Safety of Threatened Buildings Program

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Part of the NIST post-9/11 response plan

Extension and enhancement of pre-9/11ongoing R&D

Objective: To provide a technical foundation that supports improvements to codes, standards, and practices that reduce the impact of extreme threats to the safety of buildings, their occupants & emergency responders.

Anticipated Major Outcomes:

A. **Increased Structural Integrity**
B. **Enhanced Fire Resistance**
C. **Improved Emergency Egress & Access**
D. **Building Equip. Standards & Guidelines**

9/12/05

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A. Increased Structural Integrity

1. Prevention of Progressive Collapse

Objective: To develop and implement performance criteria for codes and standards, tools, and practical guidance for prevention of progressive structural collapse.

Definition of Progressive Collapse: Spread of structural failure by a chain reaction, disproportionate to a localized triggering failure.

- Loss of gravity load capacity of structural system
- Inability of the structural system to redistribute the load

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Steel Connection Model
(NIST contract with U. Michigan)

FEM
MACRO-MODEL

Top Load (kips)
Disp, in

Column member

Spring representing flange

Rigid member

Spring representing top half of web

Rigid member

Rigid member

Beam member

Spring representing shear stiffness and strength

Spring representing Panel zone stiffness and strength

Spring representing bottom half of web

Spring representing flange
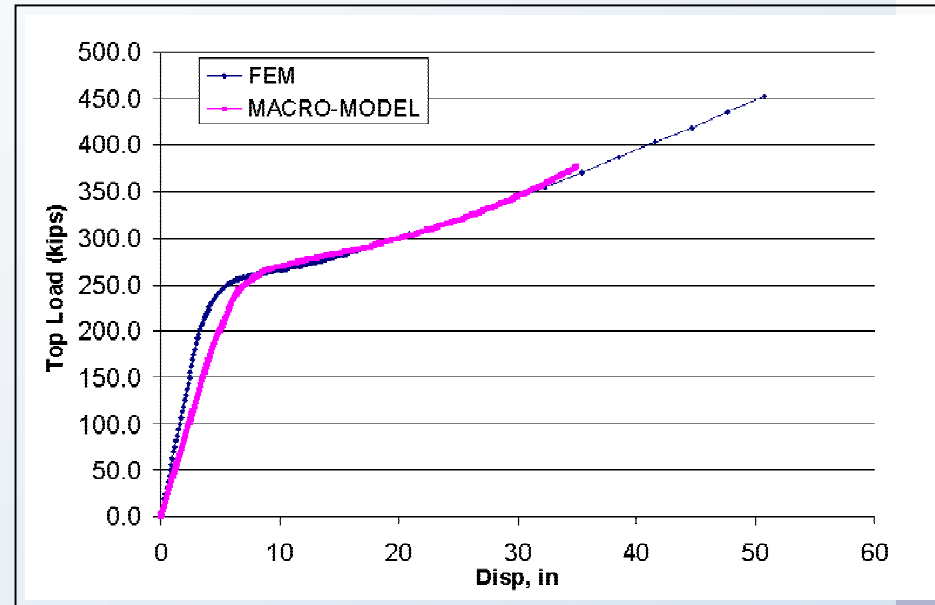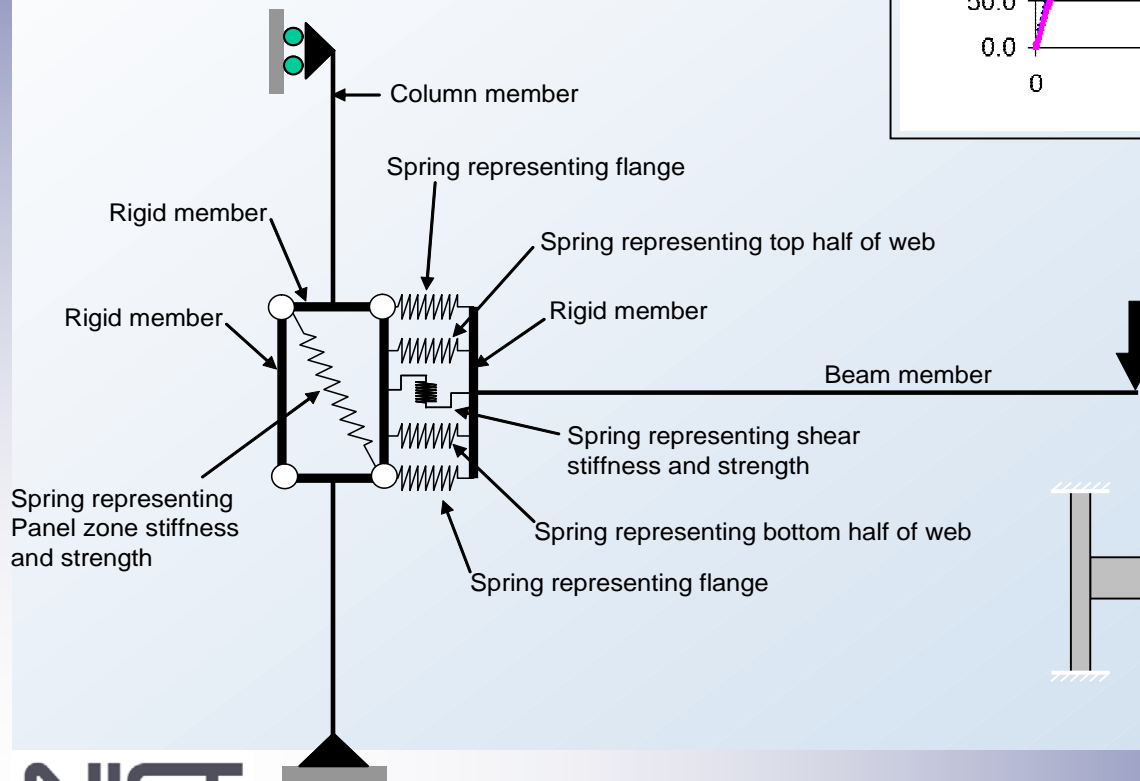
Proposed Test Setup

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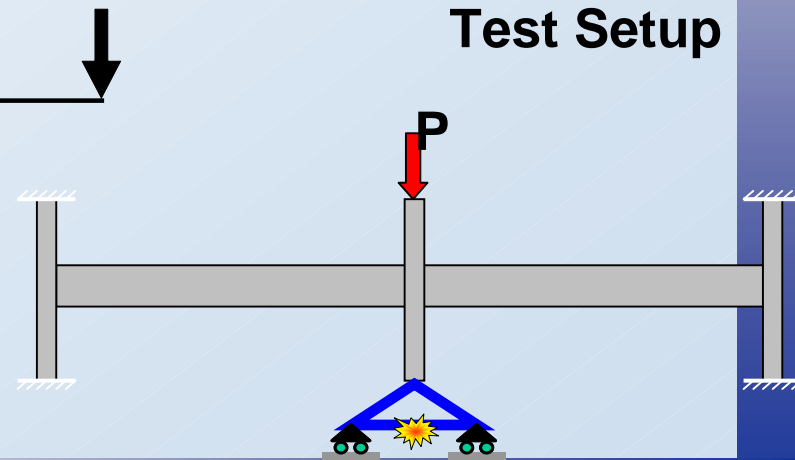
A. Increased Structural Integrity

2. Fire Safe Building Structures

Objective: To develop and implement verified and improved standards, tools, methodology and guidance for the fire safety design and retrofit of concrete and steel structures.

- National R&D Roadmap for Structural Fire Safety Design and Retrofit of Structures (w/SFPE)
- Furnace testing of composite concrete slab/steel truss floor system
- Global collaboration on insulated steel connections
- Planning for National Structural Fire Resistance Laboratory *(NSFRL)* so that safety benefit of improvements to related building fire codes & standards can be demonstrated to major stakeholders

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B. Enhanced Fire Resistance

1. Fire Resistance of Bare Structural Steel

Objectives: Develop and standardize test method for evaluating fire resistance of structural steel; and produce validated database of mechanical properties for several common construction steels.
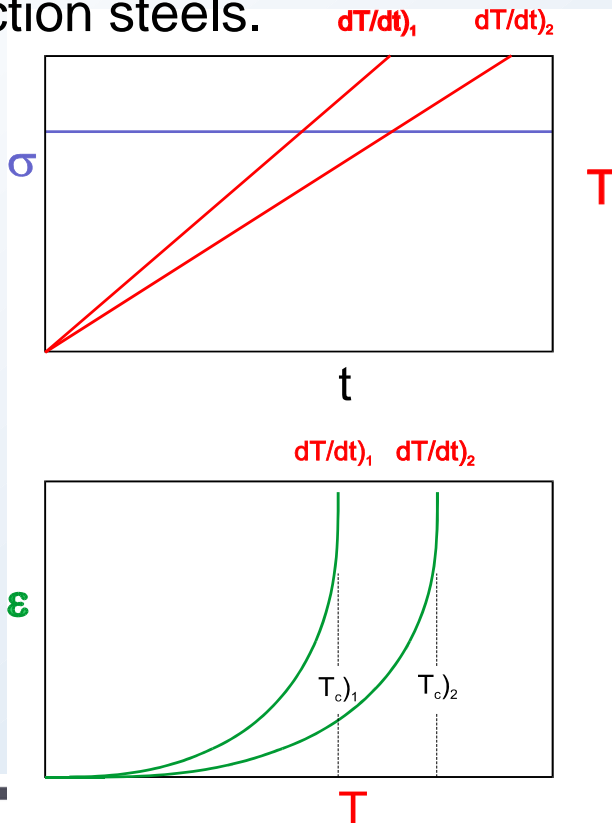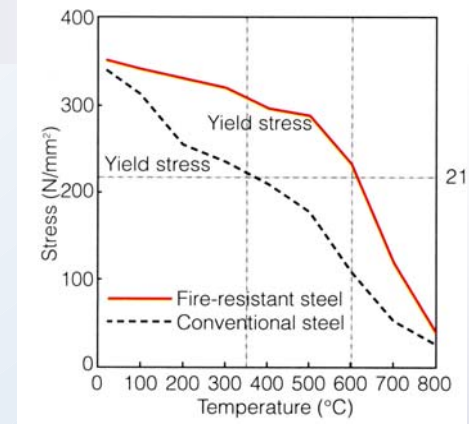
Three possible definitions of fire-resistance
- High-T tensile test (ASTM E21)
- High-T, slow-rate tensile test
- Temperature Ramp Test

B. Enhanced Fire Resistance

2. Fire Resistive Coatings for Structural Steel

Background:

- Fire resistive materials currently evaluated using ASTM E119-type testing that only provides pass/fail time rating
- Adhesion & thermophysical properties not explicitly evaluated.
- Goal is to introduce materials science to the FRM industry, focusing on
    - Adhesion
    - Microstructure
    - Thermophysical properties (mainly thermal conductivity)

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2. Fire Resistive Coatings for Structural Steel

Thermal Conductivity of Various FRMs

Microstructures characterized with respect to porosity and pore sizes using 3-D x-ray microtomography; used as input for direct computation of thermal conductivity values

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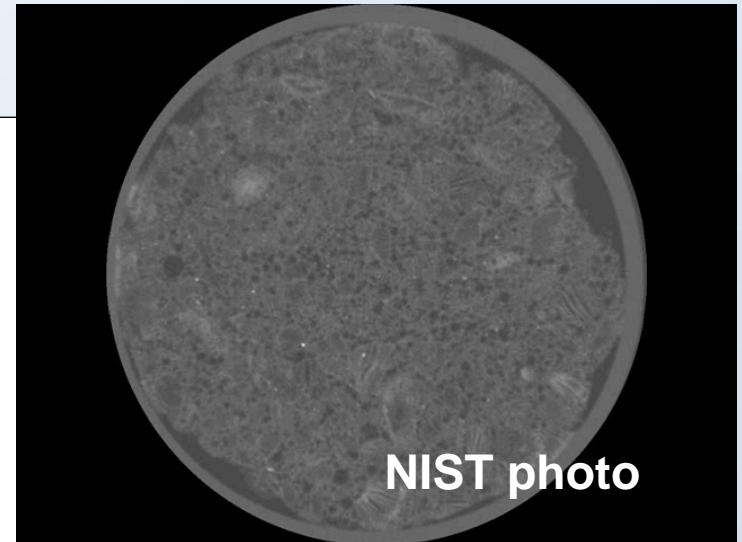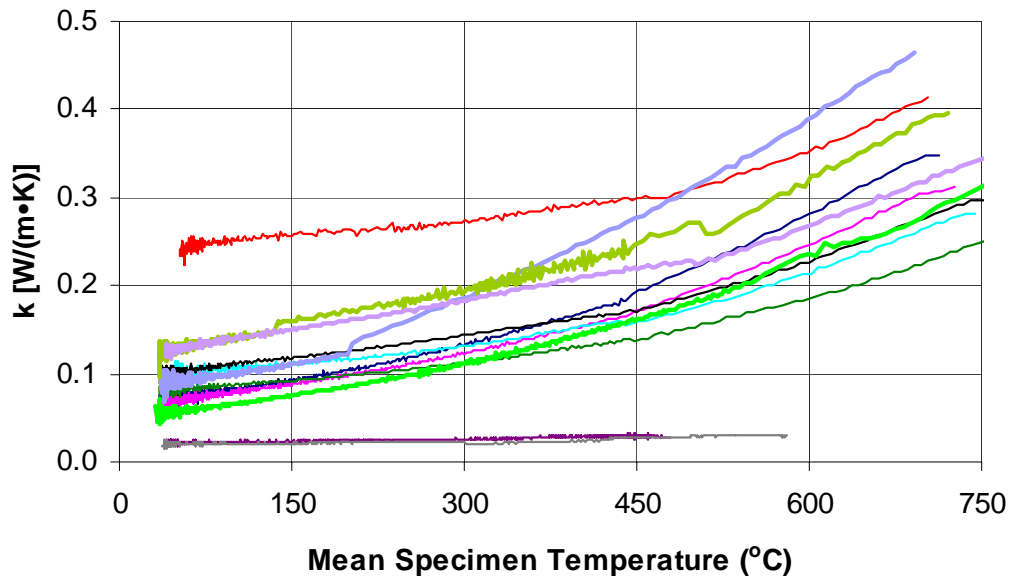
3-D Microstructure of gypsum-based fire resistive material (collaboration with Penn. State U.)

k [W/(m•K)]

Mean Specimen Temperature (°C)

B. Enhanced Fire Resistance

3. Fire Resistance of Building Partitions

- Need to confine fire for time sufficient to allow occupant evacuation
- Current standards - limited value for quantitative design
- Approach:
  - Conduct real scale tests of wall assemblies
  - Develop model of time to failure modes --
        Heat, smoke, and flames
  - Establish apparatus needed for model input data
  - Develop and validate method at minimum scale for obtaining thermal and failure data on assemblies

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Real Scale Fire Tests

- Five gypsum wall partitions, one glass wall partition tested
- Measurements: infrared and visual imagery of unexposed face, temperature, heat flux, compartment heat release rate, gas temperatures

Wall Location

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Vertical Furnace
UL Northbrook

North American Fire Testing Laboratories Round Robin

- Compare behavior of different vertical furnaces
- Data used by labs to assess relative performance of their furnaces
- Data used by NIST to develop relationship between furnace behavior and actual fires - understand cracking/failure of gypsum boards

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C. Improved Emergency Access and Egress

Objectives:
- Provide technical foundation for egress and access code requirements.
- Work with codes and standards bodies to implement findings.

Video monitoring for data collection and analysis
- Pre-evacuation activities, speed, flow, density on stairwells and horizontal surfaces, merging flows, responder counterflow.
- 13 Story mid rise baseline; 6 Story with/without counterflow.

NIST Evacuation Model (NEvac)
- Network model - person located in region
- Discrete model - person located in cell
- Continuous - person located (x,y)
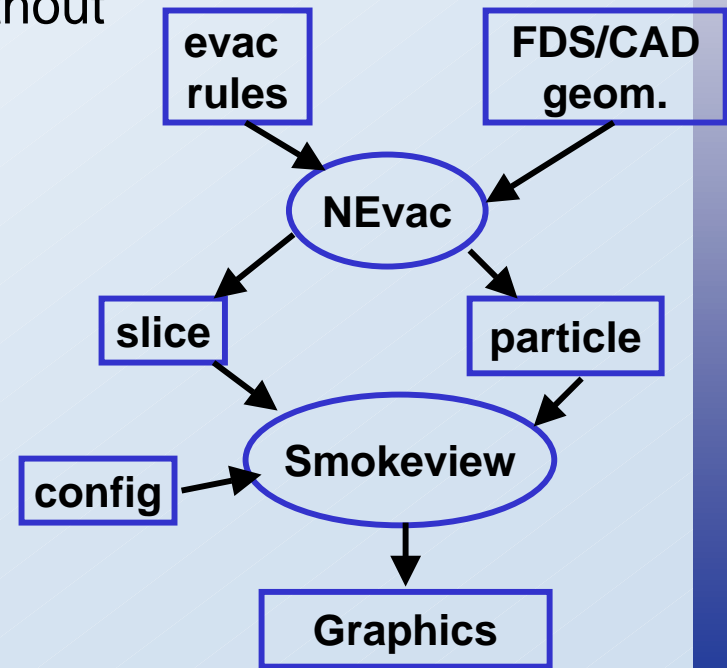
C. Improved Emergency Access and Egress

Emergency Use of Elevators

Elevator Consensus Workshop – Industry consensus on the technical approach for use of elevators for firefighter access and occupant egress
- Real-time monitoring of critical conditions in fire command center
- Real-time information systems to inform users occupants
- Protected, enclosed lobbies on every floor to serve as area of refuge

Protected elevator hazard analysis (ASME A 17.1)
- Comprehensive iterative analysis to mitigate potential hazards
- In accordance with ISO standard on risk analysis

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D. Building Equipment Standards & Guidelines

1. **Developing, Managing and Disseminating Building Information During Emergencies**
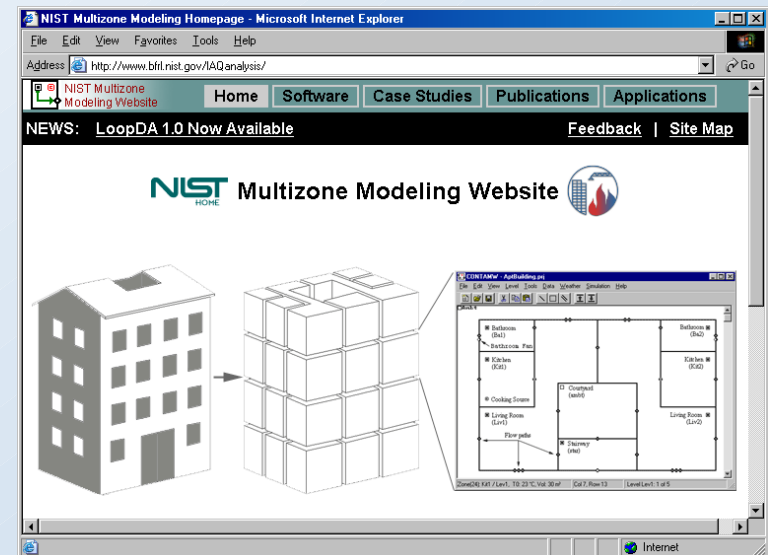
Objectives:
- Develop standard building information services that enable ready access to building systems data by first responders
- Develop standard methods for managing heterogeneous wireless sensor networks in buildings, facilitating access by first responders and other emergency personnel
- Develop methods for ensuring the secure dissemination of building information to emergency responders

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D. Building Equipment Standards & Guidelines

2. Technologies for Building Operations in CBR Attacks

CONTAM: Multizone Airflow and Contaminant Transport Analysis - Plans for Enhancements

- Deposition and accumulation of aerosols
- More realistic models of filters and air cleaners
- IFC-CONTAM converter, e.g. HVAC elements
- Momentum driven airflow
- Numerics for short time steps
- Fire and smoke transport models

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D. Building Equipment Standards & Guidelines

3. Cost-effective Risk Management Tools

Objective: Develop economic tools to aid facility owners and managers in selection of cost-effective strategies that respond to extreme events.

Problem: Need economic tools for optimizing resources to reduce
- Fatalities and personal injuries
- Financial losses
- Damages to constructed facilities
  - Buildings
  - Industrial Facilities
  - Infrastructure
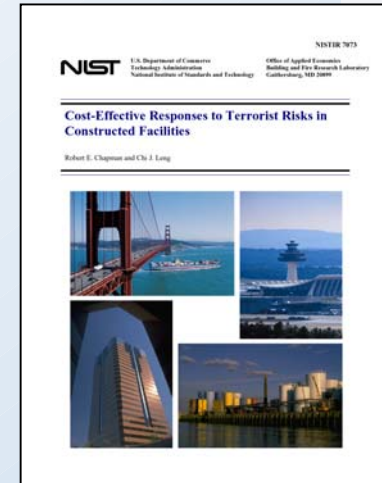
Cost-Effectiveness Software Tool

The cost-effectiveness software tool helps users make straightforward and consistent comparisons of risk mitigation strategies based on established economic evaluation practices. The uncertainty about natural and man-made hazards complicates the task of building owners and managers to identify and choose which hazards to guard against. The wide range of potential remediation measures, the permanence of investment-based solutions, and the expense of their implementation, installation, and maintenance necessitate an evaluation tool that systematically and consistently evaluates competing alternatives.

The cost-effectiveness software tool performs such evaluations by incorporating life-cycle cost analysis based on an industry consensus standard, ASTM E 917. The software allows building owners and managers to define hazard scenarios, identify possible consequences of those scenarios, and compare combinations of strategies to mitigate those consequences. The software's standardized measures allow life-cycle comparisons of alternative combinations of risk mitigation strategies based on user-defined scenarios.

Version 1.0

Version 1.0 of the software is now available for download. Version 1.0 produces the types of analysis results that provide decision makers with the basis for generating a risk mitigation plan and includes help files to assist users. Additional information on the software is available by clicking on the on-line Primer (1 MB)

The Grand Challenge of the Safety of Threatened Buildings Program

Development of <u>whole building models</u> to enable performance evaluation of alternative engineering solutions to

    A. increase structural integrity;
    B. enhance fire resistance;
    C. improve emergency egress and access; and
    D. enhance building equipment standards and guidelines

that go beyond the requirements of the code to the point of failure, and to <u>incorporate human behavior</u> and <u>economics</u> into the mix.

NIST STB R&D Program Team

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