Research & Development Program for the Safety of Threatened Buildings

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Abstract: A series of tragic events in the United States over the past decade, punctuated by the collapse of the World Trade Center on September 11, 2003, has exposed the vulnerability of public buildings to uncontrolled fires, explosions, and biological attack. While the number of such dramatic events is small, the potential (or actual) losses in terms of life and property can be staggering. The National Institute of Standards and Technology (NIST) throughout its history has sought to provide a technical foundation that supports improvements to building and fire codes, standards, and practices that reduce the impact of conventional fires, wind loads, and earthquakes on structures. However, the recent events have caused NIST to broaden the scope of its research and development to include more extreme and unconventional threats to the safety of buildings, their occupants and emergency responders. The new R&D program is described in this paper.

Key words: building fires, building performance, building egress, first responder safety

1 Introduction

Building and fire codes in the United States exist, among other reasons, to ensure the safety of occupants in the event of anticipated excessive loads due to wind, earthquake, and snow, and the likelihood of a probable worst case fire. The tragic collapse of the World Trade Center in 2001 (along with the terrorist attacks on the Pentagon, Hart Senate Office Building, and the Murrah Federal Building) has focused the general public, governments at all levels, and the construction and building products industries on the need to understand the possible impacts of terrorist acts on building operations, structural integrity, and emergency response procedures, and on the need to develop economically justifiable strategies to mitigate the potential loss of life from future extreme threats. The standard test methods and building practices upon which current building and fire codes are based rank the performance of one material, component or system against alternative designs, with the expectation that some minimum rating translates into a sufficient level of safety of the material, component or system when installed in the actual building. Safety factors are used to account for our ignorance about the magnitude of actual loads, and of the uncertainty in response of the complex building frame to these loads. The prediction of failure modes in a closely-coupled building system is beyond our current capability, and standard test methods tell nothing of the expected performance of the building should the mechanical or thermal load exceed a prescribed value. In addition, building designers, operators, occupants and first responders are faced with chemical and biological threats unforeseen as little as two years ago. How should HVAC systems be designed and operated to contain a poisonous aerosol or gas? How have peoples' behaviors changed since 9/11in response to an emergency? Should the same emergency egress and fire service access techniques and strategies be used in the case of a biological threat as for a fire? Can new technologies be developed or design practices be adapted to increase the safety of the building occupants without undue economic burden on the owners/operators? Additional research and development is being conducted in this Program to answer questions like these, to provide guidance and tools to assess and reduce future vulnerabilities, and to better prepare facility owners,

contractors, designers, and emergency personnel to respond to future disasters, natural or intentionally initiated.

2 Approach

The R&D for the Safety of Threatened Buildings Program is part of the response of NIST to the events of 9/11, and has been developed through extensive discussions and partnerships with industry, academia, professional societies, codes and standards organizations, emergency services, and other government agencies.[1] While responsive to recommendations from the FEMA Building Performance Study[2], the fruits of the research will be applicable to the built environment in general.

Four general areas of research have been targeted to support near and long term improvements to reduce the vulnerability of the structure, building occupants and first responders to extreme threats:

* Increased Structural Integrity
* Enhanced Fire Resistance
* Improved Emergency Egress and Access
* Building and Emergency Equipment Standards and Guidelines

Closely coordinated with the R&D above is the Dissemination and Technical Assistance Program (DTAP), which is aimed at gaining industry acceptance of proposed changes to practice, standards, and codes. The DTAP will help assure that the products of the R&D lead to practical guidance and tools that motivate and better prepare facility owners, contractors, designers, and emergency personnel to respond to future disasters.

Increasing Structural Integrity-Structural integrity will be increased through the development and implementation of performance criteria for codes and standards, tools and practical guidance for prevention of progressive structural collapse. System design concepts, retarded collapse mechanisms, built in redundancy, and hardening structures though retrofit will be considered. Performance criteria for fire safety design and retrofit of structures will be developed through examination of five key factors: the suitability of standard fire resistance test methods; the role of structural connections, diaphragms, and redundancy in enabling load transfer and maintaining overall structural integrity; the effectiveness of alternative retrofit, design and fire protection strategies to enhance structural fire endurance; the fire behavior of structures built with innovative materials; and models to predict the fire hazard to structures from internal and external fires. Guidance on methods to enhance fire resistance of steel and concrete structures based upon our current state of knowledge will be developed as well.

Enhancing Fire Resistance-Fire resistant steels exist and are in use elsewhere in the world. More efficient and accurate tests for performance of steels under building fire conditions are needed and will be developed to help industry incorporate fire resistant steels into U. S. construction practice. Fundamental mechanical and thermal properties of fire protective materials will be measured. This will require the development of new test methods and instrumentation, and a data base that spans the full range of expected temperatures and mechanical loads. These data will supplement, or may even supplant the need for, the ASTM E119 test[3] in certain situations, and in any case are key to the implementation of meaningful performance codes and design criteria.

Facilities do not yet exist that are suitable for demonstrating in a quantitative manner the improved performance of new materials, systems and processes in their end-use within a building under actual fire conditions. Hence, simulations are required to bridge the fundamental data and the results of bench-and pilots-cale tests to the environment in which they would be exposed during extreme fire conditions. The severity of a fire is dependent upon many parameters that are beyond the control of the building

designer, especially when one considers the range of terrorism threats that are possible. The performance in a fire of non-structural elements such as walls and ceilings is directly linked to the structural integrity of the building because a collapsed wall, ceiling or floor exposes more areas of the building to the fire while providing additional fuel and air upon which the fire can feed. The technical basis for accurate measurement methodology and simulation tools for the inclusion of fire resistant properties of walls and ceilings in performance-based fire safety design will be developed under this Program.

Improving Emergency Egress and Access-By working with the primary stakeholders (elevator and construction industries, building designers and owners, fire services, professional societies and code making bodies), the role of elevators in providing access by the fire service to a fire in a high rise building will be greatly enhanced over current practice. The development of hardened fire service elevators and new emergency operation procedures/controls will also lead to improved egress capabilities from tall buildings, especially for mobility-impaired or injured occupants. However, the behavior of people in an emergency situation has been altered in unpredictable ways by the events of 9/11. Current egress models may be inappropriate and/or insufficient for the design and placement of doors and stairways and the control of elevator movement. Behavioral and engineering studies will be conducted, drawing on experts in academia and elsewhere, to enable the development of simulation tools that better capture the movement of people within a building under fire and other emergency situations.

Developing Building and Emergency Equipment Standards and Guidelines-Partnering with the American Society of Heating. Refrigeration and Air-conditioning Engineers (ASHRAE) and other U.S. agencies, NIST-developed indoor air quality (IAQ) simulation tools will be extended to analyze and guide the assessment and subsequent reductions in the vulnerability of buildings to chemical and biological attacks. Standard building information models that facilitate the simulation of building system behavior during adverse events are being developed to allow communication among IAQ controls and other building controls associated with, for example, security, transportation, energy and fire alarm systems. Photocatalytic air cleaners are being considered as one means to reducing building vulnerability by eliminating harmful chemical and biological agents from the building environment. The mechanisms and fundamental properties controlling the effectiveness of this emerging technology will be examined in this part of the Program. A user-friendly tool will be developed for building owners and managers to aid in the selection of cost-effective strategies for the management of terrorist and environmental risks. Also, facilities will be established for science-based exposures for measurement of firefighter equipment performance attributes essential to support informed fire service procurement decisions.

3 Summary of impact

Working with partners in the private and public sector and with effective international collaboration, the Safety of Threatened Buildings R&D Program will develop and disseminate guidance and tools, assess and reduce building vulnerabilities, and produce the technical basis for cost-effective changes in building and construction practices and standards. Implementation of the results will better protect building occupants and property in the future, will enhance the safety of fire and emergency responders, and will help restore public confidence in public buildings by making buildings safer worldwide.

References

[1] http://wtc.nist.gov/

[2] World Trade Center Building Performance Study: Data Collection, Preliminary Observations, and Recommend-

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[3] ASTM E 119—98: Standard Test Methods for Fire Tests of Building Construction Materials, ASTM International, West Conshohocken, PA, 1999.