Opening Remarks[1] of
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at the
Meeting to Discuss IBC Code Change Proposal for
Progressive/Disproportionate Collapse
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NIST released the final report in October 2005 from its building and fire safety investigation of the collapses of the World Trade Center (WTC) towers on 9-11. The report included 30 recommendations for improving building and occupant safety derived from the findings. On March 24, 2006, the first 19 proposed changes to model building codes based upon and consistent with the NIST WTC recommendations were submitted to the International Code Council.

The 19 proposed changes—submitted by building code experts associated with two ICC committees, NIBS and GSA—address areas such as: increased resistance to building collapse from fire and other incidents, use of spray-applied fire resistive materials (commonly known as "fireproofing"), performance and redundancy of fire protection systems (i.e. automatic sprinklers), elevators for use by first responders and evacuating occupants, the number and location of stairwells, exit path markings, and fuel oil storage/piping.

Taken together, they are a robust, reasonable and appropriate set of advancements, and if adopted, would represent a significant improvement in public safety over current practice.[2]

One of these 19 code change proposals deals with progressive collapse or disproportionate collapse. This proposal should be considered within the broader framework of structural robustness and integrity. In recent decades, there has been an emphasis on maximizing the efficiency of the structural system to mitigate effects of the weight premium on cost, especially for super tall buildings[3].

Structural engineers, however, do not have an objective metric today for measuring the safety performance of the structure as a complete system. Thus, we cannot quantify the degree of safety of a structural system or compare the safety of one structural system relative to another system for a given performance objective. As we build increasingly taller and more efficient buildings—that pose inherently greater consequence-driven risks to known hazards and have less redundancy—it becomes vitally important to assure a minimum level of safety of the structural system in satisfying the performance objective, in addition to assuring the efficiency of the structural system (e.g., pounds per square feet of structural materials used).

[1] Edited and updated after the meeting. This document incorporates responses to discussions at the meeting.
[2] Several organizations, including NIST, are reviewing these proposals and may offer amendments or suggestions for improvement during the code development process.
[3] In theory, the most efficient structural system that can be designed is a determinate system, which lacks redundancy.

Our codes and standards focus on quantifying performance and assuring the safety of components and connections, with the exception of some instances such as in earthquake-resistant design where system performance can be quantified (e.g., using R factors). Building codes and standards typically use safety factors in deterministic design and load and resistance factors in probabilistic design to quantify the safety performance of components and connections.

Similar safety metrics should also be considered for the performance of the structural system[4]. For example, the ratio of the ultimate reserve capacity of a structural system to the design load carrying capacity of the system may be used to quantify safety performance. This metric—or global safety factor for the system—may be obtained either under purely gravity loads or under different combinations of lateral and gravity loads. The metrics may also be used to quantify the safety performance of major structural sub-systems such as the core, perimeter, and floor framing systems.

Under gravity loads, the ultimate reserve capacity of the structural system may be determined while the structure is subject to design gravity loads with appropriately applied load reduction factors. Under lateral loads, the ultimate reserve capacity of the structural system may be obtained while the structure is subject to both lateral and gravity loads consistent with typical load reduction factors.

While advanced analysis tools exist to quantify the safety performance of structural systems using these metrics, more work is needed to determine appropriate global system safety factors—or load and system resistance factors—to implement meaningful provisions in codes and standards. This will require developing comparative data regarding the safety performance of different structural systems using these metrics.[5]

Until the above information on global system safety factors becomes available, current methods for mitigation of progressive or disproportionate collapse may be used in our codes and standards to ensure a minimum level of robustness and integrity (or safety performance) of the structural system. These methods include: tying buildings components together to provide continuity and strength; providing structural redundancy via alternate load paths; and enhancing specific resistance of structural components to known hazards.

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[4] System performance metrics are routinely used in other industries and applications. For example, fuel efficiency of automobiles is similar to materials efficiency for buildings. Also, the system safety performance of an automobile, measured in terms of crashworthiness ratings, is similar to the ultimate reserve capacity of the structural system. Fuel efficiency, in turn, depends on the design of major subsystems such as the engine, aerodynamic shape of the body, and the grade of fuel. Similarly, the system safety performance depends on the design of major subsystems such as the engine, body, doors, and supplemental restraint systems. Each of the subsystems and components may be governed by standards as well.

[5] Some experts cite the excellent safety record of tall buildings in recent decades and ask whether there is a need to quantify the safety of the structural system. Statistics over several decades, however, are not adequate to quantify risks. Instead data is needed over some multiple of the expected life of a building, typically 100 years. In designing structures for hurricanes and earthquakes, it is common practice to consider rare events with return periods of 500 to 2,500 years. Similarly, long term risks should be anticipated in designing structural systems for general robustness and integrity.

Codes and standards provisions should focus on the use of threat or hazard independent methods to mitigate progressive or disproportionate collapse and to assure system safety performance[6]. When specific threats or hazards are known or can be anticipated, they should be considered explicitly in design; codes and standards should have provisions treating them as such.

Robust tools already exist for specific use in design to mitigate progressive or disproportionate collapse. The April 2006 issue of *Structure* magazine—a joint publication of NCSEA, CASE, and SEI—contains an excellent summary of these tools. The articles in the magazine also illustrate the considerable technical and professional capabilities already available within the United States.

The U.K. has had a progressive collapse standard "Standards to Avoid Progressive Collapse – Large Panel Construction" since 1968. The standard lists two methods for mitigating progressive collapse: (1) by providing alternative load paths, assuming the removal of a critical section of the load bearing system, and (2) by providing stiffness and continuity to the structural system to ensure the stability of the building against forces liable to damage the load supporting members. The standard also specifies an accidental static pressure of 5 pounds-per-square-inch and minimum tie forces for continuity. These provisions are based on engineering experience and judgment. Similar provisions have been adopted in the *Eurocode.* Currently, there is no field evidence to indicate that these provisions are not working or that the resulting building designs are less safe.

In the United States, the American Society of Civil Engineers (ASCE) has in its standard (ASCE/SEI 7), structural integrity requirements for progressive collapse mitigation. ASCE plans to develop guidance for the prevention of progressive collapse. A technical committee has been recommended, but has not yet been formed. It will be some years before a guidance document is developed and made available for code adoption.

NIST has an ongoing multi-year research project on the development of criteria for prevention of progressive collapse and is currently assessing best practices in current use. The NIST best practices document is intended to provide owners and practicing engineers with the current best practices to mitigate progressive collapse, including methods similar to those adopted in the U.K., and those used by federal agencies such as GSA, DoD, and the State Department. The draft of the document will be made available for broad review in conjunction with training seminars to be conducted by ASCE in 2006. The final document will be available by the end of 2007.

In the course of its Investigation into the collapse of the World Trade Center Towers, NIST did not find any evidence that well-tied buildings performed unfavorably (or collapse earlier) than buildings that are not well-tied. In fact NIST found that, had the major structural subsystems of the WTC towers not been tied together, the core of the towers would have collapsed earlier. The hat-truss tied the core to the perimeter walls of the towers, and thus allowed the building to

[6] The practice of removing one or more columns as part of the analysis to provide alternate load paths within a structural system has led to considerable confusion among many experts who want to know what specific hazard would cause the column or columns to fail. Instead, the focus should be on enhancing the general robustness and integrity of the structural system by providing alternate load paths using threat or hazard independent methods.

withstand the effects of the aircraft impact and subsequent fires for a much longer time—enabling large numbers of building occupants to evacuate safely.

NIST believes that it is imperative for U.S. building codes and standards to address requirements for robustness and integrity of the structure as a system, especially tall buildings. This is essential to quantify and assure a minimum level of safety for the structural system, much as U.S. codes and standards do now to quantify and assure a minimum level of safety for structural components and connections. With few exceptions, the lack of minimum requirements for global safety factors for structural systems represents a major gap in U.S. codes and standards. This gap must be closed with a sense of urgency and commitment by the professional and building official communities. We should find an efficient and effective way forward today by discussing the specific code change proposal on disproportionate collapse submitted to the IBC.

In closing, NIST welcomes and fully respects the ongoing debate among the professional and building official communities as they consider the 19 code change proposals based on the WTC recommendations for adoption.

All ICC members will have the opportunity to vote on the proposals at hearings scheduled for this fall. All changes passed and those which did not pass but for which public comments are received will then be up for approval—and inclusion in the ICC codes—when ICC Government Member representatives meet in the spring of 2007.

For more information: -- including a Web-based system for tracking the progress toward implementing all of the NIST WTC recommendations -- go to http://wtc.nist.gov . A link to "Status of NIST's Recommendations" from the WTC website lists each of the recommendations, the specific organization or organizations (e.g., standards and code developers, professional groups, state and local authorities) responsible for its implementation, the status of its implementation by organization, and the plans or work in progress to implement the recommendations. The status of the implementation of the recommendations is current as of April 10, 2006 and includes links to the nineteen code change proposals submitted to the International Code Council for the March 24, 2006 deadline and supplementary information produced by the NIBS building code experts.