



international perspective | us

# Applying the lessons of September 11, 2001 to the built environment



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**In August 2002, the U.S. Commerce Department's National Institute of Standards and Technology (NIST) began a technical investigation into the collapse of World Trade Center (WTC) Buildings 1, 2, and 7 following the terrorist attacks of Sept 11, 2001.**

The investigation is being conducted under the Congressionally mandated National Construction Safety Team Act (15 USC 7301 et seq.) where section 8 of the enabling statute (15 USC 7307) requires NIST to recommend specific improvements to building standards, codes, and practices, even though in the U.S., building regulation is the responsibility of state and local governments.

The private sector develops the model codes and standards on which building regulations are based with the federal government having no formal role in building regulation.

NIST is developing these recommendations based on findings and observations during the investigation which may or may not relate to the unique circumstances surrounding the terrorist attacks and which may be

applicable to all buildings or may be limited to certain building types (e.g., certain height, area, structural system, or use, signature/iconic status, critical functionality). NIST recommendations are related to identified issues under four major areas:

- ▶ increased structural integrity, including methods for mitigating conditions that could result in progressive collapse, standardising the estimation of wind loads that frequently govern the design of tall buildings, enhancing the stability performance of tall buildings;
- ▶ enhanced fire protection, including an appropriate balance and redundancy between passive and active measures, especially as risks to occupants increase with height;
- ▶ improved building evacuation, including system designs that facilitate safe and rapid egress, methods for ensuring clear and timely emergency communications to occupants, better occupant preparedness for evacuation during emergencies, and incorporation of appropriate egress technologies to address the needs of all occupants including those with disabilities; and

- ▶ improved emergency response, including better first responder access and operations, emergency communications, and command and control in large-scale emergencies.

Nowhere do building regulations attempt to address every potential hazard and, for hazards that are addressed, regulations incorporate thresholds that are established as a matter of public policy. Accordingly, many of the NIST recommendations will require such public policy consensus to establish appropriate thresholds.

Generally speaking, the NIST recommendations will be consistent with the concept of risk-informed regulation. This is where policy makers set thresholds and regulatory objectives so that there is a balance between society's expectations for the built environment and what society is willing to pay (in the broad sense of cost).

Risks that are not mitigated must satisfy the regulator that they are sufficiently unlikely considering the potential consequences. This threshold is the boundary between design level or maximum credible events on one hand, and the so-called extreme or rare events that are low probability, high consequence events such as the Sept. 11, 2001, terrorist attacks.

Specific details of the NIST recommendations for changes to codes, standards, and practices must await

the publication of the final report, which will be freely available on the web site (<http://wtc.nist.gov/>) later this year. In the meantime, the following provides insight into the general issues:

- ▶ *The safety design of buildings, and especially tall buildings, lacks adequate integration among the structural and fire safety engineering disciplines.* Architects are usually responsible for coordination of all work by members of the design team, consistent with the design professional in responsible charge concept currently found in U.S. building regulations, and would be expected to provide the needed integration. Trade-offs traditionally used as incentives currently are not reapplied as overlapping layers of protection as risks increase, for example with height or with large span designs. While wind design has improved greatly in the past two decades, considerable uncertainties and lack of transparency exist in the estimation of site specific wind loads and reproducibility of wind tunnel testing for tall buildings.



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## < Applying the lessons of September 11, 2001 to the built environment | continued

- ▶ *A clear objective does not exist under which structures are designed to undergo complete burnout of any space without local or global collapse.* Members necessary for this performance, including girders or floor trusses that brace columns against buckling, are not always required to have the same fire performance required of the columns (the so-called structural frame). The engineering level understanding of structural fire performance is lacking and detailed predictions of the performance of complex systems cannot be made. For example, the performance of connections between members, response to high heating rates and high thermal gradients, and in the cooling phase are not sufficiently understood to be included in analytical tools used for design and evaluation. Test and measurement methods that support this detailed predictive capability are unavailable.
- ▶ *The performance and reliability of active fire protection features such as sprinklers, alarms, standpipes, and smoke management do not adequately reflect the greater risks with increasing building height, larger uncomparted areas, iconic buildings, fire department response limits, transient fuel loads, and higher threat profiles.*

Performance attributes do not account for reliability, redundancy, and elimination of vulnerabilities to single point failures. Active systems do not provide information to the fire services that supports better incident management and situational awareness, especially the real time management of occupant evacuation and tactical decision making. Access to critical information is not available off site and recorded to support subsequent investigations.

- ▶ *Evacuation plans for tall buildings do not consider simultaneous full evacuation under a range of foreseeable conditions including widespread power outage, natural hazards, and terrorist attacks (where deemed a possibility) with sufficient redundancy and robustness.*

Large or complex buildings are often not required to implement fire warden systems to provide for evacuation management. Protected elevators that can be used as part of the means of egress are not permitted, even though this is often the only practical method to allow the mobility challenged to self-evacuate, and requires long transit times for occupants of higher floors to egress down stairs. Occupant training is not adequately realistic and designed to provide psychological comfort and familiarity with any conditions that might be encountered during egress, often due to concerns for





liability should occupants be injured while participating in an egress training exercise.

- ▶ ***Building regulations do not generally address the safety of existing buildings by the establishment of mechanisms to require retrofit of safety related features on a reasonable schedule to ensure that all public buildings meet minimum safety requirements as these evolve.***

While NIST reviewed certain, specific codes and standards in the course of the investigation, findings of limitations are not necessarily limited to those documents. There is a great deal of commonality in building codes, worldwide. For example, the findings support the “structural frame” concept that is already included in some codes.

Thus NIST is giving consideration to whether this should be included in all codes in the US or globally, independent of whether NIST reviewed that code or not. Similarly, considering the reapplication of trade offs or adding layers of protection as risk increases, improved techniques for wind design, improvements in egress

design, and application of safety requirements to existing buildings are applicable globally. Some regulators may already address these issues (for example, the Japanese recently introduced a system to prioritise improvements to existing buildings undergoing renovations) but this does not diminish the applicability of these considerations.

NIST will be making specific recommendations as part of its final investigation report. NIST has established liaison with the codes and standards developers in the United States to facilitate the incorporation of its recommendations into practice. NIST is working with ISO TC92 (Fire Safety) and with CIB W14 (Fire) and TG50 (Tall Buildings) toward international adoption.

There is considerable international interest, especially in advanced understanding of structural fire performance and in protected elevators for fire service access and occupant egress. Information sharing, and even collaborative research, is underway on these issues. Inquiries can be directed to the author or to the general web site, [www.wtc.nist.gov/](http://www.wtc.nist.gov/)