



NIST Response to the World Trade Center Disaster

**Federal Building and Fire Safety Investigation
of
the World Trade Center Disaster**

Part VI - Recommendations

April 5, 2005

**National Institute of Standards and Technology
Technology Administration
U.S. Department of Commerce**

Building and Fire Codes in the United States

- In the United States, state and local governments are responsible for promulgating and enforcing building and fire regulations.
- With some exceptions, the state and local regulations are based on national model building and fire codes developed by private sector organizations.
- The model codes, in turn, reference voluntary consensus standards developed by a large number of private sector standards development organizations (SDOs) accredited by the American National Standards Institute (ANSI).
- NIST does not set building codes and standards, but provides technical support to the private sector and other government agencies in the development of U.S. building and fire practices, standards, and codes.
- NIST recommendations are given serious consideration by private sector organizations that develop national standards and model codes – which provide minimum requirements for public welfare and safety.

Approach to Recommendations

- In accordance with Section 8 of the enabling statute (15 USC 7301 et seq.), the National Construction Safety Team's final report is required to include recommendations that address:
 - Specific improvements to building standards, codes, and practices
 - Changes to, or the establishment of, evacuation and emergency response procedures
 - Research and other appropriate actions needed to help prevent future building failures
- NIST intends to issue draft recommendations for public comment that identify specific improvements in the way buildings are designed, constructed, maintained, and used.
- NIST's recommendations will be both realistic and achievable within a reasonable period of time, and their implementation would make buildings, occupants, and first responders safer in future emergencies.
- NIST will strongly urge that immediate and serious consideration be given to its recommendations by the building and fire safety communities—especially designers, owners, developers, fire safety professionals, and emergency responders.
- NIST is making a top priority to work vigorously with these communities to assure that there is complete understanding of the recommendations and their technical basis and to provide needed technical assistance. This includes a web-based system that will be available to the public so that progress in implementing NIST's recommendations can be tracked.

Approach to Recommendations (2)

- In formulating its recommendations, NIST will consider the following:
 - **Findings from the Investigation objectives** related to building performance, evacuation and emergency response, and procedures and practices.
 - **Whether findings relate to the unique circumstances surrounding the terrorist attacks of September 11, 2001, or to normal building and fire safety considerations, including evacuation and emergency response.**
 - **Technical solutions that are needed to address potential risks to buildings, occupants, and first responders**, considering both identifiable hazards and the consequences of those hazards.
 - **Whether the risks apply to all buildings or are limited** to selected building types (e.g., buildings that exceed a certain height and floor area or that employ a specific type of structural system), buildings that contain specific design features, iconic/signature buildings, or buildings that house critical functions.

Issues Related to Practice, Standards, Codes

- Based on the Investigation findings, NIST identified a broad set of issues related to practice, standards, and codes that will provide the basis for formulating the Investigation's recommendations.
- Issues arising from the investigation are grouped under the following major categories:
 - Increased Structural Integrity
 - Enhanced Fire Protection of Structures
 - Enhanced Active Fire Protection
 - Improved Building Evacuation
 - Improved Emergency Response
 - Improved Procedures and Practices
 - Education and Training Programs

Categories of Issues

Category: Responsible Community (Level 1)

- Professional Practices
- Provisions in standards, codes and regulations
- Adoption and enforcement of the provisions
- R&D or requiring further study
- Education and training

Category: Application (Level 2)

- All tall buildings (buildings over 20 stories in height)
- Selected tall buildings (buildings over 20 stories in height that are at risk due to design, location, use, iconic status, nature of occupancy, etc.)
- Selected other buildings (buildings less than 20 stories in height that are at risk due to design, location, use, historic/iconic status, nature of occupancy, etc.)

Category: Relation to the outcome on 9/11 (Level 3)

- Related to 9/11 outcome
- Unrelated to 9/11 outcome

Issues – Increased Structural Integrity

Issue	Level 1				Level 2			Level 3		
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Availability of explicit standards, code provisions, methodology, analytical design tools, and practical design guidance for designing structures to resist progressive collapse in the event of abnormal loads.	✓	✓	✓				✓	✓	✓	
Availability of analytical methodologies for prediction of complex failure phenomena of structural systems under abnormal loads.			✓	✓		✓		✓		✓
Availability of standards for wind tunnel tests and for methods to estimate wind effects from test results for design purposes.		✓	✓				✓	✓		✓
Availability of protocols for selection of site-specific wind speed and directionality.	✓	✓	✓				✓	✓		✓
Adequacy of prescriptive wind load standards for very tall buildings.		✓	✓			✓				✓

Issues - Enhanced Fire Protection

Issue	Level 1					Level 2			Level 3	
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Availability of standards, codes, methodology, analytical design tools, and practical design guidance to permit considering fire as a design condition for the structure as a whole system.	✓	✓	✓	✓		✓				✓
Standardized design-basis fire scenarios for design of fire protection systems and analysis of structural and thermal response do not account for building-specific conditions.	✓		✓			✓		✓		✓
Availability of regulations that would adopt code provisions using the “structural frame” approach to fire resistance ratings, which requires structural members to be fire protected to the same rating as columns.		✓		✓	✓	✓		✓		✓
Conformance of applied passive fire protection to conditions in actual or equivalent tests used to establish fire resistance rating of the building component or assembly.	✓	✓	✓		✓	✓			✓	
Adequacy of ASTM E 119 to provide guidance on: <ul style="list-style-type: none"> ▪Criteria for determining structural limit states, including failure, and means for measurement ▪Scale of test assembly versus prototype application ▪Effect of end restraint conditions on test results, including influence of stiffness ▪Structural connections ▪Combination of loading and exposure (temperature profile) represent expected conditions ▪Procedures to analyze and evaluate data from fire resistance tests of other building components and assemblies to qualify an untested building element ▪Repeatability and reproduceability of test results ▪Relationships between prescriptive ratings and performance of the assembly in realistic building fires 		✓	✓			✓				✓
Technical basis for construction classification and fire rating requirements for tall buildings (fire rating, sprinkler-tradeoff, compartmentation)	✓	✓	✓			✓			✓	

Issues – Enhanced Fire Protection

Issue	Level 1					Level 2			Level 3	
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Evaluation of presently available fire-resistant steels; comparison with conventional steels; and test protocols and acceptance criteria.	✓		✓			✓		✓	✓	
Sensitivity of the level of performance of active fire protection systems (sprinklers, standpipes/hoses, fire alarms, smoke management) to the size and height of the building, compartmentation, building population, activities, transient fuel loads, fire department response, and threat profile.	✓	✓	✓			✓		✓	✓	
Ability of fire alarm and communications systems to provide continuous, reliable, accurate, and sufficient information on conditions, so building fire emergencies including the evacuation process, if needed, can be managed using that information.		✓	✓			✓			✓	
The quantity and reliability of information available to emergency responders at the fire/emergency command station.		✓	✓			✓		✓	✓	
Survivability of fire alarm system information records of alarms during emergency events for investigation purposes.		✓				✓		✓		✓
Available means to transmit outside a building the status of emergency conditions in the building from information in the fire alarm system and other monitored building systems.	✓	✓	✓			✓		✓	✓	

Issues – Improved Building Evacuation: Egress System Design

Issue	Level 1				Level 2			Level 3		
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
The egress path may be compromised prior to evacuation of the affected population due to a variety of scenarios (e.g., wind, earthquake, overpressure, impact, fire).	✓	✓					✓		✓	
Building egress systems are not designed to accommodate full building evacuation. Full building evacuation is foreseeable under conditions of widespread power outage, earthquake, fire, or terrorist attack.	✓	✓		✓		✓			✓	
Lack of adequate egress models and performance-based egress design methodology accounting for human behavior during evacuation.			✓				✓		✓	
Stairwells can be physically proximate yet considered remote by a "walking path" measurement; does not adequately meet separation requirements under non-fire conditions.		✓					✓		✓	
Mobility-challenged occupants: areas of refuge create a delay in evacuation; insufficient procedures for identifying those with challenges and assisting them. Some mobility-challenged occupants are not capable of effecting their own escape.	✓	✓		✓		✓			✓	
Required professional training or accreditation for egress system designers (often architects).	✓			✓		✓				✓

Issues - Improved Building Evacuation: Emergency Communications to Occupants

Issue	Level 1				Level 2			Level 3		
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Inadequate situational awareness from missed opportunities to better communicate information among occupants, 911 operator dispatch, fire department dispatch, and emergency management dispatch and site security	✓	✓		✓		✓		✓	✓	
A building may have no capacity for public address announcements or instructions through the floor warden system		✓				✓			✓	
Use of emergency broadcast system for major emergencies such as that which occurred on September 11, 2001	✓			✓		✓			✓	

Issues – Improved Building Evacuation: Occupant Preparedness

Issue	Level 1				Level 2			Level 3		
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Emergency plans are filed to achieve regulatory compliance, but are not adequately implemented in practice. In addition, occupants are often unprepared to evacuate a building. Preparedness includes adequate knowledge of the evacuation procedures and systems, and adequate means for pathway illumination.	✓			✓		✓			✓	
Layouts (i.e., transfer floors) can be confusing to unprepared occupants.		✓				✓			✓	
Need for floor wardens.			✓				✓			✓

Issues – Improved Building Evacuation: Egress Technology

Issue	Level 1					Level 2			Level 3	
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
The electro-mechanical systems (e.g., elevators) integral to life safety may be compromised by a single event		✓				✓			✓	
Egress systems do not enable all occupants an equal opportunity for evacuation. Hardened elevators, exterior escape devices, or stairwell navigation devices not considered.		✓	✓			✓			✓	
Elevator door restrictor plate can entrap building occupants in the event of an emergency.			✓			✓			✓	

Issues – Improved Emergency Response: Access and Firefighting

Issue	Level 1				Level 2			Level 3		
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Physiological impact on firefighters with equipment climbing more than 10 to 12 floors during an emergency.	✓	✓	✓				✓		✓	
Adequacy of capacity for egress and firefighter access during full evacuation of fully occupied tall buildings (access to tall buildings by first responders is hindered by counter flow, egress capacity, and lack of available elevators).		✓	✓				✓		✓	
Distance (i.e., remoteness) between stairwells where standpipes are located.		✓				✓				✓

Issues – Improved Emergency Response: Emergency Communications

Issue	Level 1				Level 2			Level 3		
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Lack of rigorous pre-emergency inspection and testing of radio communications systems within high-rise buildings to identify performance gaps and inadequacies.	✓		✓	✓		✓			✓	
Performance requirements for emergency communication systems in high-rise buildings (i.e., design, testing, certification standards and maintenance and inspection requirements).		✓	✓		✓	✓			✓	
Lack of communications network architecture (interoperability) and operational protocols for intra- and inter-agency communication at all levels of organizational hierarchy. This includes: <ul style="list-style-type: none"> •Overall network architecture that covers local networking at incident sites, dispatching, and wide-area urban and rural networks. •Scalability in terms of the number of first responders using the system and in providing radio coverage in large buildings with challenging radiofrequency propagating environments. •Interoperability with existing legacy emergency communication systems. •Localization techniques to identify first responders within indoor building environments. •Conventional two-way versus wireless network systems 	✓		✓				✓			

Issues – Improved Emergency Response: Command and Control

Issue	Level 1					Level 2			Level 3	
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Availability of detailed procedures and methods for gathering, processing, and delivering situational information to all first responders, including 911 operators, wardens, incident commanders, etc.; this covers voice, video, and data integration.	✓	✓	✓	✓	✓	✓			✓	
Availability of effective codes and protocols for establishment and uninterrupted operation of the incident command and control system and for preservation and dissemination of information managed by command posts. <ul style="list-style-type: none"> •Command posts established within the collapse zone of buildings that received serious structural damage and contained large multi-floor fires. •Establishing the command post prior to dispatching needed units. •Effects of self-dispatch and free-lancing of first responders and ambulances, especially teams lacking protective clothing and medical equipment. •Robustness of assignment and tracking (accountability) system for large scale emergencies. 	✓	✓	✓				✓	✓		
Secure location of state and local emergency operation centers (EOCs).	✓					✓			✓	
Rapid adoption and execution of a unified emergency response mission by all first responder ranks.	✓				✓	✓			✓	
The dispatch of large numbers of personnel and apparatus and the ability of management to maintain accountability in a timely manner associated with arrival and deployment of personnel and the ability of the incident site to effectively accommodate large numbers of personnel and apparatus.		✓	✓	✓		✓		✓	✓	

Issues – Other Major Issues

Issue	Level 1				Level 2			Level 3		
	Practices	Standards, Codes, Regulations	R&D/study Further	Education & Training	Adoption and Enforcement	All Tall Buildings	Selected Tall Buildings	Selected Other Buildings	Related to 9/11 Outcome	Unrelated to 9/11 Outcome
Availability of regulatory requirements for retention of documents related to the design, construction, operation, maintenance, and modifications of buildings, including retention offsite and accessibility of building plans for emergency response. •Maintenance and storage of documents. •Accessibility of building plans for emergency response.	✓	✓			✓	✓				✓
Structural principles education for fire protection engineers and fire protection principles education for structural engineers; structural and fire protection principles education for architects.				✓		✓				✓
Creation of broad training opportunities for rigorous use of computational fire dynamics and thermostructural analysis tools.				✓		✓				✓

Approach to Recommendations (3)

- **NIST urges organizations responsible for building and fire safety at all levels to carefully consider the draft findings, issues, and recommendations.**
- In its final report, a draft of which is expected to be released in June 2005, NIST will recommend appropriate improvements in the way buildings are designed, constructed, maintained and used. It will be important for those recommendations to be thoroughly and promptly considered by the many organizations responsible for building and fire safety.
- NIST will welcome comments from the public on the draft final report.
- As part of NIST's overall WTC response plan, the Institute has begun to reach out to these organizations to pave the way for timely, expedited consideration of recommendations stemming from this investigation.
 - NIST will hold a major conference September 13-15, 2005 to reinforce the importance of its findings and recommendations from the Investigation and encourage their implementation in practice. The public will be provided an opportunity to comment.
 - NIST will develop a web-based system that will be available to the public so that progress in implementing the recommendations can be tracked. The website will list each of the recommendations, the specific organization or organizations responsible for its implementation, the status of its implementation by the organization, and the plans or work in progress to implement the recommendation.
- NIST also has expanded its research in areas of high priority need.

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