://www.fema.gov/about/strategicplanfy08.shtm).

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A former Building Inspections Supervisor, Ingargiola is actively involved in model building codes and standards development activities in the interest of achieving consistency with the National Flood Insurance Program.